Evaluating technology options to mitigate greenhouse gas emissions

annualreview2015

IEA GREENHOUSE GAS R&D PROGRAMME

International Energy Agency

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Further information on the IEA Greenhouse Gas R&D Programmes activities can be found at: www.ieaghg.org

General enquiries can be made via: mail@ieaghg.org

Specific enquiries regarding IEAGHG's activities and membership can be made by writing to the General Manager at:

General Manager
IEA Greenhouse Gas R&D Programme
Pure Offices, Cheltenham Office Park,
Hatherley Lane, Cheltenham
Gloucestershire
GL51 6SH
United Kingdom

Or by telephoning the office on:

+44 (0)1242 802911

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Inside Cover Image: PCCC3 Delegates Viewing the Wellhead at Aquistore

Front and Back Cover Images: St Catharine's College, location for the Social Research Network Meeting; San Francisco Bay Bridge, location of the Monitoring Network Meeting; IMechE London, location of the LCA in CCUS Workshop; East Cliff at West Bay, Bridgport, during the Combined Risk and Environmental Network Meeting; Harvey Site, one of the locations visited during the Summer School in Australia

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Australian Resources Research Centre, part of the Summer School field trip / Como Lake, Milan, location for the Solid Looping Network Meeting Dinner

Chairman's Message

This year culminated in the Paris Agreement, which a major step forward in dealing with climate change. There are several points to note in this agreement...

This is an agreement reached by 195 countries covering both the developed and developing world. This shows that countries across the globe are now taking the threat and impacts of global warming seriously enough to take action.

Another key point was the desire to reduce the temperature rise to below 2^0C. This desire has of course produced some to believe that fossil fuels will be phased out entirely by the end of the century. Truthfully this is not realistic, nor is it likely that electricity generation and energy use by heavy industry across the globe will be 100% renewable by 2030. Nevertheless, setting such a goal represents a significant global ambition that we must work hard to realise with a wider portfolio of energy technology options. The Intended Nationally Determined Contributions (INDC's) framed by Governments before COP21 of course do not get us to this target, they are more likely to get us to 2.7^0C. But they represent a significant starting point. I was very pleased to see, that in the Paris Agreement, there is a commitment to refresh these in 2018 and thereon update every 5 years. This is a positive move in that now we have a pathway forward to tackle the issue.

A third point of note is that the players at COP21 were not just national Governments. There were significant inputs before COP21 from the Pope, and leaders of the Islamic and Buddhist faith's amongst others calling for action on climate change. This was quite unprecedented. Cities house more than half the world's population; they consume 75% of the world's energy and emit 80% of all greenhouse gases.

The final point is the position of Carbon Capture and Storage (CCS) going forward. CCS was only included in a few of the INDC's submitted by Governments prior to COP21. This is not surprising as the actions in the INDC's cover only the period up to 2025 or 2030 and will include early, low cost actions like energy efficiency. However, at IEAGHG we believe the new below 2^0C target makes CCS even more relevant in the future. With many developing and developed countries still planning to use fossil fuels into the cusp of the next century, it is important that decisions now on how these plants will include CCS are taken – otherwise we lock in these emissions into the future. CCS is also crucial to decarbonise heavy industry. It is likely we will need negative emission options post 2030 and Bio-CCS is an key option.

Kelly Thambimuthu,
Chairman of the IEAGHG Executive Committee

Looking at the positives, the global deployment of CCS has ramped up this year with one year of operation under the belt for Sask Power's Boundary Dam CCS power plant in Canada. I will reiterate that no longer can anyone say CCS has not been demonstrated in the power sector. This coming year will see two more power sector CCS projects come on board. Industry has always led the deployment of CCS, with the first commercial CCS plant in Norway as early as 1996. Since then we have seen further industry projects, the latest being the Lula project in Brazil and the Quest project in Canada, with projects in Australia and the UAE to follow this year.

In summary, important developments this year, but the work to deliver the cuts in greenhouse gases is nevertheless just starting with a previously absent serious intent and pathway to tackle climate change only just delivered by our political masters at COP21.

K. V. Thambimuthu.

General Manager's Summary

This has been an interesting year for IEAGHG; there have been several activities that we have been involved in that have been of some significance to the greenhouse gas and CCS communities globally.

We organised our 3rd Post Combustion Capture Conference (PCCC3) in Saskatchewan, Canada. This was our most well attended event in the series so far. I would like to think that the quality of the technical programme was the big draw but I'm sure the back drop of Boundary Dam 3 (BD3) helped. After the conference, delegates had the chance to take the 'Grand CCS Tour'; the BD3 CCS demonstration, the Shand PC test facility, Aquistore saline injection project and of course passing the Weyburn oil field en-route there and back. This is quite a unique tour.

We co-operated this year with SaskPower not only for PCCC3 but also in the publication of a joint report on the learnings from the first year of operation of BD3. The report outlines the earlier assessments SaskPower conducted before they chose post combustion capture for BD3. It outlines their thinking on choosing fossil fuels with CCS over other options and sets out the regulatory backdrop to BD3 and the changes that have occurred since. More importantly, for new projects, it sets out the training needs for new operators; and of course what went well and what didn't go quite so well. Let's be honest, the combustion component was a rebuild of an oil boiler and the CCS section was a first of a kind build; any power plant engineer would have expected teething problems. I look forward to hearing more about this project in the coming years and would love to repeat this exercise on other projects being built.

With my role as Editor in Chief, I was involved in the preparation of the International Journal of Greenhouse Control (IJGGC) special issue commemorating 10 years since the publication of the IPCC SRCCS; a publication I was also involved in. This project involved a year or more of planning, over 100 authors quoting nearly 3000 references to get a collection of 17 peer reviewed papers covering areas in which significant progress on CCS R&D was published ahead of COP21. Members of our project team wrote or co-wrote 4 of these papers. The take away message was that the science and the technologies supporting CCS as a climate change mitigation tool have greatly advanced in the last 10 years, consolidating and expanding the knowledge base to more accurately assess and manage the potential impacts, risks and cost associated with large CCS projects. I must credit Elsevier for their support and for so generously giving the CCS community free access to these papers for the first three months of its publication.

This all contributed to COP21, where in conjunction with The University of Texas, CCSA and CO2GeoNet we organised the largest official side event on CCS at any COP to date. Some 200 delegates attended the event which is quite astonishing. It shows that there is a growing interest in CCS in the COP community. Of course we used the BD3 report, and the IJGGC special issue as examples of the progress that CCS has made to those delegates that attended. In addition we managed to do our routine work: 7 technical reports and 3 technical reviews were published, 5 international research network meetings were organised as well as PCCC3. We also launched a webinar series that show cases the work we do, which has proved very successful.

For IEAGHG, two staff departed for new adventures; Prachi Singh and Samantha Neades. We wish them well in their new careers.

John Gale,
General Manager, IEAGHG

All Change at the IEA in Paris and the ETN is Renamed

This year has seen changes at the IEA in Paris which have impacted on the Energy Technology Network (ETN) of which we are a part.

Members of the IEA ETN at the first joint meeting at the IEA this year

The former Chief Economist at the International Energy Agency (IEA) Faith Birol, became the new Chief Executive, replacing Maria van Der Hoeven. Another change was that Kamel Ben Naceur was appointed as Director for Sustainability, Technology and Outlooks. Many may remember Kamel for his earlier time at the IEA, or at Schlumberger or in his role as Minister for Energy in Tunisia. His new Directorate combines the former Directorate on policies and technology (flagship publication ETP), and the one dedicated to WEO. Jean Francois Gagné will act as Division Head for ETP; WEO. The New Chief Economist will be Laszlo Varro. So all change at the top of the IEA.

The IEA plans to strengthen its role and become a global (not only OECD) voice on energy. A central theme will also be enhancing engagement with major emerging economies (e.g. Mexico, Chile) and rolling out the Non-OECD association process (China, Indonesia and Thailand have come on board using the process). Collaboration with other multilateral agencies will be strengthened, such as the CTCN and IRENA. Overall, technology and innovation will receive stronger support and play a more prominent role. The IEA plans to play a role in the Mission Innovation programme launched at COP21 through its Technology Collaboration Programme (Formerly the Energy Technology Network).

One of the new Chief Executives initiatives was to host a meeting of all the Implementing Agreements of the Energy Technology Network in Paris in late September. Almost all the 38 current members of the ETN attended, including ourselves, and all were given the opportunity to voice our views on how we can strength our linkages to the IEA and in turn the IEA can benefit from the work the network does. Subsequent to the meeting, the network was renamed the Technology Collaboration Programme, and externally groups like ourselves become Technology Collaboration Programmes or TCPs for short.

We welcome the changes at IEA of course and hope they lead to new opportunities for collaboration for ourselves.

Membership of the Programme dropped this year, mostly due to two factors; the low oil price and reducing interest on CCS in Central Europe. Our turnover last year was down on previous years at £1.8 million but our expenditure split was the same at previous years; mostly on the technical studies and staff.

IEAGHG International Research Network Activities 2015

10th Monitoring Network Meeting,

Tim Dixon, IEAGHG

We were very pleased to hold our 10th Monitoring Network meeting at Lawrence Berkeley National Laboratory in California on 10th - 12th June. The venue provided great views over the San Francisco bay area, which complemented the technical programme of presentations and discussions inside.

Attendees of the meeting

The 45 presentations and 17 posters covered a range of topics, with sessions on cost-effective monitoring of large projects, permit requirements, induced seismicity, shallow monitoring, geophysical monitoring and CO_2 relationships, pressure monitoring applications, monitoring tools for shallow, surface and deep monitoring, update on projects, and post-closure monitoring. As well as the new results and developments, new at this meeting was a group-work exercise created by Sue Hovorka of The University of Texas. This involved the groups designing monitoring plans for fictional but realistic storage sites, and then these being actually tested with leakage scenarios. The groups were able to apply what they had learnt in the meeting as well as their own expertise, and I'm pleased to say that all the monitoring plans 'caught' the various leakage scenarios!

Also, of particular note, were the international research collaborations being created around the Aquistore storage site in Saskatchewan and around the Carbon Management Canada (CMC) controlled release in overburden being developed in Alberta. The Aquistore project has just started injecting CO_2 captured from the Boundary Dam coal power station into a deep saline formation, some 7,000 tonnes injected so far. The Petroleum Technology Research Centre (PTRC) has monitoring research collaborations with 26 organisations from 7 countries at this 'field laboratory', and the first monitoring data was shared at this meeting from downhole pressure, seismic, and pulsed-neutron logging measurements.

The overall conclusions of the meeting included identifying the value of pressure based monitoring for assessing reservoir behaviour and in the overburden for leak detection, the potential in fibre-optic distributed acoustic sensing (DAS) and permanent sources, the benefits of good engagement with regulators, the importance of geomechanical analysis using the monitoring data, and the feasibility of offshore monitoring for leak detection and quantification.

Overall, a meeting packed with new developments in all aspects of monitoring CO_2 storage, shared and discussed by this group of leading international experts. Monitoring continues to make great advances.

The report of the meeting is available as IEAGHG Report 2015-07: "Monitoring Network Meeting".

5th Social Research Network Meeting,

Samantha Neades, IEAGHG

This year saw the 5th and most recent meeting of the IEAGHG Social Research Network (SRN) which was held in Cambridge, UK. The meeting was kindly hosted by the University of Cambridge at the beautiful St Catharine's College, and sponsored by the UK CCS Research Centre.

This one day meeting on Monday 6th July 2015 included captivating talks from all aspects of the topic of social research and science in relation to CCS and energy technologies. The meeting – 'Energy Transformations and the Role of Social Sciences' – started with a dinner in the Senior Combination Room at St Catharine's, where attendees were addressed by Lord R. Oxburgh, member of the House of Lords and also President of the Carbon Capture and Storage Association (CCSA), who gave a brief welcome talk on energy transitions and the importance of CCS.

St. Catharine's College; the Venue for the 5th SRN

Sessions at this year's SRN meeting – the 5th in the series – included an in-depth look into social science and the energy domain across the UK and Europe; recent research findings from the Asia Pacific region; risk and perceptions of CCS (and other energy technologies); and an insight into the history of energy transformations. Over 26 delegates attended the meeting, from 6 different countries.

Attendees of the meeting

Delegates were treated to a spectacular meeting dinner on the Monday evening, held at the prestigious Trinity Hall, where discussions from the day flowed into the dinner, allowing for yet more fruitful conversations to take place around the recent developments and importance of social research in CCS.

6th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting, Jasmin Kemper, IEAGHG

The 6th High Temperature Solid Looping Cycles Network Meeting took place from 1st to 2nd of September 2015 at the Department of Energy, Politecnico di Milano, in Italy. The 72 attendees from 19 countries enjoyed a two day programme with 45 presentations, a site visit to research facilities at Politecnico di Milano and "La Dolce Vita" during the conference dinner with a stunning view over Lake Como. The meeting was jointly organised by Politecnico di Milano and IEAGHG.

The first day of the meeting started with a brief welcome from the organisers Matteo Romano (Politecnico di Milano) and Jasmin Kemper (IEAGHG). Giovanni Lozza, Dean of the School of Industrial and Information Engineering at Politecnico di Milano, gave a short speech about the history of the department and the importance to move new technologies through to industrial commercialisation, so that they become state-of-the-art. Afterwards, Carlos Abanades (INCAR-CSIS) brought everyone up-to-date on the progress in calcium looping post-combustion technologies, before the agenda went on to provide the latest advances in calcium and chemical looping pilot plant testing, solid carrier fundamentals and process integration.

Lake Como, location for the meeting dinner

The day finished off with a gala dinner at the restaurant La Terrazza in Cernobbio, located at Lake Como, one of the most beautiful lakes in Europe. Delegates were able to taste fine regional Italian food and wine, while enjoying a breath-taking view and sunset over the lake from the panoramic terrace.

After this truly enjoyable evening, everyone gathered again on the next morning to listen to Tobias Mattisson's (Chalmers University) review on the progress in chemical looping technologies, analogous to Carlos' presentation on the day before. The programme then got deeper into calcium and chemical looping processes again, including e.g. the utilisation of biomass as a fuel, techno-economics of a large-scale packed bed reactor for chemical looping, or the application of calcium looping in cement plants. The last two parallel sessions in the afternoon subsequently covered heat integration approaches, process modelling and sorption enhanced reforming technologies. Before delegates set off for the lab visits, the meeting formally closed with a discussion forum that summarised the main conclusions from the earlier presentations and the most burning issues for the future.

The 7th HTSLCN Meeting will be in late summer 2017 at Swerea MEFOS in Luleå, Sweden and will showcase the demonstration plant that is currently underway in the EU project STEPWISE (sorption enhanced water gas shift technology platform for cost effective CO_2 reduction in the iron and steel industry).

We would like to thank all attendees for contributing to this excellent meeting and hope to see you again in Sweden.

The presentations of the meeting are available for download in the IEAGHG members' area of the HTSLCN.

For any enquiries about the HTSLCN please contact Jasmin Kemper at: jasmin.kemper@ieaghg.org.

5th IEAGHG Oxyfuel Combustion Meeting – A Success and Looking to its Future, Stanley Santos, IEAGHG

We are pleased to report a successful 5th Oxyfuel Combustion Meeting with delegates taking away an optimistic message that this technology could still be demonstrated by 2020.

The meeting was held at Wuhan, China from 27th – 30th October 2015 and, in collaboration with Huazhong University of Science and Technology (HUST), we welcomed 122 delegates from 14 different countries worldwide. The keynote addresses were presented by Ms. Jiang Wu (Capture Power Ltd.), Prof. Zheng Chuguang (HUST) and Dr. Chris Spero (Callide Oxyfuel Project Ltd.); one important key message to re-convey is that that the technology is ready for large scale demonstration.

Dr. Spero highlighted the achievement of the Callide Oxyfuel Project (which had the honour to operate the largest oxyfuel combustion power plant to date) which realised more than 14,800 operating hours with 10,200 hours in actual oxyfuel combustion. The CPU has achieved 5600 hours with a small portion of the CO_2 captured injected into the Paaratte Sandstone formation (in collaboration with CO2CRC).

Looking to the future, Ms. Jiang Wu reinforced the commitment of Capture Power Ltd. together with the UK Department of Energy and Climate Change to realise the first oxyfuel combustion power plant producing 448MWe (gross power). She updated us on the progress made and explained it expected that the financial investment decisions will be made towards May 2016. It is important to highlight the importance of this demonstration project to the members of the consortium and what the necessary steps are that must be taken to establish the business case for CCS in UK.

Prof. Zheng conveyed the steady progress made by the Chinese consortium to the development of oxyfuel combustion technology. The success in the commissioning of the 35thMWth facility provides an important platform to achieve the full scale demonstration in the coming years. We expect that the next phase will involve the development of the large pilot scale of the CPU. These results are going to feed into the on-going Front-End Engineering Design (FEED) study led by ShenhuaGuohua Electric Power to realise the retrofit of the 200MWe power plant in China.

With what has been said in mind about the HUST's 35MWth facility – it would be a lost opportunity if we did not highlight the value of this pilot plant to the oxyfuel combustion community. We would like to congratulate HUST and their partners. In particular, we would like to announce that in addition to the excellent oxyfuel boiler they have recently commissioned, they also have the world's first 3-column Air Seperation Unit (which demonstrated the current state of the art technology for oxygen production to be expected in the first generation large scale demo project).

The meeting includeed the Capacity Building Course which provided a good overview and summarised the progress made in the past 10 years. It clearly demonstrated the amount of intellectual capital invested in this technology – albeit intangible but very valuable to realise the successful commercialisation of this technology.

It is also very important to note the facility visits made together with this meeting. This consisted of a visit to Alstom's Wuhan Boiler Company's manufacturing facility (which is one of the most modern and largest boiler manufacturer site in the world), a visit to the 35MWth facility at Yingchang and ASU facility of Linde at Wuhan Iron and Steel Company.

Finally, we would like to thank our sponsors:

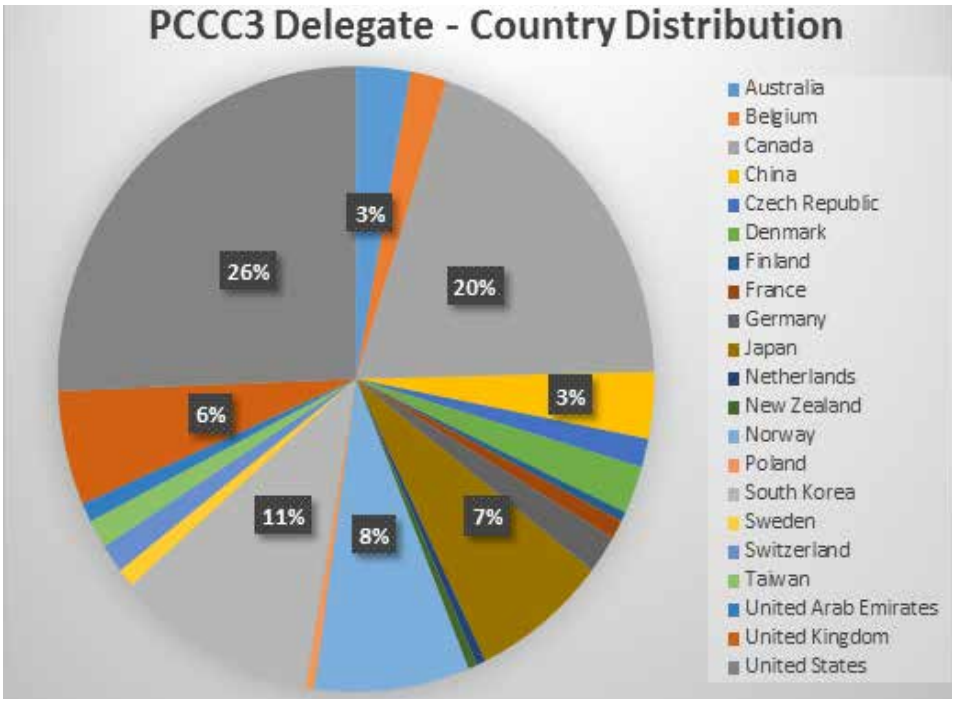
- Alstom Wuhan Boiler Company
- Dongfang Boiler Group Company Ltd.
- Sichuan Air Separation Plant (Group) Ltd.
- China Technology Strategy Alliance for CCUS
- National Natural Science Foundation of China

3rd Post Combustion Capture Conference (PCCC3),

Siân Twinning, IEAGHG

The 3rd Post Combustion Capture Conference (PCCC3) was the latest in the 20 year history of the CO_2 Capture Network meetings, this time partnering with SaskPower's CCS Symposium.

The back to back events brought over 200 experts to the town of Regina, Canada between the 8th-11th September 2015. PCCC3 presented the opportunity for delegates to update themselves with the latest research and innovations in post combustion capture (pcc) technologies, the tight schedule allowed for 82 oral presentations and 31 posters. To complement the highly technical sessions, three plenaries were held to brief the audience on the efforts to advance carbon capture technologies within the USA, Japan and Norway and their global impacts.



The SaskPower's Symposium day took on a different format, sharing with the audience not only how the decision to engineer the World's largest commercial scale capture enabled power plant but also presenting the business model required for such a venture along with outlining some of the technical and engineering challenges that were faced in completing the project.

The day also saw three major announcements; BHP Billiton and SaskPower combining to develop a knowledge sharing centre, IEAGHG releasing their report on the SaskPower Integrated CCS Project (report number 2015-06) and Climate Change Emissions Management Corporation (CCEMC) of Canada using the conference to launch their latest competition round to support innovative projects capable of providing greenhouse gas reductions.

To close out the experience, the much anticipated tour day took 160 delegates to the Boundary Dam power plant where a virtual tour of the nearby and brand new Shand CO_2 Capture Test Facility as well as a physical tour of the plant, capture facility and over to the Aquistore project, home for some of the captured CO_2 (the majority being sold for EOR). With the return journey home going through the Weyburn-Midale oil fields, the tour was dubbed the 'Grand CCS Tour' after all, where else can you go and see a test facility, commercial scale capture unit and storage project all within such a small radius?

A full summary report of the conference can be found at **www.ieaghg.org/conferences/pccc/52-conferences/pccc/470-3rd-post-combustion-capture-conference** along with the technical presentations from PCCC3 and the SaskPower Symposium presentations can be found at **http://saskpowerccs.com/2015-symposium/event-recap/**

Risk Management Network and Environment Research Network Combined Meeting, James Craig, IEAGHG

A Research Management Network and Environmental Research Network Combined meeting was held at the UK's National Oceanography Centre (NOC), in Southampton.

The meeting was attended by 62 delegates from 11 countries. The three day meeting included themes on risk assessment methodologies, risk communication and mitigation strategies as well as environmental research. There was an emphasis on potential impacts of CO_2 in marine environments, natural variability and the unscheduled release of CO_2 from pipelines. Coverage also included formation fluid release, overburden features, international initiatives and environmental impact assessments notably the Peterhead – Goldeneye project.

Grid explained the background to their Endurance project which will be Europe's first CO_2 superstore. A large deep saline aquifer off the east coast of England has been identified as a potential storage location for multiple carbon emission point sources in the Yorkshire-Humberside region. The company is also engaged in a series of R&D projects under the COOLTRANS programme to assess the risks of CO_2 pipeline transport which will lead to best practice, safe and long-term conditions for CO_2 transportation.

The environmental research topics highlighted by the meeting focused on the environmental changes caused by CO_2. In shelf seas with a high tidal flux, like the North Sea, there is rapid dispersion so the impact of CO_2 anomalies are likely to be limited. There are also wide natural variations which need to be distinguished from any artificially induced changes. The importance of overburden characterisation above caprock and storage complexes with multiple seals has been recognised. For example, chimney structures in the Gulf of Mexico and the North Sea are evidence of natural fluid flows through the overburden succession. These features need to be investigated to distinguish the origin of naturally occurring seeps and any other anomalies.

The meeting concluded that the risk assessment for CO_2 geological storage is maturing. If leaks do occur they are likely to have low environmental impacts. Wellbore issues are still the predominate risk. There are established technology solutions but more work to test and apply them was suggested. The meeting has clearly shown that great developments in understanding environmental aspects in the marine environment are taking place. Mobile sensor technology is also improving especially with the advent of long-range Autonomous Underwater Vehicles (AUVs). The meeting concluded on a successful note and clearly highlighted the advances in research on marine impacts around the world.

East Cliff at West Bay Bridport, delegates at the field trip during the Combined Risk and Environmental Network Meeting

After the meeting some of the delegates visited two key sites on Dorset's Jurassic Coast. The guided tour's first destination was the Bridport Sands. This formation is an important reservoir rock for the Wytch Farm Oilfield further to the east near Bournemouth. The formation includes calcified bands and vertical fractures. These features are important to understand because they influence fluid movement and help to explain the challenge of monitoring CO_2 injected into similar reservoirs. Delegates also visited Lulworth Cove where there is a succession from the Portland Limestone of the Upper Jurassic through the Purbeck Beds into the Cretaceous Wealden, Gault Clay, Greensands and finally Chalk. The location also displays evidence of significant folding caused during the Alpine Orogeny known locally as the Lulworth Crumple. These two locations, and other exposures along this World Heritage coast, enable geoscientists to gain a broader insight into subsurface complexities which are inferred from geophysics and wellbore sequences. The identification of secure, long-term storage reservoirs for CO_2 ultimately depends on understanding such geological complexities.

IEAGHG/CSLF Workshop on LCA in CCUS, Jasmin Kemper, IEAGHG

IEAGHG and the Carbon Sequestration Leadership Forum (CSLF) jointly organised an interactive workshop discussing issues and challenges surrounding Life Cycle Assessment (LCA) methodology in the context of Carbon Capture, Utilisation and Storage (CCUS).

This workshop built upon an earlier report by IEAGHG "2010/TR2: Environmental evaluation of CCS using Life Cycle Assessment" and addressed a request from CSLF to IEAGHG for further work on this topic. The workshop took place 12th - 13th November at the British Medical Association in London and brought together 23 participants from different backgrounds (i.e. academia, industry and NGOs) and with varying levels of LCA experience (i.e. LCA practitioners as well as users of the results).

After a welcome from Lars Eide (CSLF/Research Council of Norway) and Jasmin Kemper (IEAGHG), the first day started off with a keynote presentation from Bhawna Singh (NTNU) on the state-of-the-art and recent developments in LCA for CCUS. This was followed by a series of stakeholders' perspectives from Aïcha El Khamlichi (ADEME), Christoph Balzer (Shell) and Sean McCoy (IEA), who shared their organisations' and/or their personal interest in LCA and what they currently see as the main challenges. The next three sessions then dived deeper into the issues and challenges of the different parts of an LCA. Tim Skone (US DOE NETL) opened the discussion on "Goal and Scope Definition", Arne Kätelhön (RWTH Aachen) kick-started a debate on "Inventory Analysis" and Jasmin Kemper (IEAGHG) provided some initial questions for "Impact Assessment and Interpretation".

The second day addressed topics beyond environmental aspects of LCA, namely Social LCA (SLCA) and Life Cycle Costing (LCC), where Andrea Ramirez (Utrecht University) and Anna Korre (Imperial College London) provided the food for discussion. The workshop closed with main conclusions of the discussions in the sessions, highlighting the importance of communicating uncertainties and differences, as well as improving transparency when undertaking LCAs. However, transparency does not automatically equal high quality. In addition, a clearer distinction of LCA from GHG accounting and/or carbon footprinting will be necessary. There was no consensus on harmonisation and weighting. Both can be useful tools but need to come with a statement of underlying assumptions and intentions, and thus should only be used with care (also keeping in mind that "no weighting" means to assign equal weights). Bio-CCS and more recent Carbon Capture and Utilisation pathways require a lot more research, as they introduce new issues and increased complexity. LCC and SLCA are less mature than their environmental counterpart, so both should be taken out in parallel rather than integrated for now. The participants felt no need for formal guidelines prescribing specific frameworks, methodologies and tools but welcomed the development of a guidance document including: a) how to document and communicate LCA results for LCA practitioners, and b) how to read and interpret LCA results for non-experts and end-users.

The presentations of the meeting are available for download on IEAGHG's website. Based on the outcomes of this workshop, IEAGHG will revisit the need for producing a guidance document and for future meetings/activities on this topic.

International Interdisciplinary CCS Summer School 2015,

Karl J. McAlinden (University of Nottingham), Weparn Julian Tay (Imperial College) and Kate Stechly (University of Sheffield)

It was a great pleasure to have the opportunity to participate in the 2015 IEAGHG CCS Summer School at the University of Western Australia, Perth. Bringing together students from a wide variety of disciplines, all who are working on areas closely related to CCS, the week-long event included presentations and activities led by world-class CCS experts and scholars.

Students and Mentors at the IEAGHG Summer School, Perth, Australia

Reflecting the multidisciplinary nature of CCS, presentations included not only the technical areas of capture technologies, storage site selection, capacity monitoring and modelling, wellbore integrity and transport but also other increasing important social issues, such as international CCS cooperation, politics, policies, regulation and communications.

The carbon capture presentations focused on introducing the three main types of carbon capture technologies, demonstrating that all three offer possibilities for retrofitting existing plants. Dianne Wiley from the University of New South Wales (UNSW) gave a presentation on CO_2 transport and the economic assessment of CCS; helping us to appreciate the economic and financial requirements needed for CCS projects to be successful. Steve Whittaker from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) gave a presentation on Enhanced Oil Recovery (EOR) and used an example from the Weyburn Field to show the possibilities for CCS-EOR application. In Martin Oettinger's presentation, he stated that there are other industrial usages for anthropogenic CO_2, including in the steel and metal industries, water treatment and food and beverage industries.

Several presentations on carbon storage were also presented throughout the week, with John Kaldi from the University of Adelaide giving a presentation on the different reservoir rock types, seals and trapping mechanisms for carbon storage. Simon O'Brien from Shell gave a presentation on the wellbore integrity, mentioning the different types of wells including pressure relief well, water production well, monitoring well, injection well. Tess Dance from CSIRO talked about using models to understand carbon storage, mentioning different grid size models when determining the geology structures and the assumptions made during the modelling process. Linda Stalker, Chief Scientist of the National Geosequestration Laboratory (NGL), talked about onshore and off-shore monitoring, highlighting that it is often difficult to differentiate between the background noise and signal (small signal to noise) ratio. Two presentations about health and safety, risk assessment and mitigation were also given by Keith Spence and Simon O'Brien, while Jennifer Roberts from the University of Strathclyde gave an interesting presentation on the environmental impacts of CO_2 storage from a geological point of view.

Both scientifically and technically comprehensive, the CCS summer school also covered a wide range of policy and social issues that made it a truly interdisciplinary meeting of future CCS professionals. With the IEAGHG playing an important

role in these aspects, their Techncial Programme Manager, Tim Dixon, gave a breakdown of the programmes goals and activities, as well as the role it plays in being together research networks and collaborating with other CCS entities internationally. Tim later gave a rundown of the international legal and regulatory background, political and GHG emissions reductions developments, which was particularly relevant with the events that were currently taking place at COP21. Additionally, later in the week, Tim introduced the perspectives of international NGOs on the role of CCS in climate mitigation and the challenges CCS faces against competing with other low-carbon technologies.

David Lumley from UWA demostrating the seismic monitoring equipment at the Harvey 3 Well

The trend of increased international CCS activity was also pointed out by Chris Consoli from the Global CCS Institute (GCCSI), who gave a breakdown of the current and projected CCS projects globally, estimations for cost reductions and storage capabilities, as well as policy indicators. On a more theoretical basis, an interesting and increasingly important research area of CCS was presented by Jürgen-Friedrich Hake from the Julich Forschungszentrum Institute of Clean Energy Research. Focusing on the emergence of CCS as a tool of mitigation and its increasing role in the international sphere, Jürgen pointed out the political, policy, financial and social steps needed to motivate and incentive CCS deployment.

At the domestic level, through a presentation from Bruce Wilson from Department of Industry, Innovation and Science; students learned of the Australian Government's national CCS policy. While such government aspirations often seem lofty and idealistic, Linda Stalker provided background to Australian CCS hubs and clusters and Martin Burke from the Western Australia Department of Mines and Petroleum introduced the efforts made in that area on public engagement and communications; proving that such claims are being backed by concrete actions being taken both on the technical and social developments of CCS in Australia. With such a broad range of social issues addressed, it is encouraging to see not only CCS making technical research advancements but also advancement in the direction and scope of its social research.

After two days of intensive presentations, the group visited the National Geosequestration Laboratory (NGL), which accommodates staff and research students from CSIRO, Curtin University, University of Western Australia, Australian National Measurement Institute, CO2CRC and other research organisations. Linda Stalker gave a presentation on the background of the South West Hub project and a tour of the impressive laboratories and equipment. After the lab visit, the group travelled to Harvey were we met with the South West CO_2 Geosequestration Hub project staff and the local community leaders involved in the project, as well as visiting one of four CO_2 injection sites to learn more about the injection well and the seismic monitoring equipment used. This was an invaluable experience to learn more about the technologies up close, experience CCS in the field and to meet those that are affected by CCS in their community.

Divided into six groups, students were provided a CCS related question and two supportive mentors to help them with any questions they might have. With time throughout the week dedicated for group work, each group prepared a fifteen minute presentation to deliver to all participants, while anxiously apprehending the additional fifteen minutes of questions

from the expert panel. This was a great opportunity to draw together the specific expertise of the group members, to apply the knowledge learnt throughout the week and to hear the presentations from the other groups, as well as to learn more from the expert mentors own experiences.

With the growing potential of CCS as a climate change mitigation tool, the importance of the IEAGHG CCS summer school in raising the integrated policy knowledge and technical capabilities of young researchers is essential to the technologies' future development. From the outset, the level of support for and from the local hosts was clear through the keynote speech from the Western Australian Minister Marmion and the wide range of institutions, experts and mentors from the Australian CCS community. With this year being the ninth consecutive year of the school, it was clear that considerable time, effort and resources had been put into the organisation of the week-long event, with success having been built on the experience from previous years to make it an excellent, although demanding, programme of events. A special thank you goes to all those involved in the organisation and to the United Kingdom CCS Research Centre (UKCCSRC) for providing the UK students with travel bursaries to make our trip to Australia possible.

USDOE Carbon Storage Program: 2015 Project Peer Review,

James Craig, IEAGHG

The U.S. Department of Energy (DOE), the Office of Fossil Energy, and the National Energy Technology Laboratory (NETL) invited IEAGHG to provide an independent and impartial peer review of selected projects within the DOE Office of Fossil Energy's Carbon Storage Programme.

In March 2015 Tim Dixon, James Craig and Samantha Neades from the IEAGHG convened a panel of five leading academic and industry experts from the USA, Germany, Australia and Sweden to conduct a peer review of 12 research projects. At the conclusion of each project review, these recognised technical experts provided recommendations on how to improve the management, performance, and overall results of each individual research project.

The DOE Carbon Storage program is focused on the development of advanced technologies to enable safe, cost-effective and permanent geological storage of CO_2 both onshore and offshore. The technologies being developed will benefit both industrial and power sector facilities that will need to mitigate future CO_2 emissions. The program's aim is to improve the effectiveness of these advanced technologies to facilitate CO_2 storage in different types of geological reservoirs and improve the ability to understand the behaviour of CO_2 in the subsurface.

The panel discussed each project to identify and come to a consensus on each project's strengths, weaknesses, and recommendations for project improvement. The panel concluded that the review provided an excellent opportunity to comment on the relative strengths and weaknesses of each project. The review has also provided an insight into the range of technology development and the relative progress that has been made. The structure of the review, and the variety of different projects, has stimulated interest and engagement that should also be useful for the DOE program, especially the DOE project managers.

Facilitating Implementation

COP21

IEAGHG were busy at COP21 co-operating with our collaborators from around the world.

Panel- Tim Dixon, IEAGHG; Ton Windernberg, COGeoNet; Philip Ringrose, Statoil; Mike Marsh, Saskpower; Katherine Romanak, The University of Texas at Austin; Jukka Uosukainen, CTCN. Original Source: IISD at www.iisd.ca/climate/cop21/enbots/1dec.html#event-6.

Just ahead of COP21 the UNFCCC has just produced a new report 'Climate Action Now' to highlight early actions "with significant mitigation potential" so as to encourage countries and organisations to act sooner. This reports builds upon the UNFCCC's Technical Expert Meeting on CCS in 2014, focussed on actions to 2020 and it includes CCUS as one of the six priority areas for this early action, acknowledging the importance of Boundary Dam and Peterhead projects. It also emphasises solutions through international collaboration where it mentions IEAGHG as an example (with CSLF and GCCSI).

The main UNFCCC Side-event on CCS was organised by IEAGHG, University of Texas, CCSA and CO2GeoNet, and held on the 1st December. The event was titled "Carbon Capture and Storage (CCS): Achievements and Opportunities for Developing Country Involvement". The title tells the theme for the event. After scene-setting by IEAGHG, Philip Ringrose of Statoil presented on 19 years of operations in the North Sea region. Ton Wildenborg of CO2GeoNet presented on EU pilot projects which have collectively demonstrated the safety of storage. The Honourable Brad Wall, Premier of Saskatchewan, Canada, provided a politicians perspective and introduced Mike Marsh President of Saskpower to talk about the first year of operation at Boundary Dam. This included their global knowledge centre which is going to be launched and will be supported by BHP Billiton. Katherine Romanak of the University of Texas, BEG presented on new collaboration opportunities in offshore storage, referring to the Carbon Sequestration Leadership Forum's recent report, and a planned international workshop to share knowledge between "those who do and those who are interested in doing". The event concluded with a talk on the Climate Technology Centre and Network, a funding source for technology transfer and capacity building in developing countries, by its Director Jukka Uosukainen.

The event was very well attended, with around 200 attendees, many from developing countries, and various media. The excellent quantity and quality of questions that followed demonstrated the high level of interest and positive engagement in the event and the topics, such that discussions had to continue after the event outside the room, with panel members also being interviewed by various media.

Reporting of the event at COP by IISD can be seen at **www.iisd.ca/climate/cop21/enbots/1dec.html#event-6** , and the powerpoimtsts are available on the UNFCCC Side-event website.

In addition, the exhibit booth on CCS inside the UNFCCC area, run jointly by University of Texas, CO2GeoNet, CCSA and IEAGHG, proved very busy, with a continuous flow of COP delegates seeking a range of information on CCS. IEAGHG also contributed with others to an exhibit booth in the pubic area, which also got a lot of interest.

At the higher level, this was indeed a historic UNFCCC meeting, producing the Paris Agreement, with its 2°C target, and aim to pursue 1.5°C which will mean even further mitigation efforts will be required. We will look to see what this all means for technologies to reduce greenhouse gas emissions from fossil fuels, especially CCS, and IEAGHG will continue to support our members in their activities towards these objectives with our international R,D&D programme. IEAGHG and our partners at COP were happy to play our modest role in providing information in support of this high level agreement (see our blogs from COP), but we think that we all played a bigger role through our work over the decades, such that the IPCC and UNFCCC now recognise the need and viability of CCS. We made this knowledge available at this COP, through the UNFCCC Side-event, the booths, reports, and the Special Issue of the International Journal of Greenhouse Gas Control.

CSLF Meetings

The Carbon Sequestration Leadership Forum (CSLF) is a government-to-government agreement on developing CCS, it started in 2003 and now has 24 member countries and the European Commission, and consists of a Technical Group, a Policy Group, and Ministerial meetings. The CSLF held two sets of meetings in 2015. One set in Regina, Canada in June hosted by SaskPower, and the other set in Riyadh, Saudi Arabia in November which concluded with the 6th CSLF Ministerial Conference.

The Ministers and other heads-of-delegation agreed a Ministerial Communique "Moving Beyond the First Wave of CCS Demonstrations". This agreed key actions to progress CCS as follows:

- Advocating for clean energy policies to support CCS alongside other clean energy technologies, noting that the role of CCS is recognised in the UNFCCC.
- Foster international collaboration advancing technology development and deployment, building on CSLF initiatives.
- Importance of coordinated global R&D&D on 2nd and 3rd generation technologies…..including support and collaboration with IEA and IEAGHG.
- Create opportunities for private sector investment in 'sweet spots' for CCS.
- Supporting CCS-supporting policy frameworks.
- Supporting industrial CCS applications.
- Encourage storage exploration and transport infrastructure to de-risk projects.
- Explore potential for CO_2 utilisation.

The Communique recognised the need for the London Protocol CCS export amendment ratification. It also tasked the CSLF to establish a global CCS project network, to collaborate on R&D on CCS with freshwater co-production, encourage work to recognise and credit BioCCS and CO_2-EOR, and undertake outreach to academic community. The chairmanship of the CO_2 Capture International Test Center Network will move from Norway to the USA, and the CSLF announced the formation of a Large-Scale Saline Storage Project Network to share knowledge and experiences. Two new members joined CSLF, Romania and Serbia.

The CSLF Policy Group endorsed five new projects as recommended by the Technical Group: Dry solid sorbent CO_2 capture project in Korea; CO_2 Capture Project Phase 4; the CO2CRC Otway Stage 2; Oxy-combustion of Oil Heavy Residues in Saudi Arabia and USA; and a CCU Network in Saudi Arabia. The CSLF Technical Group also started three new Task Forces on Offshore CO_2-EOR, on BioCCS and on Improved Pore Space Utilization. IEAGHG's work will be relevant to all of these.

A substantial contribution to the Technical Group was a report from the Offshore Task Force on the potential and challenges of sub-seabed CO_2 storage. IEAGHG contributed significantly to this report (see IEAGHG Information Paper

2015-36). Throughout the CSLF Technical Group, the Policy Group and the Ministerial, offshore CCS was raised in terms of the encouragement of international knowledge sharing. This will be followed-up by a planned workshop to facilitate international knowledge sharing on offshore CCS, to be held at the University of Texas BEG in April 2016 in collaboration with the South African National Energy Development Institute and IEAGHG, and supported by the CSLF.

IEAGHG participates directly in the CSLF through a collaboration agreement with the CSLF Technical Group, and contributes in its Task Forces where appropriate such as the Offshore Task Force, and in support of the International Energy Agency in the Policy Group.

This was the best attended CSLF Ministerial that we have seen, with ten Ministers plus several Deputy-Ministers, representation from the UN's Secretary-General, and plenty of media coverage as a result. Compliments to the hosts, the Ministry of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia, for a very impressive set of CSLF meetings. Details of the Communique and other meeting documents and reports can be found at **http://www.cslforum.net/** .

Regulatory and Standards Activities

IEAGHG contributes the results from its technical programme into regulatory and standards activities where it will be of appropriate benefit. The following summarise the main IEAGHG activities in these areas in 2015.

After being in existence for five years, the EU's CCS Directive was reviewed by the European Commission in 2014-2015. This was done by consultants using an extensive stakeholder process. IEAGHG provided a submission and other input and was invited to two stakeholder meetings. The IEAGHG input drew upon what we consider as some potentially useful outputs from our technical work programme, specifically the definition of capture-ready from our 2007 report on Capture Ready, monitoring capability improvements (from our network meetings), accounting for BioCCS (from our report from 2014), bankable storage analysis from the Global Storage Gap Analysis report (2011), and on CCS in the London Protocol. The consultants' report drew all of the inputs from stakeholders together to make conclusions and recommendations to the European Commission. This report was published in January 2015 'Support to the review of Directive 2009/31/EC on the geological storage of carbon dioxide (CCS Directive)' by Triple E, Ricardo-AEA, TNO . The main recommendation was not re-open the CCS Directive for revision, because of the risks and uncertainty it would create and that there is nothing significantly wrong with the CCS Directive to warrant it, although not fully tested on real projects yet. Where there are improvements needed, these can be dealt with in the supporting Guidance Documents. As one of the earliest CCS-specific regulations, drawing upon IPCC and IEAGHG work, this is a positive conclusion. The main technical area for improvement relates to improving understanding and clarity on capture-ready, and the 2007-04 IEAGHG technical report became a major contribution being referenced by many stakeholders. The concluding recommendation was to produce a new guidance document on capture-ready, drawing upon the 2007 IEAGHG report. Other non-technical recommendations included on the financial security requirements, to be dealt with in revisions to the relevant guidance document. The European Commission then produced its own report on these recommendations, "Report on review of Directive 2009/31/EC on the geological storage of carbon dioxide", (18 November COM(2015) 576 final). This concluded simply that the Directive was 'fit-for-purpose' and should not be re-opened.

ISO Technical Committee 265 is an ISO committee established in 2012 to prepare standards across the whole CCS chain. There are 20 participating countries, 8 observer countries, and 7 Liaison organisations. It has a Canadian Chair and Canadian and Chinese Secretariat, and consists of six working groups: WG 1 Capture (lead by Japan); WG 2 Transport (lead by Germany); WG 3 Storage (lead by Canada and Japan); WG 4 Quantification and Verification (lead by China and France); WG 5 Cross-cutting issues (lead by France and China); WG 6 CO_2-EOR (lead by USA and Norway). IEAGHG is a Liaison Organisation to TC265 and an active member of WGs 1, 3 and 4. Several draft International Standards are being developed, for pipeline transport, storage, terminology, and capture performance assessment. Technical Reports are being produced on capture technologies and on quantification and verification of GHG performance. Drafts of these are shared by IEAGHG with its

members. The 5th meeting of the ISO TC265 was held in Birmingham Alabama in January 2015, and the 6th meeting of the ISO TC265 was held in Oslo in September 2015. IEAGHG attended both, presented updates on the IEAGHG technical programme and activities relevant to the ISO work, and participated in WG1, WG3 and WG4.

Tim Dixon at the London Convention Meeting

The London Convention and the London Protocol are the global treaties that protect the marine environment. The main amendment to allow CCS was in 2006. The detailed work on transboundary CCS was completed in 2012 (see IEAGHG 2013-IP26 and 2014-IP19), but outstanding is the ratification of the 2009 CO_2 export amendment which is hence still a barrier to transboundary projects offshore, and there is an ongoing request for information and experiences with offshore CCS. It was the annual meetings of these in London in October. In terms of ratification of the CO_2 export amendment, UK and Norway had previously ratified, and the Netherlands announced at this meeting that they have now also ratified. There were no reports of ratification progress by other countries, although last year Korea, Canada and Australia and Sweden announced they are working on ratification. So it appears there is very poor progress given that two thirds of the 45 Parties to the London Protocol are needed to ratify the export amendment for it to come into force. IEAGHG gave its regular intervention in plenary, covering activities by IEAGHG, IEA, CSLF (the Offshore Task Force report) and the IJGGC. It was important to highlight that there is considerable progress being made with offshore CCS. There was specific interest in the results of the IEAGHG Networks meeting held at the National Oceanography Centre and in the "Review of Monitoring for Offshore CCS Projects" report and webinar. IEAGHG and IEA continue to be a primary information source on CCS in the London Protocol.

The International Energy Agency's CCS Unit held their 7th meeting of the International CCS Regulatory Network in Paris in April. Sessions looked at country updates from the EU, the USA, Canada and Korea, and on international standards, on project experiences, on CO_2-EOR, and on emission trading schemes. At this meeting IEAGHG presented updates from the London Protocol and from UNFCCC. IEAGHG had previously organised a session at the 6th meeting on technical developments influencing regulation of CCS, and continues such assessments at all our storage Network meetings.

A review paper on legal and regulatory developments over the last ten years was produced for the IJGGC Special Issue (Dixon, T, McCoy, S, Havercroft, I, Legal and Regulatory Developments on CCS. International Journal of Greenhouse Gas Control 40 (2015) 431–448.

IEAGHG continues to monitor technical needs arising and technical developments relevant to regulations and standards, and responds accordingly with our technical R&D programme to address issues and by providing information in order to improve regulations and standards for CCS.

IEAGHG Social Media

IEAGHG have a number of publications that are disseminated regularly to the Executive Committee and released into the public forum – including technical reports, technical reviews, information papers and one-off informative publications.

In 2015, 5 technical reports were published (see page 23 full overviews or 30 for the list), in addition to 2 reports on IEAGHG Network activity and 3 technical reviews.

The IEAGHG Blog

www.ieaghg.org/publications/blog

The IEAGHG blog, live since December 2011, features both IEAGHG and external contributors, reporting on any and all IEAGHG activities – workshops, network meetings and conferences, promoting to its readers when a new technical report is published and also giving overviews of any significant external events that may be attended by us or our colleagues. The blog is still proving very popular! The Programme published 65 blogs during 2015.

Information Papers

http://ieaghg.org/publications/information-papers

In 2012, IEAGHG began producing and publishing Information Papers (IPs) as an additional communication tool. These continue to be extremely popular, both with IEAGHG Members and the public. The IPs are short summaries of new research developments in CCS, developments with other mitigation options and summaries of policy activities around the world on low carbon technology, and are an ideal way of satisfying the Programme's broader remit of reviewing all greenhouse gas mitigation options. If there are interesting developments from the IPs we would then undertake a technical review to understand better the issues and the political landscape, then if necessary, propose a detailed study to our members.

The majority of our IPs are free to access and are publicly available as soon as they are published. Occasionally, however, an IP will be deemed 'Confidential' or 'for the Executive Committee only' – in which case the document will not be available to download. We welcome Members and other external parties to submit relevant ideas to be made into an IP. IEAGHG published 27 IPs in 2015.

IEAGHG Social Media

https://twitter.com/IEAGHG
www.linkedin.com/groups/IEAGHG-4841998
www.facebook.com/pages/IEA-Greenhouse-Gas-RD-Programme/112541615461568?ref=aymt_homepage_panel

The Programme's Twitter, LinkedIn and Facebook pages are thriving and being kept updated and current with regular posts on IEAGHG activities and other relevant news.

Since the publication of the 2014 Annual Review....

786 Followers (65% increase)

facebook
1220 Likes (232% increase)

LinkedIn
518 Group Members (57% increase)

Key IEAGHG Achievements in 2015

9 Meetings / Events

Presentations made by IEAGHG at External mMeetings

Published to Online Media

678 Total Attendees

6 Webinars

51,112 Unique Users of IEAGHG Website with 91,123 Sessions in Total

IEAGHG 2015 Studies

2015-01 IEAGHG Monitoring Network and Modelling Network Meeting, Morgantown, WV, study managed by James Craig and TIm Dixon

A combined Modelling and Monitoring network meeting was hosted by the National Coal Research Center for Coal and Energy (NCRCCE), West Virginia University at Morgantown on 5th - 7th August. The meeting brought over 60 delegates from 8 countries including Australia, Canada, France Germany, Japan as well as the UK and USA. The three day meeting focussed on the theme of reducing uncertainty with the application and effectiveness of monitoring and modelling.

The first day concentrated on the latest research on the ability to monitor CO_2 in the overburden with the use of isotopes. There were also contributions from speakers on some of the challenges of monitoring CO_2 from controlled release experiments into the atmosphere and into the sea where rapid dispersion can made reliable measurements difficult. Detailed appreciation of near surface sediment conditions, and background baseline monitoring, can help to show where CO_2 emissions might occur. Some excellent examples of seismic monitoring were presented which demonstrated how effective the technique can be for monitoring plume migration.

Key Messages from the Report:

- Pressure monitoring is providing a lot of information at many sites in terms of reservoir performance and overburden monitoring, and is likely to be an early indicator of leakage.
- Microseismicity has distinct benefits. Data from current projects is reducing uncertainty by highlighting small scale structures within reservoirs and reducing uncertainty.
- The application of tracers may be possible to detect the origin of CO_2 in the overburden, but there is uncertainty over their effectiveness.
- Recent advances in seismic using a P-cable configuration are providing high resolution on shallow overburden off the coast of Texas.
- Seismic surveys applied offshore can be cheaper than onshore per unit area.
- There is a need for benchmarking and more accurate commercial sensors for near-surface monitoring.

The discussion on modelling opened the debate on the length of time that should be considered especially in the context of public perception. This was the first meeting where the impact of glaciation was raised. The discussion also revealed that models can help to simulate different conditions such as pressure build up within reservoirs and fault behaviour under shear processes.

The meeting concluded with a discussion between three storage site developers, two from the USA and one from the UK, and a representative from the US Environmental Protection Agency (EPA). Much of the discussion focussed on the Class VI regulations for CO_2 injection and storage. There have recently been the first five permits issued (to ADM and to FutureGen2) which will set precedents for meeting the requirements. Applications under this regulation need to be science-based and well documented. Experience from both the US and UK shows that there have been, and continue to be, open and detailed dialogue between regulators, site developers and the research community. This was welcomed.

Overall, it is clear from a number of projects around the world that monitoring data continues to improve to model predictions. Continual iteration between observed and predicted phenomena is essential and is proving effective. In the future improvements in real time continuous monitoring, using robust and reliable sensors, will be essential. The goal of reaching the right balance between cost and achieving the right level of sensitivity to meet regulatory requirements at a commercial scale will need to be addressed and developed.

The meeting included a visit to the NETL facilities in Morgantown and a geological field trip to recently exposed rock formations relating to CO_2 storage in the Central Appalachians.

2015-02 Review of Offshore Monitoring for CCS Projects, study managed by James Craig and Tim Dixon

Since the inception of CO_2 injection into the Sleipner gas field in 1996 there has been considerable progress in monitoring offshore geological storage sites. There have also been recent developments, in-situ experiments, large-scale tests, and reviews on monitoring techniques for offshore monitoring applications.

Some of these developments have occurred outside of the CCS sector. This is in addition to the deep monitoring for Statoil's Sleipner project in the North Sea and Snøhvit project in the Barents Sea.

In addition to technology developments there has been a corresponding series of regulations and related objectives which are designed to ensure that CO_2 storage in offshore reservoirs can be retained within secure repositories without detrimental environmental effects. As with onshore CO_2 geological storage, the objectives for offshore monitoring include: CO_2 geological storage performance, baseline studies, leakage detection, and flux emission quantification.

Key Messages from the Report

- A range of monitoring techniques are available for CO_2 geological storage offshore, both deep-focussed (providing surveillance of the reservoir and deeper overburden) and shallow-focussed (providing surveillance of the near seabed, seabed and water-column).
- Deep-focussed operational monitoring systems have been deployed for a number of years at Sleipner, Snøhvit and also at the pilot-scale K12-B project in the offshore Netherlands, and conclusions regarding the efficacy of key technologies are starting to emerge. 3D seismic surveys have been highly effective for tracking CO_2 plume development in Sleipner and Snøhvit reservoirs. Measurement of downhole pressure was crucial in establishing non-conformance at Snøhvit. A combination of 3D seismic and downhole pressure / temperature monitoring at Snøhvit has demonstrated the benefit of complementary techniques.
- Shallow-focussed monitoring systems are being developed and demonstrated. New marine sensor and existing underwater platform technology such as Automated Underwater Vehicles (AUVs) and mini-Remotely Operated Vehicles (Mini-ROVs) enable deployment and observation over large areas at potentially relatively low cost. Seafloor and ocean monitoring technologies can detect both dissolved phase CO_2 and precursor fluids (using chemical analysis) and gas phase CO_2.
- Developments in geophysical techniques, such as the P-Cable seismic system for higher resolution 3D data collection in the overburden, have been demonstrated successfully and effective integration of these shallow subsurface technologies with the seabed monitoring data can help to understand shallow migration processes.

Controlled release sites such as QICS have proved to be useful test-beds for shallow seismic techniques and acoustic detection systems. They can also reveal how CO_2 migrates through, and is partially retained by, unconsolidated sediments.

Monitoring strategies need to be devised to cover large areas, typically tens to hundreds of km^2 and also achieve accurate measurement and characterisation possibly over lengthy periods. Limited spatial coverage could lead to the risk that anomalies remain undetected or are only detected after a lengthy period of time. Ameliorative measures might then be harder to implement.

Search areas could be narrowed down by the integration of information from deeper-focussed monitoring such as 3D seismics, which can identify migration pathways, with shallow surface monitoring such as acoustic detection.

Assessment of the results from both the operational (predominantly deep-focussed) and research (predominantly shallow-focussed) monitoring activities from Sleipner and Snøhvit indicates that many elements of the European storage requirements have been met at these large-scale sites which were both initiated before the CCS Directive was introduced.

2015-03 Carbon Capture and Storage Cluster Projects: Review and Future Opportunities, study managed by Jasmin Kemper

Carbon capture and storage (CCS) has the potential to significantly contribute to greenhouse gas emissions reductions. In this regard, development of cluster structures offers the potential for cost reduction through sharing of infrastructure and organisational and regulatory efforts.

The main objectives of this study are to identify gaps, risks and challenges related to CCS clusters, to compare their business models and to reveal factors for successful development and suitable locations for future clusters.

The approach for this work consists of an extensive review of the literature on CCS clusters. The existing information was sufficient to review 12 clusters with different levels of maturity in detail and to discuss a number of others at a more general level.

Based on an analysis of gaps, risks and challenges of clusters (both technical and commercial), the study develops criteria for the selection of future cluster locations and recommendations for increasing the likelihood of successful cluster implementation.

Following are the key messages from the report:

- The most successful clusters remain those based on the use of CO_2 for enhanced oil recovery (EOR) application in the US.
- Clustering may slightly reduce costs but the savings are insufficient to fill the cost-revenue gap, so clusters will likely require substantial, i.e. 50% or more, government support. There is large value in the (shared) pre-investment in pipelines and storage in order to generate the confidence needed for investment decisions on capture facilities. Further cost savings can arise from sharing organisational costs and from tying specialist services.
- The main risks for clusters are of commercial nature and include e.g. collapse of the CO_2 price, loss of key partners and/or customers, availability of low-cost alternative EOR methods but also major pipeline accident and failure to gain permits.
- A major obstacle in early years is maintaining a core organisation which is able to carry a CCS cluster project forwards.
- New methods to attract international investment in CCS capacity are necessary to exploit the full low cost potential of the best cluster locations.
- Promising future cluster locations include e.g. Mexico, Indonesia, Russia, former Soviet Union states and China.
- Workshops could help exploring more systematic development of business plans for CCS clusters with emphasis on customers and revenues.

2015-04 Criteria of Fault Geomechanical Stability during Pressure Build-Up, study managed by James Craig

The storage of CO2 in geological reservoirs requires relatively permeable conditions bounded by very low permeable layers. Reservoirs can be bounded by faults that can act as seals if, for example, an impermeable formation is juxtaposed against it. The presence of faults in virtually all geological formations is a key consideration as their stability is crucial for the integrity of storage sites.

Fault stability is affected by multiple factors including fault structure, material properties, geochemical reactions between CO_2 and fault gouges and pore pressure changes. Injection operation and pressurization of reservoirs usually changes the state of the in-situ stresses which may cause destabilization of previously stable faults. Instability occurs in the form of slip along pre-existing fault or fracture systems, which may be associated with seismicity. In addition, movement along fault planes, and the generation of factures, may create open conduits that breach the integrity of the storage site. Understanding how faults might respond to stress conditions caused by CO_2 injection is therefore fundamental.

Recent geomechanical studies for CO_2 geological storage have focused on initialising stresses in the overburden based on all available geological and well engineering data, modelling the impact of fluid/gas pressure build up on stresses in the storage formations, the caprock and the overburden in general. The challenge is to predict the acceptable overpressure before shear failure, or reactivation of a fault/

natural fracture occurs. The prediction process begins by using a verified geomechanical model to calculate the effective normal stresses and shear stresses occurring along all the faults/fractures. These stresses are evaluated in the context of fault cohesion and sliding friction to predict the pre-injection state of stress on these features and to determine the critical fluid/gas pressure required to initiate shear failure on what may have previously been a stable fault/fracture. Stress and fault properties can vary in space and time.

Key messages:

- Faults typically consist of two sub-structures: a fault core; and a wider fault damage zone. Faults in low porosity rocks tend to have a fine-grained fault core whereas faults in coarse-grained, high porosity rocks, usually have low porosity deformation bands that can develop into high permeable slip surfaces.
- Fault zone permeability increases with increasing fluid pressure but permeability varies both across and along faults. Hydraulic properties also vary between the damage zone and the core where gouge material is concentrated. This concentration of fine grained minerals also reduces the mechanical strength of faults.
- Mechanical failure or reactivation occurs either when shear stress exceeds normal strength or when hydraulic fracturing is induced.
- Fault deformation can be either brittle or ductile. The former leads to the formation of cataclastite (fine grained granular) and shear fractures which dilate under low effective normal stress that can cause permeability enhancement. With increasing shear deformation, fracture asperities are sheared off leading to gouge production and a reduction in permeability. Thus, in brittle deformation permeability will generally increase under low effective stresses and small displacements but decreases with increasing effective stress and magnitude of displacement. Shear fractures created in ductile deformation contract during shearing and tend not to lead to an increase in permeability.
- Reactivation of faults can be assessed using both analytical and numerical approaches, but assessment is usually based on the Mohr-Coulomb failure criterion. This method can be used to determine the critical injection pressure.
- Numerical modelling can provide predictions of fault stability at different scales and incorporate different parameters such as the geometry of different faults. Numerical methods can be effective for identifying leakage potential and seal failure especially where dilatancy and stress dependent permeability changes occur.
- Experimental tests on minerals and rock samples exposed to CO_2 tentatively indicate that the coefficient of friction is not radically changed, however, this conclusion is based on limited exposure to CO_2.
- There is limited observational data on stress regimes and direct pore pressure measurements from core samples from cap rocks and fault zones. Acquisition of key data would enhance stress regime modelling and fault behavior.

2015-05 Oxy-Combustion Turbine Power Plants,
study managed by John Davison

Post combustion capture is usually considered to be the leading option for capture of CO2 at natural gas fired power plants but there is increasing interest in the alternative of oxy-combustion turbines which use recycled CO2 and/or H2O as the working fluid instead of air.

IEAGHG has engaged Amec Foster Wheeler, in collaboration with Politecnico di Milano, to carry out a study to assess the performance and costs of various oxy-combustion turbine power cycles, in particular the supercritical oxy-combustion combined cycle (SCOC-CC), S-Graz cycles and cycles being developed by NET Power and Clean Energy Systems (CES).

The main highlights of the study are:

- The predicted thermal efficiencies of the cycles assessed in this study range from 55% (LHV basis) for the NET Power cycle to around 49% for the other base case cycles. For comparison, a recent IEAGHG study predicted an efficiency of 52% for a natural gas combined cycle plant with post combustion capture using a proprietary solvent.
- There was shown to be scope for improving the thermal efficiencies in future for example by making use of materials capable of

withstanding higher temperatures. Proprietary improvements by process developers may also result in higher efficiencies.

- The levelised cost of electricity (LCOE) of base-load plants using natural gas at 8 €/GJ are estimated to be 84-95 €/MWh, including CO_2 transport and storage costs. The lowest cost oxy-combustion plant (NET Power) has a slightly lower LCOE than a conventional gas turbine combined cycle with post combustion capture using a proprietary solvent.
- The cost of CO_2 emission avoidance of the various cycles compared to a reference conventional natural gas combined cycle plant is 68-106 €/t CO_2 avoided.
- The base case percentage capture of CO_2 in this study was set at 90% but it was determined that it could be increased to 98% without increasing the cost per tonne of CO_2 avoided, or essentially 100% if lower purity CO_2 was acceptable.
- The base case percentage capture of CO_2 in this study was set at 90% but it was determined that it could be increased to 98% without increasing the cost per tonne of CO_2 avoided, or essentially 100% if lower purity CO_2 was acceptable.
- The water formed by combustion is condensed in oxy-combustion turbine cycles which would mean that if air cooling was used, the power plants could be net producers of water, which could be an advantage in places where water is scarce, although air cooling would reduce the thermal efficiency.
- Oxy-combustion cycles could have advantages at compact sites. The total area of an oxy-combustion combined cycle plant is estimated to be slightly less than that of a conventional combined cycle with post combustion capture. The ASU could be located off-site if required to further reduce the power plant area. In addition, regenerative oxy-combustion cycles are significantly more compact than combined cycles.
- Oxy-combustion turbines could be combined with coal gasification. The predicted thermal efficiency of a coal gasification plant with a SCOC-CC is 34% (LHV basis), which is similar to that of more conventional CCS technologies (IGCC with pre-combustion capture and supercritical pulverised coal with post combustion amine scrubbing) but the estimated capital cost and cost of electricity of the oxy-combustion turbine plant are significantly higher.

2015-06 Integrated CCS Project at SaskPower's Boundary Dam Power Station,
study managed by John Gale and Samantha Neades

On October 2nd, 2014, the first-ever, commercial-scale, coal-fired power plant incorporating amine solvent absorption carbon capture began operation near Estevan, Saskatchewan, Canada at the Boundary Dam Power Station, Unit 3 (BD3).

This was a global landmark event. Although carbon capture technologies had been pilot tested prior to this, a commercial-scale power plant now exists that has demonstrated a number of high-risk technology and business issues have been overcome.

The coal-fired BD3 power plant that was retrofitted to incorporate carbon capture was over 40 years old. This retrofit enables SaskPower to continue operating it under new Canadian GHG regulation that came into effect in July 2015. The CO_2 captured at BD3 is geologically stored at two locations: in an oil reservoir at Cenovus' CO_2-EOR operation near Weyburn, Saskatchewan, and in a deep saline aquifer at the SaskPower Carbon Storage and Research Centre, located near the Boundary Dam Power Station.

This report released by IEAGHG on August 31st, 2015 summarizes the experience and learnings of SaskPower to provide some insights to other clean-coal initiatives on a wide variety of issues during the design, construction, and first year of operation of BD3. It explores the journey that SaskPower made from the 1980s to mid-2015 in pursuit of clean-coal power generation. SaskPower pursued various technology options for carbon capture from oxyfuel combustion to amine solvent absorption that ultimately led to the decision to select the commercially unproven CANSOLV amine solvent carbon dioxide capture process. SaskPower then coupled that technology with Shell Cansolv's proven sulphur dioxide capture process to simplify the capture plant operation and to further reduce emissions.

2015-07 Monitoring Network Meeting, study managed by James Craig

We were very pleased to hold our 10th Monitoring Network meeting at Lawrence Berkeley National Laboratory in California on 10th - 12th June.

The venue provided great views over San Francisco bay area, which complemented the technical programme of presentations and discussions inside.

The 45 presentations and 17 posters covered a range of topics, with sessions on cost-effective monitoring of large projects, permit requirements, induced seismicity, shallow monitoring, geophysical monitoring and CO_2 relationships, pressure monitoring applications, monitoring tools for shallow, surface and deep monitoring, update on projects, and post-closure monitoring. As well as the new results and developments, new at this meeting was a group-work exercise created by Sue Hovorka of the University of Texas. This involved the groups designing monitoring plans for fictional but realistic storage sites, and then these being actually tested with leakage scenarios. The groups were able to apply what they had learnt in the meeting as well as their own expertise, and I'm pleased to say that all the monitoring plans 'caught' the various leakage scenarios!

Also of particular note were the international research collaborations being created around the Aquistore storage site in Saskatchewan and around the CMC controlled release in overburden being developed in Alberta. The Aquistore project has just started injecting CO_2 captured from the Boundary Dam coal power station into a deep saline formation, some 7,000 tonnes injected so far. PTRC has monitoring research collaborations with 26 organisations from 7 countries at this 'field laboratory', and the first monitoring data was shared at this meeting from downhole pressure, seismic, and pulsed-neutron logging measurements.

The overall conclusions of the meeting included identifying the value of pressure based monitoring for assessing reservoir behaviour and in the overburden for leak detection, the potential in fibre-optic distributed acoustic sensing (DAS) and permanent sources, the benefits of good engagement with regulators, the importance of geomechanical analysis using the monitoring data, and the feasibility of offshore monitoring for leak detection and quantification.

Overall, a meeting packed with new developments in all aspects of monitoring CO_2 storage, shared and discussed by this group of leading international experts. Monitoring continues to make great advances.

Webinars

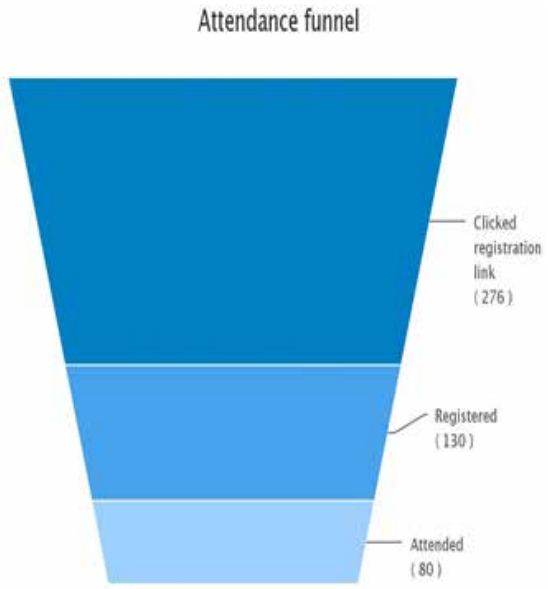
One of IEAGHG's key deliverables is dissemination. With the move to new offices and reliable fast broadband connections, we have been able to expand our repertoire beyond presentations and written reports to now include webinars.

Each year, the technical team manage a number of technical studies and reviews, some of these having a similar theme but different focus. Rather than just present a summary of these via webinar, IEAGHG decided that to add extra value, the team would bring these clustered reports together and present on the overall findings and thus was born the first webinar combining reports on CCS in the process industries. Additionally, we have run a number of stand-alone webinars providing an insight into unique reports and issues that we feel are of interest to our members.

To date, it would appear that this approach has proved popular, registrations regularly exceed the 100 mark and evidence that those joining the events stay for the duration (as shown in the attendance funnel and attendees in session charts - please see overleaf).

Attendees can also make the most of having access to the presenter with the webinar closing out on a Q&A session.

To offset the timing issues with webinars, given the global nature and heavy workloads of the community we are reaching out to, there is never going to be one time that suits all, each webinar is recorded and within a couple of hours posted to the IEAGHG YouTube Channel for those unable to attend to view at their convenience.



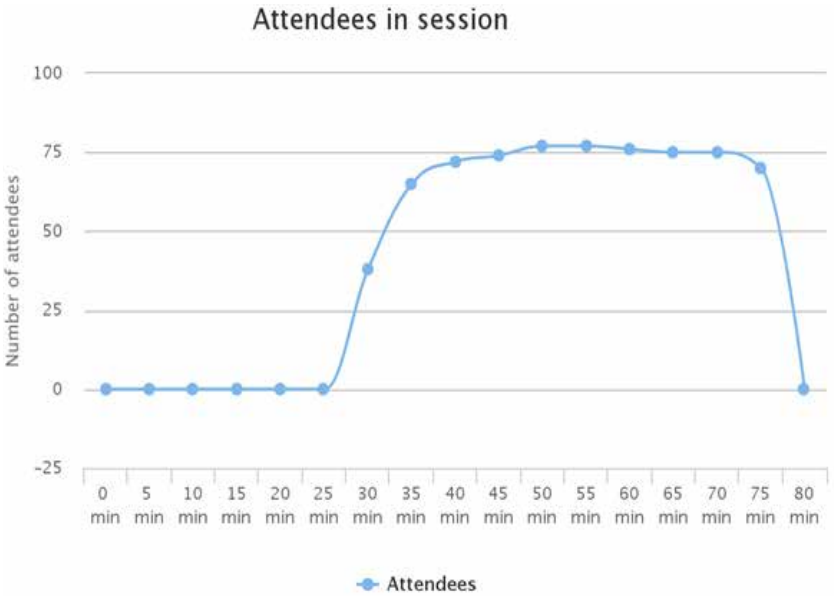


Table 1, below, provides an overview of the webinars, attendance and online views. Having added this new communications stream with such positive results, more are in the planning – details are sent out via our mailing list. If you do not receive our emails, please contact Becky.Kemp@ieaghg.org to be included.

Webinar Title	Date	No. Attendees	No. YouTube Views to Date
CCS in the Process Industries	24/06/2015	39	112
Biomass with CCS	26/08/2015	72	157
Offshore Monitoring for CO_2 Storage	28/10/2015	53	79
Integrated CCS at Boundary Dam	04/11/2015	46	247
IJGGC Special Issue	24/11/2015	61	71
Oxycombustion Turbine Power Plants	16/12/2015	46	179
A Reflection on COP21 and CCS	2/02/2016	82	99

Table 1: Webinar Titles, Attendance and Online Views

Technical Reports, Technical Reviews, Information Papers and Blogs

Report No.	Technical Report Title	Issue Date
2015/01	Monitoring Network and Modelling Network – Combined Meeting	March
2015/02	Review of Offshore Monitoring for CCS Projects	July
2015/03	CCS Cluster Projects: Review and Future Opportunities	April
2015/04	Criteria of Fault Geomechanical Stability	April
2015/05	Oxy-Combustion Turbine Power Plants	September
2015/06	Integrated CCS Project at SaskPower's Boundary Dam Power Station	September
2015/07	Monitoring Network Meeting	January

Table 2: List of 2015 Technical Reports

Review No.	Technical Review Title	Issue Date
2015-TR1	Peer Review (CONFIDENTIAL)	October
2015-TR2	Carbon Storage FY2015 Peer Review	October
2015-TR3	CCS Deployment in the Context of Regional Developments in Meeting Long-Term Climate Change Objectives	July

Table 3: List of 2015 Technical Reviews

IP No.	Information Paper Title	Issue Date
2015-IP1	GHGT-12 Feedback and Conference Statistics	January
2015-IP2	The Finance Sector Needs CCS. So is this a New source of Funding for Demonstration and Deployment of CCS Projects	January
2015-IP3	U.S. and India Climate and Clean Energy Cooperation	January
2015-IP4	US Actions to Reduce Methane Emissions	January
2015-IP5	The World of Carbon Trading: As It Stands Today	February
2015-IP6	Rivers in the Sky? No, it's Not Science Fiction	Februar
2015-IP7	IEA Industry Co-ordination Group Webinar in Waste Heat Recovery	February
2015-IP8	The Case for a Low Carbon Energy Transition in the UK	February
2015-IP9	The Water/Climate Change Nexus	March
2015-IP10	The Earth's Getting Hotter and So Does the Scientific Debate	March
2015-IP11	Global Emissions of Carbon Dioxide from the Energy Sector Stalled in 2014 – A Brief Review of what the Media have been Saying	March
2015-IP12	Exploring Methane Emissions with IPIECA	June

IP No.	Information Paper Title	Issue Date
2015-IP13	ADEME's CCUS Symposium	July
2015-IP14	Is a Mini Ice Age on the Way that will Stop Global Warming	July
2015-IP15	Rating Country Commitments to COP21	July
2015-IP16	The IEA Position on CCS	July
2015-IP17	First Reports Released from UK FEED on Peterhead and White Rose Projects	July
2015-IP18	Impact of other GHG's and Air Pollutants on the 2^0C Carbon Budget	July
2015-IP19	CO_2MultiStore: Optimising CO_2 Storage around the UK - London Launch	September
2015-IP20	Risk Management Network and Environment Research Network Combined Meeting Concludes	October
2015-IP21	Report on London Convention meeting LC-37 / LP-10. Very Poor Progress on the Export Amendment for CCS	October
2015-IP22	Energy Storage	October
2015-IP23	Status Report on Direct Air Capture	November
2015-IP24	INDC's and Implications for CCS	November
2015-IP25	CSLF Ministerial in Riyadh	November
2015-IP26	Extreme Weather and Climate Change – *"The proof if is proof was needed".*	November
2015-IP27	"Pathways to Commercialisation" Event	November
2015-IP28	HFCs included In Montreal Protocol	November
2015-IP29	Emissions Performance Standards	November
2015-IP30	Special Issue 10 year Anniversary IPCC	November
2015-IP31	Analysis: the Key Announcements from Day 1 at COP21 (30th November 2015)	December
2015-IP32	Carbon Capture and Storage: Achievements and Opportunities for Developing Country Involvement	December
2015-IP33	IEA CCS High Level Dialogue (CONFIDENTIAL)	December
2015-IP34	ENGO support for CCS	December
2015-IP35	49th Meeting of the Working Party on Fossil Fuels (CONFIDENTIAL)	December
2015-IP36	CSLF Report on Technical Barriers and R&D Opportunities for Offshore, Sub-Seabed Geologic Storage of CO_2	December

Table 4: List of 2015 Information Papers

Blog Title	Author	Issue Date
The Finance Sector needs CCS. So is this a New Source of Funding for Demonstration and Deployment of CCS Projects?	TD	January
Visiting the Kemper CCS Project	TD	February
Rivers in the Sky? No, it's not Science Fiction.	JG	February
In the Solar Glare – WFES 2015	JG	February
Biochar and Disjointed Research	JG	February
CCS in the Process Industries	JG	March
International Forum on Developments on CCS implementation	JG	March
It's all about Clouds	JG	April
IEAGHG Report: Carbon Capture and Storage Cluster Projects: Review and Future Opportunities	JK	April
IEAGHG Report: Criteria of Fault Geomechanical Stability during Pressure Build-up	JC	April
UKCCSRC Workshop on PCC Cost Reduction for the Power Sector	JG	April
7th IEA CCS Regulatory Network meeting	TD	April
14th Annual CCUS Conference	TD	April
Results from EU FP7 Project GHG EUROPE – GHG Management in EU Land Use Systems	JK	April
CCS Roadmap	JG	May
ADEME's CCUS Workshop in Le Havre – French Efforts in Carbon Dioxide Utilisation	JK	May
IEAGHG 47th Executive Committee Meeting	SN	May
IEAGHG joins the UNFCCC Climate Technology Centre and Network	TD	May
10th CO_2GeoNet Open Forum, May, 2015, Venice	JC	May
Norcem CO_2 Capture Project International Conference	JD	May
G20, OECD and Export Credits for Clean Coal Plants	JG	May
IEAGHG's upcoming 6th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting	JK	June
IEAGHG Launch Webinar Series	ST	June
Special Issue Announcement	JG	June
Monitoring Network Meeting 2015	TD	June
The Popes Encyclical on the Environment and Climate Change	JG	June
Official Opening of SaskPower's Carbon Capture Test Facility	TD	June
UK Targets CCS Phase 2	JG	June
New Secretary of State speaks at CCSA Presidents Reception 2015	TD	June

Blog Title	Author	Issue Date
Dutch go through the Courts to get more Action on Climate Change	JG	June
IEAGHG Launches Webinar Series	JG	July
What Geological CO_2 Storage can bring to Mitigating Climate Change – UK Research Perspective	JC	July
IEAGHG 5th Social Research Network Meeting	SN	July
A Mini ice Age – Really?	JG	July
Offshore CO_2 Environmental Impacts and Monitoring - QICS Project Results Published in a Special Issue of the International Journal of Greenhouse Gas Control	TD	July
Review of Offshore Monitoring for CCS Projects	JC	July
New IEAGHG Technical Review: CCS Deployment in the Context of Regional Developments in Meeting Long-Term Climate Change Objectives	JK	July
The World's Mayors and the Pope meet to discuss Climate Change	JG	July
IEAGHG Webinar on YouTube	ST	August
US DOE Carbon Storage Meeting and IEAGHG Monitoring Network	TD	August
New IEAGHG Report 2015-05: Oxy-Combustion Turbine Power Plants	JD	August
Updating the SRCCS	JG	September
IEAGHG's 6th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting	JK	September
ISO learns about Cement plant CO_2 Capture and Eight-Legged Horses in Norway	TD	September
Post Combustion Capture Experts Flock to Regina	ST	September
Early Autumn Highlights	JG	September
CO_2MultiStore: Optimising CO_2 Storage around the UK - London Launch	JC	September
Risk and Environment Meeting Concludes	TD	October
Project News at Risk and Environment Meeting – Endurance	TD	October
Risk Management Network and Environment Research Network Combined Meeting	JC	October
ICEF 2015 Japan	JG	October
USDOE Carbon Storage Program: 2015 Project Peer Review	JC	October
Very Poor Progress on the Export Amendment for CCS	TD	October
CCS Status in Japan	JG	October
Exciting Progress at Shell's Quest CCS project	AR	October
CSLF Ministerial in Riyadh	TD	November
The Long-Term Fate of CO_2 during Geological Storage – ULTimateCO_2 Technical Workshop	JC	November
Extreme Weather influenced by Climate Change	JG	November

Blog Title	Author	Issue Date
5th IEAGHG Oxyfuel Combustion Meeting –A Success and Looking to its Future	SS	November
New IPCC Chair Endorses need for CCS.	JG	November
IEAGHG/CSLF Workshop on LCA in CCUS	JK	November
UK Commitment to Climate Change and CCS	JG	November
New Direction at the IEA	JG	November
Blog from the start of COP-21, Paris	TD	November
New initiative launched at COP21	JG	December
CCS side event at COP21	TD	December
ADB and China Announce Road Map for CCS in China.	JG	December
OCED Agreement on Export Credits for Coal Plants Agreed	JG	December
Mid-way in COP	TD	December
Reflection on COP21 Day 8	JG	December
COP-21 outcomes	TD	December
2nd International Forum on Recent Developments of CCS – the Impact of Impurities on the Whole CCS Chain from Capture to Transport and Storage	JC	December

Table 5: List of 2015 IEAGHG Blogs

Presentations made in 2015

Date	Location	Presentation Title	Speaker
Jan	UNESCWA, Masdar, IEA Expert Workshop, Abu Dhabi	CO_2-EOR Status, Experiences and as a Storage Resource	JG
Jan	BEG, University of Texas	Update on CCS in the Global Climate Picture	TD
Jan	Birmingham, Alabama	Update Report on Activities to ISO TC 265	TD
March	Joint Workshop IEAGHG and IETS, Lisbon, Portugal	CO_2 Capture Storage, Use or Recycle	JG
March	Joint Workshop IEAGHG and IETS, Lisbon, Portugal	Understanding the Potential of CCS in Hydrogen Production (Review of Current State-of-the-Art)	SS
March	Leading the way to a Low Carbon Future, Athens, Greece	International Forum on Recent International Forum on Recent Developments of CCS Implementation	JG
April		IEA CCS Roadmap - and What's Next?	JG on behalf of JL
April	IEA Regulatory Network, Paris, France	Update on London Protocol	TD
April	IEA Regulatory Network, Paris, France	Update on CCS in the UNFCCC	TD & EL
April	UKCCSRC Biannual Meeting, Cranfield, UK	CCS in the Process Industries	JG
May	The Annual CCUS Conference, Pittsburgh, USA	CCS Cluster Projects - Review and Future Opportunities	TD on behalf of JK
May	The Annual CCUS Conference, Pittsburgh, USA	An Update on the View of CCS in the Global Climate Picture	TD
May	The Annual CCUS Conference, Pittsburgh, USA	Update on London Protocol - Developments on Transboundary CCS and on Geoengineering	TD & EK
June	Industry CCS Scoping Workshop, Birmingham, UK	CCUS in Industry Review of the Current State of Art (Case Studies for H_2 Production and Steel Industry	SS
June	CSLF Technical Group	Update on ISO TC 265 - 'Carbon Dioxide Capture, Transportation & Geological Storage'	TD
June	O_2Gen Workshop	Oxy-CFB Combustion Technology	SS
June	NETL CO_2 Capture Meeting, Pittsburgh	Emerging CO_2 Capture Technologies and their Cost Reduction Potential	JK
June	Canmet, Ottawa, Canada	IEAGHG - An Overview	JK
July	UKCCSRC, London, UK	What Next for CCS in the UK?	TD
Aug	US DOE Carbon Storage R&D Project Review Meeting, Pittsburgh	IEAGHG Monitoring Network - Updates from June Meeting	TD
Sep	2015 SaskPower CCS Symposium, Regina, Saskatchewan, Canada	Key Developments in CCS and Saskatchewan's Input	JG
Sep	Oslo, Norway	Update Report on Activities to ISO TC 265	TD

Date	Location	Presentation Title	Speaker
Oct	CCS Session at ICEF 2015, Tokyo, Japan	CCS Current Global Status	JG
Oct	CCS Technical Workshop 2015, Tokyo, Japan	World CCS: Current Status, Challenges and Future Directions	JG
Oct	MIT Carbon Sequestration Forum 17, Cambridge, USA	IPCC SRCCS - 10 Years Later	JG
Oct	5th Oxy-combustion Network Meeting, Wuhan, China	Techno-Economic Assessment of Oxy-Combustion Turbine Power Plants with CO_2 Capture	SS on behalf of JD
Nov	CSLF Technical Group, Saudi Arabia	IEAGHG Update to CSLF	TD
Nov	LCA in CCUS Workshop, London	LCA in CCUS Workshop Welcome	JK
Nov	LCA in CCUS Workshop, London	LCS in CCUS Workshop - Questions for Sessions	JK
Dec	UNFCCC Side Event, COP 21, Paris, France	CCS: Achievements and Opportunities for Developing Country Involvement	TD
Dec	49th WPFF, Paris France	Greenhouse Gas R&D Programme Update of Activities	JG
Dec	49th WPFF, Paris France	Progress on CCS at COP-21	JG
Dec	2nd International Forum on Recent Developments of CCS Implementation	Operational Flexibility of CO_2 Transport and Storage	JC
Dec	Methanol Technology and Policy Congress, Frankfurt, Germany	CCS and CCU their Role in the Mitigation of Greenhouse Gas Emissions from Energy Intensive Industry	SS

Speaker Abbreviations:

JC: James Craig: JD: John Davison JG : John Gale JK: Jasmin Kemper
SS: Stanley Santos TD: Tim Dixon

JL: Juho Lipponen EK: Edward Kleverlaan EL: Ellina Levina

Table 6: List of 2015 Presentations

Members of the Programme

AUSTRALIA

Mr Lincoln Paterson (M) | Dr Kelly Thambimuthu (Chairman)

AUSTRIA

Mr Theodor Zillner (M)

CANADA

Dr Eddy Chui (M)

DENMARK

Mr Eric Bjorklund (M)

EUROPEAN COMMISSION

Dr Vassilios Kougionas (M) | Jeroen Schuppers (A) | Wolfgang Schneider (A)

FINLAND

Mrs Pia Salokoski (M) | Mr. Eemeli Tsupari (A)

FRANCE

Ms Anne Varet (M) | Ms Aïcha El Khamlichi(A)

INDIA

Dr Atul Kumar (M)

JAPAN

Mr Ryozo Tanaka (M) | Dr. Ziqui Xue (A)

KOREA

Dr Jang Kyung-Ryong (M)

NEW ZEALAND

Mr Mark Pickup (M)

NORWAY

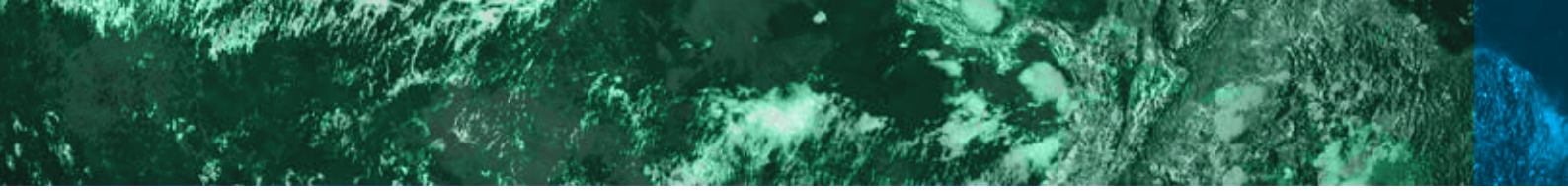
Mr Hans Jörg Fell (M) | Dr Åse Slagtern (VC)

OPEC

Mr Moufid Benmerabet (M) | Dr Mohammad Taeb (A)

SOUTH AFRICA

Dr Anthony Surridge (M)



SWEDEN

Mr Sven-Olov Ericson (VC) | Coralie Chasset (A)

SWITZERLAND

Dr Gunter Siddiqi (VC) | Dr – Ing Peter Jansohn (M)

UNITED KINGDOM

Mr Brian Allison (M) | Mr Will Lochhead (A)

USA

Jarad Daniels (M) | Mark Ackiewicz (M)

BG GROUP

Mr David Jones (M)

Chevron

Mr Arthur Lee (M)

CIAB

Mr Cartan Sumner (M)

Doosan Babcock

Mr Gerry Hesselmann (M)

EnBW

Dr.-Ing Sven Unterberger

EPRI

Mr Richard Rhudy

ExxonMobil

Dr Steve Lyons

GE ENERGY

Dr Markus Wolf (M)

INSTITUTO DE INVESTIGACIONES ELECTRICAS / IIE

Dr José Luis Fernández Zayas (M) | Zdzislaw Mazur (A)

JGC

Mr Natsuo Tashiro (M) | Mr Tsukasa Kumagai (A)

JÜLICH FORSCHUNGSZENTRUM

Mr Jürgen-Friedrich Hake (M) | Dr. Hubert H. Höwener (A)

Masdar INSTITUTE

Mohammad Abu Zahra (M)

Ms Viviana Canhão Bernardes Coelho (M)	Mr Paulo Negrais Carneiro Seabra (A)

Dr Reinhold Elsen

Mr Bill Spence

Britta Paasch(M)	Mr Henrik Solgaaard Andersen (A)

Mr Dominique Copin

Juho Lipponen

Evaluating technology options to mitigate greenhouse gas emissions

IEA Greenhouse Gas R&D Programme

Pure Offices, Cheltenham Office Park, Hatherley Lane,
Cheltenham, Glos. GL51 6SH, UK

Tel: +44 1242 802911 mail@ieaghg.org
www.ieaghg.org