carbon capture journal

January / February 2009 Issue 7

ELCOGAS: Europe's IGCC pilot

CCS in Japan

Review of 2008:

Legal and regulatory developments

First CCS laws are not poles apart

CCS: where are we now?

CGGVeritas: land seismic monitoring for CCS

The value of carbon oxides for CO2 storage

UK Committee on Climate Change report: CCS is essential technology


www.senergyltd.com/altenergy
senergy
alternative energy
Your answer to carbon storage issues is here
Creating the future together
More than 350 leading geological, geophysical, reservoir engineering and well engineering consultants across several international locations, engineering the smart solutions to your carbon storage challenges.
Senergy - results driven by Brainergy®
Site selection, injectivity, storage capacity, reservoir integrity, flow/phase studies, storage simulation, enhanced hydrocarbon recovery, monitoring, facilities requirements, commercial services.
United Kingdom Ireland United Arab Emirates Malaysia Australia New Zealand
Oil & Gas Survey & GeoEngineering Alternative Energy Technology Training

carbon capture journal

January/February 2009 Issue 7

Carbon Capture Journal
213 Marsh Wall, London, E14 9FJ, UK
www.carboncapturejournal.com
Tel +44 (0)207 510 4935
Fax +44 (0)207 510 2344

Editor
Keith Forward
editor@carboncapturejournal.com

Publisher
Karl Jeffery
jeffery@thedigitalship.com

Subscriptions
subs@carboncapturejournal.com

Advertising sales
Alec Egan
Tel +44 (0)207 510 4944
aegan@onlymedia.co.uk

Carbon Capture Journal is your one stop information source for new technical developments, opinion, regulatory and research activity with carbon capture, transport and storage.

Carbon Capture Journal print magazine is mailed to over 2,000 power company executives, government policy makers, investors and researchers, with a further 500-1000 copies distributed at trade shows, as well as being downloaded approx. 2,000 times as a pdf.

Subscriptions: £195 a year for 6 issues. To subscribe, please contact Karl Jeffery on subs@carboncapturejournal.com
Alternatively you can subscribe online at www.d-e-j.com/store

Front cover: The ELCOGAS integrated IGCC carbon capture pilot plant (see page 21)

Contents

Carbon capture journal (Print) ISSN 1757-1995
Carbon capture journal (Online) ISSN 1757-2509

CCS Legal Review of 2008

2008 has been the most important year to date in the development of the legal framework governing the implementation of CCS projects in the UK and Europe. In this article **Calum Hughes and Catherine Burke of Martineau** review the unfolding European CCS legislative structure and discuss some of the issues which will be of concern to CCS project investors and developers.

European CCS Directive and Alterations to the ETS Directive

In January 2008 the European Commission adopted a proposal for a Directive on the Geological Storage of Carbon Dioxide (the CCSD).

It sets out a legislative framework which concentrates mainly on CO2 storage but, despite the narrow title, also addresses CO2 capture and transportation.

In December 2008 the European Parliament (EP) approved the CCSD subject to certain amendments. These have been agreed by the Commission and the CCSD is likely to become law in early 2009.

The CCSD is intended to remove legal obstacles to CCS in Europe and provide a clear legal structure in which CCS projects can be developed. The fine detail of CCS law will vary from member state to member state and any organisation developing CCS within the EU will need to consider these variations.

The CCSD governs CO2 storage in the onshore and offshore territories of the European member states but it also prohibits CO2 geological storage by EU member states beyond specified geographical boundaries.

The intended effect of this prohibition is not entirely clear. It could be to prevent the export of CO2 for sequestration outside the EU, or to prevent storage sites inside Europe with boundaries extending past EU borders from being used, or possibly both.

Whatever the case, clarification will be important for projects close to the edge of EU territories (including offshore territories) and any projects where export from, or import into, the EU is proposed.

A large portion of the CCSD addresses the selection, evaluation and permitting of CO2 storage sites. Member states are free to choose the areas within their territories from which potential storage sites will be selected but in doing this should consider the requirement that any selected sites must pose no significant risk of negative environmental effects, CO2 leakage or detriment to human health.

The CCSD requires that the level of these risks be assessed using geotechnical data in the categories it prescribes. Where this data is not already available and exploration of the proposed storage site is required to obtain it such exploration may only be performed by the holder of an exploration permit.

Exploration permits will be issued by the member states and will give the holder an exclusive right to explore a fixed territorial area for a fixed amount of time. There is no indication given in the CCSD that the party carrying out the data collection, analysis, etc. will have exclusive rights over the data it collects and the granting of an exploration licence does not guarantee that a storage permit, allowing the licensee to operate the site, will be granted.

Following the EP's recent amendments, the exploration licensee will be given 'priority', under certain circumstances, in the granting of an operation licence for the site which they have explored. It seems likely that typical oil and gas concession licensing models will be followed and exploration licensees will be given first refusal of operations licences.

However, some commentators have suggested that the intention of the CCSD's wording in this area is to leave the way open for a state funded exploration phase and subsequent leasing of storage sites to operators.

It remains to be seen how the various member states will use the legislative flexibility given by the CCSD when drafting their national legislation but it is difficult to conceive of private investors undergoing the expense of finding and proving the suitability of a storage site without either being paid or having the prospect of obtaining rights in relation to its exploitation.

Once a storage site has been approved its operator will require a storage permit. Initial proposals for the CCSD gave the European Commission powers to review and reject applications for storage permits.

This met with opposition and the Commission's right to reject has been removed although the right of review remains. Sensibly, time limits on the Commission review process have been applied by the EP, but the application of these is indefinite.

The Commission is required to issue its opinion on an application within four months of receiving a draft storage permit but there is no limit on how long is to be taken for the Member State to provide the Commission with that draft permit. An operation licence cannot be issued until either, the Commission's opinion has been received, or the four months time limit is up, and there is therefore no restriction on how long the licensing process might take.

"The emerging legal framework for the governance of CCS projects must be seen as a positive step towards the realisation of this essential technology." - Calum Hughes, trainee solicitor, Martineau

This will be a crucial issue for those scheduling CCS projects and prudent potential investors are likely to allow for additional delay, and additional cost, unless the review procedure timescales are clarified.

The CCSD also deals with two of the largest financial risks in CCS projects: the liability for leaks and maintenance of the site after injection of CO2 ceases; and the achievement of the conditions precedent to the eventual hand-over of the closed site, along with its associated liabilities, to the state.

Storage permit obligations on operators will include the provision of monitoring, corrective measures and post-closure plans and there is a requirement for the provision of financial security to cover the associated post closure costs as well as the cost of any leaks.

Carbon storage pilot projects around the world (Image ©CO2CRC)

Exactly how the value of these securities will be calculated is not yet clear. Transfer of responsibility for closed sites to the state can only occur once evidence has been provided that the stored CO2 is completely contained for the indefinite future.

What evidence will be required before a member state becomes obliged to accept hand-over of, and the ongoing liability for, a closed storage site from an operator is also unclear.

What is clear is that the level of risk chosen as acceptable for the selection of a storage site: that 'there is no significant risk of leakage' is lower than that required for the hand-over of the site to the state: that CO2 will be 'completely and permanently contained for the indefinite future'.

The recent EP amendments have also added that there shall be no transfer of a site until the end of a non-specified term, to be determined by the member state, and unlikely to be less than 20 years, and that the operator shall have made an 'financial contribution' to the member state.

These are sure to be key issues for those considering venturing into a CCS project in Europe.

Another point of financial interest associated with the CCSD is that it refers to the inclusion of CSS within the EU Emissions Trading Scheme (ETS) post 2012. This inclusion has been presented by many as recognising, for the first time, that a plant fitted with CCS can take credit for the CO2 it stores.

However, the existing ETS system does not require carbon credit surrender unless CO2 is emitted into the atmosphere. CO2 capture would prevent such emissions and avoid this requirement whether or not CCS is explicitly within the scheme.

Therefore, the inclusion of CCS in the ETS actually only ensures that there is a penalty, and therefore deterrent, applied to leaks from CO2 storage sites in the form of a requirement to furnish carbon credits commensurate with such leaks.

While a deterrent against leaking sites is obviously required for environmental protection, the financial burden that underwriting this risk will place on a project budget is enormous, and could have been reduced, or at least better quantified.

There are several other key issues raised by the CCSD but, overall, it seems clear that the EU recognises that its UN obligations with respect to Greenhouse Gas (GHG) reduction will not be achieved without CCS and it wishes to facilitate CCS development in Europe.

However, while the CCSD addresses comprehensively environmental risks and the permitting of CCS operations, it places all the concomitant financial cost and risks entirely with the project developer and avoids the partial distribution of these to itself or the member states.

There are opportunities for these burdens to be minimised when the CCSD is transposed into national law and how far this is done will be of key importance to the speed at which CCS projects obtain sanction.

UK Energy Act

The Energy Bill received royal assent and became the Energy Act on 26 November 2008. The sections dealing with CCS have not yet been brought into force, but when this is done they will introduce a licensing regime for the storage of CO2 in UK waters and the associated exploration and construction works.

The Act does not deal with CO2 capture or transportation or onshore storage. It is also worth mentioning that the Act is not pursuant to any European legislation and does not cover all of the provisions of the CCSD.

Therefore, additional UK law will be needed to comply with the CCSD once it enters into force. Nevertheless, in the areas that it does cover, the Act appears to conform to the requirements of the CCSD and should not therefore require modification once the CCSD is law.

The Act is worded very broadly and provides that CO2 storage and related activities shall not be carried out except in accordance with a duly issued licence.

The Act does not require that the party carrying out the activities hold a licence; a licence holder could appoint a third party to carry out the licensed activities provided it ensures the licence conditions are not breached. It should be noted however, that, although it is not mentioned in the Act, if licences are to comply with the CCSD, they will have to apply conditions as to the personnel actually managing and operating the site and their competence.

In addition, while there is no specific provision in the Act for separate exploration and operation licences to be issued, it would seem that such separate licences will be required if the licensing system under the Act is to meet the requirements of the CCSD.

The terms and conditions imposed by the licence are entirely at the discretion of the Secretary of State but there are some indicators in the Act of what these might be. In general the suggestion is that the increasingly typical risk management model comprising: operator provided financial security to cover licence obligations; continuing operator responsibility after site closure; and the eventual hand-over of the site, and its obligations, to the state, will be followed.

The Act makes it a criminal offence to breach the conditions of a licence, or to carry on activities which require a licence if a licence has not been issued. Where licence provisions are not complied with, directions can be made for corrective measures and ,if these are not complied with by the licence holder, the licensing authority is empowered to have the measures carried out and recover the costs from the licence holder.

Certain, as yet undefined, data relating to each storage site will be held on a public register. There is a requirement that information unreasonably prejudicial to any party's commercial interests should not be held on the register, but it remains to be seen what information will be considered to fall within this category.

The Act addresses the issue of CCS installation decommissioning costs by applying the rules for abandonment of oil and gas installations contained in the 1998 Petroleum Act. This will require the submission, upon request, of an acceptable abandonment programme and the subsequent carrying out of the programme.

Unlike the oil and gas case however, the Act does not provide for the abandonment provisions to cover for submarine pipelines. This omission may be addressed once the CCSD becomes law.

The interaction of CCS with oil and gas operations is also vaguely dealt with in the Act. Carbon storage for the purposes of enhanced oil recovery (EOR) falls within the auspices of the Act only in circumstances yet to be specified by the Secretary of State. Given the potential role of EOR in the financing of early CCS projects it should be hoped that clarity on this issue is provided as soon as possible.

The fact that the UK is pushing ahead with CCS legislation before the CCSD is adopted in final form gives a strong indication that the UK government recognises the importance and potential of CCS and wishes to be pro-active in encouraging the industry's development. However, as with the CCSD, the detail is not yet present to allow those developing project budgets to adequately quantify some large line-item costs with sufficient confidence, particularly with respect to post-closure risks.

International legislation

Internationally there is also a great deal of positive legislative activity: modifications of international marine legislation to remove legal barriers to sub-sea CO2 storage; progress in the debate regarding the inclusion of CCS into the Kyoto flexible project mechanisms; the continued development of a replacement for the Kyoto protocol; and the recent amendments to Australian legislation to incorporate CCS.

Conclusions

The emerging legal framework for the governance of CCS projects must be seen as a positive step towards the realisation of this essential technology. The CCSD and Energy Act provide adequately for workable licensing regimes and the protection of the environment. However, the legislation as it stands is not drafted to give financial predictability to those preparing budgets for CCS projects and seeking funding.

About the authors

Calum Hughes has 20 years experience in engineering and the project management of upstream oil and gas and gas storage projects and is currently completing his training as a Solicitor at Martineau.
Catherine Burke is a partner in the Energy and Projects team at Martineau.

First CCS laws are not poles apart

British and Australian Federal and State governments passed the first laws for Carbon Capture and Storage at the end of last year and a European Union Directive is nearing adoption. This article sets out the new laws and examine how far a common system of regulation is emerging.

By Richard Harwood, barrister, 39 Essex Street Chambers, London and Claire Smith, Senior Associate, Clayton Utz, Sydney

The draft European Union Directive

In January 2008 the European Commission proposed a European Union Directive on Geological Storage of Carbon Dioxide. The directive will provide for carbon capture to be regulated by Integrated Pollution Prevention and Control and pipeline transport and storage would be subject to Environmental Impact Assessment.

New large combustion plants will have to be carbon capture ready. However the main purpose of the Directive is to create a new regulatory regime for on-shore and off-shore carbon CO2.

The aim of geological storage will be 'permanent containment of CO2 in such a way as to prevent or reduce as far as possible negative effects on the environment and any resulting risk to human health'.

Waste and water directives will be amended to permit CO2 storage. On 17 December 2008 the European Parliament adopted the proposal with amendments which had been agreed by the Commission and the Council of member states. The Directive is therefore likely to be adopted soon.

United Kingdom Energy Act 2008

The British government is proposing off-shore carbon storage in a process licensed by the Energy Act which was enacted on 26th November 2008.

The use of a 'place in, under or over' the territorial sea or waters in a Gas Importation and Storage Zone for the storage of CO2, or conversion of any natural feature there for such storage or exploration will require a licence.

Gas Importation and Storage Zones will be designated in the UK's 'Exclusive Economic Zone'.

Whilst the Act allows storage 'in' the sea, the relevant international conventions (the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972 London Convention) and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) have only been amended to permit CO2 storage in sub-seabed geological formations rather than the water column itself.

The licensing authorities will be the Secretary of State for Energy and Climate Change and the Scottish Ministers. As the government owns the seabed within United Kingdom waters the expectation is that the operator will also enter into a Crown lease.

Installing carbon capture equipment and any requirement that combustion plants are carbon capture ready will be dealt with by development consent and IPPC regimes. On shore power station projects above 50 MW will now require development consent under the Planning Act 2008 rather than Electricity Act consent.

Smaller projects may obtain planning permission from local authorities. There is no specific UK regime for on-shore carbon storage, but it could be promoted as underground gas storage under the Planning Act

platts
100 YEARS

3rd Annual

European Carbon Capture and Storage

Overcoming Obstacles and Achieving Value



February 26-27, 2009
Hilton Brussels
Brussels, Belgium

Platts **3rd Annual European Carbon Capture and Storage** conference will once again assemble the CCS community to debate the structural challenges faced, discuss and review CCS projects in their various stages and look to uncover opportunities in what will become a changed regulatory environment to ensure CCS lives up to its potential.

Event Highlights Include:

- **Delivering the new EU regulatory framework**
- **Project progress reports from** *Shell, BP Alternative Energy, E.ON Energie, RWE Power, TOTAL, Vattenfall Group, StatoilHydro ASA, Hydrogen Energy and ConocoPhillips European Power*
- **Overcoming the obstacles needed to successfully deploy CCS**

Hear From the Following Organisations:

Bellona Europa aisbl, Bluesource, BP Alternative Energy, Carbon Capture & Storage Association, CCS Rapporteur, CERES, Climate Change Capital, ConocoPhillips European Power, E.ON Energie, Greenpeace, Hydrogen Energy, Institute for European Environmental Policy (IEEP), Platts, Pöyry Energy Consulting, RWE Power, Schlumberger Carbon Services, Shell International Petroleum Company Limited, StatoilHydro ASA, TOTAL, US Department of Energy, Vattenfall Group

Executive Sponsor:
Schlumberger

Networking Reception Sponsor:
PÖYRY

For more information quote 'CCJAD' and contact:
Stacey Knox
stacey_knox@platts.com
+44(0)-20-7176-6226
www.events.platts.com

The McGraw-Hill Companies

2008 or, for smaller schemes, under the Gas Act 1965 or planning applications. However the British government does not presently support on-shore storage.

Australia – Federal – Offshore Petroleum Amendment (Greenhouse Gas Storage) Act 2008

Australia has been a little quicker than the UK and Europe on introducing carbon storage legislation both offshore and on-shore.

On 21st November 2008 the Australian Federal Parliament approved the Offshore Petroleum Amendment (Greenhouse Gas Storage) Act 2008.

The legislation is extremely detailed (comprising 444 pages of amendments) and applies to waters between the 3 mile nautical limit and outer limit of continental shelf. Initially the greenhouse gas to be regulated is CO2 but other substances could be encompassed in the regime.

Didcot power station in the UK where a carbon capture test facility was opened last year (Image ©RWE Npower)

Australian – States – Western Australia, Victoria, South Australia and Queensland

The first project specific legislation incorporating CO2 injection and storage activities was adopted by Western Australia in the Barrow Island Act 2003.

This implemented an agreement between the State government and a joint venture for a gas processing project on Barrow Island. It provides that ministerial approval is required for the injection of CO2 into underground reservoirs.

The first standalone carbon storage legislation in Australia was the Greenhouse Gas Geological Sequestration Act 2008 passed by the State of Victoria on 5th November 2008.

The Act states that its purpose is to 'facilitate and regulate the injection of greenhouse gas substances into underground geological formations for the purpose of permanent storage of those gases, including to facilitate and regulate the exploration for suitable underground geological storage formations, as part of Victoria's commitment to the reduction of atmospheric greenhouse gas emissions'.

The State of Queensland's Greenhouse Gas Storage Bill, released in December 2008, has a similar purpose, and is expected to become law in 2009. The State of South Australia has amended its existing Petroleum Act 2000 to allow CO2 injection into natural reservoirs.

It is envisaged that installation of carbon capture equipment (including retrofitting activities) will be dealt with under existing State and Territory environment and planning regimes.

How the CCS regimes will function

It is useful to consider how the European, Australian and British laws deal with major issues which will arise: licensing; protection of other interests; site closure; financial security; compensation for those affected by CCS activities, penalties and long-term liability.

Licensing

All the legislation provides for licensing of exploration, site preparation and storage activities. Usually permits will be granted for different stages, with the draft Directive distinguishing between exploration permits and storage/injection licences.

In the European Union exploration permits will be for three years, with a potential three year renewal, but Australian assessment or exploration permits will last between five years up to a maximum of twelve years, indicating a difference between Federal, Victorian and Queensland Government views on how long the exploration phase should last. Federal and Victorian laws also envisage the granting of special authorisations for particular investigations (e.g. seismic surveys and baseline investigations involving well drilling) and a licence for injection activities.

In comparison, the Queensland Bill proposes to regulate injection and storage activities under a lease. The UK legislation is more general, but a Crown lease may be required.

Australian Federal and Victorian Acts allow the relevant minister to authorise an operator to hold a potential site dormant between exploration and injection for up to 15 years until projects become commercially viable.

The Queensland Bill also allows permit holders to apply to the relevant minister for a declaration to preserve their interests for up to 10 years. The draft Directive does not have a dormant period, but the UK envisages this could be done by a Crown lease.

Protection of other interests

There is a danger of conflict between carbon storage and other interests, particularly existing petroleum titles.

The draft Directive was amended by the European Parliament to ensure that the storage sites selected 'should not jeopardise other energy options such as renewables or the security of the EU's energy supply' and to allow member states to preserve their economic interests in hydrocarbons.

Conflicting uses would be prohibited. In Australia the potential for adverse impacts from greenhouse gas activities (e.g. drilling exploration wells or injection activities) on petroleum operations (or vice versa) will not necessarily be a sufficient reason for prohibiting them.

If there are competing interests the Federal Government will encourage parties to reach commercial agreements. Where that is not possible, the Federal Government has included a "significant risk of a significant impact test" in the Act to provide some investment certainty for greenhouse gas proponents and to protect petroleum titleholders.

This test is based on the probability of the adverse impact occurring and the economic consequences of that impact such as increased capital and operating costs or reduction in petroleum recovery or greenhouse gas injection rates or storage capacity.

For greenhouse gas and petroleum titles (created post-commencement of the legislation), protection is given to the first rights to be granted. Ultimately, the relevant minister will have the final say as to which activity proceeds taking into account the public interest.

The Victorian Act and Queensland Bill adopts a similar approach, although in Queensland the minister can approve a "co-ordination arrangement" that deals with safety and the spatial relationship of each party.

A feature of the draft Directive is its concern that access to permits and storage sites will be granted on a fair and open basis. Other companies should be able to use CO_2 transport networks and storage sites, for payment, in accordance with certain criteria, to prevent operators being shut out of energy supply by a lack of CO_2 storage capacity.

In Victoria the minister will be able to grant access to storage facilities where commercial agreements cannot be reached.

Site closure and handover

The closure of a site is the final cessation of CO_2 injection. However it must then be ensured that the site is safe. That raises a major issue. The only entity able to monitor and rectify sites over hundreds of years is a national or international governmental body.

Private companies are unlikely to last that long, so ultimately sites have to become a state responsibility. Governments do not though wish to pick up the costs of commercial storage sites so the question arises as to when responsibility changes from the operator to the state.

Broadly a storage licence, permit or lease can only be surrendered when the site is safe (i.e. does not present a risk to public health or the environment). The Australian Federal Act sets out a number of prescriptive requirements that the minister can direct the licence-holder to do such as plugging or closing off any wells in the licence area (whether or not they were made by the licence-holder) and undertaking various activities to eliminate or mitigate the risk of greenhouse gas leakage on other activities (e,g. fishing and petroleum operations) and protect the environment and health and safety.

The Victorian Act and Queensland Bill require the operator to have reduced storage leakage risks to as low as reasonably practicable. The draft Directive requires all available evidence to indicate that the stored CO_2 will be completely contained for the indefinite future.

Unless the member state is satisfied that the site is secure, a minimum of 20 years will have to elapse following closure before a site can be transferred. This is consistent with the Australian Federal Government's estimates.

Financial security

All regimes enable financial security to be required for the future licence obligations, including the final closure procedures and post-closure monitoring of the site. These securities will need to be long term in nature, particularly given the prolonged periods before responsibility can be transferred.

Compensation for landowners

Storing any substance under a person's land without their consent is trespass and a landowner would therefore expect to receive some payment for allowing storage. Offshore storage will usually be in seabed owned by the State itself, and the British and Australian Federal legislation both envisage that the right to store will be leased from the Crown.

The Victorian law gives the Crown ownership of all 'underground geological storage formations' more than 15.24 metres below the ground, without compensation to landowners. This mirrors the approach of most states to the expropriation of oil and gas reserves.

Compensation is however payable to resource authorities' whose resources are sterilised or landowners whose property is affected by the operations (including decreases in market value of the land).

In Queensland, occupiers may also be eligible for compensation. The draft Directive does not deal with landowner rights at all. UK legislation on onshore underground gas storage requires landowners to be compensated if storage rights are compulsorily acquired.

Penalties and Long-term Liabilities

Each legislative regime has introduced a range of offences and penalties for non-compliance but there is very little consistency. The UK proposes unlimited fines and up to 2 years imprisonment.

In Australia, the Federal Government has imposed a 5 year imprisonment sentence for unauthorised exploration and injection activities. In contrast, the State regimes only have monetary penalties with the proposed Queensland bill envisaging a maximum penalty of A$750,000 compared to a maximum of only A$11,000 for offences under the Federal regime.

Long-term liability has been a hotly debated issue in Australia. The Federal Act includes an express indemnity provision in favour of any registered licence-holder if specific criteria are met.

In comparison, the Victorian Act and Queensland Bill are silent in respect of the transfer of long-term common law liabilities from the operator to the State and the Barrow Island Act contains an indemnity from the Joint Venture in favour of the Western Australian government.

It remains to be seen whether State Governments will amend their legislation to ensure consistency with the Federal Act.

Conclusion

The first carbon capture and storage legislation has been enacted. Common issues have been identified and there are similarities in the general approaches.

Much is likely to evolve in time as this lawmaking is dealing with a technique which is not yet in use and many of the practical and scientific problems have yet to be addressed.

It would be a miracle if legislators had successfully predicted and answered all the legal problems that lie ahead.

About the authors

Richard Harwood
richard.harwood@39essex.com

Richard is a barrister at 39 Essex Street Chambers, London. 39 Essex Street is one of the top ten barristers' chambers and has been awarded Environmental and Planning Chambers of the Year for the last two years. Richard is also a case editor of the Journal of Planning and Environmental Law.

Claire Smith
claire.smith@claytonutz.com

Claire is a Senior Associate at Clayton Utz, Sydney. Claire previously worked as an environment counsel for BP plc on global environment and climate change issues.

CCS: Where are we today?

In a presentation at The 2nd Annual European Carbon Capture and Storage Summit in London, Lord Oxburgh set out the progress made in 2008 and looked forward to some of the challenges ahead.

Lord Ronald Oxburgh, Past Chairman, Shell Transport and Trading and President of the CCS Association

The Cost Curve

Lord Oxburgh began by looking at the McKinsey abatement curve (right). Plotted vertically is price in euros, going from 0-150, and plotted horizontally is a number which is gigatonnes of CO2, which goes out to 28. "On the McKinsey/Vattenfall calculation we need to be somewhere in the region of 30 Gt/year saving by 2030," he said.

"These columns represent a series of measures which can be taken to abate CO2. All the things over on the right have negative costs, so those are things that we should be doing already simply to save money regardless of saving CO2. On the left is a series of more expensive ways of saving carbon."

"I think McKinsey and Vattenfall would be the first to say that you can criticise a great deal in detail about the numbers here, but I think the broad scope of the thing is roughly right. Carbon capture and storage appears in three places here: within enhanced oil recovery (EOR), on new coal-fired and retrofitted to existing power stations. Overall, this is based on getting about 3 Gt. Remember that number because we are going to come back to it later and I think it is probably too small, for reasons that will emerge."

"The one general point to make is if you are in a situation where politicians are talking about this, there is sometimes a tendency to think of this as a priority list, do the cheap things first. Obviously, that is true. Over here to the left are things we ought to be doing anyway."

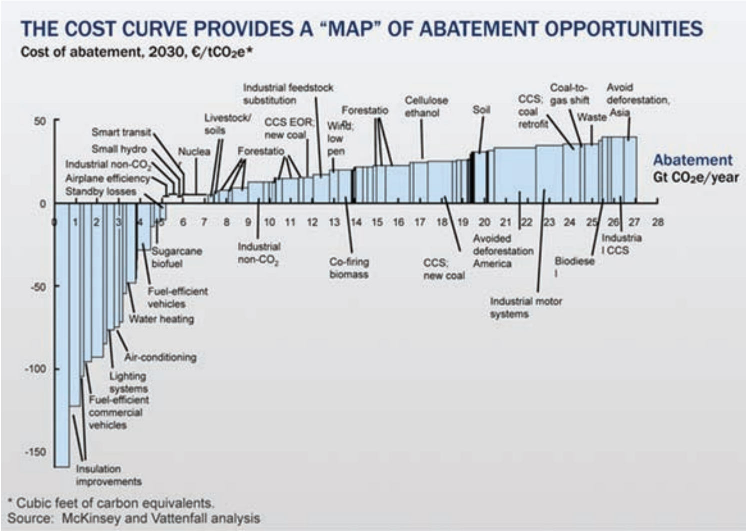
"However, the important thing to recognise is that the different columns have different time constants associated with them and if you want to do some of these things by 2030 or 2020 you have to be starting now. It is not a time priority list at all, therefore, and it is important to remember that."

Aspects of the World Distribution of Oil, Gas and Coal

"The thing you need to remember is that the reason that coal is so important is that it is going to be burnt. Why is it going to be burnt?"

"Clearly, the USA, China and India are the three most energy hungry economies in the world and they have rather more than half of the world's coal resources. The USA is undoubtedly going to burn that coal for reasons of energy security and China and India are going to burn it because they are poor countries and do not have a lot else."

"Given that if you burn it in a power station, it is the most CO2-rich source per unit energy produced, clearly we have to do something about coal. Not only coal, but coal is the main driver if we are going to control climate change and emissions."



Carbon Capture Technology

"Capture technology continues to move forward, but on the other hand I think there is still enormous scope for technical development here. We have pre-combustion, IGCC and oxyburn. We know that these are feasible technologies."

"Then we have post-combustion, largely today based on solvent extraction of CO2, you might think of using membranes, but there is a big footprint and this is the technology which we will have to use, retrofitting legacy coal-fired power stations, and it is worryingly space-consuming."

EU carbon capture test facility

"The Esbjerg DONG plant on the west coast of Denmark is where the EU CASTOR project built a solvent-based extraction system. I want you to concentrate on the area circled around a big open space. The next slide shows the plant after the CCS element has been put in and you can see that it increases the footprint of the power station by about 25%. That represents a space challenge and obviously it represents a financial challenge as well. This is going to be a serious limitation if we have to find that amount of space for every legacy power station where CCS is applied."

New approaches

"All of these techniques involve relatively high additional capex and, of course, an efficiency loss and we now have to ask whether there are new approaches. I think these are things that are going to attract a great deal of attention here because, as I shall emphasise in a minute, the capture is the most expensive part of the operation and probably the one where there is greatest scope for cost reduction."

"There is a lot of work going on in new solvents. There is a very interesting approach by a Danish company, Novozymes, who believe that they will be able to develop an enzyme which will make the extraction process in the solvent very much more efficient."

"Of course, if it becomes much more efficient you can put the gases that you have to treat through more rapidly and you can therefore deal with smaller plant and reduce the large footprint that I showed you a moment ago to something much smaller."

"Their CEO spoke at a conference I attended a couple of weeks ago, would you believe in the Taj Mahal in Mumbai, of getting a 90% reduction in plant size; if that works, fantastic."

"There are other approaches. The solvent approach is largely chemical, but one could also think of various physical approaches as well."

Transport and Storage

"I think transport and storage are pretty well understood. You need pipeline networks and there are going to be people talking about that today. There is a lot of experience of moving around CO2 in the US where it has been used for enhanced oil recovery for over 30 years."

"However, it is a major logistic challenge. It is just a matter of getting everything

right, getting your sources on time at the same time as your transport network so that people do not have temporarily stranded assets."

"It is a big organisational role and in Britain this could be a serious practical limitation simply because there are major planning constraints and the long time taken for construction. However I do not think there are likely to be many technical surprises here; they are mostly organisational."

"On storage, again there is a reasonably good understanding of CO2 underground from the enhanced oil recovery and we have spoken about abandoned oil and gas reservoirs and saline aquifers. Using these technologies there is not a big technical challenge, there is just a great amount of work to be done and knowing it can be done is not a reason for delaying it. Since we know how to do it, it should not be put off. That is going to take a lot of time and needs starting very soon."

"There are other approaches, of course. A number of countries are talking about using deep sea ponds, shallow depressions on the ocean floor and putting high-density CO2 liquid in those. It will probably turn rather rapidly into hydrate and sit there for quite long lengths of time. That has not been researched, but some countries may feel that they do not have an alternative."

"There is also the possibility, which may be applicable in some countries, of reacting hot CO2 streams with powdered silicates to produce carbonates and then you have materials that you can use for building".

"Long into the distant future I think the Holy Grail here is to take the CO2 that you are producing in these situations and artificially reproduce photosynthesis, because of course what plants do is pull CO2 from the atmosphere, take water and fundamentally they make complex organic molecules."

"This is what some chemists are now trying to do and if you could do that at power stations, the implications would go long, long beyond carbon capture and storage. There would be a whole new fuel source, a whole new source of materials and what have you. These things have to be thought about for the distant future."

Capture Cost Estimates

"The best study I think so far on the cost of all this is still the Climate Change Capital one which was done a little over a year ago. As can be seen on this slide, it shows the increased capex for capture. It increases the cost of the power plant by somewhere between 20% and 50%, the opex for capture somewhere between 10% and 30% and the efficiency loss the same."

"This adds up to something like a 30% increase in the cost of electricity. However, I cannot emphasis too much the uncertainty of these numbers, because no one has really done this in anger and done it properly yet. Some of these costs may turn out to be too high and some too low, but the point is that at costs like this it is going to be very difficult to see extensive development in the developing world and that is the real prize, as I shall emphasise in a minute or two, because there you have to retrofit."

"Taking a Chinese power station and telling the operator, 'We would like you to put on this kit which will mean that you will get less electricity from the fuel that you put in and per unit tonne' when he is selling into a price-capped market does not look like a winner. Therefore, these costs really do have to come down."

Where Are We Today?

"As I said at the beginning, we are a great deal further on than we were this time last year. There is an increasing EU commitment to carbon capture and storage."

"A couple of months ago the Australian government committed AUS$100 million per annum to setting up a new global carbon capture and storage institute. Just a little over a week ago they held a meeting in London to discuss how this institute should be set up."

"The rationale given by Kevin Rudd, their Prime Minister, who attended this meeting by video conference, was that something like a global institute on CCS is needed to spread experience and to get people talking to each other. He said, 'If we wait for the normal international processes to churn away, take full course, we will set this thing up in five years time.'

'It is much better', he said, 'if we put the money on the table now. We want it to be global. We do not want it to be an Australian thing, but we will finance it now and then we hope that it will be useful and other people will come in and it will be an international contribution operation and the Australians can then fade into the background.' That is an important new initiative."

"We also have the Vattenfall initiative at Schwarze Pumpe, which is now working. It is an oxyburn initiative and on this slide is the site. They are taking something off the stream of this larger power station. This is the little bit that you can see in the picture. I think that is a major step forward. It is only 30 MW, but it is doing the whole thing."

"We have a number of projects which are much closer to fruition than they were last year: one in Abu Dhabi, Mongstad in Norway, and at Eston Grange in the UK, and a number of others."

Current CCS proposals

"If we look at the map on this slide, which comes from the Scottish Centre for Carbon Storage website, the balloons represent places around the world where things are going on and it represents quite a lot."

"Thus we have made progress, but there are areas in which we have to make a lot more progress. First of all, how are we going to pay for carbon capture and storage? Ideally, it should cost emitters less to use carbon capture and storage than to pay the carbon price, but of course the trouble is that at present CCS is relatively expensive and the carbon price is low."

"For investment in CCS you have to have a stable carbon price and it has to be relatively high, probably around $60/tonne, something of that sort. The point is that by the time you get this through market mechanisms it is probably going to be too late."

Why should government share cost?

"Why should government share the cost? It is partly that the carbon price is uncertain and partly that there simply is no commercial incentive. However, there is also the urgency. Implementation is necessarily slow, it is heavy engineering, it is know-how and learn by doing, it cannot be done fast."

"In addition, early movers are carrying risks. They carry technology risks that what they are trying to do may turn out to be more expensive or will not quite work as they want it to.

Perhaps more importantly though, as the technology moves on their kit is already in place and other people can do it more cheaply, so there is a serious risk of stranded assets. A variety of mechanisms could be used to support this, which I am not going to talk about, but I am sure other people will today."

"Of course, the regulatory aspects are important. There has been a lot of work on this and, indeed, a lot of progress, I have to say. Verification, liability for emissions escape, licensing, compliance, all of these things are making headway. In addition, there is the question of monitoring and the question of insurance."

Scale of Future CCS Business - Trillion dollars per year

"It is worth recognising how big this is going to be. Around about 8 Gt of CO2 are emitted per annum today and if you assume that the cost of CCS is round about $60/tonne and around about 50% of the available point sources are captured and you do a little bit of multiplication (you can use pretty much any figure you like), you come out with some-

thing that is close to a trillion dollars a year business. That is not very different from the present oil industry."

"If you look at the business shares of where this is going to go, you have the capture and gas handling, which is going to be power plant manufacturers, operators, and international oil companies. You have transport, pipeline constructors, operators and managers and again international oil companies."

"You have the storage site identification and management and that is going to be geological surveys and international oil companies. It could well be that carbon capture and storage becomes a major new business for international oil companies."

Energy and Emissions

"To drive home the importance of what we are doing look at my penultimate slide (right) in which I plot tonnes of oil equivalent, amount of energy used per capita vertically and population horizontally. It is a very unusual slide, but it is worth paying some attention to. I have this shown for China and you can see that in 1965 the per capita use of energy was very small and the population was just under 800 million."

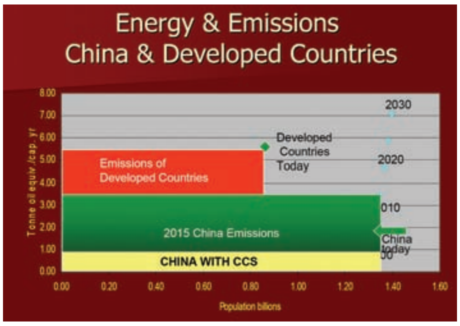
"As we went through the 1970s, 1980s and 1990s, per capita use of energy rose very slowly and then, suddenly, per capita use went up very rapidly and you can see where China is today. You can see where the developed countries are, with just fewer than one billion people but with roughly five times per capita energy use of the Chinese today."

"If you think about it, if you multiply a per capita use of energy by number of people you end up with an area which is proportional to the energy use and because it is largely fossil fuel, it is the emissions of the developed countries. If you do the same for China, it looks like that and you can see that today Chinese emissions are roughly half those of the developed world."

"If we look at Chinese coal-fired plant building plans going forward to 2015 however, Chinese emissions are comparable to those of the developed world. Frankly, if that happens and the same thing happens in India and elsewhere, we are on a hiding to nothing in managing climate change, but if we apply CCS it goes down. That is the goal."

Conclusions

"My conclusions are, first of all, that there is an urgent global need for CCS. Secondly,



conventional market forces simply will not deliver in time and therefore government intervention is needed, partly to share the technology risk, partly to share the risk of stranded assets, and partly to ensure that the appropriate framework is in sight for the right infrastructure to be built in time. This is a major business opportunity for the oil industry and, indeed, many others, but the business potential is massive."

Further information

From a presentation given on Tuesday 3rd December 2008 at The 2nd Annual European Carbon Capture and Storage Summit in London.

www.cityandfinancial.com/ccs2

CO_2 Capture, Sequestration & Utilisation

5–6 March 09 | BEIJING, CHINA
Crowne Plaza Park View Wuzhou Beijing

Attend CMT's CO_2 Capture, Sequestration & Utilisation 2009 to:

- Hear from oil majors and NOCs on their perspective and contribution towards CCS
- Why CCS and its value chain? – concept, economics and stakeholders' role
- Zoom in with details on **Enhanced Oil Recovery (EOR)** in Algeria, China and Norway
- Assess the economics between cost of CCS with price of CO_2
- Understand how emission trading mechanism can incentivise CCS or CO_2 utilization
- Meet key technologies providers as they discuss on the development of cost effective carbon capture technologies
- Be updated on the clean coal technology implementation in China and **Post Combustion Capture (PCC)** technology installed in coal fired power plants in Australia and China
- Evaluate alternative utilization for CO_2 – chemicals, fertilizers and algae biomass
- Find out the criteria and challenges in CO_2 logistics and geological storage

Sign up with your team to enjoy attractive group discount.
Register online @ **www.cmtevents.com** with your team today!

Confirmed speakers

- *Beijing Research Institute of China Shenhua Coal to Liquid and Chemical Co. Ltd.*
- *World Resources Institute*
- *Mckinsey & Company*
- *Shell Downstream Services International*
- *BP Alternative Energy*
- *Uhde Shedden*
- *AirLiquide*
- *Schlumberger Carbon Services*
- *CSIRO*
- *BRGM*
- *DNV Energy*
- *Holcim Services*
- *I.M. Skaugen SE*
- *Enviro Energy Int'l Holdings Ltd*
- *EcoSecurities Group China*
- *Development Solutions*
- *ACCA21, China*

You will network with

Presidents, CEOs, VPs & Directors, Analysts, General Managers, Commercial Managers, Business Development Executives, Research Directors, Sales & Marketing Managers, Technical Advisors involved in: Coal, CTL/GTL, Gasification, Liquefaction, Refinery Industrial Gas, Chemicals, Methanol, Olefins, Catalysts, EPC, Power & Utilities, Engineering Companies, Lubricant Companies, Gas Separation, Equipment and Technologies providers

promotion partners

EMCA 中国节能服务网 · CHINAHEDGE · Interfax China · China Coal Resource · EUREKAHEDGE www.eurekahedge.com · carbon capture journal · GasificationNEWS · China Power 中国电力.com.cn

❑ Register Me ❑ Send sponsorship/exhibitors details

Name ______________________ Position ______________________
Company ______________________
Email ______________________
Address ______________________
____
Tel ______________________ Fax ______________________

TO REGISTER

Online: **www.cmtevents.com**
Email: **sasha@cmtsp.com.sg**
Fax: **(65) 6345 5928**
Tel: **(65) 6346 9124**
Post to: 80 Marine Parade Rd
#13-02 Parkway Parade
Singapore 449269

CCC report outlines UK plans to tackle climate change

The Committee on climate change (CCC) in the UK has recommended a minimum 34% cut in greenhouse gas emissions by 2020, with a 42% cut if a global deal is achieved. CCS is cited as an essential technology for these plans.

The report highlights the need for a rapid development of CCS and the emissions targets it proposes will make building new coal fired power plants without CCS virtually impossible after 2020.

It calls for a virtual complete decarbonisation of the power sector by 2030, using a range of option including renewables, new nuclear build and CCS.

"CCS generation is an essential technology for reducing global emissions, but needs to be developed rapidly. CCS will always be more expensive than conventional fossil fuel generation because of the additional process steps involved. But it is a technically feasible solution and best estimates suggest that it is likely to play a major role in a cost-efficient global abatement strategy," says the report.

"It is now essential to invest in projects which demonstrate the effectiveness of various CCS technologies in large-scale installations, and which identify the feasible timescales and likely costs of extensive deployment."

It also mentions that the application of new technologies such as CCS in cement and steel is likely to be feasible and economically viable.

It sets out three budgetary periods, 2008-12, 2013-17 and 2018-22 and says that CCS may be demonstrated to be economic towards the end of the last period.

"The contribution of CCS during the first three budget periods [...] is likely to be limited given that this technology has not yet been demonstrated at the appropriate scale."

It call for a ban on conventional coal-fired power generation without CCS. A conventional coal plant “should only be built on the expectation that it will be retrofitted with CCS equipment by the early 2020s,” it concludes.

“Given reasonable estimates of likely carbon prices in the 2020s, it is unlikely that conventional coal-fired generation will be economic even if no other policy levers are in place. But there is a danger that uncertainties about future carbon prices could result in investments that lock the UK in to carbon intense generating plant.”

“There is therefore a strong case for buttressing the carbon price lever by establishing a clear and publicly stated expectation that coal-fired power stations will not be able to generate unabated beyond the early 2020s.”

“One way to achieve this would be to establish a requirement that coal-fired power stations cannot be built beyond a certain date without CCS (say 2020), that those built before that date will be given a deadline for retrofitting CCS (say in the period 2020-2025), or that plants which choose not to retrofit should be allowed to generate for a very limited number of hours.”

Alternatives could be:

(i) to set emissions standards (i.e. company specific ceilings on the g/kWh emissions from power generation)

(ii) to establish a floor price within the EU ETS.

“These and other possible options warrant further consideration.”

About the report

The Committee on Climate Change was appointed in ‘shadow’ form in March 2008, becoming a statutory committee on 1st December 2008 when the Climate Change Bill became law.

Its core function is to recommend what the level of the UK’s ‘carbon budgets’ should be. These budgets are established by the Climate Change Act and will define the maximum level of CO2 and (potentially) of other greenhouse gases (GHG) which the UK will emit in each 5 year budget period, beginning with 2008-12.

The Climate Change Act requires the Government to gain Parliament’s approval to a proposed level for the next three budgets, setting a trajectory of UK CO2/GHG emissions over the next 15 years. The Committee is required to make recommendations on this basis.

This first report of the Committee on Climate Change therefore recommends UK carbon budgets for the three periods 2008-12, 2013-17 and 2018-22. In addition, it covers issues on which the CCC is required to report by the Climate Change Act, or on which it has been asked by the Secretary of State to provide an opinion. These include:

- What should be the target for UK emissions reduction by 2050?
- Whether budgets should cover CO2 emissions, or all greenhouse gas (GHG) emissions, including the relevant non-CO2 gases
- How far CO2/GHG emissions reduction should be achieved by domestic UK action, and what reliance on emissions reduction credits bought from other countries is acceptable?
- Whether and how international aviation and shipping should be included in the UK’s targets and budgets
- The implications of the recommended budgets for economic growth, energy security, the competitiveness of particular industrial sectors, fuel poverty, and for specific regions and devolved administrations.

The Committee’s recommendations on the first of these issues – the target for 2050 – have already been presented in a letter to the Secretary to State delivered on 7th October 2008.

www.theccc.org.uk

CCS UK Experts Mission to Japan

A mission of UK experts on CCS was undertaken to Japan from 29 September to 3 October 2008, with support from the Science and Innovation Section of the British Embassy Tokyo. A wide range of discussions were held with officials from government departments, and public and private sector organisations. We summarise the main outcomes.

Policy

The Japanese Government appears to apply a more interventionist role in helping CCS to develop in Japan than the UK government does in the UK. Whereas Japan applies a dirigiste model, the UK has tended to adopt a laissez-faire or free-market approach.

The Japanese Government, through the Ministry of Economy, Trade and Industry (METI), has undertaken a consensual planning approach with the key companies and research institutes. There is, consequently, a strong ownership of, and identification with, the national CCS programme.

There also appeared to be a reasonable level of clarity in the roles ascribed to each organisation and over a reasonable length of time. This dirigiste approach has advantages in reducing inefficient competition and in encouraging long-term commitment to investment.

The Technology for the Earth (RITE) centre, based in Kyoto, conducts research into the complete CCS value-chain from capture to storage, and includes engineering, geology, economics, systems analysis and public perceptions. The Institute also has a strong relationship with industry. The existence of RITE depends upon a strategic, focused and secure funding stream from METI.

Regulation

Domestic regulations regarding CO2 storage in Japan (onshore and offshore) are currently being formulated by the Japanese Government.

As described in the London Convention, the purity of CO2 for geological storage must be 'overwhelmingly CO2'. For capture with amine-based solvents, the Ministry of Environment (MoE) has interpreted the term 'overwhelmingly CO2' as ≥99% CO2.

For other capture processes, the MoE has not yet come to a decision. For oxyfuel, for example, the requisite purity level could conceivably be lower. It appears that the licensee with be required to make a case to the MoE if the purity of CO2 in the captured stream is to be less than 99%.

The Japanese Government has not, as yet, adopted the notion of handover of the CO2 storage site to the state in the post-closure period. It was felt that the approach taken by the UK Government (led by the Department of Energy and Climate Change), including its consultation on regulation and its associated approach to implementation of the requirements of the EU Directive, would be of value to the Japanese Government.

Finance

Japan does not have an emissions trading scheme, though there has apparently been some initial discussion on establishing one. Without an ETS, or an equivalent carbon tax, it is not clear how the financial incentives for developing and deploying CCS will be present in the Japanese context.

The immediate priority appears to be the development of one or more pilot plants. In December 2008, the European Union agreed a package of climate and energy measures, including a directive on CCS and inclusion of CCS within the EU ETS.

As a consequence, the EU ETS remains the principal policy instrument internationally for facilitating CCS deployment. Japanese companies will be looking eagerly to the European market for opportunities to export their CO2 capture technologies.

Public awareness

Kansai Electric Power Plant Company (KEPCO) has an excellent programme of public engagement and dissemination. A key focus of KEPCO concerns its relationship to its local and wider community.

It was felt that the UK power utilities could draw constructive lessons from this positive attitude of engagement and the commitment to being a real part of, and contributing to, the community.

Storage

Estimates of geological storage capacity in Japan have been updated since they were previously reported in the early-1990s. The new estimates provide higher values than the earlier study indicated. The new estimates are summarised in Table 1.

Though this is encouraging, a note of caution is required. The updated estimates are probably over-optimistic; they are based upon generic assessments of suitable geological formations, rather than on the detailed assessment of potential storage reservoirs that will take substantially longer to establish.

Type of Formation	Anticline capacity, Gt CO2	Sedimentary basin capacity, Gt CO2
Depleted oil and gas	3.5	27.5
Identified aquifer	5.2	
Identified closure	21.4	88.5
Total capacity	30.1	116.0
Grand total	146.1	

Table 1: Estimates of geological storage capacity in Japan

There is an absence of the basic geological data that would permit a more detailed evaluation of the storage capacity. With the exception of Hokkaido Island and one or two other locations in Japan, which have been explored for oil and gas, there are very few bore holes at a sufficient depth in Japan. This makes it difficult to evaluate the geology and, consequently, CO2 storage capacity in detail.

In the Osaka Bay area, there are a small number of deep boreholes, which has permitted a provisional assessment. A storage capacity of around 4.2Gt CO2 has been estimated. A programme of seismic surveying and targeted deep drilling is now required to make a more realistic estimate of capacity.

Capture

The extent of investment by Japanese companies such as Mitsubishi, J-Power, Hitachi, KEPCO, Toshiba and others, in one or more of the capture technologies, was impressive. In a couple of cases, the investment dated back to the early- to mid-1990s.

Post-combustion capture technology appears to have been developed incrementally since that time. Not only that, but several companies were exploring all three of the main capture technologies. This portfolio approach keeps the selection of capture technology, for particular circumstances, open.

The extent of investment by industry in capture technology reflects a long-term com-

mitment to CCS. This, of course, is instrumental in the involvement of Japanese companies in projects internationally, e.g. in Australia, Germany, Norway, the UK and the USA.

Furthermore, a company such as Mitsubishi Heavy Industries (MHI) may be involved in the entire CCS chain up to the point of CO2 compression for transportation to the storage site. It possesses the capability to design and manufacture the power plant equipment, the CO2 capture plant and the solvent.

This involvement allows the potential for greater integration and optimisation at the plant design stage, as well as the potential for lower transaction costs arising from companies working together along the value-chain. This integration could, in principle, encourage a 'virtuous circle', in which innovation and learning are facilitated and communicated along the value-chain.

For post-combustion capture at large-scale, chemical absorption is likely to be the preferred route for the next several years. Detailed discussions during site visits suggested that it would be possible to scale-up existing amine-based technologies (operating at about 300 tonnes of CO2 capture per day) to a sufficient size for a typical coal-fired power plant (producing, say, 20,000 tonnes CO2 per day).

A possible constraining factor could be the logistics of manufacturing the CO2 capture plant; economies of scale favour operation at a relatively large scale. The logistical challenges in assembling or constructing large CO2 capture removal plant may present a problem in some parts of the world.

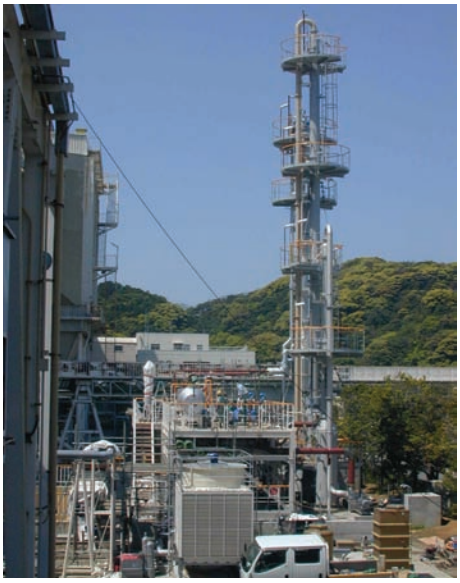
The IEA's 'Blue Map trajectory' (Energy Technology Perspectives 2008, IEA, Paris) anticipates the need for 55 new 500 MW power plants with CCS to be installed every year from 2020 onwards.

Based on discussions with MHI, the total amount of amine required on a daily basis (to replenish the solvent) can be estimated. These preliminary calculations indicated that, in principle, there were no constraints to the use of amine-based capture technology with respect to logistics of production and supply of the amine itself.

Since some amine-solvents are on the 'red list' of EC50 chemicals (a measure of toxicity), however, there are still questions regarding their environmental impacts that need to be addressed.

There were also some encouraging estimates of overall post-combustion CO2 capture costs (gate costs) from a coal-fired power plant with amine-based solvent of approximately US$60/tonne CO2 - assuming that other impurities in the flue gas had been removed.

These compare with estimates made in the context of the EU Directive of approximately US$120/tCO2 for first-of-a-kind demonstration plants and between US$30 and US$55 per tCO2 when the technology was fully advanced.



Mitsubishi's 10 ton/day coal fired CO2 capture demonstration plant in Matsushima, Japan

Deployment

Japanese companies are well placed to exploit opportunities from 'low hanging fruit'. This includes CO2 capture arising from Clean Development Mechanism (CDM) projects, e.g. at gas processing plants. On the other hand, the Conference of the Parties to the UNFCCC 14th Meeting (COP14) in Poznan, Poland, in December 2008, failed to come to agreement on inclusion of CCS within the CDM. The Japanese firms visited are also investigating CO2 capture from cement and steel plants.

Policy, company and regulation news

Global Carbon Capture and Storage Institute to be launched

www.pm.gov.au

The Australian Government has begun plans to launch the Global Carbon Capture and Storage Institute (GCCSI) in January 2009.

The Global CCS Institute, which will be headquartered in Australia, will provide international policy and management oversight to the goal of delivering at least 20 commercial scale CCS plants around the world by 2020.

The Prime Minister of Australia, Kevin Rudd, announced the establishment of the GCCSI in September, with a commitment to provide $100 million per annum in funding.

So far eight organisations have signed up as founder members: Shell International Petroleum; Rio Tinto Ltd; Mitsubishi Corporation; Anglo American; Xstrata Coal; Services Petroliers Schlumberger; Alstom; and The Climate Group.

It aims to accelerate the development of CCS technology and pave the way for its commercial deployment, and is the only organisation working with governments and industry on a global basis to achieve the advancement of CCS.

It will also facilitate the G8 goal of delivering at least 20 commercial scale CCS plants around the world by 2020.

An initial meeting in London in November 2008 was attended by more than 165 delegates, including representatives from 21 key countries such as China, India, Japan, the United Kingdom, Norway, Netherlands, the United States, and Canada, as well as multinational companies, and a range of research organisations.

RWE npower buys into UK CCS competition entry

www.rwe.com

RWE npower has taken a 75% stake in Peel Energy CCS Ltd, formerly jointly owned by Peel Energy and Danish company DONG Energy, restructuring a joint venture pre-qualified for the UK Government's CCS Demonstration competition.

Should the project be successful in the competition, RWE npower would be involved in the 400MW CCS project to capture CO2 whihc would then be transported to disused gas fields in the North Sea where it would be permanently stored.

The project could be up and running by 2014.

RWE npower has already commissioned a separate test facility at its Didcot coal-fired power station in Oxfordshire, capturing CO2 using both Post-Combustion (PCC) and Oxyfuel carbon capture methods.

RWE npower is also due to begin construction of a CCS pilot plant at its Aberthaw coal-fired station in Wales next year. The plant, due to be complete in 2010 will be the first to capture CO2 direct from a commercially operating power station in the UK.

DONG Energy is also actively involved in the development of CCS technology. Its CCS pilot plant at Esbjerg Power Station in Denmark, part of the CASTOR R&D project, is Europe's largest CO2 capture facility to date and has been capturing the gas since 2005.

BP pull out of UK CCS competition

www.bp.com

BP has confirmed its intention to withdraw its entry to the UK CCS post combustion pilot demonstration competition.

BP cited its failure to pull together a consortium to take the project forward, after initially entering a sole bid.

Environmental Finance has reported that RWE npower is asking the UK's High Court to review the government's decision to leave it off the shortlist.

According to Environmental Finance, the company believes it was not treated fairly in being allowed to respond to any shortcomings in the initial bid.

It was initially excluded on a 'technicality'.

EU commissioner supports CCS investment through ETS

europa.eu

At the Zero Emission Platform (ZEP) General Assembly in Brussels, EU energy commissioner Andris Piebalgs stated his support for using carbon allowances under the ETS to fund 12 CCS demonstration projects.

Commissioner Pielbags said that the Commission will be sending a positive signal regarding the so-called Doyle-Davies amendment, to use 500 million ETS Emissions allowances from the ETS New Entrants Reserve for the building of 12 CCS demo projects.

This fund could be worth up to €20 billion depending on the cost of carbon emission allowances.

"The amendment can offer means of helping all new low carbon technologies demonstration, including early CCS projects, to cover part of the additional demonstration costs regular power plants will not face. However, any use of the EU ETS new entrants' reserve for low carbon technologies, including CCS, must also be acceptable to Member States," said Commissioner Pielbags.

He also stressed that the funding must be structured to avoid windfall profits for the operators, to the ETS as little as possible and to meet state aid rules.

The ZEP at the same time unveiled a new report aimed at speeding up the deployment of the EU-wide CCS Demonstration Programme which is intended to achieve the commercial availability of CCS by 2020.

"It is widely accepted that CCS is one of the key solutions for combating climate change - while building a bridge to a truly sustainable energy system," said Dr. Graeme Sweeney, Chairman, ZEP, and Executive Vice-President of Future Fuels & CO2, Shell.

"As a result, it is imperative that CCS receives the support and structure required to become a commercial reality and realize its potential of reducing CO2 emissions in the EU by up to 400 million tonnes a year by 2030," he added.

The report concluded that the currently proposed CCS projects across the EU can satisfy the majority of the criteria that need to be tested, within the programme of 10-12 demonstrations.

It also said that industry is prepared to take on the commercial and technical risks associated with building the demonstration projects, although a funding gap of €7-12 billion will remain to meet the costs of building and running the additional CCS installations and reduced plant efficiency.

It said that the speeding up of the tendering and permitting process, and creating an appropriate regulatory climate, is integral to ensuring the EU CCS Demonstration Programme delivers CCS as a commercially viable technology by 2020.

It wants to see a 'fast track' process where the demonstration plants are planned and permitted by 2010, built by 2013 and fully operational from 2015, opening the way to up to 120 full-scale CCS plants in Europe by 2030.

Various emissions sources, including power plants with different fuels and the CO2 streams from other industries, like steel or cement plants should be looked at, and the three primary means of capturing CO2 - pre- and post-combustion and oxyfuel tested.

Different modes of transporting CO2 - pipelines on- and offshore and across borders, and transport by ship and the two primary means of storing CO2 - depleted oil and gas fields and saline aquifers should be investigated.

Epcor progresses with CCS project in Alberta

www.epcor.ca

Epcor Utilities has been invited to prepare more detailed proposals for the company's two projects that were submitted to the $2 billion Alberta CCS fund for consideration.

The first application was for its Integrated Gasification Combined Cycle (IGCC) project to be located at Genesee.

The project has the potential to capture more than one and a quarter million tonnes of carbon dioxide emissions a year when running at full capacity.

The second proposal was for a pilot project, located at EPCOR's Genesee 1 power generation plant, which would test an amine scrubbing process to remove CO2 emissions from the flue gas and be designed to reduce carbon dioxide emissions by between eight and 10%.

Epcor must now prepare a fully integrated proposal that also includes capture, transportation and storage of carbon dioxide.

EPCOR is also involved with the Alberta Saline Aquifer Project (ASAP), the Integrated CO2 Network (ICO2N) plan, the Heartland Area Redwater Project and the Wabamun Area Storage Project (WASP).

These consortiums include more than 35 organisations that are working to address the transportation and sequestration of CO2 and the regulatory, safety and permitting issues associated with CCS.

Epcor's Genesee Generating Station where the pilot project and IGCC plant will be situated

Mustang Engineering secures design contract for Masdar

www.mustangeng.com

Mustang Engineering, based in Houston and a subsidiary of international energy services company John Wood Group, has been selected to provide front-end engineering and design (FEED) services for Masdar's CCS project in the United Arab Emirates.

The project constitutes the first phase in a series of facilities capturing carbon dioxide emissions from Abu Dhabi's industrial and power generation plants.

The CO2 will be transported in a pipeline network and injected in Abu Dhabi's oil reservoirs for enhanced oil recovery.

The objective of the CCS network is to reduce Abu Dhabi's carbon footprint and replace the vast amount of natural gas currently re-injected into oil reservoirs.

In the first phase ending in 2013, around 5 million tons of CO2 per year will be captured from three emission sources: a gas-fired power plant, an aluminium smelter and a steel mill.

"This project marks a major milestone in our leadership's vision to provide clean energy, reduce carbon emissions and promote sustainable development," said Masdar CEO Dr. Sultan Al Jaber.

The FEED follows a successful eight-month feasibility study conducted by Masdar in 2007 to investigate CO2 emission sources in Abu Dhabi and evaluate the technical and economic feasibility of CO2 capture and transportation to oil reservoirs.

J P Kenny, also a Wood Group company and operating from their Abu Dhabi office, will be responsible for FEED services for the CO2 pipeline network that will connect the capture sites in Abu Dhabi to the oilfield injection sites. This work is scheduled for completion in the 4th quarter 2009.

ETI launches first CCS project proposal

www.energytechnologies.co.uk

The ETI is looking for a lead coordinator for a project to accurately assess the UK's storage capacity for CO2.

The ETI aims to create a portfolio of CCS projects and has significant funding available. This is the first such project. The deadline for this stage was 6pm on Friday 28th November.

It will be a desk-based study, using public domain and (where appropriate) data from offshore operators. The ETI says it anticipates that the results from this appraisal will go into the public domain.

The project aims to bring together a consortium of key UK universities and other organisations able to make a significant contribution to meeting the project objectives.

Shell and Essent study CCS in Holland

www.shell.com

Essent and Shell have signed an MoU for a feasibility study into a 1GW low CO2 IGCC power plant in the south-west part of the Netherlands.

Shell and Essent will evaluate the feasibility of combining a high-efficiency gasifier, a power generation plant and equipment to capture and store CO2.

The plant would use coal and solid biomass. The companies are evaluating possible sites.

The study will assess which depleted oil and gas fields would be suitable for CO2 storage. Because of the volume of CO2 involved, the study will consider both onshore and offshore fields.

Setback for CCS inclusion in CDM

unfccc.int

Plans to allow organisations to earn credits for CCS under the clean development mechanism (CDM) have been dropped at the climate change talks in Poznan.

The proposal, led by Australia, was supported by a majority of representatives and the IEA but Brazil and a few other countries blocked the move. The decision will now be postponed until next year.

This effectively rules out its inclusion in the new climate change treaty which will be signed in Copenhagen next year.

FutureGen back on the table?

www.thesouthern.com

Discussions regarding reviving FutureGen have been held with President-elect Barack Obama's nominee for energy secretary, Steven Chu according to Illinois newspaper The Southern.

U.S. Senator Dick Durbin and a delegation of Illinois congressional members attended the discussions where they made sure, according to Durbin, that "Dr. Chu understands the importance of FutureGen to Illinois and is fully aware of the delegation's commitment to moving the project forward."

Dr. Chu has not yet made any firm committments, although he said DOE would focus on "bringing [CCS] technology along as quickly as possible." Obama has however previously talked about reviving the project.

Elliot Kennel (left), research professor in the Department of Chemical Engineering, describes for Wu Xiuzhang (right) the process developed at WVU to convert coal directly to liquids at low temperature and pressure. Coal liquefaction typically requires high temperature and pressure, which translates into higher cost. Wu, the deputy chief engineer of the Shenhua Group of China, and his colleagues met with experts at WVU under a U.S. Department of Energy agreement between the organizations to share information and expertise. (Photo: Trina Wafle, NRCCE)

New research institute at Stanford

gcep.stanford.edu

Stanford is establishing a $100 million research institute to focus on energy issues, including CCS.

Lynn Orr has been named overall director of the new institute, which will function as an independent laboratory reporting to the dean of research.

Orr is a professor in energy resources engineering. He has been the director of Stanford's Global Climate and Energy Project (GCEP), where researchers are involved in more than 40 research projects to find ways to reduce greenhouse gas emissions associated with energy.

GCEP's research portfolio includes the science of materials used to convert solar energy to electricity, biomass energy conversions, advanced batteries, fuel cells, advanced combustion, and carbon capture and storage.

GCEP, launched in 2002, will become a part of the new institute, as will the 2-year-old Precourt Institute for Energy Efficiency (renamed the Precourt Center for Energy Efficiency), an organization dedicated to finding ways to wring more energy savings out of buildings, cars, the electricity grid and basic human behavior.

Greening the Grid Powering Alberta's Future with Renewable Energy

pubs.pembina.org/reports/greeningthegrid-report.pdf

A Pembina Institute report says that Alberta should invest at least as much in renewable energies as CCS.

The report shows how Alberta can switch its electricity source from coal to clean renewable energy sources in 20 years, creating jobs, reducing greenhouse gas and creating a more stable price for energy.

The purpose of the report is to determine to what extent cleaner alternatives to coal, nuclear and other non-renewable resources can be deployed to meet Alberta's electricity consumption over the next 20 years, which is expected to be almost twice the current levels of consumption.

"Findings show that it is possible to meet all future requirements for electricity in the province using a combination of renewable plus cleaner transitional technologies," the report says.

It concludes that "The preferred approach of the Alberta government to date — carbon capture and storage — may or may not need to play a role in reducing the environmental impact of electricity in the most cost effective way."

Two scenarios are presented. In the pale green scenario, renewable energy sources push the dominant conventional coal source from 74 per cent in the current electricity mix down to 25 per cent.

In the pure green scenario, coal power sources, retrofitted with carbon capture and storage, provide the source of seven per cent of Alberta's electricity.

WVU experts meet with Chinese coal to liquids leaders

wvutoday.wvu.edu

Officials from China's leading research and corporate energy organizations met with West Virginia University faculty and U.S. Department of Energy leaders to discuss advances in converting coal to transportation fuels while capturing and storing CO2 emissions.

The meeting was organized by the U.S. China Energy Center, a program of the National Research Center for Coal and Energy at WVU.

The Shenhua Group in China is developing the world's first commercial direct coal liquefaction plant in northwestern China at a cost of about $1.5 billion. The plant will eventually transform millions of tons of coal into thousands of barrels of liquid fuel per day.

WVU experts said the Shenhua Direct Coal Liquefaction plant will likely be well suited to a large scale carbon capture and storage project. Fletcher and his colleagues, WVU professor Tim Carr and Julio Friedman of Lawrence Livermore National Laboratory, noted that the Ordos basin in China, where the plant is under construction, has the geological resources necessary to support a sequestration project.

With support from the U.S. Department of Energy, WVU and Shenhua Group have been evaluating the economic and environmental impacts of the direct coal liquefaction technology.

While commercial coal-to-liquids processes exist, these are known as indirect coal liquefaction and require breaking coal down into molecules of carbon monoxide and hydrogen, which are building blocks that are then processed into diesel fuel. Direct coal liquefaction processes attempt to bypass the breakdown of the coal into such small molecules to make liquid fuels directly.

Information gained by the researchers will be shared with those in the U.S. to help promote the transfer clean coal technologies.

WVU has been working with the U.S. Department of Energy and the China National Development and Reform Commission under an agreement known as the Protocol on Cooperation in the Field of Fossil Energy Technology Development and Utilization since 2002.

Report finds clean technologies are not reaching developing nations

www.cerna.ensmp.fr

A report into climate related technologies has found that much more could be done to transfer innovations to the developing nations.

The report, Invention and Transfer of

Climate Change Mitigation Technologies on a Global Scale, comes from the CERNA Research Programme on Technology Transfer and Climate Change, supported by the OECD and the Centre for Industrial Economics at the Ecole des Mines de Paris.

It looked at the development of clean technologies, including CCS, over a 25 year period, and found that those countries that ratified the Kyoto protocol saw an acceleration in patent filings over the period 1998-2003.

It also looked at how many of those patents were shared beyond the country of origin. Only 18 per cent of clean technology patents were extended beyond developed countries to developing countries, while three quarters was between developed countries.

China, Russia and South Korea were exceptions, being major innovators in their own right.

Zurich launches CCS insurance products

www.zurichna.com

Zurich Financial Services Group has introduced Carbon Capture and Sequestration Liability Insurance and Geologic Sequestration Financial Assurance.

The products are designed to meet the insurance needs of CCS projects from design and operational phases through to closure and post closure events at the geologic storage sites.

They can be applied not only to cleaner coal operations, but also to a variety of industrial processes, onshore and offshore, although not all coverages are available in all jurisdictions.

The CCS Liability Insurance Policy covers pollution event liability, business interruption, control of well, transmission liability and geomechanical liability.

The GSFA Policy covers specified closure and post closure activities.

Zurich said the products "have eliminated a significant barrier to widespread deployment of this critical technology in the long-term mitigation of carbon emissions."

US utilities back 'aggressive' CCS deployment

www.eei.org

An industry association of US electric utilities has put forward an updated climate change framework, calling for an 80 percent reduction of carbon emissions by 2050 from current levels.

"The aggressive development and deployment of carbon capture and storage coupled with advanced coal technologies are necessary to preserving the coal option," it says.

It also gives support for key concepts underlying the Boucher CCS bill.

The Edison Electric Institute (EEI) Board of Directors framework for the first time recommends to Congress a unified industry position for allocating emissions allowances distributed to the utility sector under potential cap-and-trade legislation.

The EEI Board recommended that the initial emission allowance allocation to the electric power sector should be 40 percent, equal to its portion of U.S. carbon emissions.

It also sets out the technologies that are essential to achieving emissions reductions.

"Near term targets should be guided by efforts on energy efficiency, renewable energy and, to some extent, new nuclear," it says. "Medium-term targets (10-20 year time frame) should be synchronised with deployment of other technologies, including advanced clean coal with carbon capture and storage and new nuclear."

European CCS research initiative receives funding

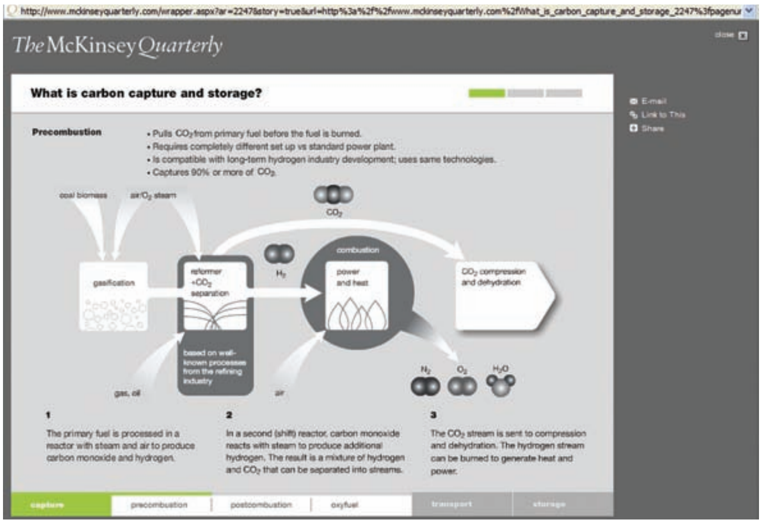
www.ntnu.no/eccsel

The European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) initiative will receive €81 million in funding to set up a research infrastructure.

Norway, Germany, France, Switzerland, the Netherlands, Hungary. Poland, Croatia and Denmark are all involved, with around a third of the funding going to Norway.

The Norwegian University of Science and Technology (NTNU) and independent research organisation SINTEF are coordinating the international effort, which will see 15 joint laboratories built across nine countries. Norway will host five of the 15 laboratories at a hub in Trondheim.

Two new labs in Norway, which will cost around €23 million in total, will focus on scrubbing and low temperature separation technologies for removing CO2 from power station flue gases. Other labs will investigate storage technology, improving combustion and the materials and processes used.



The McKinsey Quarterly CCS presentation reviews the technology for capture, transport and storage of CO2

McKinsey Quarterly CCS presentation

www.mckinseyquarterly.com

McKinsey has released an interactive depiction of the technologies involved in CO2 capture, transport and storage, which it says is intended to provide a background for informed discussion.

USCAP releases blueprint for climate legislation

www.us-cap.org

The U.S. Climate Action Partnership (USCAP) has released a set of policy recommendations, "A Blueprint for Legislative Action", for developing legislation that would create an environmentally effective and economically sustainable national climate protection program.

The report says a robust technology transformation program that results in substantial investment in new technologies is a critical complementary measure to a national strategy to cap and reduce GHG emissions. USCAP recommends a program that features federal support for emerging technology research and early demonstration and deployment of new technologies.

"USCAP recommends that Congress provide needed regulatory certainty and substantial financial incentives to facilitate and accelerate the early deployment of carbon capture and storage (CCS) technology, including addressing financial and regulatory barriers that could delay wide-spread deployment."

"USCAP recommends implementing CO2 emissions standards for coal plants initially permitted after January 1, 2015, subject to Congress providing adequate funding for CCS and needed regulatory certainty being in place; and retrofit requirements for coal plants initially permitted after January 1, 2009 and prior to January 1, 2015, subject to deployment thresholds being met."

Capture news

Toshiba Corporation to build CO2 capture pilot plant

www.toshiba.co.jp

Toshiba Corporation will install a post combustion capture pilot plant at Sigma Power Ariake Co. Ltd.'s Mikawa Power Plant, in Omuta City, Fukuoka, Japan.

Construction of the plant is scheduled to start in spring 2009, and the commissioning and validation testing is expected to begin in August.

Toshiba says it has succeeded in developing an amine solvent that consumes minimal energy during CO2 separation and capture, and has confirmed on a bench-scale test that it matches industry leading standards.

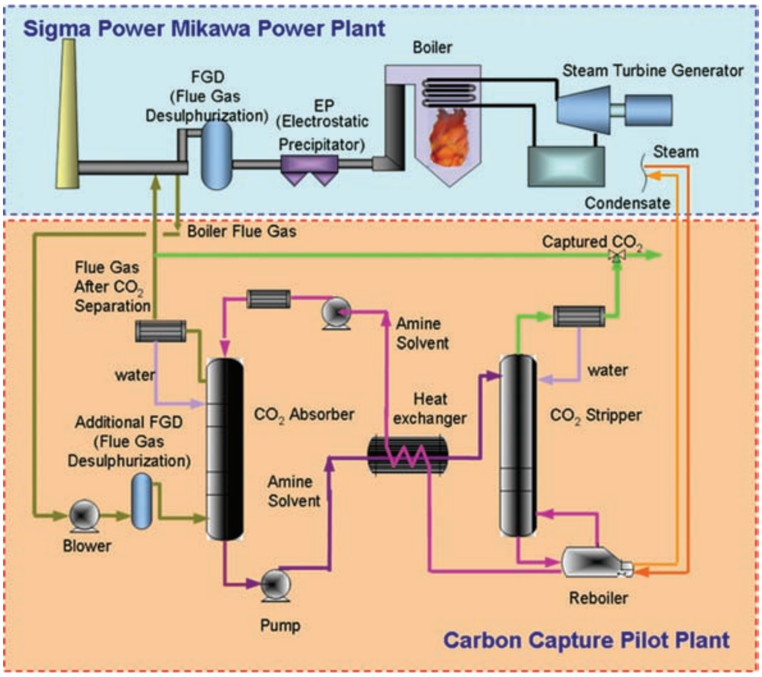
The Mikawa pilot plant is designed to capture 10 tons of CO2 a day from the boiler flue gas of the coal fired thermal power plant.

Beyond proving system performance, plant verification will encompass a wide range of tests aimed to accumulate know-how required for the design of utility-scale power plant application, says Toshiba.

These include the effects of the thermal power plant flue gas contents, such as SOx, on the operation of the system when integrated with other power plant equipment, such as turbines and boilers.

Toshiba is targeting installation of its system in demonstration plants in Japan and overseas in parallel with the validation tests at the Mikawa pilot plant.

Its goal is to meet emerging needs for commercial scale CCS systems for thermal power plants, an area where demand is expected to grow from around 2015. Toshiba says it will accelerate its research and development efforts to support early establishment of this business.



Toshiba's post combustion pilot at the Sigma Power Mikawa power plant in Japan will test a low energy amine solvent

Air Products oxyfuel capture technology paper

www.airproducts.com/co2_capture

The paper describes Air Products' oxyfuel sour compression technology that optimises the compression process to remove impurities in the gas to make carbon sequestration possible.

Air Products' Vince White presented the paper, called "Purification of Oxyfuel-Derived CO2", at the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9) in Washington, D.C.

White said oxyfuel technology can reduce the cost of capturing CO2 for the power industry and that Air Products has specifically focused on the purification of the resulting oxyfuel combustion flue gas, developing a robust process for the efficient removal of trace impurities.

The reduction of these impurities to an acceptable purity level is necessary before any carbon captured could be transported for underground storage.

White described Air Products' patented sour compression technology, which uses a staged compression process to optimise pressure, hold-up and residence time to allow removal of impurities including sulphur dioxide, nitrous oxides, mercury, and other heavy metals from the CO2 containing gas during the compression process.

This allows cost savings in the oxyfuel combustion process and minimises the content of these components in the sequestered CO2, White said.

Air Products' oxyfuel sour compression technology has been demonstrated in experimental work carried out by Imperial College London with actual flue gas from Doosan Babcock's 160kW coal-fired rig in Renfrew, Scotland, as part of the Oxycoal-UK Project.

White presented the findings of this work in the paper which he co-authored with Laura Torrente Murciano and David Chadwick, both of the Chemical Engineering Department at Imperial College, and David Sturgeon of Doosan Babcock Energy Limited.

"The data shows that impurities removal can be achieved during compression and without more expensive and complex flue gas de-sulfurization units and de-NOx units," said White.

Alstom to construct pilot in Poland

www.alstom.com

Alstom and PGE Elektrownia Bełchatów S.A. have signed a MoU for the development and implementation of carbon capture and storage (CCS) technology at the Bełchatów power plant in Poland.

In a first phase, Alstom will design and construct a pilot carbon capture plant at the existing unit 12 of the Bełchatów power plant, which would capture approximately 100,000 tonnes per year of CO2 using Alstom's amines technology.

The pilot will be jointly operated by Alstom and Elektrownia Bełchatów and is expected to be in operation by mid 2011.

During the second phase, Alstom and PGE plan to build a larger CCS project to capture CO2 produced by the new 858 MW lignite-fired unit currently being built by Alstom for Elektrownia Bełchatów. This CCS plant will be in operation by 2015.

Lignite and hard coal are the mainstay of the Polish power generation sector and the reduction in CO2 emissions resulting from the Belchatow CCS project would be higher than 1 million tonnes per year.

The Bełchatów CCS initiative is one of the candidate projects to the EU Flagship Programme for Carbon Capture and Storage.

ELCOGAS - integrating IGCC with CCS

ELCOGAS, a consortium shared by European utilities, is building the first pilot plant for CO2 capture and hydrogen production to be integrated in an operating 335 MW IGCC plant.

The ELCOGAS IGCC plant is the largest IGCC plant in the world to use a single gasifier and gas turbine, and in 2008 celebrated the 10th anniversary of commercial operation with coal gas.

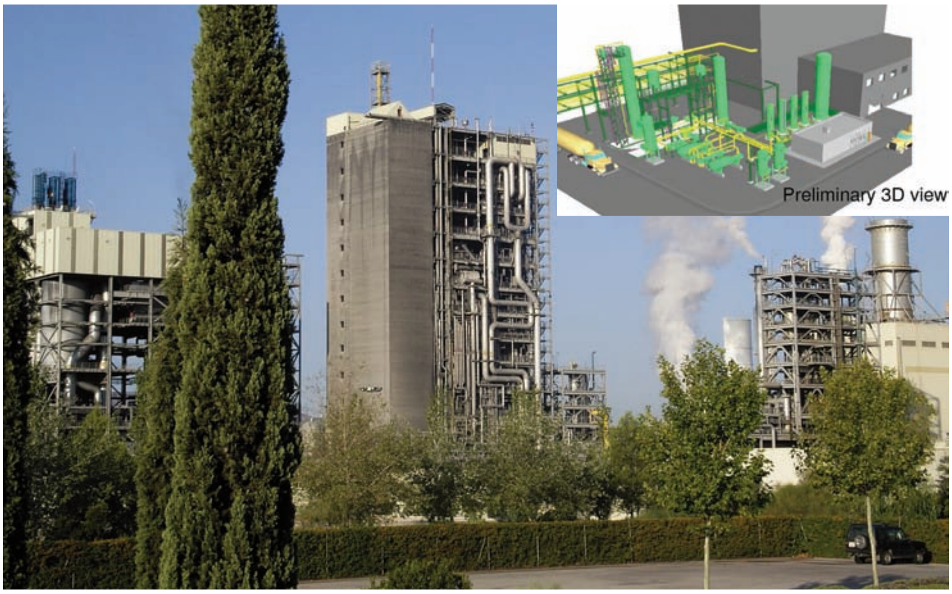
Since 2005 ELCOGAS has been involved in a CO2 capture research project, with the objective of validating at industrial, bench and laboratory scale the technologies of pre-combustion CO2 capture and H2 production associated to an IGCC Power Plant.

The industrial scope will be tackled through the assessment of commercial technologies for CO2 separation and H2 production in a 14 MWt Pilot Plant installation to be integrated in the infrastructure of the Puertollano IGCC Plant.

This installation is being realized as a modification of the existing IGCC process, and conceptually is an extension of the gas cleaning processes already existing in the plant.

According to ELCOGAS the installation will become a unique carbon capture facility providing a multi-fuel capacity (coal gas with and without sulphur compounds), and generating a multi-product portfolio: 'pure' CO2 (95% purity), CO2 with H2S, H2 rich stream (80% purity), pure H2 (99.99% purity), and a residual gas (containing 50% H2).

Civil works started in December 2008, and construction will be finished in mid 2009.



The ELCOGAS plant with a 3D schematic of the new IGCC plant

IGCC pilot

The ELCOGAS IGCC plant produces electricity from solid fuels (fuel design is a mixture of coal and petcoke). The solid fuel is gasified to obtain a synthesis gas that is driven through a cleaning process to remove fly-ash and other pollutants such as halogens, cyanides, sulphur and nitrogen compounds. The clean gas is used in a combined cycle to produce electricity.

Project targets

The targets of the project are:

1) to demonstrate the feasibility of CO2 capture and H2 production in an IGCC power plant that uses solid fossil fuels and wastes as main feedstock.

2) to obtain economic data enough to scale it to the full Puertollano IGCC capacity in synthetic gas production.

The project is being developed by ELCOGAS in collaboration with UCLM university and Spanish research institutions INCARCSIC and Ciemat.

It is granted by MICINN and JCCM (national and regional government) and it is part of a Spanish national initiative, "Advanced technologies of CO2 conversion, capture and storage" that integrates other related projects:

• Project #2 explores CO2 capture with oxyfuel technology and is being coordinated by CIUDEN

• Project #3 deals with study and regulation of geological storage of CO2 in Spain and is being developed by IGME

• Project #4 focuses on public awareness of CO2 capture and storage technologies and is being developed by Ciemat.

Process

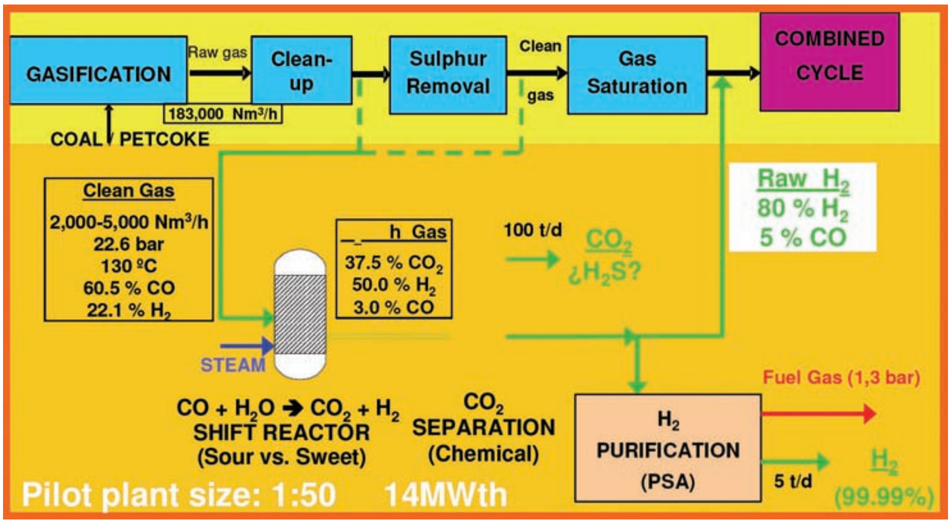
The process consists of a shifting unit to convert CO to CO2, a CO2 separation unit, based on absorption processes with amines, and a H2 purification unit (PSA).

Sour and sweet catalysts will be tested to obtain technical and economic yields at full scale, obtaining CO2 capture costs at different purity grades.

Status

Main equipment design and supply has been contracted:

• Engineering: Empresarios Agrupados (June 2007)



The process in ELCOGAS' IGGC pilot plant

• CO_2 and PSA units: Linde (Jan 2008)
• Reactors: Tecnical (May 2008)
• Catalysts: Johnson Matthey (Feb 2008)
• Control: Zeus Control (May 2008)

Construction started in November 2008 to finish in July 2009.

One year of tests is expected to obtain detailed data at different conditions and different grades of CO_2 and H_2 purities.

After 2010 the pilot plant will be offered to the R&D and industry community as a platform, integrated in an operative IGCC, to projects researching syngas uses, CO_2 separation and treatment processes, and H_2 purification and use.

Future research and development

The main focus areas of ELCOGAS' R&D plan are:

• CO_2 emission reduction in utilization of fossil fuels: pilot plant for CO_2 capture and production of H_2 and electricity (PSECO2 project)

• IGCC efficiency optimisation (improve auxiliaries consumption, improvements of efficiency based on CARNOT assessment, supervision online of main equipment.)

• H_2 production by gasification of fossil fuels: H_2 production studies (HYDROSEP project), H_2 treatment and purification research (SPHERA project).

• Diversification of raw fuels and products: XtL (biofuels and less carbon intensive liquid fuels production); new uses of syngas (as fuel for fishing ships: PEIXEVERDE project); co-gasification of coal, wastes and biomass (PIBE project); other fuels: municipal wastes, automotive wastes.

"The integration in an existing IGCC plant of this Pilot Plant for CO2 capture is a great engineering challenge" - Pedro Casero, pilot plant project manager

• Other environmental improvements: liquid wastes reduction, improvement of gas cleaning systems, improvement of sulphur recovery system, optimisation of operation and additive parameters, emissions reduction during startup and other transitory situations.

• IGCC process optimisation: analysis of gasifier materials, control of syngas corrosion processes, control of membrane corrosion in the reaction chamber, improvements on ceramic filters performance, increase of gas turbine and other equipment availability, improvement of IGCC integration.

• Dissemination of results: participation on forums and conferences, offering of consultant services, promotion of technical visits to the plant.

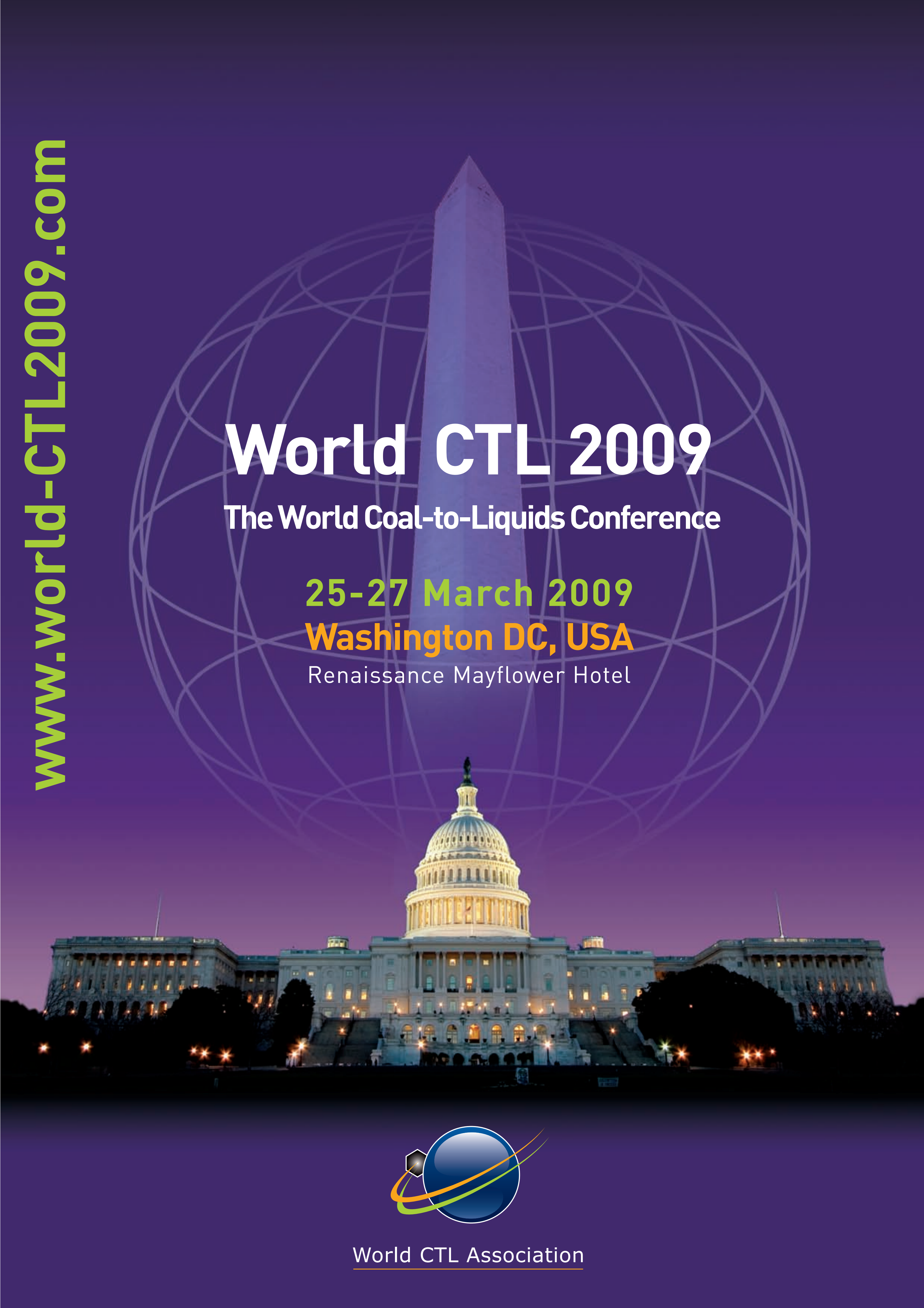
About the company

ELCOGAS is a European company established in April 1992 to undertake the planning, construction, management and operation of a Gasification Integrated CombinedCycle plant of 335MW, located in Puertollano (Spain).

It is a demonstration project,supported by the European Commission under the THERMIE Program. Its objective is to prove the feasibility of using low value fuels in power plants,with lower environmental impact, in order to develop a sustainable model of "cleanenergy" production.

ELCOGAS is shared by European utilities (Portugal:EDP; Italy:ENEL; France:EDF; Germany:Siemens, Krupp-Koppers; Spain:ENDESA, Iberdrola, Hidrocantábrico).

The plant started its commercial operation in 1996 with natural gas and with syngas in 1998. Up to December 2007 its total accumulated electricity production was 16,062GWh and 10,314GWh when considering IGCC operation.


www.world-CTL2009.com
World CTL 2009
The World Coal-to-Liquids Conference
25-27 March 2009
Washington DC, USA
Renaissance Mayflower Hotel
World CTL Association

Latest technology advances in land seismic monitoring for carbon capture and storage

Seismic offers a robust solution to the problem of monitoring geological CO2 storage over time.

By Jean-Louis Gelot, Country Manager Russia, CGGVeritas

During the last 10 years, the seismic industry has jumped into the 4th dimension, time.

By repeating seismic surveys at various time intervals during the production of an oil and gas field and comparing these surveys, seismic is able to show the fluid movements and pressure changes in a reservoir, and undrained compartments can be more easily identified.

Time-lapse or 4D seismic is becoming part of the reservoir management toolkit and today most offshore wells are drilled with the support of 4D seismic images.

In carbon capture and storage, 4D seismic is also a key technique for the monitoring of the injection: how is the CO2 bubble expending laterally? Are there leakages laterally or through cracks in upper aquifers or up to the surface?

The following examples reveal various technologies that are operational for seismic monitoring of CCS in salt caverns, depleted oil and gas reservoirs or aquifers.

Figure 1 shows the seismic amplitude sections for 4 surveys (1994, 1999, 2001, 2002) over the offshore Norwegian Sleipner CO2 storage area. There, the extension of gas plume and cap rock integrity can be monitored with a high degree of precision and accuracy.

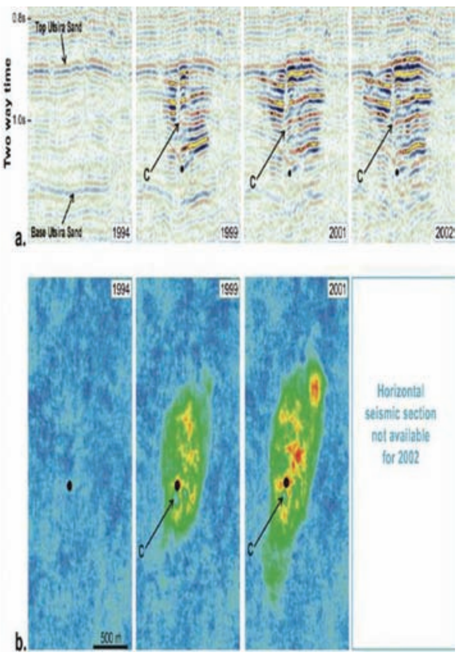


Figure 1: CO2 sequestration

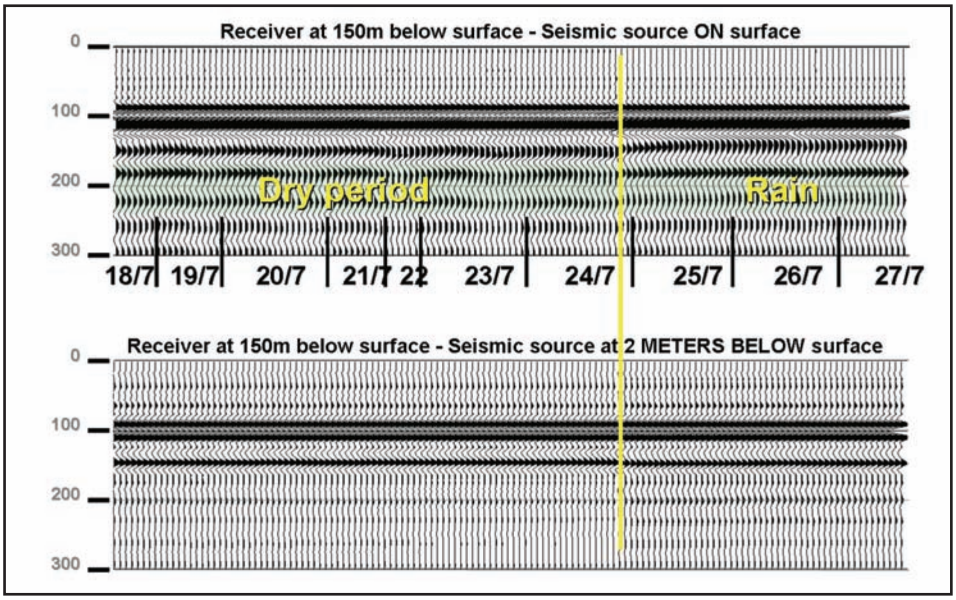


Figure 2 : repeatability test

Field applications of seismic monitoring are very wide and include: fracturing, natural depletion of oil and gas fields, injection of water, gas, CO2, underground gas storage, sequestration of CO2 and acid gases. The time scale is also very wide ranging from a few hours for fracturing to hundreds/thousands of years for sequestration.

The repeat cadence is also highly variable ranging from non-stop to lapse of a few years between surveys. In this article we will focus on some new technology developed for the seismic monitoring of onshore reservoirs. Other geophysical methods such as gravimetry and electromagnetic survey are also tested. However, they do not offer the spatial resolution of seismic.

Seismic monitoring techniques include active seismic (usually reflection seismic, just called seismic in this article) and passive seismic (microseismic). Seismic usually will monitor changes in fluids contacts and saturation and pressure within the reservoir itself or within other layers where fluids might have migrated. Passive seismic will monitor for example the expansion of fractures during a fracturing job, the preferred path of water in fractured carbonates, the reactivation of cracks and faults during gas or liquids injection and or withdrawal.

Active Seismic

The main challenge of 4D seismic is the repeatability. Seismic images from different surveys should be the same except for the producing reservoir or storage zone. The repeatability quality will depend on the:

• accuracy of sources and receivers location. Ideally locations should be the same. If this can be achieved on land, it is more difficult with marine streamers due to marine currents.

• changes in surface conditions: water temperature in marine seismic, weathered zone in land etc.

• geophysical instrumentation which might not be the same from one survey to the next: different source signal, radiation patterns, recording system.

Only sophisticated processing techniques can compensate partially the errors due to lack of repeatability. Ideally acquisition must be carried out with better repeatability

Land seismic has a lower quality due to noisier environments and changing weathered zone conditions during seasons. Figure 2 shows a simple test of repeatability over a nine day period. In both cases, the receiver is 150 meters deep. The seismic source is on the ground surface for the upper case and two meters deep for the lower. The impact

of the heavy rain on July 24th on the seismic response is very important when the seismic source is on the surface. It is much lower in the other case and a 4D signal for a deeper reservoir would be masked.

Usually, the most robust attribute to identify changes in the reservoir is the travel time within the reservoir. The monitoring might need measurements of travel time changes as low as 1/10 msec. 10 years of 4D technology development with French Institute of Petroleum and Gaz de France have led CGGVeritas to design a unique system based on buried sources and receivers. The system SEISMOVIE™ uses low energy (1Kw) piezo-electric vibrators (fig. 3) cemented in holes at 10cm intervals and hundreds of single or multicomponent geophones cemented at 10 to 30m depth. Therefore the impact of weathered zone becomes less and the geometry is fixed with perfect repeatability.

Figure 3: SEISMOVIE buried source

Seismic response change in an heavy oil reservoir in Canada under an EOR process of steam injection (SAGD) can be monitored daily (fig 4).

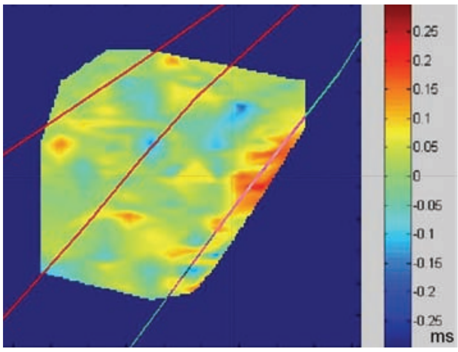


Figure 4: Monitoring SAGD heavy oil recovery

The seismic response was recorded continuously, with one new shot every 30 seconds, during only one month period. Every day, more than 2000 shots were stacked in order to get a reliable seismic image. The 30 images were compared. The 0.15 msec red anomaly located on the right pair of horizontal wells represents the change in travel time and is related to the steam front propagation.

Passive Seismic

Changes in subsurface pressure create micro-earthquakes. The magnitude of these events might be as low as -3 on the pseudo-Richter scale (fig 5). A -2 event corresponds to a crack of 0.3m² with a slip of 0.1mm (energy of 1 gram of dynamite). This is the domain of microseismicity.

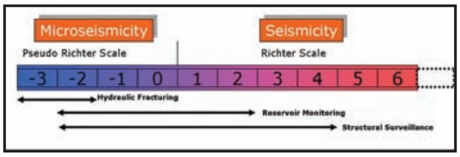


Figure 5: Microseismic events magnitude

The following example shows the application of microseismic during water injection in a carbonate reservoir. (fig 6)

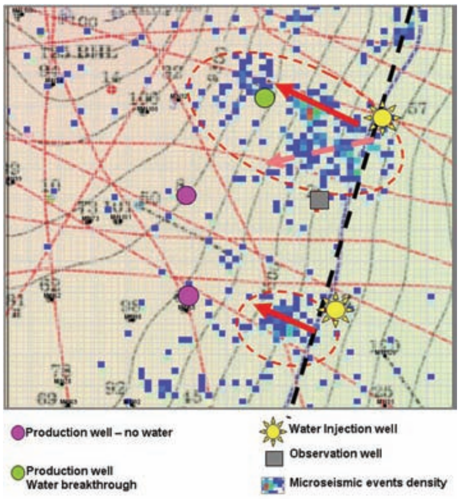


Figure 6: carbonate waterflood monitoring

From a single observation well, 2000 events were recorded during a 49 day period. They show a seismic corridor between the 2 northern injection and producing wells which are already producing water. Other producing wells are not wet yet but will be in the future as microcracks are likely to connect and communicate between them and injection wells.

The construction of a cavern in a salt formation for an underground gas storage requires a careful monitoring of the cap rock integrity (fig 7). 6822 microseismic events were recorded during a 2 year period.

They are associated to the salt dissolution process. At the beginning, events are located around the injection well. After 1 year,

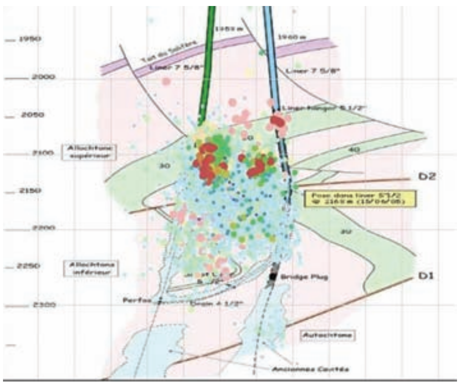


Figure 7: Salt cavern for underground gas storage

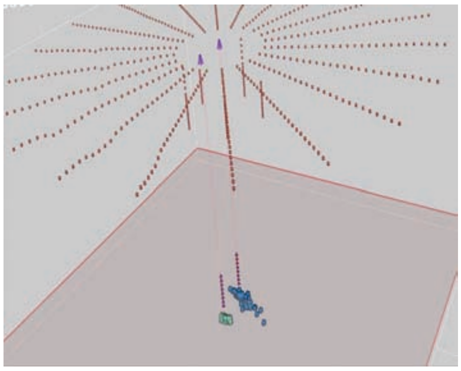


Figure 8: Fracturing monitoring

injection and salt solution production wells were inverted, a microseismic corridor was detected between the 2 wells, then some events were related to the reactivation of faults in the cap rock and well collapse.

Well productivity can be largely improved by fracturing the producing formation. Fracturing jobs are complex. New fractures must not reach surrounding aquifers; quantity of propant must be properly estimated. Real time recording of microseismic events will help to control the fracture growth during the few hours of the fracturing job.

Usually a few multicomponent re-

About the company

CGGVeritas says it has been pushing the limits of seismic for more than 70 years and has taken the leadership for the 4th dimension. CGGVeritas manufactures most of the industry equipment (SERCEL affiliate), acquires, processes and interprets data all over the world.

Jean-Louis Gelot, Country Manager Russia, CGGVeritas

VSFUSION, a joint venture with BAKER, builds upon the two companies' expertise in VSP processing services and enhances them using CGGVeritas expertise in surface and ocean-bottom cable seismic acquisition and processing.
www.vsfusion.com

The author would like to thank CGGVeritas LAND 4D division and MAGNITUDE, the Microseismic division of VSFUSION for their contribution.

Contact: jean-louis.gelot at cggveritas.com

ceivers are installed in an observation well located at less than 500m from the treated well. New real-time migration processing technology can be used with a few hundred surface receivers offering more flexibility as no observation well is required. Figure 8 shows the events of new fractures located by a radial geometry of the surface receivers.

Simultaneous active and passive seismic monitoring

With a permanent installed seismic monitoring system, processing techniques allow us to separate both the active and passive part. (fig 9) Then they are both processed and interpreted for their various objectives. Passive seismic data is acquired at no additional cost. Sources can be activated and new seismic data acquired on demand at specific phases of the project or for a few days every few months.

Planning a seismic monitoring project

Seismic monitoring projects will fail due to poor design. Their implementation must be carefully prepared, including:

- a feasibility study. All existing data (geology, geophysics, logs, production, etc.) are taken into account. Models are built, 4D seismic responses are estimated and an acquisition geometry is recommended.
- A small scale field pilot monitoring of no more than a few months is performed in order to validate modeled parameters and design the large scale industrial monitoring project. This step might be skipped when enough experience has been accumulated for similar conditions.
- Finally the full scale monitoring project is implemented.

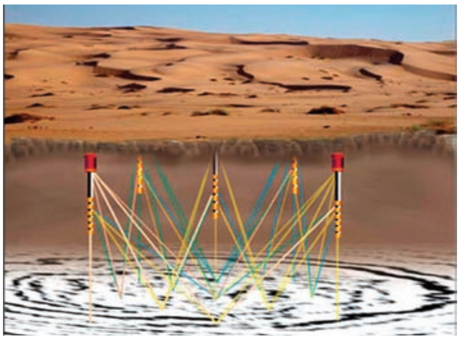


Figure 9: Permanent active and passive monitoring system

Transport and storage news

University of Texas engineer presents 'leak free' CO2 storage method

www.utexas.edu

Steven Bryant, engineering professor at The University of Texas at Austin, will present new research at the ninth annual International Conference on Greenhouse Gas Control Technologies that examines a storage method that could eliminate the risk of CO2 escaping via buoyancy.

The biggest risk associated with geologic carbon-dioxide sequestration is that the CO2, which is less dense than water, will escape from the storage formation through buoyancy. But Bryant, who directs the Geological CO2 Storage Research Project at The University of Texas at Austin, believes he and his team have a novel solution.

Instead of injecting the compressed CO2 directly into a deep underground formation, Bryant offers this alternative: drill wells in the deep, salt-water filled formation, pump out the salt water, dissolve the carbon dioxide into the salt water in a mixing tank at the surface, and then inject the CO2-laden water back into the same formation.

The CO2-laden water is much more dense than compressed CO2, and slightly denser than the original brine. Thus, it will have no tendency to rise toward the earth's surface, in contrast to compressed CO2, which is buoyant under typical storage conditions.

"Our idea is the equivalent of injecting carbonated water. This process has several advantages, but the most important is that it eliminates the risk of sequestered carbon dioxide escaping from the storage formation," Bryant says.

"Our work shows that this alternative process does cost more than the standard approach, but not prohibitively more. In essence, the incremental cost can be regarded as the price of risk reduction. This is an important consideration because all stakeholders will want the greatest assurance of secure storage for the lowest cost."

The talk was on Nov. 19 at the Omni Shoreham Hotel in Washington, D.C.

DNV coordinates unified approach to qualifying CO2 storage sites

www.dnv.com

DNV is now developing a standard methodology for characterising, selecting and qualifying proper sites for geological storage of CO2 – both offshore and onshore. This work is being carried out together with Norwegian authorities and more than 10 of the world's key oil, gas and coal players.

DNV has assembled key industry players and launched a joint industry project (JIP) to develop a standard methodology for characterising, selecting and qualifying proper sites – both offshore and onshore.

This will provide guidance on how to establish permanent, safe and cost-efficient storage of CO2. The JIP is open to new participants until the end of 2008.

The JIP has attracted wide interest from the authorities and oil, gas and coal-fired power industries. In addition to DNV, the partners so far are Gassnova SF (responsible for managing the Norwegian state's involvement in CCS activities), Gassco AS, IEA Greenhouse Gas R&D Programme, StatoilHydro, BP, Shell, Petrobras, RWE Dea, Schlumberger, Vattenfall AB, BG Group and DONG Energy.

"The key to a successful CO2 storage project is appropriate selection criteria and a proper understanding of how to manage risks and geological uncertainties," says DNV.

The current JIP focuses on establishing a transparent, predictable and cost-effective site selection approach by:

- providing guidance on the proper management of risks and geological uncertainties
- providing guidance in deploying concurrent best engineering practices
- providing open references to ensure the confidence and trust of stakeholders and the public
- simplifying demonstrations of compliance with legal and regulatory requirements in legislation, directives, conventions, etc, and harmonizing implementation
- explaining how to obtain emission reduction credits. The framework developed by the JIP should also provide a protocol with links to decision gates in field development projects to assist operators, authorities, verifiers and other stakeholders to:
- define the desired storage site attributes, including the data and analysis requirements necessary to provide confidence that the storage site has the desired attributes
- assign and rank risks (and uncertainties) based on the available (and missing) data
- define an environmentally friendly and economically acceptable site operation procedure, including compliance with standards, legislation and applicable directives
- define requirements for a Monitoring, Verification, Accounting & Reporting (MVAR) programme, including requirements for mitigation and remediation plans
- manage storage sites in accordance with a transparent, consistent and cost-effective process that meets the expectations of the authorities, stakeholders and general public.

The Value of Carbon Oxides

Commercially valuable chemical compounds, such as synthesis gas, formaldehyde, methanol and acetic acid can be synthesized from CO2. Their production can be an aid in the deferment of the expense of carbon capture and sequestration.

By Harrell Sellers, IBM Systems and Technology Group, and Michael Perrone, IBM Watson Research Center

Taking care of the environment will have its price

The second law of thermodynamics requires that any event that happens is accompanied by a "tax" or expense that must be paid in order for that event to occur.

This applies to everything including carbon capture and sequestration. There will be an expense associated with the reduction or elimination of carbon oxide emissions from any process.

Underground storage incurs transportation and monitoring expenses, deep sea storage is accompanied by transportation expenses, mineralization generates bulky, heavy carbonates to dispose of that sequester more oxygen and alkaline earth metals than carbon (calcium carbonate, limestone, is CaCO3 having as many calcium atoms as carbon and three times as much oxygen).

A strategy to offset much of the expense of carbon capture and sequestration is to use the carbon dioxide as a raw material to make chemical compounds that have down-stream commercial value.

Compounds with commercial value that can be synthesized from carbon dioxide include methanol, acetic acid, formic acid, C2 hydrocarbons, formaldehyde, synthesis gas (a mixture of carbon monoxide and hydrogen), fuel-hydrogen and others.

For example, the methanol institute indicates that the world-wide market for methanol is presently 47 million metric tons (1 metric ton is 2,204.62 lbs). The price of methanol was recently $0.33 per gallon (one metric ton methanol is 333 gallons). This is presently a 5.2 billion dollar per year commodity.

With the methanol demand from China rising and the use by Toshiba of methanol-driven fuel cell applications, including micro-methanol fuel cells, the market is expected to increase by at least a billion dollars per year for the next ten years.

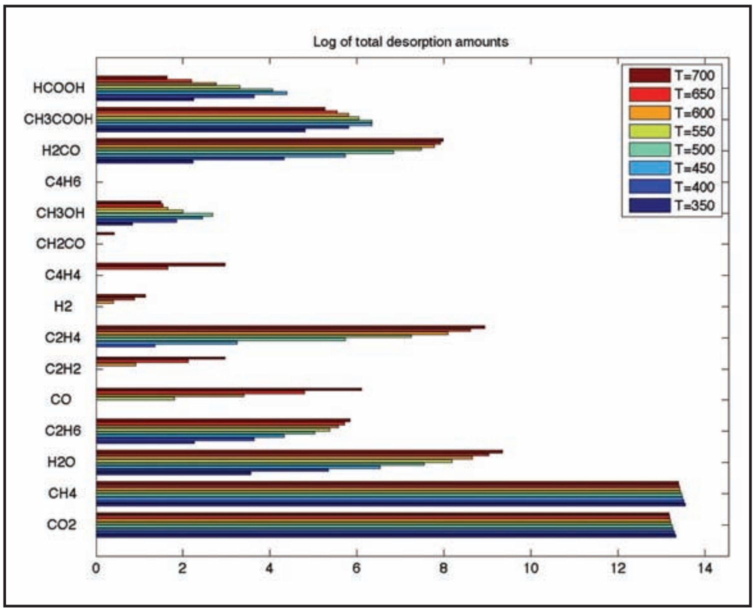


Figure 1- the results of reactor simulations employing palladium as the catalytic metal and a feed gas composed of carbon dioxide and methane

The annual world-wide acetic acid demand is about 14 billion pounds and increasing at about 3% per year. Formaldehyde production is 13 billion pounds per year.

Among the promising products of the conversion of CO2 is the production of polycarbonate plastics. Since 1996, when the demand for polycarbonate plastics was 2 billion lbs, the world-wide demand has grown 10% per year.

Polycarbonate plastics can be stored for future use, for example, replacing the extracted coal in coal mines.

The synthesis gas (syngas) is an extremely important raw material in the chemical industry. In industrial processes syngas is a precursor in the syntheses of ammonia, methanol, amino-resins, petrochemicals such as vinyl acetate and many others.

There is significant opportunity to, at least partially, abate the expense of the carbon oxide environmental issue by producing commercially valuable chemicals.

Feasibility: energetics and compound purification

Since carbon dioxide is a very stable gas-phase molecule, there is a tendency to believe that it is not suitable for use as an oxygen source or that it is difficult to make other compounds with it. This is not the case.

For example the reaction between carbon dioxide and methane to make graphite and water is thermodynamically favorable at room temperature ($\Delta G° = -29$ kJ/mol).

The challenge in this case is to find a catalyst that will accelerate the rate of the reaction so that the reaction will occur in a timely fashion.

The traditional method for producing synthesis gas, a mixture of CO and hydrogen is to react methane with water as the oxygen source. The process runs at around 700 °C over a Ni catalyst. This is considered to be the most economical way to produce hydrogen gas.

The reaction between methane with CO2 as the oxygen source is only slightly less thermodynamically favorable and, when incorporated as part of the carbon sequestration technology at coal-fired electrical generating stations, the process can utilize the waste heat that otherwise leaves the exhaust stack.

The reaction between CO2 and excess methane generates water, graphite (or soot) and hydrogen gas. This may well become a prominent method for obtaining fuel-hydrogen (hydrogen gas).

The commercially valuable products we discuss are either gases, such as synthesis gas (CO + H2), formaldehyde, and the C2 hydrocarbons or liquids at room temperature such as methanol, acetic acid, and others. Technology exists for the separation of gases. The Air Products corporation makes available gas separation technology.

The liquids, water, methanol, acetic acid, formic acid and others can be separated by distillation utilizing the waste heat from the coal-fired electrical generating station.

The sea-level boiling points of methanol, acetic acid and formic acid are: 64.7, 118.1, 100.8 °C, respectively. These temperatures are well below the stack temperature of an operating coal-fired electrical generating plant so there is more than enough waste heat for the distillation separation of these liquids from a mixture.

Proof of concept: the catalytic approach to CO2 conversion to commercially valuable products

We have developed a computational model of catalytic reactors for the conversion of carbon dioxide to compounds having down-stream commercial value.

The computational model describes the adsorption and desorption of chemical species and the reactions that take place on the surfaces of the catalysts. Results of reactor simulations agree well with results from experimental observations in the chemical literature.

An important result is that the catalytic surfaces do not lose efficacy due to buildup of carbon on the catalytic surface when CO2 is a component of the feed gas.

The modeling reveals that this is due to the fact that CO2 is a good scavenger of atomic carbon on the metal surface forming two molecules of carbon monoxide.

Previous experimental studies have noted this but were not able to elucidate the underlying reason.

Other important modeling results are the distribution of products from the reactor. Palladium was chosen as the catalytic metal in these simulations because it is a common catalytic metal and there are experimentally derived results with which we can compare.

However, palladium may not be the best catalytic metal for this application. Figure 1 shows the results of reactor simulations employing palladium as the catalytic metal and a feed gas composed of carbon dioxide and methane.

These results are relevant to the first thin slice (differential slice) of a plug-flow reactor and the amounts determined after one week of reactor operation. In this simulation the amounts of CO2 and CH4 in the feed gas are equal and the total pressure is 1 bar.

The operating temperature ranges from 350 to 700 K. The catalytic surface (palladium) does not have any intentionally adsorbed promoters or inhibitors.

Certainly the components of the feed gas are the most abundant chemical species evolving from the catalyst surface of the first differential slice and many differential slices are necessary for efficient conversion of CO2.

These results indicate that a number of compounds having down-stream commercial value can be synthesized from a feed gas the components of which are readily avail-

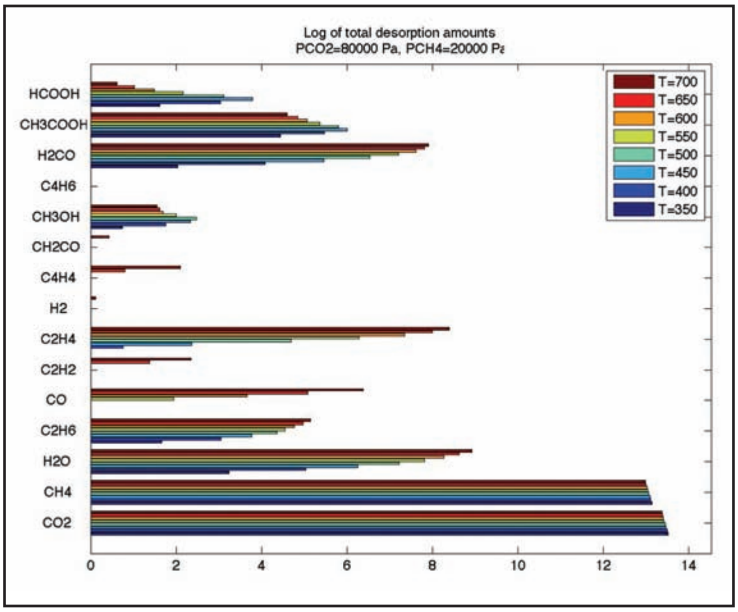


Figure 2 - products from reactor simulation (first differential slice) having feed gas composition of 80% CO2 and 20% CH4

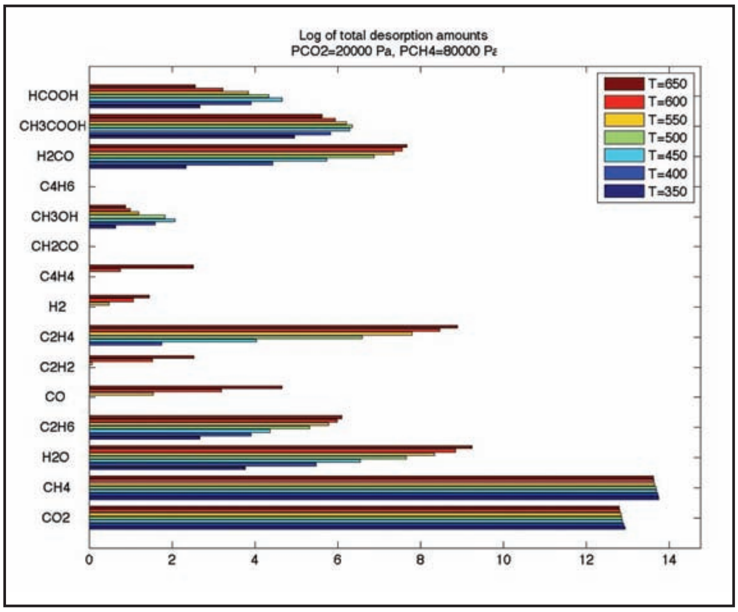


Figure 3 - products from reactor simulation (first differential slice) having feed gas composition of 20% CO2 and 80% CH4

able onsite of a coal-fired electrical generating station.

An important aspect of the modeling is that we are free to vary the conditions under which the reactor operates. These conditions are temperature, pressure, feed gas composition, catalyst composition and the presence or absence of co-adsorbed inhibitors and promoters.

We can vary these parameters and computationally optimize the reactor performance. In this discussion the ‘desorption amount’ is the total amount of a certain compound that has come off the catalyst surface (first differential slice) in a week of reactor run-time.

Figure 2 is a graph of the total desorption amounts at a total pressure of one bar and an 80% / 20% feed gas mixture of CO2 and methane.

Figure 3 shows the total desorption amounts with a 20% / 80% feed gas composition. Certainly there will be a point at which the compounds desorbing will be drastically different, for example with a 100% / 0% mixture, but, when compared to the data in Figure 1, the data in Figures 2 and 3 show the sensitivity of the desorption amounts to the relative feed gas composition.

There are changes in the desorption amounts with perhaps the most striking being the attenuation of the molecular hydrogen desorption and the C2 hydrocarbon evolution with elevated CO2 levels in the feed gas (Figure 2).

As one might expect the data in Figures 2 and 3 indicate increased molecular hydrogen evolution and increased total desorption of the C2 hydrocarbons when the feed gas is impoverished with respect to carbon dioxide.

The total desorption amounts of the oxygen-bearing species seem to be less sensitive although there are trends evident. Formic acid and water show a greater sensitivity to changes in partial pressures of the components in the feed gas than do formaldehyde, methanol, and acetic acid.

A small number of experiments exist that are suitable for comparison purposes with our simulation results. Acetic acid, methanol, formaldehyde, carbon monoxide and other compounds have been observed evolving from palladium surfaces.

Those experiments that employed CO2 as a component of the feed gas did not find a decrease in catalyst efficacy due to the buildup of atomic carbon on the catalyst surface. Our simulations identify the underlying reason for this as mentioned above.

Conclusions

Carbon dioxide is a valuable precursor to a number of commercially valuable compounds. Commercially valuable chemical compounds can be synthesized from CO2 to aid in the deferment of the expense of carbon capture and sequestration.

This can be facilitated by employing a catalytic approach. The state of the art is now such that reactor simulations from computational models of catalytic reactors can contribute significantly to the development of this technology.

References

“CO2 and CH4 chemistry over Pd: Results of Kinetic Simulations Relevant to Environmental Issues”, H. Sellers, R. Spiteri and M. Perrone, J. Phys. Chem., in press (accepted for publication); Methanol Institute; Wikipedia.

The authors

Michael Perrone

Harrel Sellers

RPS



What if...

you were thinking about **Carbon Capture and Storage**, but weren't certain of the best partner to work with?

Our energy and environmental experience is unique in being able to offer clients the immense breadth of support required to develop their CCS projects at each stage of the lifecycle.

Just some of our areas of expertise:

- Integrated Carbon Management Services
- Technical and commercial counsel from source to sink
- Guidance in legislative and market developments
- Planning and consenting advice
- Environmental and monitoring assistance

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

Contact: **T:** +44 (0) 1491 415 400 **Email:** ccs@rpsgroup.com **rpsgroup.com/energy**