
# Greenhouse News

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## GHGT-11 Update, by Siân Twinning, IEAGHG

**With 2012 now well underway, GHGT-11 now less than 9 months away, the call for papers is now closed and preparation for the conference is gaining momentum. IEAGHG and RITE would like to thank everyone who has submitted an abstract to the conference as once again we have broken previous abstract submission records having received 1220 abstracts over 14 themes. This proves that GHGT is *the* conference for both presenters and delegates. A panel of 160 experts has been compiled to review the abstracts and we have great expectations for a very high standard of presentations, both oral and poster, over the 4 day conference.**

GHGT-11 will accommodate 10 technical sessions with up to 7 parallel topics each – the problem for delegates will be which one to choose! The draft programme for the conference will be available online from the 25th June with delegates being able to access abstracts in order to assist with the choice of sessions to attend during the week.

Also planned are 9 keynotes focussing on current topics along with 6 panel sessions reflective of the conference theme 'CCS: ready to move forward' designed to get the discussion on hot topics flowing and add to the outcomes of the conference.

Early Bird registration will open on the 23rd April and all details will be on the conference website www.ghgt.info.

Following the success of the first exhibition at GHGT-10, plans are in place for an extensive exhibition to compliment the conference, giving delegates the opportunity to meet with and talk to leading providers and stakeholders in the CCS industry. If you are interested in exhibiting, please contact the Congress Management Office for GHGT-11 at: ghgt11@convention.co.jp

Schlumberger Carbon Services, Gassnova, Alstom, GCCSI, Statoil, ExxonMobil and China National Petroleum Corporation (CNPC) are the first to have committed their support to the conference, there are still a few opportunities for sponsorship of the conference left, for further information, please contact Toby Aiken: Toby.aiken@ieaghg.org

## In this issue

# Durban Delivers! by Tim Dixon, IEAGHG

**Durban was hot and exciting for many reasons, not least CCS was one of the issues to be potentially addressed and concluded there, as well as future global climate agreements.**

The mandate for activity on CCS was set by the Cancun Decision, which put in place a work programme for 2011 in terms of addressing the issues of concern within new Modalities and Procedures (i.e. rules) for the Clean Development Mechanism (CDM). This work programme consisted of submissions, then a technical and legal workshop of experts in Abu Dhabi in September, then the UNFCCC Secretariat produced draft modalities and procedures drawing upon these inputs. These were issued just two weeks before COP-17 at Durban, and their 20 pages of detail provided the basis for negotiations in Durban.

After over 32 hours of intense negotiations in Durban, on Friday 9th December, Parties (countries) agreed and adopted the Modalities and Procedures to allow CCS in the CDM. These Modalities and Procedures include provisions for participation requirements (including national regulations), site selection and characterisation, risk and safety assessment, monitoring, liabilities, financial provision, environmental and social impact assessments, responsibilities for long term non-permanence, and timing of the CDM-project end. They draw from existing examples of CCS regulation, and will ensure both a high level of environmental protection and are workable for projects.

*Photograph courtesy of IISD/Earth Negotiations Bulletin*


*Photograph courtesy of IISD/Earth Negotiations Bulletin*

A key concept is the 'net reversal of storage', where there are seepage emissions after project closure, or at a greater rate than injection. A key issue was the responsibility for net reversal of emissions in the long term (i.e. non-permanence). The solution agreed was to allow host countries to choose either to accept this obligation to replace the Certified Emission Reductions (CERs) for the leakage amount, or to transfer this obligation to the buyers of the CERs. In this case, a new type of CERs would be created, ones with responsibility. The issue of transboundary activities and a global CER reserve will be deferred to CMP 8. Thus, a historic day for CCS, following six years of hard work but with little progress. The draft Decision and the Modalities and Procedures as adopted can be found at http://unfccc.int/2860.php.

This is important official recognition by the UNFCCC of the role of CCS in mitigating global climate change in developing countries and sets an important precedent for the inclusion of CCS into other financing and technology support mechanisms. The Modalities and Procedures also establish the benchmark for managing CCS projects in developing countries.

In terms of the bigger picture, Ministerial level negotiations continued intensely, both informally and formally into the early hours of Sunday 11th, concluding at 6:22am! After several heart-

stopping moments, significant agreements were achieved. These are for a process to a binding agreement that includes all countries (developed and developing) taking on emissions targets, to be agreed by 2015 and implemented from 2020 (known as the Durban Platform for Enhanced Action). Importantly, it was also agreed, to avoid a gap, that a second commitment period for the Kyoto Protocol will be agreed by the end of 2012 which will continue 'project-based mechanisms' such as the CDM. Also, further details on the Green Climate Fund and the Technology Mechanism were agreed, which will help developing countries for both mitigation and adaptation activities.

Details of all are available on http://unfccc.int/2860.php.●

# IEAGHG and CCS in the UNFCCC, by Tim Dixon, IEAGHG

**Since 2005, the question of whether CCS should be eligible in the Kyoto Protocol's Clean Development Mechanism (CDM) has been debated and negotiated without much progress. The negotiations have been characterised by a few countries having strong views against CCS and some more having strong views for CCS, but the UNFCCC process needs consensus in order to progress. The main issues of concern have included: market effects, discrepancies between benefit and liability time periods, non-permanence; monitoring and verification; environmental impacts on ecosystems and climate (including a concept of "massive catastrophic release"), project boundaries and transboundary issues, liability, perverse outcomes, safety, and insurance and compensation for leakage.**

Over these years, IEAGHG has contributed information to this process. With input from IEAGHG workshops and studies and reports addressing CDM-specific issues of concern such as:

- 'Use of the CDM for CCS' (IEAGHG PH4/36, Dec 2004),
- 'ERM - CCS in the CDM' (IEAGHG 2007/TR2 Apr 2007),
- 'CCS in the CDM: Assessing Market Effects of Inclusion' (Report 2008/13, Nov 2008)

IEAGHG also contributed to the 'Expert's Report' formally titled 'Implications of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activities' (UNFCCC EB50 2009), and in numerous presentations at side-events at the UNFCCC SBSTA and CMP meetings.


*Abu Dhabi workshop. Courtesy K.Romanak. University of Texas*

Progress was then made at CMP6/COP16 (2010) in Cancun when it was agreed that CCS could be eligible for the CDM providing the range of issues of concern could be addressed in the modalities and procedures (ie the rules) for the CDM. A work programme was put in place consisting of submissions, a technical and legal workshop in Abu Dhabi in September 2011, and the production of draft modalities and procedures by the UNFCCC for negotiation at CMP7/COP17.

IEAGHG then used the leading international technical expertise within three of its international research network meetings in 2011 (Modelling, Monitoring, and Risk Assessment) to address and discuss the relevant issues.

These 'Cancun Decision issues' included the following examples;

*In the area of the Monitoring Network:* "Stringent monitoring plans shall be in place and be applied during and beyond the crediting period in order to reduce the risk to the environmental integrity of carbon dioxide capture and storage in geological formations;"

*In the area of the Modelling Network:* "Further consideration is required as regards the suitability of the use of modelling, taking into account the scientific uncertainties surrounding existing models, in meeting the stringency requirements of such monitoring plans;"

*Durban CCS negotiations. Courtesy H.Olson. University of Texas*

*In the area of the Risk Assessment Network:*

"A thorough risk and safety assessment using a methodology specified in the modalities and procedures, as well as a comprehensive socio-environmental impacts assessment, shall be undertaken;

The risk and safety assessment shall include, *inter alia*, the assessment of risk and proposal of mitigation actions related to emissions from injection points, emissions from above-ground and underground installations and reservoirs, seepage, lateral flows, migrating plumes, including carbon dioxide dissolved in aqueous medium migrating outside the project boundary, massive and catastrophic release of stored carbon dioxide, and impacts on human health and ecosystems, as well as an assessment of the consequences of such a release for the climate".

IEAGHG then ensured that the respective Networks' outcomes and conclusions on these and other issues were shared in the UNFCCC workshop in Abu Dhabi. This workshop brought CCS negotiators into contact with some 28 experts, including IEAGHG and several who are members of the IEAGHG Networks. Presentations and discussions included on monitoring, modelling, risk assessment, environmental impacts and groundwater protection, and transboundary issues. This was in an environment very conducive to good and open discussion among negotiators and experts on all the issues of concern. The impact of this workshop was significant, in that technical concerns appeared to reduce, and negotiators appeared to have more confidence in the science and the technologies. This workshop, along with the submissions, provide the UNFCCC with the material for them to draft the 20 pages of detail for the CCS-specific modalities and procedures. These formed the basis for negotiations in Durban.


*Durban CCSA Side-event. Courtesy H.Olson. University of Texas*

With input from IEAGHG, elements from this workshop were also repeated in a CCSA side event in Durban, the only 'official' side-event on CCS.

As a general observation, the level of informed negotiation on the technical issues was much enhanced at Durban, and valid concerns were able to be addressed appropriately in the modalities and procedures whilst still progressing negotiations.

The end result from CMP7/COP17 was that it was agreed that CCS can be included in the CDM, with a set of CCS-specific modalities and procedures to ensure environmental integrity whilst also being workable by projects. This is official recognition by the UNFCCC that CCS is a technology for use in developing countries, and sets an important precedent for the inclusion of CCS into other financial and support mechanisms. This is particularly relevant given the other achievements at Durban on future climate agreements and mechanisms.

More information is available on the Durban outcomes at http://unfccc.int/2860.php, and on the Abu Dhabi workshop at http://unfccc.int/methods_and_science/other_methodological_issues/items/6144.php.

We believe that science and technology better informing negotiations during 2011 greatly assisted in achieving inclusion of CCS in the CDM, and IEAGHG was pleased to play a role in this. IEAGHG was also pleased to work with GCCSI, CCSA, UK DECC, IEA and others in this process.

Reference: UNFCCC, Carbon dioxide capture and storage in geological formations as clean development mechanism project activities. FCCC/KP/CMP/2010/L.10

# 6th IEAGHG International CCS Summer School in China, by Ameena Camps, IEAGHG


*Tsinghui University Wall Gate*

**This year's IEAGHG International CCS Summer School will be hosted by Tsinghua University in Bejing, China from the 12th to the 18th of August. This 6th CCS Summer School follows on from the success of IEAGHG CCS Summer Schools in Kloster Seeon, Germany; Tigh-Na-Mara, Vancouver Island, Canada; Lorne, Australia; Longyearbyen, Svalbard, Norway and, Champaign, Illinois, USA last year.**

The IEAGHG CCS summer school series provides students and young professionals from diverse academic backgrounds from around the world with a broad understanding of the issues surrounding CCS, nurturing their potential and encouraging active participation in this expanding field. From its inception the alumni of the IEAGHG CCS Summer School has grown to an impressive 279, many of whom are now actively involved in the development of CCS.

The jam-packed Summer School lasts for one week, including presentations and discussions led by international experts in CCS; teaching the full chain of CCS, including capture technologies, storage, selection, capacity and modelling, wellbore integrity and transport; as well as issues such as regulations, health and safety, and public communication; to provide the students with a strong grounding in each area. Discussions go on throughout the week with peers and expert mentors, including during the student group work which challenges the students to bring together everything they are learning to try and develop solutions to interesting questions and, the field trip allows hands-on experience of important aspects of the CCS chain bringing together theory with practice.

We are delighted Tsinghua University will be hosting this year's CCS Summer School in China, and are very much looking forward to meeting all of our 2012 IEAGHG CCS Summer School students.

For more details on the CCS Summer School, visit our website on: http://www.ieaghg.org/index.php?/20120117278/summer-school-2012.html

# UK Energy Mix and the Future for CCS in the UK?

## by Toby Aiken, IEAGHG

**Last week, there was a debate in the UK Parliament on the cancellation of the proposed Longannet CCS plant, and what this means for the CCS industry in the UK. Firstly, don't be under any illusion that the matter is closed and that the decision on CCS in the UK is made; far from it. Having read the transcript of the debate, I was struck by the depth of argument on both sides, and the level of awareness of the place that CCS could take in our future energy mix.**

The point was raised that following the Longannet decision, what was to become of the £1 billion of funding that was ring-fenced for the project? Will this be subsumed into the other energy infrastructure development that is proceeding? Or would this funding be retained for a future project? The good news for proponents of CCS in the UK, is that it would appear that this level of funding remains, albeit in a state of limbo. The current fund may be redistributed, but it will be replaced if it is spent elsewhere. It appears that the government remains positive about CCS, just not at Longannet.

The debate addressed concerns over what place CCS has in the UK's energy mix, and concerns on our reliance on foreign gas supplies, as well as the view of some that all of our power should be generated by wind and tidal means. The advantages and drawbacks of these schemes was debated, and this moved the discussion onto the impact of CCS investment; on a local level there was a great deal of hope that the development of the Longannet site would generate employment and opportunities for local people to find employment, and learn new skills, and now these hopes have been scuppered. The juxtaposed views of proceeding and withholding were debated, with one side postulating that spending £1 billion of investment on a single project was unfeasible in the current economic climate, and the flip side of the argument suggesting that the UK stood to potentially lose out if investment was withheld, in a similar manner as that of the wind generation market some years ago. The UK is one of the windiest countries on the planet, but a lack of firm leadership and a lack of investment from either public or private funds resulted in the UK playing catch up, and as a result other countries pioneered the technology, and the UK now imports the vast majority of equipment and technology for our wind generation projects. To invest now in CCS could make the UK the world leaders of such technology, and the investment this would bring into the country would more than offset the initial cost. It is suggested that CCS could create up to 13,000 jobs in Scotland, and an additional 14,000 in the rest of the UK. By 2025 it is estimated that the sector could be worth more than £10 billion a year to the UK economy. It is conservatively estimated that the global market in technology alone is $10 billion, and this is a technology which the Institute of Mechanical Engineers are very clear about, stating that it is 'perfectly practical'.

***What will the future of CCS in the UK be?***
***Where will the investment land?***
***Will we be world leaders in this exciting new technology?***
***Or will we be left behind again?***

Only time will tell.

# IEAGHG Wellbore Integrity Network Summary Report,

## by Samantha Neades, IEAGHG

**IEAGHG currently runs five international research networks on $CO_2$ geological storage, namely Risk Assessment, Wellbore Integrity, Monitoring, Modelling and Social Research. These networks meet on an annual basis, bringing together experts from industry, research institutions and regulatory agencies to discuss technical issues in the context of CCS deployment.**

Maintaining the integrity of wellbores is widely accepted as a vital issue for $CO_2$ geological storage, due to the requirements for sites to securely store $CO_2$ over long timescales. In cases where storage sites are located in sedimentary basins with a history of oil and gas exploration/production, existing wellbores could represent the most likely leakage pathway from storage reservoirs to subsurface resources, environmental receptors or the atmosphere.

The purpose of this report was to describe the Wellbore Integrity Network, summarise past meetings, outline key findings and identify the current state of knowledge. The first network meeting was held in Houston, in 2005, and settings for the following year's meetings included two other locations in the US (Princeton and Santa Fe), and others in France, Canada and the Netherlands. The last meeting was held in 2011 in Perth, Australia and was a combined effort with the IEAGHG Modelling Network.

Some of the key findings throughout the past 6 years of Network operation included thoughts on the durability of cement, the importance of interfaces, geochemistry, the corrosion of steel, and cement formulations. Other topics looked at include the origin of wellbore problems, co-contaminants, materials in wellbores, permeability of wellbores and the factors governing wellbore performance.

The potential areas identified in the Wellbore Network meetings for future work include long-term integrity of wellbores, multiphase flow processes, frequency of different aspects of well failure, leak detection, geomechanics, self-healing occurrences and the fate of leaking fluids. Priority areas for further work were identified as providing standard definitions for wellbore integrity issues, looking at the mechanical properties of carbonated or degraded cements, further field sampling of materials that have been exposed to $CO_2$ at reservoir conditions, and the development of quantitative modelling and integration into risk assessments.

The network has provided a valuable international forum for discussion of wellbore integrity issues pertinent to $CO_2$ geological storage since its inception in 2005. Research over the last 6 years has greatly improved our understanding of processes linked to potential alteration and degradation of wellbore materials, especially cements. Much of the relevant research is included within presentations made at network meetings.

For more information on the Wellbore Integrity Network, please contact Samantha.Neades@ieaghg.org. A copy of the report can also be requested via Becky.Kemp@ieaghg.org, quoting report number 2012/01 (Wellbore Integrity Network Summary Report).

# Feasibility of Monitoring Techniques for Substances Mobilised by $CO_2$ Storage in Geological Formations,

## by Millie Basava-Reddi, IEAGHG

**Monitoring programmes for geological storage of $CO_2$ have been focussed on techniques for detecting leakage of $CO_2$. However, it has been recognised that $CO_2$ may mobilise other substances and can cause displacement of saline water. All of which could have an environmental impact in the event of leakage from the geological storage formation to potable water, the water column, soil and the atmosphere. Several regulatory regimes, including the guidelines for $CO_2$ storage in the London Protocol and OSPAR conventions, require that any effects of such substances mobilised by the $CO_2$ and any displaced saline water be included in the effects assessment and potentially monitored.**

IEAGHG commissioned CO2CRC, lead by CSIRO of Australia, to investigate this topic through a literature review and analysis of available monitoring techniques.

The effects that could be monitored were divided into physical and flow effects, effects on the near surface biosphere, geochemical effects, hydrocarbons/organics and captured gas compositions. The various analytes that can be monitored, and under what conditions, are summarised in table 1.

When looking at what potential technologies could be used, the approach taken in the study was to consider anything from soil surface to deep subsurface and includes physical, such as pressure monitoring and geophysical methods; chemical, such as in-situ methods like ion-selective electrode; biological, such as sampling and biosensors and other approaches to identify tools. The full list of potentially available technologies is large, the analysis of the methods can be found in the full report.

The different methods described in the report are likely to be applicable at different depths and may therefore serve different purposes, this is summarised in figure 1.
The key physical parameter measured in the subsurface is pressure as it covers an area much larger than that of the plume. Within the storage interval the main tools considered are geophysical, though some geochemical monitoring can happen at depth. Biological monitoring is currently restricted to the near surface.

| (a) Analytes | Levels |
|---|---|
| $CO_2$ | ppb to percent |
| pH | Relative change |
| Hydrocarbons | ppb to percent |
| Anions and cations | mMol |
| Tracers or contaminants | ppb to percent |
| Pressure/temperature | kPa/°C |
| Geophysical properties | Varies with methods employed |
| Biological properties | Varies with methods employed |

| (b) Considerations | Approximate Ranges |
|---|---|
| Depth | Soil surface to +3km depth |
| Temperature | 4°C to ~ 150°C |
| Aqueous environment | Yes |
| Power | 240v maximum |
| Data transmission | Wire or wireless |
| Lifetime | Short to long-term |
| Self-calibration | Drift rates |
| Redundant/robust | Environmental challenges |
| Relative cost | Indicative costs |

*Table 1 (a) Analytes and detection levels of substances that could be mobilised by $CO_2$ and (b) the conditions, limitations and ranges of deployment of such tools*

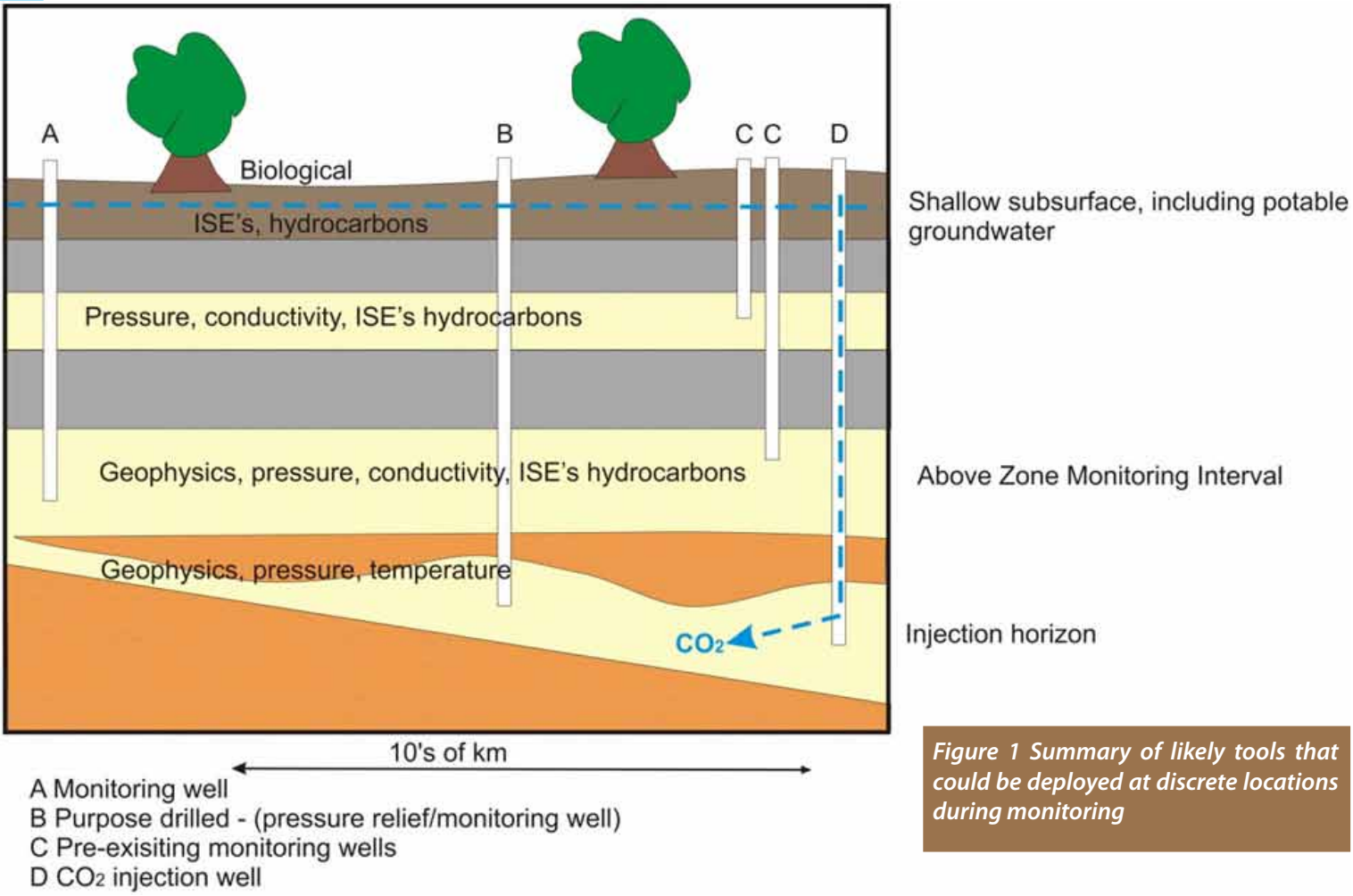



*Figure 1 Summary of likely tools that could be deployed at discrete locations during monitoring*

Many tools and new technologies identified have not yet been tested in the field. Tools that have been deployed at previous and current sites have not been deployed across all sites, for reasons including costs, inappropriateness for site conditions or mixed experience with tools or datasets generated. Many current CCS sites have relied strongly on equipment from the oil and gas sector, where tools are already appropriately rated for pressure and temperature, but not always tested in terms of longevity, ease of data retrieval or manipulating the extensive data generated.

In almost all cases, tools have been deployed to investigate the injection horizon, some shallow aquifers, soil-gas or atmosphere. Monitoring the formation directly overlying the injection horizon has been mostly limited to indirect measurements. There is a specific monitoring zone above the first sealing unit where pre-existing wells could be equipped with monitoring tools relatively cost effectively. More focus with selected tools sampling the zone directly overlying the injection horizon would provide detection of substances mobilised by a potential leak.

Improvements in several tools include miniaturisation, ruggedisation, lower costs, lower detection levels and increasing electronic communications to report the data obtained.

Tools can be split into different technology readiness levels, which might be a good way to flag tools that could be trialled alongside proven technologies during future storage operations.

Future goals identified are field testing at natural analogue sites and if possible, at $CO_2$ storage sites. The longevity, stability and operational costs need to be identified in order to quantify the true cost of M&V and also assess the relevance of different tools in different settings.

Any mechanism that provides low cost, large spatial coverage of a CCS site and assurance that $CO_2$ is safely stored is an important outcome, however significant testing and augmentation of many tools may be required before we achieve a full toolbox of techniques that can fit any geological storage site.

# Emissions of Substances Other Than $CO_2$ From Power Plants With CCS, by Mike Haines, Cofree Technology Ltd

**IEAGHG recently published report 2012-04 titled: 'Emissions of Substance Other than $CO_2$ from Power Plants with CCS'.**

The emissions of $CO_2$ from power plants equipped with $CO_2$ capture systems are reduced by upwards of 85% compared to equivalent plants without capture. However the full environmental impact of a plant fitted with $CO_2$ capture will depend also on what changes are induced in emissions of other substances in gaseous, liquid and solid forms. Furthermore, due to the increase in fuel and chemical consumption typical for a CCS plant, emissions due to the "upstream" and "downstream" processes and particularly those associated with increased fuel use, will also increase. Both these effects need to be taken into account if the technology is to be assessed on a life cycle basis. This study focuses only on the changes which are to be expected in the direct emissions, discharges and solid wastes of substances other than $CO_2$ from within the boundary of power plants fitted with $CO_2$ capture.

Approach

The study completed by TNO of The Netherlands provides an assessment covering the main technologies for $CO_2$ capture for coal and natural gas fired systems and includes the three main technology routes of post, pre and oxy combustion. Estimation of emissions and wastes is complex and accurate prediction of the amounts and composition of some categories of waste at the design stage is not possible. Because of this, TNO adopted two approaches in making their estimations;

- Literature review, which include both theoretical predictions and actual measurements from pilot, demonstration and commercial units.
- Modelling, using models to come up with an estimate of emissions and wastes.

The results would thus show the degree of variation and hence indicate areas of uncertainty and would also by comparison of the two approaches indicate where undue optimism or pessimism might prevail in the modeling methods being used for design of CCS plants. The modeling approach also relies on data extracted from literature, typically for estimating the removal efficiency of the unit operations employed in CCS. A clear distinction is made between these two approaches. The literature based approach is taking plant emission values as reported in literature. The modeling synthesises the values for each of the selected processes based on estimates of the performance of the various unit operations which make up the complete power plant.

A part of the literature based estimation was to make appropriate allowances for variations in baseline assumptions for the various plants in the references. This "harmonisation" methodology was applied to take account of variations in sulphur content of coals and the percentage capture of $CO_2$ where solvent based absorption processes were applied. This process thus attempts to ensure that "like for like" situations are being compared. All the raw and harmonised data from the literature was assembled in a database, which was used to make statistical estimations of the most likely changes in emissions and wastes and also the ranges which could be expected.

# $CO_2$ Capture Project Completes Phase One of $CO_2$ Impurities Study, by Scott Imbus, Storage Team Lead, Chevron

**The $CO_2$ Capture Project (CCP) has completed the first phase of a study into the impact of $CO_2$ impurities on geological storage of $CO_2$. Through reservoir simulation and laboratory experiments, the CCP is building an understanding of the potential impacts to storage containment as a result of impure $CO_2$ streams. The potential for cost savings by delivering less pure $CO_2$ streams to the storage reservoir are significant if it can be shown that these impurities do not adversely impact injectivity, conformance or containment. The study is being undertaken in conjunction with the Bureau for Economic Geology.**

The $CO_2$ streams captured from industrial emissions sources as part of Carbon Capture and Storage (CCS) projects are expected to contain various impurities depending on the process and extent of post-capture gas treatment. The potential for cost savings by delivering less pure $CO_2$ streams to the storage reservoir are substantial if, transportation notwithstanding, it can be shown that these impurities do not adversely impact injectivity, conformance or containment.

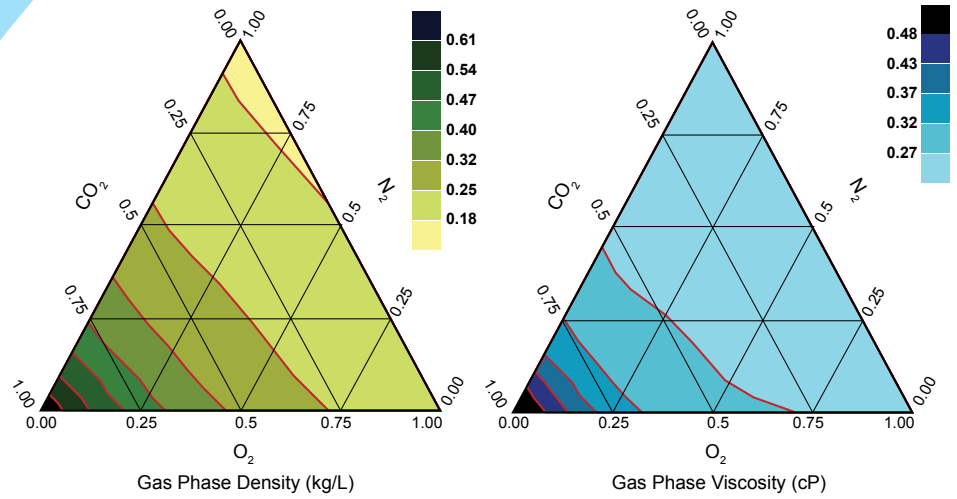



**FIG1: $CO_2$ impurities impact on mixed gas plume density and viscosity**

In all cases, viscosity and density of the mixtures are lower than that of pure $CO_2$ (only $SO_2$ would have the opposite impact). Figure 1 displays mixture density (left) and viscosity (right) properties expected at ~1.5 km (~5000 ft) deep U.S. Gulf Coast reservoir at 58ºC (135ºF) and 17 MPa (2500 psi)

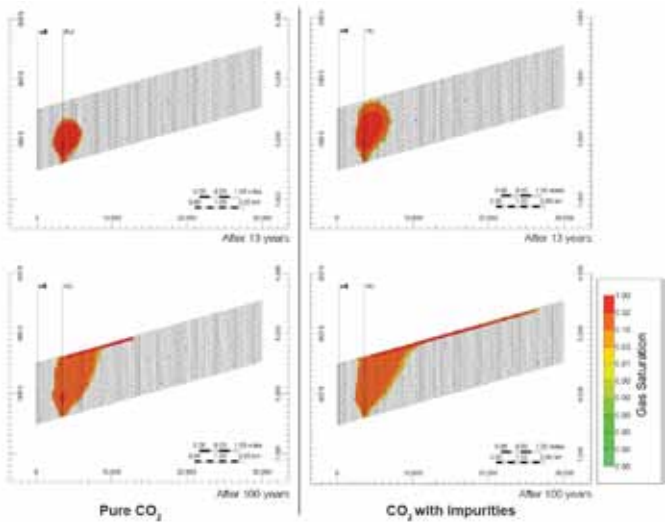
Non-compressible gases (e.g. $N_2$, $CH_4$, Ar) would be expected to impact flow properties and dynamics of the $CO_2$ stream whereas reactive gases (e.g. CO, SOx) may result in dissolution or precipitation of minerals which could impact reservoir or seal permeability and mechanical strength. The behavior of other gases (e.g. $H_2$, $O_2$) is likely to be complex in terms of plume dynamics and reactivity. Through reservoir simulation and laboratory experiments the CCP3 $CO_2$ Impurities Study aims to understand potential impacts and complications to storage containment as a result of variously impure $CO_2$ streams.

The project is divided into three phases:

1) *Reservoir Simulation* - Develop static reservoir models encompassing a range of heterogeneity. Simulate injection and plume migration of $CO_2$ streams with single and multiple non-compressible gas impurities with the following maximum concentrations (mol%): N2 (15), O2 (5), Ar (5) with $CH_4$ considered as an impurity 'exsolved' from brine. Plume behavior metrics (rate of vertical ascent, lateral extent and time for CO2 trapping) were examined for the low dip reservoir models at two depths: 1.5 and 3 km (~5000 and 10,000ft, called 'shallow' and 'deep' respectively).

**FIG 2: $CO_2$-stream impurities impact on lateral extent of $CO_2$ plume (shallow depth - axes in feet)**

Pure $CO_2$ is injected in the lower part of a sloping aquifer for 30 years at a rate of 0.74 million m³/day (26 MMSCFD) (top left). The $CO_2$ plume migrates upward, assuming homogeneous permeability in the field, until it reaches the top of the formation. Once the top is reached, the plume progresses up dip until the injected material is exhausted and entirely trapped through residual saturation and dissolution (chart bottom left). For the 81mol% $CO_2$ ($N_2$:15%; $O_2$: 2.1%; Ar, 1.7%) impurity case (top right) migration is faster because mixtures or non compressible gases always have a lower density (and thus greater buoyancy) and viscosity than pure $CO_2$. After 13 years of injection, the mixed-gas $CO_2$ has already reach the top of the formation whereas pure $CO_2$ has not (top right and left, respectively). At 100 years after start of injection, mixed-gas $CO_2$ (bottom right) has advanced further than pure $CO_2$ (bottom left) and ultimately mixed-gas $CO_2$ is trapped faster with no remaining mobile gas than pure $CO_2$.




2) *Static Experiments* - Conduct batch autoclave experiments using pure $CO_2$ and $CO_2$:$O_2$ (95:5mol%) with reaction modeling of other species SOx (0.15mol%), CO (2mol%), and $H_2$ (0.4mol%). Detailed pre- and post-reaction water chemistry and rock petrographic, petrophysical and chemical analyses will be used to document alteration for the $CO_2$ and $O_2$ and to 'history match' the experiments using batch geochemical numerical code.

3) Integration – Flow and geochemical results will be integrated into a framework to assess the impact of impurities on plume shape and evolution, $CO_2$ storage capacity, storage reservoir integrity and well injectivity.

## PHASE 1 RESULTS – RESERVOIR SIMULATION

*Flow Dynamics*

Because of the lack of accurate data on viscosity and density, a series of experiments was performed at selected pressures and temperatures and for selected multi-component gas mixtures to accurately determine their physical characteristics (PVT data) (Figure 1). In addition, a comprehensive literature audit helped in estimating aqueous solubility of the mixture components at various pressure, temperature, and salinity conditions.

Reservoir simulation revealed that impurities impact $CO_2$ plume shape (rate of vertical ascent and lateral extent) more markedly at shallow depths where the contrast in density and viscosity with pure $CO_2$ is at its largest (Figure 2). For example, a 4% mole fraction impurity in a binary system is sufficient to increase plume length in 'shallow' low-dip sloping layers by 25%, whereas a mole fraction of 9 to 15%, depending on the component, is needed to create the same impact in a 'deep' system.

In all cases, plume extent is greater when impurities are present although residual trapping (retention in pores) occurs more rapidly when this is the case. This is generally the case regardless of reservoir heterogeneity and complexity although heterogeneity tends to moderate the

impact of impurities on plume extent. The modeling also shows differential dissolution at the front and edges of the plume. In general, there is a trade-off between larger plume lateral extent due to the presence of impurities and decreased risk owing to faster trapping (pressure management).

*Implications for costs and reliability of CCS*

From these findings, the implications for the cost of capture and the reliability of long term geological storage could be significant. Long term reliability of $CO_2$ storage seems unlikely to be compromised by the presence of impurities in the $CO_2$ stream – indeed trapping timescales may be reduced in many cases, thereby decreasing risk to containment.

However, it seems that the presence of impurities can impact behavior of the $CO_2$ plume, implying that reservoir modelling for commercial projects needs to factor this in so that the presence of $CO_2$ in reservoirs can be better understood.

The later phases - static experiments and integration - are expected to be completed later this year. To receive updates on the project please register on the CCP website: **www.co2captureproject.com**

The $CO_2$ Capture Project (CCP) is a partnership of several major energy companies working to advance the technologies that will underpin the deployment of industrial-scale $CO_2$ capture and storage.

# Dutch CATO-programme well on track,

## by Marlies Verlinde, Utrecht Sustainability Institute

**Halfway through its planned duration, the Dutch CATO-2 research programme is making good progress toward realising its goals. This was the general observation of the Advisory Board in a recent meeting with CATO staff. In this meeting subprogramme leaders presented their work and received constructive feedback from the Advisory Board members. A brief overview.**

*CATO programme outline*

The CATO-2 programme is a demand driven R&D programme and focuses on facilitating and enabling integrated development. This means that government and industries set the priorities within the research programme: the 'problem owners' are leading. The core of the CATO-2 work (ca. 70% of the R&D effort) is built around 11 sites that each offer opportunities for applied research on CCS. In combination, they cover the entire CCS chain. The remainder of the resources will be spent on general applied research on cross cutting issues in support of these initiatives and on fundamental (application potential 5 to 10 years) research.

CATO-2 research is performed in five subprogamme lines. Dissemination and international cooperation are listed under programme coordination. Quite recently, the website **www.co2-cato.nl** went online to educate the general public about climate change, $CO_2$ and CCS.

The five subprogrammes are:

- $CO_2$ Capture
- Transport and CCS chain integration
- Subsurface storage of $CO_2$ and monitoring storage
- Regulation and safety
- Public perception

The biggest advantage of the CATO-programme is its broad scope, ranging from fundamental research to practical application. A demonstration project such as ROAD taps into all the knowledge that has been accumulated in CATO-1 and CATO-2. The presence of many different participants is valuable as well: each CATO-partner can play into his own strength and the combined result is more than the sum of the individual parts. In other words, the CATO-programme acts as a multiplier for several loose clusters across subprogrammes that work well together.

*Changing energy landscape in the Netherlands*

Jan Brouwer, the programme director, informed the Advisory Board members of some important changes in the past year. The Dutch cabinet's decision to discontinue onshore storage led to significant changes, where part of the programme was discontinued and other elements were added.

The strength of the programme is that it is demand-driven and flexible. For 2012, around 1 million euro has been reallocated for new research and 20 proposals were submitted to the Board for consideration. These proposals range from highly technical research to a proposal to build a bridge between the project's social science results and the day to day communication practice both nationally and locally.

*Managing interaction*

Since it is such a big programme, with over 400 participants, ensuring a good flow of information between workpackages is both essential and difficult. It is not always obvious which workpackage should take the lead in a specific topic. Several workpackages were advised by the Advisory Board to pay attention to this problem.

Another risk is that the CATO-community loses sight of similar research being carried out elsewhere. The Advisory Board also gave some

good suggestions to make use of international studies, for instance on the possible consequences for maritime habitats of storing carbon dioxide offshore.

Finally, from time to time it is necessary to look at the broader perspective and to think out of the box. The Advisory Board welcomed the initative for the 'Day at the Zoo' meeting in June 2011 where workpackage leaders got together to discuss the programme's blind spots. It is important to keep asking the question: is there anything we need to investigate that is not currently part of the programme? Societal questions, especially, can be overlooked when the programme focuses too much on the advancement of (fundamental) science.

More information: go to www.co2-cato.org (English) or www.co2-cato.nl (Dutch)

# News from the IEA Clean Coal Centre,

## by Debo Adams, IEACCC

**The IEA Clean Coal Centre is organising three workshops in the next three months. The 2nd Workshop on Cofiring Biomass with Coal will be held on 27th-28th March in Copenhagen, Denmark. There will be sessions on: the status of cofiring; operational experience; biomass fuels and processing; combustion/gasification; emissions and ash; and the future of cofiring. More information can be found at http://cofiring2.coalconferences.org.**

The **1st Workshop on Upgrading and Efficiency Improvements in Coal-fired Power plants** will be held on 19th-20th April in Melbourne, Australia. Concerns about the environmental impacts of power generation are leading to a rapid increase in the use of renewable energy sources such as wind and solar. However, the reality is that fossil fuels still provide the major share of power generation with coal alone accounting for 40% of the world's electricity, a situation that will not change in the near term. Uncertainties in future regulations and policies are resulting in utilities delaying commitments to build major new coal-fired plants. A comprehensive carbon management strategy needs to reduce emissions through changes in the fundamental energy supply structure whilst simultaneously improving the performance of the existing infrastructure. One option is to increase the thermal efficiency of existing coal-fired power plants which can achieve near-term and sustainable reductions in greenhouse gases, conventional pollutants, and coal use. The workshop will bring together the world's experts to identify and share expertise on:

- technical opportunities to improve the thermal efficiency of existing coal-fired plants
- barriers and challenges to these opportunities
- specific initiatives that can increase efficiency substantially.

The workshop website is http://upgrading.coalconferences.org

The **9th Workshop on Mercury Emissions from Coal** will be held on 22nd-23rd May in St Petersburg, Russia. The call for papers is open - papers relating to mercury emissions from coal combustion - measurement, monitoring, behaviour and control - are welcome. However, we are especially interested in papers relating to low cost options for mercury monitoring and control in developing countries and economies in transition. The workshop website is http://mec9.coalconferences.org.

All these events are popular, so early registration at the workshop websites is recommended.

Three reports have been published recently by the IEA CCC, and they are all available in PDF form from our website www.iea-coal.org. The reports are: Prospects for coal and clean coal technologies in Kazakhstan, CCC/192 by Morel Oprisan; CCS Challenges and opportunities for China, CCC/190 by Andrew Minchener; and Integrating intermittent renewable energy technologies with coal-fired power plant, CCC/189 by Steve Mills. Two are summarised here.

**CCS Challenges and opportunities for China, CCC/190 by Andrew Minchener**

CCS is a R&D priority for China, covering all capture options, transport and storage, together with a strong level of international co-operation. With regard to progression beyond research, there are some very significant large industrial scale trials that are being funded and implemented by various Chinese power generation, coal and oil companies. As well as part $CO_2$ capture from coal fired power plants, these include a full chain CCS trial on a coal to synthetic oil unit, which comprises part capture of the $CO_2$ vented from the coal gasifiers together with

*Main structure showing the $CO_2$ stripper (left) and absorber (right) on the sidestream from the Gaobeidian PC CHP plant in Beijing*

subsequent transport and storage in an aquifer. There are also various $CO_2$ enhanced oil recovery activities underway, reflecting China's interest in $CO_2$ utilisation. From a technical perspective, China is well positioned to move forward from these trials towards demonstrations of various $CO_2$ capture and utilisation/storage options. However, this will require the global CCS community to fully engage with China as to how these projects can be best financed and how (and to what level) the information arising can be disseminated to aid complementary projects elsewhere. While the primary focus will be on the power sector, the prospect of establishing CCS on clusters of coal to chemicals gasification units in certain regions of China offers some early, lower cost opportunities for demonstration.

Details, including likely $CO_2$ emission levels, on the modern, oxygen blown gasification units that are either operational or at the contracted design/construction stage in China are included within an extensive annex to this report. At the same time, China might benefit from further assistance with regard to characterisation of nationwide $CO_2$ storage opportunities and in establishing regulations to ensure that large-scale commercial initiatives do not compromise health, safety, and the environment.

Integrating intermittent renewable energy technologies with coal-fired power plant, CCC/189
by Steve Mills.

Historically, coal-fired power plants have faced competition from other forms of power generation such as nuclear, natural gas and oil. Like most coal-fired plants, many of these were designed to operate primarily on base load. However, competition is now increasingly coming from a range of renewable energy sources that include biomass, geothermal, hydro, solar, and wind. Unlike conventional power plants, several of these (particularly wind and solar power) are wholly dependent on prevailing weather patterns and consequently only generate electricity on an intermittent/variable basis. Changes in operating patterns mean that many existing coal-fired power plants no longer operate solely on base load, but are now subject to two-shifting or some other irregular form of operation. Switching a plant originally designed for base load can have implications in a number of areas that include plant economics, operation and performance. Environmental performance may also be impaired. This report discusses the growing level of intermittent renewable energy in the global power sector and examines the potential impact on associated coal-fired plants that have been obliged to change their mode of operation.

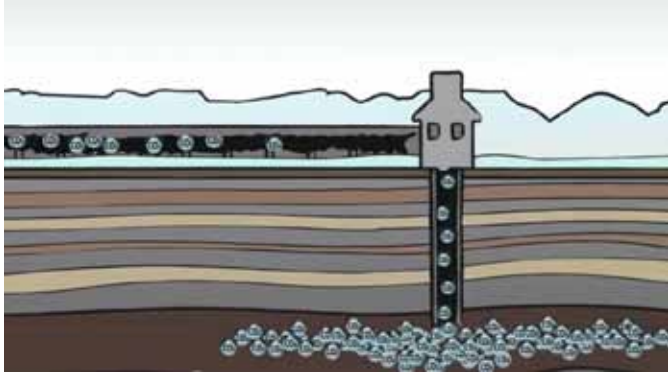
Visit www.iea-coal.org for more information about the work of the IEA Clean Coal Centre. ●

# UNIS and Kairostudio Introduce Dioxy and her friends

A new series of short animated videos brings to life the character Dioxy, who tells the story of $CO_2$ Capture and Storage. In early December 2011 you may have seen a trailer for "The Arctic Adventures of Dioxy".

Funded by Svalbard Environmental Protection Fund and realised by Kairòs Studio, the movie previewed on 19th January, at the Svalbard-seminaret 2012 and we are now pleased to announce from the 06.02.2012 the entire video will be available online as a series of 9 episodes 2 episodes will be released every Monday from the 6th to the 27th of February.

See all the videos on http://www.youtube.com/user/TheKairostudio



# Carbon Capture and Storage: Science, Technology, and Policy, MIT, Cambridge, Massachusetts, USA, July 23rd - 25th July 2012

This energy short course covers the science, technology, and policy aspects of CCS, focusing on the role of CCS in the climate change mitigation portfolio; the technical approaches to $CO_2$ capture; the science behind geologic storage, site selection, and risk evaluation; and the role of policy in establishing a market and business opportunities for CCS. For more information, visit the course website at:
http://web.mit.edu/professional/short-programs/courses/carbon_capture_storage.html

# IEAGHG Publish Updated Brochure – Capture, Transport and Storage of $CO_2$, by Toby Aiken, IEAGHG

Over the course of 2011, IEAGHG welcomed 2 undergraduate placements, Sarah Onions and Chris Evans. Part of the work they undertook while on placement with us was to review the public summary brochures IEAGHG have produced in the past and assess whether they answer the likely questions asked by members of the public on CCS.

The work they produced was integrated into the existing CCS brochures, updating where necessary, and adding content where appropriate. The resulting brochure now provides an outline introduction to CCS, including capture, transport and storage, and highlights further sources of information for those interested.

A PDF of the brochure will be available on the IEAGHG Website: www.ieaghg.org.

# Save the Date Symposium


**IEA-EOR**
**Enhanced Oil Recovery Research Program**
**33rd Annual Symposium, Regina, Saskatchewan, Canada**

**August 26th to 30th**

**Preliminary Program Outline**


*Sunday, August 26th*

Meeting of the Executive Committee
Executive Committee Dinner (Location TBD)

*Monday, August 27th: Symposium*

| | |
|---|---|
| 08:00 | Breakfast |
| 09:00 – 12:00 | Session 1: Theme A – Studies of Fluids and Interfaces in Porous Media |
| Noon – 13:00 | Lunch |
| 13:00 – 16:30 | Session 2: Theme B – Fundamental Research on Surfactants and Polymers |
| 18:30 – 21:00 | Drinks and Conference Dinner (TBD) |

*Tuesday, August 28th: Symposium*

| | |
|---|---|
| 08:00 | Breakfast |
| 09:00 – 12:00 | Session 3: Theme C – Thermal Recovery |
| Noon – 13:00 | Lunch |
| 13:00 – 15:00 | Session 4: Theme D – Development of Gas Flooding Technologies |
| 15:00 – 15:15 | Break |
| 15:15 – 17:30 | Session 5: Theme E – Reservoir Characterization |
| Free Evening | Participants provided with list of restaurants |

*Wednesday, August 29th: One Day Conference on Advances is CO2-EOR Research*

| | |
|---|---|
| 08:00 | Breakfast |
| 09:00 – 12:00 | Presentations/Papers |
| Noon – 13:00 | Lunch |
| 13:00 – 16:00 | Papers/Presentations |
| 18:00 | Closing dinner and reception (Innovation Place) |

*Thursday, August 30th:*

Tour of the SaskPower Boundary Dam Project, and the Cenovus Weyburn $CO_2$-EOR Facility (Tentative)
Transport and lunch provided.

SPOUSAL/PARTNER ACTIVITIES

*Monday, August 27th – Tentative*

AM: Visit to Saskatchewan Government House and RCMP Heritage Centre
Lunch provided at local restaurant (TBD)
(Tour bus transportation provided)

*Tuesday, August 29th – Tentative*

AM: Opportunity to Visit the Royal Saskatchewan Museum or MacKenzie Art Gallery
(Tour bus transportation provided)
Note: Possible additional option of visit to Moose Jaw's Temple Gardens Spa, and
Al Capone-era bootlegging tunnels. ●

# Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2012. Full details will be posted on the networks and meetings pages of our website at www.ieaghg.org.

If you have an event you would like to see listed here, please email the dates, information and details to: toby.aiken@ieaghg.org.

Please note that inclusion of events in this section is at the discretion of IEAGHG.

### 3rd Social Research Network
12th - 13th April 2012; Brisbane, Australia

### 7th $CO_2$GeoNet Open Forum and CGS Europe Workshop
17th - 19th April 2012; Venice, Italy

### 11th Annual Carbon Cature Utilisation and Sequestration Conference
30th April - 3rd May 2012; Pittsburgh, USA

### 4th Carbon Capture and Storage Summit
16th - 17th May 2012; Düsseldorf, Germany

### 2nd Joint Network Meeting
18th - 20th June 2012; Santa Fe, NM, USA

### Carbon Capture and Storage: Science, Technology and Policy
23rd - 25th July 2012; MIT, Cambridge, Massachusetts, USA

### $CO_2$Seq Symposium at the 34th Internat. Geo. Congress
5th - 10th August 2012; Brisbane, Australia

### IEA-EOR 33rd Annual Symposium
26th - 30th August 2012; Regina, Saskatchewan, Canada

### GHGT-11
18th - 22nd November 2012; Kyoto, Japan

**Greenhouse News**
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Greenhouse News is the newsletter of the IEA Greenhouse Gas R&D Programme (IEAGHG). IEAGHG is funded by member contributions from IEA member countries as well as other developed and developing countries and industrial organisations that have an interest in implementing technical options for GHG mitigation. A list of this membership can be found on the website. Greenhouse News provides information on worldwide developments in the field of GHG abatement and mitigation. It is published four times a year and is free of charge. Mailing address changes and requests for copies of this newsletter should be sent to the address below. For further information about IEAGHG and suggestions for articles, please email or write to the :

IEAGHG • Orchard Business Centre • Stoke Orchard • Cheltenham, Glos. GL52 7RZ • United Kingdom.
Tel: +44 (0) 1242 680753 • Fax: +44 (0) 1242 680758 • mail@ieaghg.org • www.ieaghg.org