

# Greenhouse News

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

The finalised programme for the conference can be found on the website at [www.ghgt.info](http://www.ghgt.info), with 296 oral presentations and over 700 posters there will be plenty for everyone.

*Kyoto International Conference Center GHGT-11 Venue*



Keynote speeches will cover such topics as 'Beyond Kyoto', Japanese storage potential, CCS in the steel industry, Natural gas and the impact on CCS, an update on the IEA CCS roadmap, CCS infrastructure.

Once again we have included 6 of the popular discussion panel sessions focusing on Costs, Weyburn Midale (including the leak allegation), Storage Capacity – What do we Know and What has Changed?, Making CCS Demonstrations Happen, Impacts of wide Scale Renewable Energy Adoption on CCS and Asian Development Banks' involvement in CCS in South East Asia.

At the end of the Early Bird registration offer

we had 721 delegates registered and are now well on course to exceed 1,200. The welcome reception and conference dinner give wonderful opportunities for catching up and networking.

With the GHGT-11 conference series going from strength to strength, this proves to be the conference to be seen at and the hottest CCS seats in town.

We would like to thank the sponsors of the conference; Statoil, Schlumberger Carbon Services, Hitachi, Mitsubishi Heavy Industries, Toshiba, US DOE, Global CCS Institute, Gassnova, Alstom, JX Nippon Oil & Energy Corporation, JGC, MOECO, INPEX, JAPEX and Chiyoda along with the supporters; China National Petroleum Corporation and ExxonMobil. Donations to the event have also been received from the Japan Iron & Steel Federation, the Federation of Electric Power Companies of Japan, Kawasaki, Petroleum Association of Japan and Sumitomo Chemical. ●

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# Aquistore: Global Beacon of Integrity, Excellence, by A.M. Young, PTRC

Aquistore is an independent research and monitoring project which intends to demonstrate that storing liquid carbon dioxide (CO<sub>2</sub>) in a saline sandstone formation is a safe, workable solution to reducing greenhouse gases.

Not only is Aquistore the first commercial-scale CO<sub>2</sub> storage project in Canada – it is also the first in the world to integrate CO<sub>2</sub> capture, transportation, and injection from a coal-fired electrical generating station. Furthermore, it will be the first project globally to demonstrate CO<sub>2</sub> capture from a coal fired power plant for storage into a deep geological formation. SaskPower's Boundary Dam Power Station will capture approximately 3,000 tonnes/day CO<sub>2</sub> using an amine-based system.

In late July, the Aquistore Team, along with SaskPower, hosted a day of tours for national and international visitors from local, provincial, and federal governments, as well as partner organizations from Korea, Japan, and the US, to celebrate the spuding of the injection and evaluation well. Aquistore is not only committed to developing international public awareness of carbon capture, utilisation and storage (CCUS), but also local community engagement. The local Member of Saskatchewan's Legislative Assembly,

the Mayor of the City of Estevan, as well as the Reeve (rural representative) of the local municipality were present in support of the project.

Treated to a day of presentations and tours, the 'ground-drilling' event began at SaskPower's Boundary Dam Power Station with presentations focused on the company's capture and sequestration program. The remainder of the day focused on Aquistore's leading edge research and technological installations. Guests had a chance to explore the project's world-leading measurement, monitoring and verification (MMV) program including a 3D and permanent seismic array, soil gas sampling, and ground-water monitoring. The visitors also had an opportunity to examine various cuttings and geological samples with the well-site geologist.

In addition to the international partners present, two geologists from South Africa's Council for Geoscience and the South African National Energy Development Institute (SANEDI) made the 15,711km trek. As a major player in the global coal markets, South Africa has a fledgling interest in carbon capture, utilisation and storage. Supportive of the development and co-operation of the global CCUS industry, the PTRC and Aquistore spent two weeks sharing their time and expertise with the



nascent South African industry.

A two-stage project, Aquistore is well into its first phase, focused on drilling two wells: an injection/evaluation well, and an observation well. The two Aquistore wells will eventually reach the pre-Cambrian basement, at a depth of 3.2 km. The injection and evaluation well is currently in the process of being drilled, to-date at a depth of 3103 meters. The MMV program and baseline surveying have been conducted and are in the process of being analysed. The second phase of the project is expected to begin in 2014, with the ultimate commercialisation of Aquistore. Of the CO<sub>2</sub> captured at Boundary Dam, initially up to 2,000 tonnes/day may be targeted for dedicated geologic storage.

Aquistore is yet another groundbreaking project for the PTRC, who bring to the table their decade of expertise and management of the IEAGHG Weyburn-Midale Monitoring & Storage Project. ●

## CCUS on the Canadian Prairie: Aquistore gets International and Hospitable, by A.M. Young, PTRC

As the Aquistore rig drills closer and closer to the pre-Cambrian bedrock, their dedicated team – and patient crew – have hosted over 150 site visitors since drilling began in early July.

Interest in Aquistore – a \$26.5M independent research project focused on storing liquid CO<sub>2</sub> in a saline sandstone formation as a safe, workable solution to reducing greenhouse gases – is growing by leaps and bounds. Visitors from Saskatchewan's provincial government ministries of the Economy and the Environment have attended in droves, along with summer students and aspiring geologists.

Federal government officials have come for one-, two-, three-day stays to explore Aquistore's cutting edge measurement, monitoring and verification (MMV) program.

Local dignitaries and landholders have visited, in a show of community support for the project which is contributing to international name recognition for their town of 15,000 people, and creating multi-generational job security.

Delegations have come from further abroad – the United Kingdom, Japan, South Africa, the United

States and Korea. – all interested in this first-in-the-world carbon storage program. Aquistore is the first commercial-scale CO<sub>2</sub> saline aquifer storage project in the country. In addition, it's a global first of its kind – the only project which is integrating CO<sub>2</sub> capture, transportation, and injection from a coal-fired electrical generating station; many jurisdictions globally have planned such projects, only Saskatchewan is this advanced in putting a project in place.

Aligned with the PTRC's staunch belief in growing public awareness and acceptance of CCUS, visitors have the chance to tour the rig, visit the future home of the observation well, engage with and examine geological samples with leading local geologists and examine state of the art well logging and monitoring equipment.

Drilling of both the injection/observation well and the monitoring well are expected to be complete in October 2012, after which tours will wind down in anticipation of the forthcoming exciting test injection. Prior to the commercialisation of Aquistore, this test injection of foodgrade CO<sub>2</sub> will be conducted, followed by a period of evaluation and observation. From community engagement to innovation – Aquistore is a first for Saskatchewan, a first for Canada, and a first for the world.●

## **IEAGHG Weyburn-Midale CO<sub>2</sub> Monitoring and Storage Project publishes Best Practices for the Validation of CO<sub>2</sub> Geological Storage, by Neil Wildgust, PTRC**

2012 marks the completion of the final phase of research in the IEAGHG Weyburn-Midale CO<sub>2</sub> Monitoring and Storage Project (WMP). Since 2000, over 22Mt of anthropogenic CO<sub>2</sub> has been injected and stored by the neighbouring CO<sub>2</sub>-EOR operations of Cenovus Energy and Apache Canada in southern Saskatchewan – providing WMP researchers with the opportunity to study the world's largest existing CO<sub>2</sub> geological storage site. Technical highlights from this decade of research have included the successful application of 3D time-lapse seismic surveys to map the distribution of CO<sub>2</sub> within the storage reservoir, characterisation of the reservoir and adjacent environment to allow comprehensive storage risk assessment, and development of new tools to aid in the assessment of wellbore integrity. WMP research also enabled the unequivocal disproof of leakage allegations made against the Weyburn site in January 2011.

One of the key deliverables from the final phase of research will be a Best Practice Manual, describing lessons learnt by the project team and giving technical guidance on site characterisation, predictive modelling, monitoring, history matching, wellbore integrity assessment, risk assessment and public outreach. Whilst collated from research undertaken in the context of CO<sub>2</sub>-EOR operations, the guidance offered will be relevant to other storage scenarios including deep saline formations. Entitled 'Best Practices for Validating CO<sub>2</sub> Geological Storage', the publication will be available through PTRC or Geoscience Publishing ([www.geosciencepublishing.ca](http://www.geosciencepublishing.ca)) from October 2012. For further details, please contact Neil Wildgust or Norm Sacuta through the PTRC website, [www.ptrc.ca](http://www.ptrc.ca).●

## **Masdar Institute of Science and Technology Established the Separation Technology Laboratory to Work on CO<sub>2</sub> Capture, by Mohammad Abu Zahra, Masdar**

As part of the overall efforts and vision of the United Arab Emirates in developing new clean sources of energy and to reduce the greenhouse gas emissions; Masdar Institute of Science and Technology, an independent, research-driven graduate-level university focused on advanced energy and sustainable technologies; established the separation technology laboratory to work on developing new technologies for CO<sub>2</sub> capture and removal. This research group is led by Dr. Mohammad Abu Zahra, the assistant professor in the chemical engineering program and consists of 10 graduate students and researchers focusing their research activities in the area of CO<sub>2</sub> post-combustion capture.

These activities include, among others: advanced solvent systems development and characterisation, solid-based sorbent development and evaluation, CCS life cycle analysis, solvent environmental impacts and degradation, process integration, development and simulation. These activities are divided between experimental lab work and simulation desk-based projects.

Recently Masdar institute (MI) commissioned the solvent development and characterisation facilities, which are used to evaluate novel amine-based blended solvents. These facilities with a budget exceeded \$350,000 are currently used for the MI - Massachusetts Institute of Technology (MIT) collaborative 2 year project between Prof. Alan Hatton of MIT and Dr Abu Zahra of MI on the 'Development of New Sorbents Systems for CO<sub>2</sub> Post-Combustion Capture. The focus of this project is on the selection, characterisation and testing of amine-based aqueous solutions for CO<sub>2</sub> capture applications.

Another STL major project is the 3 year project funded by Masdar Clean Power, which is part of the DOE funded project coordinated by RTI in North Carolina. This project is



Masdar's new lab facility

aiming to develop and demonstrate new solid-based sorbents for CO<sub>2</sub> post-combustion capture from natural gas combined cycle application.

Siemens AG has been the major industrial sponsor and partner with MI in the field of CO<sub>2</sub> post-combustion capture. The long term collaboration between Siemens and MI is aiming for the

development and evaluation of novel capture systems, CCS capacity building in UAE by providing the students with a fellowship program in the area of CCS and to support MI in establishing state-of-the-art lab facilities to be used for testing and developing new capture technologies. The first project between MI and Siemens on the CO<sub>2</sub> purification requirement and technologies was concluded in May 2012 and another two new projects started or will start later this year in the field of waste handling and advance solvent systems.

In addition, STL is running smaller projects and established international connections and collaborations with the University of Edinburgh, CSIRO and

the University of Sydney. With these international relations MI is aiming to build human capital and develop innovators of the future in the CO<sub>2</sub> capture field.

Established as an on-going collaboration with the Massachusetts Institute of Technology (MIT), MI integrates theory and practice to incubate a culture of innovation and entrepreneurship, working to develop the critical thinkers and leaders of tomorrow. With its world-class faculty and top tier students, the Institute is committed to finding solutions to the challenges of clean energy and climate change through education and research. ●

## CO<sub>2</sub> Capture at Gas Fired Power Plants,

by John Davison, IEAGHG

Gas-fired power generation currently accounts for around 20% of global electricity generation capacity and in the past twenty years it has been a popular choice for new plants, particularly in many developed countries, due to its high efficiency, low installed costs and good reliability and flexibility. Interest in natural gas fired power generation has increased recently because of the increasing availability of natural gas from shale and greater concerns about nuclear power in some countries.

A switch from coal to gas can help to reduce emissions from power generation substantially but it is not a CO<sub>2</sub>-free generation option. In the longer term it is likely that new gas fired power plants will be required to be built and operated with CCS to achieve deep reductions in emissions. Development of CCS has so far concentrated mainly on coal and relatively little information on the performance and costs of gas fired power plants with CCS has been published. IEAGHG has therefore commissioned Parsons Brinckerhoff to undertake a techno-economic study on natural gas combined cycle (NGCC) power plants with CCS.

The study assesses a reference NGCC plant without capture, and plants with post combustion capture based on two types of solvent; conventional non-proprietary MEA and proprietary higher efficiency solvent. A further case is assessed in which some of the cooled gas turbine exhaust gas is recycled to the turbine compressor inlet to reduce the volume of gas that is fed to the capture unit and to increase its CO<sub>2</sub> concentration.

The study shows that adding post combustion capture reduces the thermal efficiency of an NGCC plant by around 7-8 percentage points, increases the capital cost per kW by around 80-120% and increases the cost of base load electricity generation by around 30-40%.

The cost of CO<sub>2</sub> emission avoidance, i.e. the carbon emission cost required to give the same electricity cost from base load NGCC plants with and without CCS, is about €65/tonne in the lowest cost plant evaluated in this study (post combustion capture with proprietary solvent). The abatement cost compared to an alternative base line such as a coal fired plant without CCS may be lower mainly because the quantity of CO<sub>2</sub> emissions avoided would be substantially higher.

Recycling flue gas to the gas turbine compressor inlet could increase the thermal efficiency by up to 0.3 percentage points and reduce the cost of electricity by up to 8%.

NGCCs with CCS may be called upon to operate at annual capacity factors lower than base load because of the variability of electricity demand, the variability of renewable energy sources such as wind and solar and the relatively high fixed costs and poor flexibility of nuclear plants. NGCCs with lower annual capacity factors would have higher costs of CO<sub>2</sub> avoidance, for example reducing the capacity factor from 90% to 50% would increase the cost from 65 to 87 €/tonne of CO<sub>2</sub>.

The study also assesses two plants with pre-combustion capture, an integrated plant and a non-integrated plant which includes intermediate storage of hydrogen-rich fuel gas in underground salt caverns to smooth of the variability in demand for non-base load operation. The plants with pre-combustion capture, based on current technology, are in general not economically competitive with the plants with post combustion capture. However, earlier studies by IEAGHG have shown that for coal based plants, pre-combustion capture with hydrogen storage can be an attractive option for non-base load generation.●

## Operating Flexibility of Power Plants with CO<sub>2</sub> Capture by John Davison, IEAGHG

**Power plants with CCS will need to be able to operate flexibly to cope with the variability of electricity demand, increased use of variable renewable energy sources such as wind and solar and the relatively poor flexibility of some other low-CO<sub>2</sub> generation technologies such as nuclear.**

IEAGHG has recently published the report of a study undertaken by Foster Wheeler which reviews the operating flexibility of the current leading power generation technologies with CO<sub>2</sub> capture, namely pulverised coal and natural gas combined cycle plants with post combustion capture using solvent scrubbing, integrated coal gasification combined cycle (IGCC) plants with pre-combustion solvent scrubbing and pulverised coal oxy-combustion plants.

The study also assesses various techniques for improving operating flexibility, including:

- Turning down or turning off CO<sub>2</sub> capture
- Storage of post combustion capture solvent
- Storage of liquid oxygen
- Storage of hydrogen
- Storage of CO<sub>2</sub>

CO<sub>2</sub> capture may impose additional constraints on the flexible operation of power plants particularly with post combustion capture but there are techniques which could overcome the limitations identified in the study. Power plants with CO<sub>2</sub> capture may even be able to operate more flexibly than plants without capture using the techniques assessed in this study.

Turning down or turning off capture could increase the net power output by up to 27% for a pulverised coal fired plant and 16% for a natural gas combined cycle plant, to help to satisfy peak electricity demands. This may be an attractive technique for short periods, depending on the peak power price and CO<sub>2</sub> emission cost, but alternative techniques such as simple cycle gas turbines may be a lower cost option for peak load generation. Turning off capture would result in a substantial increase in CO<sub>2</sub> emissions and regulations would need to allow this, for example by averaging emission performance standards over a long period.

Storing CO<sub>2</sub>-rich solvent and regenerating it at a later time may be

attractive as a way of improving power plant start-up times and ramp rates and for increasing the net power output to satisfy short term peaks in power demand. However, the large quantity of solvent that would have to be stored would mean that operating at peak output for longer periods of time would not be realistic.

Liquid oxygen and air/nitrogen could be stored in oxy-combustion and IGCC plants to improve flexibility and increase net peak generation by 5-10%. From an economic perspective this is expected to be a relatively attractive option for short term peak power generation.

Hydrogen produced in IGCC plants with pre-combustion capture could be stored for example in underground salt caverns, which are commercially proven. This would enable the gasification and CCS equipment to operate at continuous full load and only the combined cycle plant would need to operate flexibly to cope with variable power demand. This would be a significant practical and economic advantage for non-base load power generation.●

## IEAGHG News Format and Focus, and Information Papers, by Toby Aiken, IEAGHG

For some time, IEAGHG have been supplementing this newsletter with a weekly news update that has been sent to Executive Committee members and a few other recipients. With some tweaks and developments, this weekly news update is now ready to be rolled out to a wider audience, and as such you may have already started to receive the weekly news update via email from either Becky Kemp or myself. If you would rather not receive this, please let us know by replying with an Unsubscribe message and we will remove you from the weekly news mailing list.

With this development comes a change in focus. At the Executive Committee meeting in Bergen, members were questioned as to their preferences for Greenhouse News, and how they wished it to continue. The overwhelming consensus was to continue much as it is, with an increased



IPs available on the IEAGHG website

focus on IEAGHG activities, member activities, and major CCS news items. Members are therefore invited (as always) to submit articles or subjects they would like to see in print to [toby.aiken@ieaghg.org](mailto:toby.aiken@ieaghg.org) and we will do our best to encompass them within the quarterly newsletter or weekly update where suitable.

With this focus for Greenhouse News, the question we then looked at was on what to focus the weekly news update. There are numerous daily and weekly newsletters which most people have access to that detail most of the CCS project news and developments, and to avoid simply repeating these to an audience who have already heard the stories, we are aiming to cover some different aspects in our weekly news

updates. The remit of IEAGHG is to evaluate technologies that have the potential to mitigate greenhouse gas emissions, and primarily this involves CCS however, there are other factors that can have an impact on CCS, and many of the stories that come under this heading are not as readily reported and hence IEAGHG have decided to focus their weekly news update on the following topics:

- Key Climate Change News,
- Global Climate Policy Developments,
- Low Carbon Technology Implementation,
- Key CCS Developments,
- Key CCS Technological Advances,
- IEAGHG Reports & Publications

Another new branch of IEAGHG's information dissemination is the concept of Information Papers (IP's). These are short summaries of topics that while not within the research remit of IEAGHG, could well be of interest to our membership, and readers of our news. These IP's are typically 1-4 page documents, on topics that could potentially have an impact or are related to CCS, but not necessarily within IEAGHG's sphere of influence.

Topics covered to date include:

- Air Conditioning Units and their impact on Climate Change,
- Direct Air Capture
- Renewable Energy Issues
- Public Acceptance of Wind Energy,
- Ocean Fertilisation

IP's are publicly available, and can be viewed and downloaded from the IEAGHG website, with the exception of a few that have an impact on the future work programme of IEAGHG, and these are restricted to Executive Committee members only. These are not available on our website.

If you have any ideas or topics that you feel could be written up as IP's, please let Toby Aiken know [toby.aiken@ieaghg.org](mailto:toby.aiken@ieaghg.org).

## 2<sup>nd</sup> IEAGHG Joint Network Meeting, by Ameena Camps, Tim Dixon, Samantha Neades & Millie Reddi, IEAGHG

The Joint Network Meeting co-ordinates all four of the geological storage networks, Risk Assessment, Monitoring, Modelling, and Wellbore Integrity and the Environmental Impacts of CO<sub>2</sub> Storage Workshop Series.

The 2<sup>nd</sup> IEAGHG Joint Storage Network meeting was held from the 19<sup>th</sup> to the 21<sup>st</sup> of June 2012 in Santa Fe, New Mexico, USA. It was hosted by Los Alamos National Laboratory and sponsored by Sandia National Laboratories, Los Alamos National Laboratory and Schlumberger Carbon Services. 68 delegates attended, representing 11 different countries.

The aims of the meeting were:

- to ensure the Networks are working in the most efficient way without duplication or gaps
- to identify cross-cutting issues and their consequences; requiring input from more than one Network
- to set the framework for the future direction of the Networks

The first day considered how far have we come, and included updates from the IEAGHG CO<sub>2</sub> Storage projects and lessons learnt from CO<sub>2</sub> storage projects, followed by breakout discussion sessions to consider lessons learnt.

In reviewing the progress made since the 1<sup>st</sup> Joint Network Meeting in 2008, the Networks reviewed developments in their own areas. The attendees also heard from real large-scale projects and how these are now achieving progress and success on cross-network issues previously identified. The regulatory environment is maturing, with fairly stringent regulations in place in many regions. The knowledge and techniques exists in the storage area so that there seem to be

no significant technical barriers to CO<sub>2</sub> meeting these requirements. Expertise from the networks has been able to be drawn upon for peer reviews of the CO2CRC Otway Project and US EPA Vulnerability Evaluation Framework, and in providing significant input to the UNFCCC Technical Workshop, Abu Dhabi 2011, which aided development of rules for CCS in the CDM.

The second day was highly discussion based and considered where do we go next? This included sessions to identify R & D knowledge gaps and reviewing the current networks to see how they can be used to meet the needs of the R & D and wider CCS community.

During breakout discussions each Network identified its areas for future focus, the priorities, and also ways of working with other Networks.

In conclusion, areas of common need identified were:

- Systematic iterative links between risk assessment, monitoring, verification, best practices
- Dealing with the consequences of uncertainty mitigation plans
- Defining criteria and thresholds for acceptable deviations from expected storage behaviour

And the final recommendations were:



Joint Network Meeting delegates, Santa Fe

- More Network to Network collaboration
- Virtual meetings on hot topics for rapid response on public issues
- Topic-based workshops requiring expertise from different networks, e.g. performance assessment, mitigation and remediation
- Risk Assessment Network to expand to Risk Management, including mitigation and remediation actions
- Steering Committees to be refreshed
- Further activities in between meetings
- More interaction with the Social Science Network

An overall conclusion that can be drawn from the meeting is that, with a maturing regulatory environment, the technical knowledge and methods now exist in the area of storage so that there

seem to be no significant technical barriers to projects meeting the requirements from the fairly stringent regulations in place in many regions. However there may be practical issues to be resolved with the emplacement and handling of technical regulations by the responsible authorities. The IEAGHG Research Networks have contributed to this move from research to application. Also, that the Research Networks are highly appreciated by their members who wish them all to continue.

A full report of the 2<sup>nd</sup> Joint Network Meeting will be issued by IEAGHG. All presentations will be available soon at: <http://ieaghg.org/index.php/20120223293/2nd-joint-network-meeting.html> ●

## The 3<sup>rd</sup> International Forum on Transportation of CO<sub>2</sub> by Pipeline by Prachi Singh, IEAGHG

Following the success of the previous conferences in 2010 and 2011, Tiratsoo Technical and Clarion together with the University of Newcastle upon Tyne organised third forum on CO<sub>2</sub> transport by pipeline on 20<sup>th</sup> - 21<sup>st</sup> June in Newcastle, UK. This international forum covered the issues from a number of viewpoints for CO<sub>2</sub> transportation: technical, regulatory, practical, and social.

Important issues for CO<sub>2</sub> pipeline transportation related to the effect of impurities on phase behaviour and pipeline hydraulics, pipeline fracture, corrosion and cracking were some of the main focuses of the presentations. Regarding the CCS pipeline network, the key message was that significant mitigation from alternative routing, valve positioning, modest impact and rollout cost should be considered. Consequence and risk analysis for CCS pipeline network should be performed at an early stage of the design process. Outcomes of various international CO<sub>2</sub> transportation projects like SARCO2 RFCS, CO2VIP, Cooltrans, CO2PipeTrans, Mattran were presented at this forum. IEAGHG gave presentations on different CO<sub>2</sub> compression and drying processes from various CO<sub>2</sub> capture technologies, which is based on an IEAGHG study: 'Rotating Equipment for Carbon Capture and Storage'. This forum provided IEAGHG with the opportunity to share the knowledge on CO<sub>2</sub> compression with the experts active in the field of CO<sub>2</sub> transportation. ●

# CO<sub>2</sub> Injection Experiments Within The EU

## Auli Niemi, Coordinator of the MUSTANG Project

The objective of the EU FP7 MUSTANG project is to provide methods, models and understanding for the characterisation of deep saline aquifers for storage of CO<sub>2</sub>. The large-scale integrating project led by Uppsala University has 19 institutions as active partners and additional 25 organisations contributing to the project via the Scientific, Industrial and Regulatory Advisory Board (SIRAB).

The project has three main components; a field component, including analysis of existing data from a number of locations in Europe as well as dedicated experiments in two sites; a laboratory analysis component and modeling/performance assessment component. A deep CO<sub>2</sub> injection experiment will take place in Heletz, Israel, with injection of supercritical CO<sub>2</sub> at a depth of 1600m. The objective of this scientifically motivated experiment is to get an improved understanding of in-situ values of two important trapping mechanisms, the residual and dissolution trapping, with a special interest to the sensitivity of the measurable quantities to characteristics in-situ. Additionally, a shallow CO<sub>2</sub> injection will be carried out at the Maquelone site, France, to cross-validate MMV technologies at shallow depth.

Analysis of existing field data from a number of different saline aquifer locations in Europe has been completed, with the aim of providing an understanding of the range of properties that can be encountered and how to account for them in predictive modelling. Identification of data gaps reveals a general lack of information on cap rocks. Development of field investigation technologies has a special focus on geo-electric and seismic monitoring, tracer techniques as well as well instrumentation for injection/monitoring and related sampling at depth. Model improvements have focused on improved models

for coupled THMC processes, for heterogeneous systems and for upscaling. The laboratory experiments will provide information on the rock properties' change when in contact with CO<sub>2</sub> or brine/CO<sub>2</sub> mixtures, both through laboratory experiments simulating in-situ conditions and through analyses of data from natural analogues.

The two CO<sub>2</sub> injection experiments have a key role in the project. At the Maguelone shallow (gas) injection site the MMV spread has now been fully instrumented and the capacity of the installations to detect and quantify the presence of gas was recently demonstrated during the recent nitrogen injection experiments. CO<sub>2</sub> injection will follow later in 2012.

At the Heletz deep CO<sub>2</sub> injection site both a push-pull and a dipole CO<sub>2</sub> injection experiment are planned, to be preceded by hydraulic and tracer tests for pre-test characterization. To enable the experiments, two new wells are being drilled in the saline part of the depleted oil reservoir, where the layer properties are relatively well understood due to a number of previous wells. The drilling of the first well (the injection well) was completed in May 2012, including core retrieval for various testing purposes. The drilling of the second well (monitoring well) is presently at 1,500 m depth and thereby near completion. Parallel, extensive work has included design of well instrumentation, preparation of the injection permit, detailed modeling and design of the experimental sequence and design of the facilities on the ground. In the coming months the pre-injection characterization will take place and the injection is presently planned for spring 2013.

More information about the project and the recent progress at [www.co2mustang.eu](http://www.co2mustang.eu)





# IEAGHG Environmental Assessment of CO<sub>2</sub> Storage Workshop, by Millie Reddi & Tim Dixon, IEAGHG<sup>2</sup>

*Delegates of Environmental Assessment Workshop*



**This workshop was the third workshop in the Environmental Impacts Workshop Series. It was hosted by Montana State University in Bozeman, Montana, over 17<sup>th</sup> - 19<sup>th</sup> July 2012, with sponsorship from MSU, Southern company and the Center for Advanced Energy Studies. The workshop was attended by 48 delegates from 12 countries.**

The main focus of this workshop was on controlled release projects. As such, it brought together for the first time most of the world's controlled release projects, ten in number. Several are recently operational, and so we were privileged to hear the early results. These include the world's first offshore sub-seabed sediment release project, QICS, in Scotland. This created the opportunity not just for sharing of results but for future sharing of facilities and techniques, opportunities which were taken advantage of during the meeting.

There were sessions on Environmental Impact Assessments and Regulations, Monitoring, overburden/mechanisms of migration from deep to shallow subsurface, leakage scenarios and communication of leakage.

In the Environmental Assessments session details were given by Shell on the Quest project and its recent approval. In the area of monitoring, great progress is being made. Firstly with the capabilities and new experiences offshore, the very realisable capability for large-area monitoring was shown, with the potential capability of leak detection, and work on offshore baselines also being ground-breaking. Exciting developments in onshore monitoring included the process-based technique, for assessing the source of CO<sub>2</sub> found in the near-subsurface, i.e. whether it is from leakage or biogenic sources, without the need for a baseline.

This was demonstrated and proven as a technique at the ZERT facility during the workshop.

Key points included:

- EIA regulations are not a barrier to projects
- There are now a good number of controlled release projects, providing

useful knowledge

- CO<sub>2</sub> release behaviour in the near-subsurface can be unpredictable
- Marine work – very good progress on monitoring and on baselines
- Electro-magnetic remote monitoring of brine appears very useful for 'early' leakage detection
- Environmental Assessments will be substantially different for offshore to onshore
- If leakage does occur it will be patchy and in small localised areas, not over a large area
- The Process-based technique is an example of monitoring moving in right direction – able to provide important information where there are no baselines. This technique uses ratios of gases present to determine source of CO<sub>2</sub>
- Need baselines for leak detection and impact assessment
- Indicator species are being identified, especially benthic and terrestrial plants
- Seasonality and timing can effect leakage impact
- Broader acceptance of near-surface monitoring than in 2008

Research needs or gaps identified included:

- Need for deep subsurface release experiment
- Understanding overburden processes
- More on brine intrusion – industrial analogues
- Bringing in new research communities
- Challenging to find small leakage spots
- Need more wide area monitoring techniques and prove: need for high spatial resolution
- Need to understand how analogues compare to CCS sites

The recommendations from attendees included:

- Keep up the good work!
- Consistency in terminology
- Data sharing in between projects, and engaging with other research communities
- Further meetings could be focussed on transport mechanisms through the overburden and surface expression
- Remediation – risk assessment network?
- Biological impacts
- Groundwater impacts
- Comparison of environments: systems assessment

The meeting concluded with a request from participants to become a full IEAGHG Network, called the "Environmental Research into CO<sub>2</sub> Storage Network". The Network should have the aim of a "A network to build and advance knowledge for environmental research of geological CO<sub>2</sub> storage", with the Objectives being to "Stimulate and nurture international collaboration and knowledge sharing to improve understanding for environmental research of CO<sub>2</sub> storage, and to Act as a source of technical information".

A report for the meeting will be available soon and the presentations can be found at: <http://ieaghg.org/index.php?/2012-environmental-impacts-of-co2-storage-workshop.html>

## 3<sup>rd</sup> IEAGHG International Oxyfuel Combustion Conference Announcement

IEAGHG in collaboration with CIUDEN is pleased to announce the 3<sup>rd</sup> International Oxyfuel Combustion Conference



Oxyfuel Combustion Conference 3

(OCC3), which will be held in Leon, Spain from 9<sup>th</sup> - 13<sup>th</sup> September 2013 and will include a visit to CIUDEN's Pilot Plant Facility.

### Diary Dates

1 <sup>st</sup> November 2012	Call for abstracts opens
1 <sup>st</sup> December 2012	Registration opens
25 <sup>th</sup> January 2013	Deadline for receipt of abstracts
17 <sup>th</sup> May 2013	Authors notified and draft programme on website
12 <sup>th</sup> June 2013	Early Bird registration closes
26 <sup>th</sup> June 2013	Final Programme available
9 <sup>th</sup> September 2013	Conference starts

Oxyfuel Combustion is ready for demonstration; this will be the focal point of discussion for OCC3. The conference will also present the lessons learnt in the development of oxy-CFB. Key results from Callide Oxyfuel Projects and other large scale demonstration pilot plants will be sharing their experience in the discussion on demonstration of oxyfuel combustion technology.

By keeping its tradition, this event shall provide a forum to continue to discuss the remaining issues relevant to the demonstration of oxyfuel combustion technologies and share what we have learnt from the experience of operating various oxyfuel pilot plants.

The main topics for discussion will be:

### Boiler and Burner Development

- Char combustion, devolatilisation kinetics, modeling
- Heat transfer experiments, modeling
- Ash slagging, fouling and deposition
- Fate of sulfur during oxyfuel combustion, modeling
- In furnace sulfur reduction concepts
- NO<sub>x</sub> emissions mechanisms, in furnace reduction control, modeling
- N<sub>2</sub>O emissions mechanisms (for oxy-CFB)
- Mercury and other trace elements
- Oxy-PC and Oxy-CFB Boiler design
- Air ingress management

### Oxygen Production

- Conventional Air Separation Unit
- Novel Oxygen Production and Membrane technology

### Novel Oxyfuel Processes

- Chemical Looping

### Combustion

- Oxyfuel + Steam type burner
- In-furnace flue gas recirculation type burner
- Oxyfuel cyclone boiler

### Flue Gas Processing

- Electrostatic Precipitator or Fabric Filter operation
- Water removal processes & moisture control techniques
- Halides removal processes
- SCR and FGD operation
- Alternative NO<sub>x</sub> and SO<sub>x</sub> removal processes
- Mercury removal processes

### CO<sub>2</sub> Processing Unit

- Process Integration
- CO<sub>2</sub> liquefaction processes
- CO<sub>2</sub> compressor and pump
- Vapor Liquid Equilibria Experimental results and modeling
- CO<sub>2</sub> membrane technology

### Process Control and Process Integration

- Process dynamics and control
- Process integration concept
- Burner and flue gas control management

### Regulatory, Permitting, Policy Development

- CO<sub>2</sub> Quality
- Permitting process, vent stream regulation, accidental release
- Legal framework development

### Large Scale Pilot and Demonstration Projects

- Current on-going projects and update
- Results of large scale burner testing
- New project announcement and update

The call for abstracts will open on the 1<sup>st</sup> November, full details for submission will be on the website. Please note, the submitted abstract should clearly demonstrate the scope of the proposed paper or poster. It should also contain enough information for the reviewers to make an informed decision.

For further information:

<http://www.ieaghg.org/index.php?/20120814317/3rd-oxyfuel-combustion-conference.html>

# Post Combustion Capture Conference 2 (PCCC2)

17<sup>th</sup>-19<sup>th</sup> Sept. 2013, Bergen, Norway, by Prachi Singh, IEAGHG

Following the success of PCCC1 in Abu Dhabi, 2011 and the preceding series of 12 International Post Combustion Capture Network meetings since 2000, IEAGHG is pleased to announce PCCC2 Conference to be held in Bergen, 2013. The first conference proved to be a very important gathering for post-combustion capture experts to share their knowledge, findings and expertise. PCCC2 aims to continue this forum to discuss the various issues related to post-combustion capture technology status and development. PCCC2 will provide an opportunity to encourage technology providers and developers to share their experiences and knowledge.



## Topics for PCCC2:

- Solvent Development
- Solvent Degradation
- Environmental Impact
- Process Integration
- Pilot Plant Evaluation
- Large Scale Demo Projects

## Conference Publication

Selected papers from PCCC2 will be published in a special edition of the International Journal of Greenhouse Gas Control

## Important Dates:

**Conference Date:** 17<sup>th</sup> - 19<sup>th</sup> Sept. 2013  
**Site Visit:** 20<sup>th</sup> Sept. 2013

## Technical Steering Committee:

- |                                   |                              |
|-----------------------------------|------------------------------|
| • Prof. G.T. Rochelle             | The University of Texas, USA |
| • Prof. Hallvard Svendsen         | NTNU, Norway                 |
| • Prof. Paitoon Tontiwachwuthikul | University of Regina, Canada |
| • Paul Feron                      | CSIRO, Australia             |
| • John Topper                     | IEAEPL                       |
| • Prachi Singh                    | IEAGHG R&D Programme         |

Venue: Hotel Grand Terminus

## Venue Address:

Zander Kaaes Gate 6, 5015 Bergen, Norway  
Tel. +47 55 21 25 00, Fax. 55 21 25 01  
E-mail: [booking@ght.no](mailto:booking@ght.no)  
Website: [www.grandterminus.no/en/](http://www.grandterminus.no/en/) ●

For more information contact: [prachi.singh@ieaghg.org](mailto:prachi.singh@ieaghg.org)

Or visit our website: [www.ieaghg.org](http://www.ieaghg.org)

Venue Information: Location: Bergen, Norway

## Outstanding Impact Factor for International Journal of Greenhouse Gas Control, by Clare Lehane, IJGGC Publisher, Elsevier

On June 28<sup>th</sup> Thomson Reuters released the latest Journal Citation Reports® for 2011 and the International Journal of Greenhouse Gas Control (IJGGC) achieved an impact factor of 5.111, an increase of 25% on the 2010 impact factor. Impact factors refer to a journal's average number of citations per article over a two year period and can be used as an indicator of how well a journal's papers are being cited by the community. IJGGC also ranks in the first quartile in each of the three subject categories that it is assigned to in the JCR (namely the categories Energy & Fuels, Engineering – Environmental and Meteorology & Atmospheric Science).

The increased impact factor is testament to the time and effort invested in the journal by the editors, reviewer and authors. All papers that are submitted to the journal are first checked by the editors to ensure that they fit the aims and scope of the journal and if so each paper is assigned a set of reviewers who work with the editor and (anonymously) with the author to ensure that the paper (if accepted and published) is clear, concise, accurate and of benefit to the community. Some of the top cited papers in the journal describe subjects including the US Department of Energy's Carbon Sequestration program, solid fuels in chemical-looping combustion and CO<sub>2</sub> capture by adsorption.

In the past year the aims and scope of the journal has been revisited to reflect the changes in the CCS environment since 2007 and to better indicate the research areas that the journal is interested in.

IJGGC has reached its 6<sup>th</sup> year of publication in 2012 and the excellent work of the editors, authors and reviewers has and will ensure a continued upward trajectory in terms of

publishing quality papers that help move CCS research forward.

As publisher for the journal, I would like to take this opportunity to thank everyone who has been involved in making the journal the success it is but especially the editor in chief John Gale and associate

editors Olav Bolland, Stefan Bachu, Ziqiu Xue and Jim Dooley.

Please do come visit our stand at the upcoming GHGT-11 conference in Kyoto to find out more about this great journal! ●

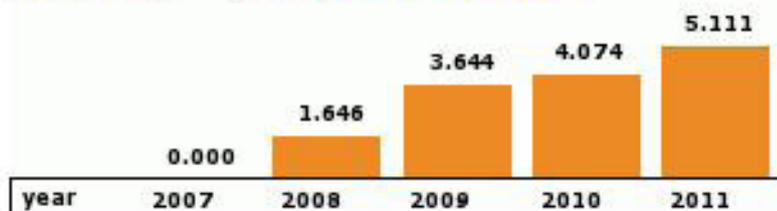
## International Journal of Greenhouse Gas Control

2010 Impact Factor

WAS  
4.074

2011 Impact Factor

NOW  
5.111



## International Journal of Greenhouse Gas Control – Best Reviewers, by John Gale, Editor in Chief, International Journal of Greenhouse Gas Control

I am extremely pleased to see that Elsevier have acknowledged the contribution of the reviewers to the journal since its inception by announcing a list of best reviewers from 2007 to 2011. The list of reviewers is given below.

Based on both the quality and quantity of the reviews, the final winners were evaluated and selected by the Editorial Team:

- Mohammad Abu Zahra
- Edward John Anthony
- Alfredo Battistelli
- Sally Benson
- Frank van Bergen
- Bert Van der Meer
- John Bradshaw
- Daniel Broseta
- Andreas Busch
- J. William Carey
- Andrew Cavanagh
- Mike Celia
- Andy Chadwick
- Baixian Chen
- Laxmi Chikatamarla
- John Davison
- Jonathan Ennis-King
- Mike Haines
- Hassan Hassanzadeh
- Chris Hawkes
- Howard Herzog
- Sam Holloway
- Susan Hovorka
- Raphael O. Idem
- Ronald W. Klusman
- Anna Korre
- Sam Krevor
- Hanne Kvamsdal
- Jean-Philippe Nicot
- Ernest Perkins
- Luis M Romeo
- Stanley Santos
- Herbert Todd Schaeff
- Ji Quan Shi
- Hamidreza Soltanzadeh
- Philip Henry Stauffer
- Muhammad Rehan Ur-Raza Naqvi
- Hajime Yamamoto

I would like to take this opportunity to personally thank not just these reviewers but everyone who has taken the time to reviewer's submitted papers for the journal. You are the previously unacknowledged beating heart of the journal, without your endeavours the journal would not have been the success it has become.

Also, I would like to note that four of these best reviewers were staff members at IEAGHG at the time, Mohammad, John, Mike and Stanley well done all of you.

*John Gale, Editor in Chief ●*

## CGS Europe CCS-awareness-raising workshop "CO<sub>2</sub> Capture and Storage – Regional Awareness Raising Workshop", Turkey, by Prachi Singh, IEAGHG

The 2<sup>nd</sup> CGS Europe CCS-awareness-raising workshop "CO<sub>2</sub> Capture and Storage – Regional Awareness Raising Workshop" took place in Ankara, Turkey, on 13<sup>th</sup> - 14<sup>th</sup> June 2012. It was held at the Middle East Technical University Cultural and Convention Centre. The participants were from the Turkish university, research institutes, government, industry and funding agencies. This workshop was the 4<sup>th</sup> event in the series related to CCS and CO<sub>2</sub> storage in the context of climate change organised in Turkey since 2006.

The two day workshop covered various topics related to CCS by international and Turkish experts. In this workshop insight on the future of CCS technology and various European CCS projects by Statoil and Czech Geological Survey was gained.

IEAGHG and Shell gave presentation on various CO<sub>2</sub> capture technologies in the power and industry sector. Key highlights and lessons learned from In Salah Gas CCS Project were shared by BP. Challenges and an opportunity related to CO<sub>2</sub>

sequestration in unconventional gas reservoirs was brought to focus by Penn State University. British Geological Survey presented an overview on the various monitoring techniques for CO<sub>2</sub> storage sites.

In this workshop UNDP Turkey presented the impact of climate change in Turkey. The Ministry of Environment and Urbanisation Turkey gave information on the regulations related to climate change in Turkey and its 'National Climate Change Strategy Action Plan 2010-2023'. It was mentioned that 2010 greenhouse gas emission in Turkey were majorly from the energy sector at 71% whereas 13% came from industrial processes. Turkey's activities on CO<sub>2</sub> storage are mainly in the CO<sub>2</sub>-EOR area. Projects such as the Bati Raman Field convey this. The Turkish Petroleum Corporation mentioned that they have found potential for CO<sub>2</sub> storage in TPAO fields. Turkey's largest petrochemical company, Tüpraş is also very actively involved in several energy efficiency improvement project in their oil refinery to reduce their greenhouse gas emission. Overall, there are several activities being undertaken in Turkey to combat climate change and this workshop was very useful to bring knowledge on CCS to various Turkish research organisations and companies. ●

## New ZEP Report - CCS Creating a Secure Environment for Investment in Europe

CCS will play a critical role in meeting EU and global climate targets cost-effectively – as confirmed by the EU Energy Roadmap, the IEA and almost every global emissions reduction scenario. The technology is on a critical delivery path as demonstration projects must take FID imminently so that commercial projects can operate from 2020 with widespread deployment from 2030. However, the long-term business case – which relies on a strong EUA price – is now seriously undermined.

In response to this challenge, top economists from all of ZEP's constituencies have produced a ground-breaking piece of work to resolve this blocker: a set of clear recommendations for action at EU and Member State level. While the ETS must remain the backbone of an overall incentive system, a wide variety of instruments were examined and recommended. These include, in the short-term, an EUA set-aside and capacity payments, amongst others, all the way to longer-term actions such as the need to extend the ETS cap from 2020 to 2030 and apply it across all sectors. All measures should complement the ETS – which should be adjusted to take them into account. Equally important is that while measures are divided into short, medium and long term, the earlier they are all adopted, the greater the impact on earlier stages due to anticipation effects.

You can download the report here: <http://www.zeroemissionsplatform.eu/library/publication/211-ccs-market-report.html> ●

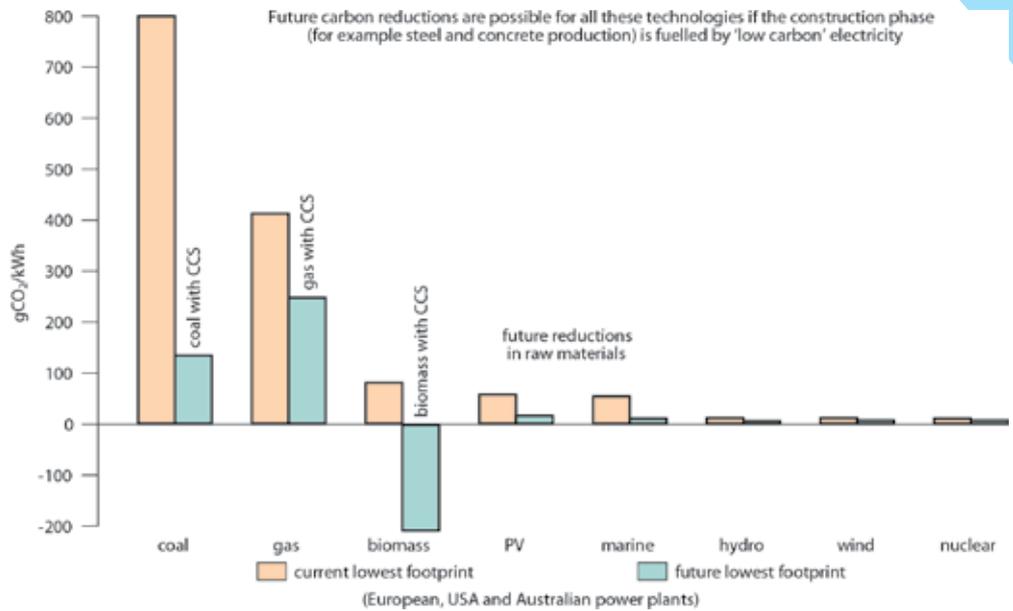


## News from the IEA Clean Coal Centre, by Debo Adams, IEACCC

Carbon mitigation technologies for emerging economies, CCC/198 is the latest report by Andrew Minchener for the IEA CCC. The report provides a review of the various options being pursued to reduce carbon intensities in five developing countries, namely Brazil, China, India, Indonesia and South Africa.

These are major emerging economies, all of which are vulnerable to adverse effects from climate change, and their governments have to balance economic, environmental and social priorities. All have large carbon footprints; however, in each case, they have made commitments to reduce carbon intensities over the period to 2030 and, in some cases, beyond. The approach to be adopted varies from country to country, depending on both technical and economic drivers. China, India, Indonesia and South Africa have fossil fuel based economies, in which in three cases coal is the dominant energy source while for the other (Indonesia) coal is an important and growing component of the energy mix. In all four countries, while the introduction of renewable energy and nuclear power is being addressed to varying degrees, establishing higher efficiency coal-fired power plants is seen as an important and near-term step in reducing carbon intensities. At the same time, China, Indonesia and South Africa have shown interest in CCS as a future mitigation option, with government policies identifying it as a key development priority. In contrast, in India, there is at present little interest in the technology. In the case of Brazil, the very different energy mix compared

to the other four countries means that there is little interest in CCS for the power sector since that is dominated by renewable energy use. However, while there is a lack of policies to support CCS, the government's limitations on CO<sub>2</sub> release from oil and gas extraction from the newly discovered deposits has provided a powerful driver for CCS related R&D. Following a description of the respective programmes, suggestions are made on the need to accelerate the development and deployment of CCS technologies, especially in those developing countries that have established policies to counter climate change and have recognised the potential importance of CCS as a carbon mitigation technique. It is also suggested that it is important to support the nearer-term but equally critical initiatives to establish higher efficiency and cleaner coal units for power and non-power applications. The 65 page report is available from the IEA CCC bookshop <http://bookshop.iea-coal.org.uk/site/uk/clean-coal-technology-research-reports> and an



executive summary is available for free download at <http://www.iea-coal.org/site/2010/publications-section/profiles>.

#### IEA CCC webinars

Each month an expert from the IEA Clean Coal Centre presents the findings of their latest report as a webinar. IEA CCC webinars usually take place on the second Wednesday of the month

at midday (UK time). They are free to view, but registration is required. They can also be viewed from the IEA CCC website at any time after the event. On 12<sup>th</sup> September Ian Barnes will present a webinar on Understanding pulverised coal, biomass and waste combustion. More information is available at <http://www.iea-coal.org/site/2010/news/webinars?LanguageId=0> ●

## IEAGHG Member Updates

### Canada, by Eddy Chui (NRCan) & Malcolm Wilson (PTRC)

#### New CCS activities that have been undertaken this month

Public announcement of the Aquistore project, July 24<sup>th</sup>, 2012. The tour of the drilling site included representatives from South Africa, Japan and South Korea. Drilling of the well is currently underway, with a depth (August 7<sup>th</sup>) of about 2700m with an estimated total depth of 3300m.

As part of Aquistore, the PTRC invited representatives from South Africa to visit Regina to gain some insight into the requirements for developing an Aquistore like project. The representatives were here for two weeks and were able to spend time at the site and gaining insight into regulation, project management, project design etc.

### KEPRI of KEPCO, by Ryu Chong Kul & Jang, Kyung-Ryong

#### New CCS activities that have been undertaken this month

1. Groundbreaking Ceremony of 10 MW Dry CO<sub>2</sub> capture plant at Hadong Power Plant (08/24), Scheduled completion date: March, 2013
2. Construction of 10 MW amine-based CO<sub>2</sub> capture plant at Boryung Power Plant (cont'd)
3. Steel structure & grating installation

#### New CCS research that has been undertaken this month

1. Completion of Detail Design for 10 MW Dry CO<sub>2</sub> capture plant
2. Project Review Meeting for the Construction of 10 MW Dry CO<sub>2</sub> capture plant
3. Survey on the Dry Sorbents called KEP-CO2P4
4. Performance evaluation of coal-fired power plant with CO<sub>2</sub> capture using KEPCO's proprietary solvent KoSol-4 ●

# 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](http://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](mailto:toby.aiken@ieaghg.org).

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

## National CCS Conference

21<sup>st</sup>- 23<sup>rd</sup> October 2012; Perth, Australia

## GHGT-11

18<sup>th</sup>- 22<sup>nd</sup> November 2012; Kyoto, Japan

## OCC3

9<sup>th</sup>- 13<sup>th</sup> September 2013; Leon, Spain

## PCC2

17<sup>th</sup>- 19<sup>th</sup> September 2013; Bergen, Norway



## Greenhouse News

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For further information about IEAGHG and suggestions for articles, please email or write to the :

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Greenhouse News is an environmentally responsible publication. All efforts were made to consider the efficient use of resources in the production of this newsletter.