Greenhouse News

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Landmark Carbon Capture and Storage (CCS) Project Opens, Tim Bertels, Shell

On 6th November, Shell's CEO Ben van Beurden officially launched Quest carbon capture and storage (CCS), a project to advance CCS technology further for a lower-carbon world.

More than 300 people from a dozen countries gathered in Alberta, Canada to join Shell's CEO for the official opening of Quest, showing the world that CCS is happening. Quest is designed to capture and safely store more than one million tonnes of carbon dioxide (CO_2) each year – equal to the emissions from about 250,000 cars.

Addressing guests at the official opening, Ben van Beurden said: "Quest represents a significant milestone in the successful design, construction and use of CCS technology on a commercial scale. Quest is a blueprint for future CCS projects globally."

Technologies that make up CCS have been used for decades and are now being brought together to capture and store CO_2. Quest captures emissions from Shell's Scotford Upgrader, which turns oil sands bitumen into synthetic crude that can be refined into fuel and other products. At Quest, CO_2 is first extracted from process gas streams using Shell's ADIP-X amine technology. The captured CO_2 is then compressed into a liquid state, transported through a 65-kilometre pipeline and injected more than two kilometres underground below multiple layers of impermeable rock formations.

Storing CO_2 Safely and Permanently

Shell has decades of experience with subsurface reservoirs, rock properties and the ways in which gases are transported and stored. The storage site for Quest – the Basal Cambrian Sandstone – is considered particularly ideal for safe CO_2 storage. It is more than two kilometres beneath multiple overlying layers of impermeable rock formations. The comprehensive system in place for measurement, monitoring and verification further ensures the captured CO_2 remains safely and permanently stored.

Supportive Partners and Neighbours

Quest is a strong example of business, government and civil society working together on low-carbon

In this issue

Aerial view of Scotford near Edmonton, Alberta

solutions. Quest was made possible through strong support from the governments of both Alberta and Canada (funding totaling C$865M). As part of its funding arrangements, Shell is sharing information on Quest's design, processes and lessons learned. The British government and the United States Department of Energy are also collaborating with Shell at Quest on additional research and field testing.

First CO_2 Injection Well

The Shell Scotford Upgrader

Local community support was essential to build Quest. Early consultation efforts focused on landowners and residents living along the proposed CO_2 pipeline route or near the proposed injection wells, and local government. Stakeholder input led Shell to pipeline route adjustments and its route followed 28 kilometres of existing pipeline to minimize the impact to the environment. A Community Advisory Panel made up of local residents, regulatory agencies and members from the academic community meets quarterly to review the results of Quest's monitoring programs. ●

IEAGHG CCS Side Event at COP21, by Tim Dixon, IEAGHG

Tuesday 1st December 2015 saw the main UNFCCC Side-event on CCS, organised by IEAGHG, University of Texas, CCSA and CO_2GeoNet. The event was titled "Carbon Capture and Storage (CCS): Achievements and Opportunities for Developing Country Involvement". The event was very well attended, with around 200 attendees, many from developing countries, and various media.

Tim Dixon at the COP21 IEAGHG Side Event


A brilliant turnout at the COP21 IEAGHG Side Event

After scene-setting by myself, Philip Ringrose of Statoil presented on 19 years of operations in the North Sea region, which appeared to be impressive news to some that CCS had been in operation so long. Ton Wildenborg of CO_2GeoNet presented on EU pilot projects which have collectively demonstrated the safety of storage. We were privileged to have The Honourable Brad Wall, Premier of Saskatchewan, Canada, provide a politicians perspective and to introduce 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. This will be a new international research centre based around SaskPower's facilities and experiences with capture at Boundary Dam and storage at Aquistore, and which will be open to international participation. 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 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. Not surprisingly, questions were asked and concerns were expressed around the UK government's recent policy change on the CCS Competition.

Overall, I think that the side-event achieved its objectives of communicating the messages that CCS projects have successfully operated for many years, from small pilot-scale projects to large-scale such as at Boundary Dam, and new opportunities are becoming available to share this knowledge and these experiences, such as through SaskPower's new global knowledge centre and in offshore storage.

Reporting of the event at COP by IISD can be seen at **www.iisd.ca/climate/cop21/enbots/1dec.html#event-6**, and the Powerpoints are available on the UNFCCC Side-event website at **https://seors.unfccc.int/seors/reports/events_list.html?session_id=COP21** (see Tuesday 1st December 15:00).

In addition, the exhibit booth on CCS, run jointly by the University of Texas, CO_2GeoNet, CCSA and IEAGHG, proved very busy, with a continuous flow of COP delegates seeking a range of information on CCS. IEAGHG used it in particular to promote the International Journal of Greenhouse Gas Control Special Issue and the new report on Boundary Dam. (technical report number 2015-06).

(Article photos courtesy of UKCCSRC) ●

Final Call for Abstracts – GHGT-13,

by Siân Twinning, IEAGHG

The deadline for submission of abstracts is the 10th February 2016. The Technical Programme Committee (TPC) would like to challenge every European CCS project to submit and present their work at the conference. With the venue in Switzerland, this would be an ideal opportunity to demonstrate to the wider CCS community that CCS in Europe is still very much alive and kicking. Of course, having thrown down this gauntlet to Europe, it is up to projects in the rest of the world to shout about their activities so that together, we can present the global CCS scene.

As always we are encouraging submission across the broad spectrum of CCS and if there is an area we don't name and you would like to see at the conference, please submit and encourage others, the programme is defined by the abstracts we receive!

We are very pleased to announce our first keynote speaker has been confirmed, Mr. Kamel Bennacuer who has recently been appointed Director of Sustainable Energy Policy and Technology at the International Energy Agency. With the organisation gathering pace, we are also glad to welcome on board ExxonMobil, Gassnova and TCM as conference sponsors.

We look forward to receiving your abstracts and seeing you in Lausanne in November.

More details can be found at **www.ghgt.info**

This will be your final reminder for submission!

PCCC3 Summary Brochure, by Siân Twinning, IEAGHG

Hot on the heels of the most successful Post Combustion Capture Conference (PCCC) in the series to date with over 190 attendees (a 22% increase), IEAGHG have produced a summary brochure looking at the key highlights presented at the meeting.

The Conference was supported by a one day Symposium hosted by SaskPower to celebrate one year since commissioning of the capture plant was completed at Boundary Dam. The day gave unparalleled insight into the business case, the policy issues faced and conquered, as well as some very frank technical presentations giving the audience a rounded view of the project with the specific aim to cultivate a sharing ethos.

As you would expect, 190 people did not go all the way to Regina, Canada without the anticipation of a visit to the Boundary Dam site itself. Well they ended up with much more than that. With what became dubbed the 'Grand CCS Tour', attendees were treated to a 2 ½ hour drive through some of the flattest scenery where only the curvature of the Earth spoils the view down to Estevan and Boundary Dam. Time constraints meant that the tour of the Shand CO_2 Capture facility was a virtual but very informative one and after a tour of the Boundary Dam 3 site, attendees moved on to the Aquistore project site to be given a presentation on the injection and monitoring activities underway there. The journey back passed through the Weyburn-Midale site – where else can you find such a concentration of CCS activity?

Almost as notable as the conference and conjoining SaskPower Symposium day were side events timed to coincide with the Conference and Symposium. Taking advantage of having the world's leading PCC researchers and industrial suppliers gathered, SaskPower announced the signing of a Memorandum of Understanding (MoU) with BHP Billiton to allow the development of a knowledge sharing centre aimed at accelerating

the deployment of CCS through shared learning. IEAGHG launched their report 'Integrated CCS Project at SaskPower's Boundary Dam' (2015/06) during a presentation on the report by its author Dr Carolyn Preston. This has since been the subject of a webinar the recording of which can be found at www.youtube.com/watch?v=JQcxy4hbet8 . The final announcement came from one of the Conference sponsors, Climate Change Emissions Management Corporation (CCEMC) of Canada. They announced the opening of the next round of their 'Grand Challenge', attendees were invited to apply for funding from a 35 million Canadian Dollar pot. Projects that will provide significant and verifiable GHG reductions can apply at http://ccemc.ca/grand-challenge before the 18th January.

A copy of the Summary report can be found on our website at www.ieaghg.org/conferences/pccc/52-conferences/pccc/470-3rd-post-combustion-capture-conference

IEAGHG would like to acknowledge and thank Dr. Gary Rochelle and his students from the University of Texas at Austin who provided technical input and session summaries to allow the compilation of this publication.

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

The 5th Oxyfuel Combustion Meeting is the 8th in the series of oxyfuel combustion meetings, workshops and conferences organised by IEAGHG. This meeting was held in Wuhan, China from 27th – 30th October 2015. In collaboration with Huazhong University of Science and Technology (HUST), we welcomed 122 delegates from 14 different countries worldwide.

We are pleased to report the successful end to this, the largest gathering of oxyfuel combustion experts worldwide, with the delegates taking away an optimistic message that this technology could still be demonstrated by 2020.

The keynote addresses were presented by Ms. Jiang Wu (Capture Power Ltd.), Prof. Zheng Chuguang (HUST) and Dr. Chris Spero (Callide Oxyfuel Project Ltd.).

An important key message to re-convey is that the technology is ready for large scale demonstration.

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 with the progress that has been made. It expected that FID 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 are the necessary steps taken to establish the business case of CCS in UK.

Prof. Zheng conveyed the steady progress made by the Chinese consortium with regard to development of oxyfuel combustion technology. The success in commissioning of the 35th MWth 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 a large pilot scale of the CPU. These results feed into the on-going FEED study led by Shenhua Guohua Electric Power to realise the retrofit of the 200MWe power plant in China.

Dr. Spero highlighted the achievement of the Callide Oxyfuel Project (having the honour to operate the largest oxyfuel combustion power plant to date) realising 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).

Having mentioned the HUST's 35MWth facility – it would be a big miss 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 ASU (which demonstrated the current state of the art technology for oxygen production to be expected in the first generation large scale demo project).

Ms. Jiang Wu presenting the progress of the White Rose Project

The meeting included the Capacity Building Course which provides a good overview and

Visit to the HUST 35MWth Facility

Participation to the 5th Oxyfuel Combustion Research Network Meeting

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 in realising the successful commercialisation of this technology.

It is very important to note the facility visits made together with this meeting. These consisted of the visit to Alstom's WBC manufacturing facility (which is one of the most modern and largest boiler manufacturer sites in the world). It also included 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

All the meeting presentations have been uploaded to the IEAGHG website. You can download them by registering yourself to the IEAGHG Research Network and following the link: **www.ieaghg.org/networks/oxy-fuel-combustion-network** ●

IEAGHG/CSLF Workshop on LCA in CCUS,

by 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 myself, 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 I provided some initial questions for "Impact

Assessment and Interpretation".

The second day then addressed topics beyond environmental aspects of LCA, namely social LCA 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 a summary and main conclusions of the discussions in the sessions, highlighting the importance of transparency and the communication of uncertainties when undertaking LCAs.

We would like to thank all attendees for contributing to the excellent and constructive discussions and the members of the Steering Committee (Lars Eide, Andrea Ramirez, Anna Korre and Sarah Forbes) for helping with the organisation of the technical content of the workshop.

The presentations of the meeting will be available soon for download on IEAGHG's website and we will also produce a short summary report about the meeting, which will include more details regarding the conclusions from the discussions and recommendations for further actions in this area.

For more information, please contact Jasmin Kemper at jasmin.kemper@ieaghg.org

IEAGHG Co-ordinates High-Level Peer Review of US DOE Research Projects, by 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 recognized 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 carbon dioxide (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.

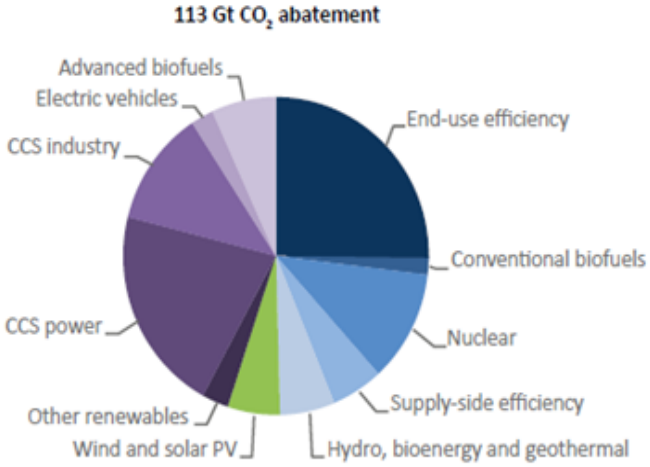
IEA World Energy Outlook Special Report: Energy Climate and Change, by IEA Secretariat, IEA

In June 2015, the International Energy Agency (IEA), published a World Energy Outlook Special Report on Energy Climate and Change. The report aims to support the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) which was held in Paris in the first 2 weeks of December 2015.

The report:

- Presents a detailed assessment of the energy sector impact of Intended Nationally Determined Contributions (INDCs) submitted COP21;
- Proposes a bridging strategy to deliver a near-term peak in global energy-related greenhouse-gas emissions;
- Highlights the urgent need to accelerate the development of emerging technologies that are, ultimately, essential to transforming the global energy;
- Recommends four key pillars on which COP21 can build success, from an energy sector perspective.

Figure 4.1 ▷ **Global cumulative CO_2 emissions reductions in the 450 Scenario relative to the Bridge Scenario by measure, 2015-2040**



Notes: End-use efficiency includes the effect of reduced activity levels, process changes and fuel switching. Supply-side efficiency includes fuel switching by sector, such as coal-to-gas switching in power generation. Electric vehicles here take into account pure-electric and plug-in passenger and commercial light-duty vehicles.

The IEA assessment of INDCs in the Special Report, most recently updated in October 2015, shows that annual energy-related emissions are expected to increase by 3.7 $GtCO_2$ from 2014 to 2030, reaching a total of 38.4 $GtCO_2$ per year in 2030. This would lead to a global temperature increase of around 2.7 °C by 2100, with a continued rise in temperature thereafter. Thus, the INDCs fall short of being sufficient to move the energy sector onto a pathway consistent with limiting long-term temperature rise to 2 °C; however, they do form a basis upon which to build ambition.

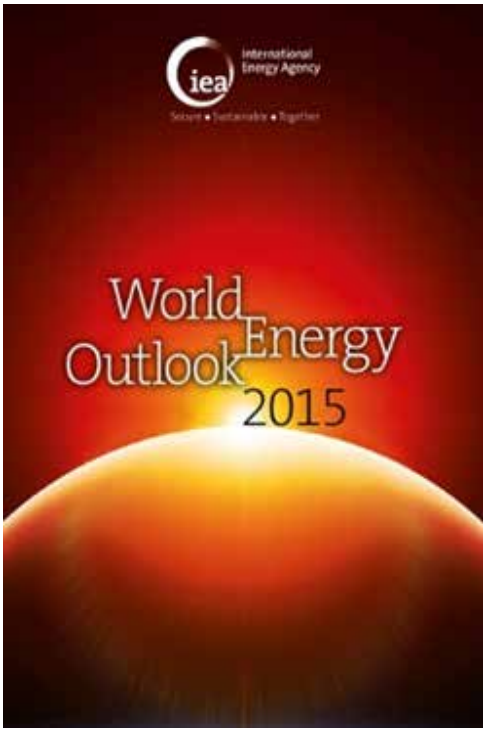
The Special Report identifies a near-term strategy, building on available technology and five proven policy measures that would allow the energy sector to achieve a peak in GHG emissions by around 2020. This strategy is developed and illustrated in the "Bridge Scenario". Adoption of these measures can be an important first step in moving towards a path consistent (through the adoption of further measures later) with the 2 °C climate goal.

The five policy measures are:

1. Increasing energy efficiency in the industry, buildings and transport sectors.
2. Phasing-out the use of the least-efficient coal-fired power plants.
3. Increasing investment in renewable energy technologies (including hydropower) over time, reaching at least $400 billion in 2030.
4. Gradual phasing out of inefficient fossil-fuel subsidies to end-users.
5. Reducing methane emissions from oil and gas production.

Achieving the long-term transition of the energy system to one consistent with the 2 °C goal will require further development and use of technology. While a wide range of technologies will contribute to the transition (see Figure top right), the Special Report focuses on three sets of technologies in particular: variable renewables, carbon capture and storage (CCS), and alternative fuelled vehicles.

In the 450 Scenario, rapid CCS expansion occurs after 2025, matching the pace of expansion of gas-fired capacity between 1990 and 2010. By 2040, 5.1 $GtCO_2$ is captured and stored annually – nearly triple India's energy sector emissions today – from both power generation and industry. The report finds that wide deployment of CCS technologies in industry and in the power sector will require substantial unit cost reductions and the identification of storage opportunities. This can be facilitated by Regulatory measures and targeted incentives to promote more large-scale projects; the continued pursuit of research and development to improve technologies and address challenges that arise during early commercialisation; and through public policies to encourage the early exploration for and development of CO_2 storage capacity.



The Special Report proposes four key pillars for success in Paris, the first of which is to set the conditions which will achieve an early peak in global energy-related emissions. This could, for example, be achieved by integrating the energy sector measures of the Bridge Scenario into nationally determined climate goals. Indeed, the ministers participating in the recent IEA Ministerial issued a statement calling for a successful outcome at COP21 and endorsing the five policy measures that underpin the Bridge Scenario. The ministerial statement also emphasises the need to accelerate innovation in safe and sustainable low-carbon technologies, consistent with the Special Report. ●

IEAGHG 10th International CCS Summer School,
by Siân Twinning, IEAGHG

There are very few places you can go for just one week and be presented to by experts, the entire CCS value chain. IEAGHG set up the International Interdisciplinary Summer School to achieve just this in 2007. Nine years later, the event is proving as popular as ever with an application to place ration of 2.6:1. 2016 will see the 10th Summer School return to Canada (last visit 2008), this time our hosts will be SaskPower and the event will be held in Regina with all the opportunities that being at the centre of excellence for CCS will provide. In addition to the Integrated CCS project at Boundary Dam, Saskatchewan is also home to the CO_2 Capture test facility at Shand, the IEAGHG Weyburn-Midale CO_2-EOR monitoring and storage project and the Carbon Storage and Research Centre (Aquistore).

With the event being held in July, we are now inviting applications to attend the week long programme from students and early career researchers working within the field of CCS or who are interested in moving into CCS. Series and local sponsorship allows us to make the event free to attend with the weeks programme, accommodation and meals provided.

Reflections on the IEAGHG Summer School 2015, Australia

For more information and to apply, please see our website: **www.ieaghg.org/education/summer-school**

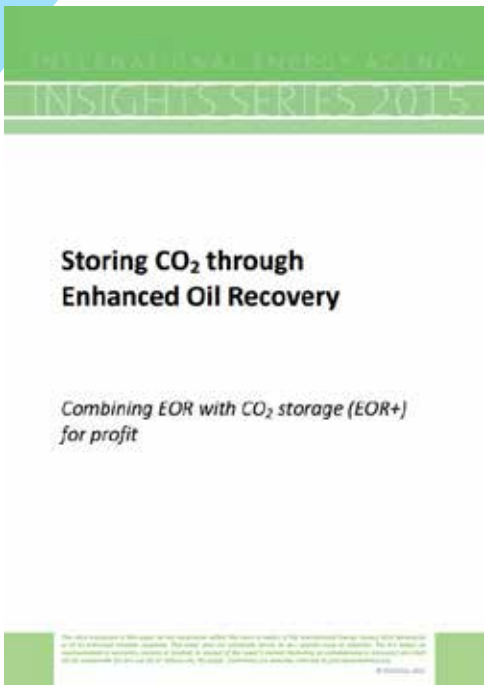
Storing CO_2 Through Enhanced Oil Recovery - Combining EOR with CO_2 storage (EOR+) for Profit, New Report by the IEA

Carbon dioxide (CO_2) has been used commercially for decades to increase recovery from oil fields in a process called "CO_2-enhanced oil recovery" or CO_2-EOR. Harnessing this practice for permanent storage of CO_2 is possible, but requires a major paradigm shift from conventional EOR to "EOR+".

The new IEA publication Storing CO_2 through Enhanced Oil Recovery finds that EOR+ requires at least four additional activities that build confidence that injected CO_2 will remain in the reservoir:

- site characterisation and risk assessment to validate storage capability
- monitoring of fugitive emissions
- enhanced surveillance and subsurface monitoring
- changes to field abandonment practices.

EOR+ can offer a way to combine CO_2 storage with increased oil production, and give a boost to CCS technologies as a whole. Our analysis of a hypothetical, representative oil field



demonstrates that EOR+ can under the right conditions be more profitable than traditional EOR – if in addition to the benefit that comes from additional oil production, the EOR+ operator receives a benefit from storing CO_2 resulting for example from an adequate price on carbon.

IEA analysis shows that EOR+ practice can be beneficial for the climate, as CO_2 stored under EOR+ operations can significantly outweigh the CO_2 resulting from additional oil production. But assessing those benefits is complex and depends on field-specific factors and changes in oil markets. And the climate benefit can be realised only when the CO_2 used in EOR+ comes from power plants or industry – not from natural geologic sources, as is common with conventional EOR today.

In aggregate, EOR+ offers a significant prize. Up to 375 billion barrels of additional oil could be produced from suitable fields across the globe. Between 60 and 240 gigatonnes of CO_2 could be stored underground in the process.

We hope you find the report interesting. Should you have comments – please contact Mr. Juho Lipponen, Head of the CCS Unit at juho.lipponen@iea.org

Press Release: CCP Publishes Results From Third Phase Of Program

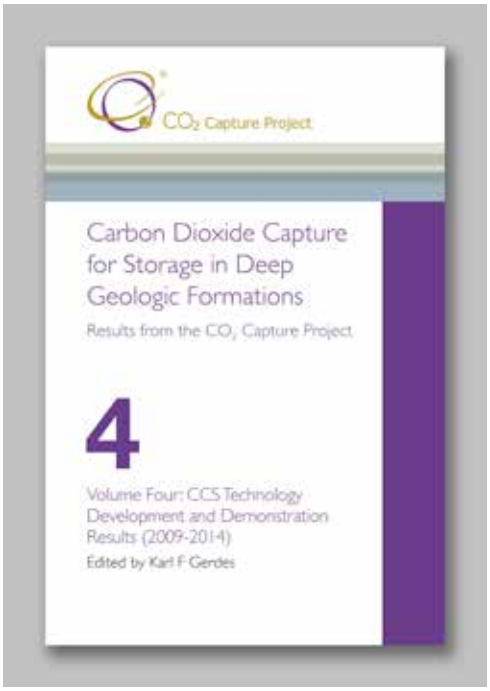
The CCP (CO_2 Capture Project) has published comprehensive results of work from its award-winning third phase of activity, CCP3, in a new volume entitled Carbon Dioxide Capture for Storage in Deep Geologic Formations – Results from the CO_2 Capture Project Volume 4.

The new volume – which follows those published for the first two phases of CCP activity – is available to download at www.co2captureproject.org/reports.html.

CCP3 was recently recognised with a CSLF Global Achievement Award, reflecting CCP's role as an exemplary model of science-based research, development and demonstration. Key CCP3 projects featured in the new volume include two field-based capture demonstrations, R&D results for new, promising CO_2 capture technologies, a comprehensive set of studies evaluating the deployment of CO_2 capture in oil and gas applications, a series of storage monitoring technology field trials, and a range of studies and reports that have significantly increased understanding of CCS potential for the oil and gas sector.

Newly elected CCP Chair Jonathan Forsyth, comments: "The sharing of results and insights from our CCS R&D with the technology community and wider energy-industry stakeholders is an important aspect of the work of the CCP. We are therefore delighted to have published this latest volume of our work and hope that the findings from the last five years of our program will help to inform the progress of low-carbon energy solutions."

CCP3 delivered a portfolio of CO_2 capture projects including demonstrations at representative industrial scale for key technologies of interest, supported a shortlist of new technologies to advance their development towards readiness for field-based pilot testing,



scanned the landscape for emerging new technologies to understand their potential and evaluated the application of state of the art technology for specific applications.

One of the key capture projects highlighted is a Once Through Steam Generator (OTSG) oxyfiring pilot for steam-assisted heavy oil extraction – carried out in Alberta, Canada on a retrofitted 50 MMBTU/hr OTSG unit. The recently released results contained in the volume showed that the OTSG could

be operated safely in oxy-firing mode and that the transitions between oxy-firing and air-firing could be carried out smoothly and safely. This result confirmed that existing commercial OTSGs could be retrofitted for CO_2 capture and could provide operational flexibility by smoothly transitioning from oxy-firing to air-firing whilst maintaining constant steam output.

With regard to CO_2 storage, the new volume details the considerable progress made in supporting the technical case for CO_2 assurance. The programme focused on better understanding and challenging assumptions around the behaviour of CO_2 stored underground, development of monitoring and verification technologies and contingencies planning to demonstrate safe and secure geological containment. Work included modelling and simulation, lab experiments and field deployments.

The work of CCP over the last 15 years has created a significant body of knowledge. CCP remains committed to its central objectives of driving down the cost of CO_2 capture technologies for future use by the oil, gas and power generation industries and of building better understanding of CO_2 storage and monitoring technologies.

A new program – CCP4 – is underway with an overall focus on supporting the development and demonstration of new CCS technologies for both CO_2 capture and storage. To find out more about CCP4 and for updates on CCP news, register at www.co2captureproject.org, while a CCS educational tool is also available at www.ccsbrowser.com. ●

The Long-Term Fate of CO_2 During Geological Storage – ULTimateCO_2 Technical Workshop,

by James Craig, IEAGHG

The ULTimateCO_2 project, managed by the French geological survey BRGM, is drawing to a close. The aim of this project is to advance the understanding of processes that affect the long-term storage of CO_2 and the production of guidance for predicting the long-term retention of CO_2.

This four-year project has united 12 partners including research institutes, universities and industry from 10 countries. The culmination of the research was presented at a technical workshop in Paris in October. The meeting reviewed how a combination of model projections, lab experiments and the study of natural analogues can be used to predict how CO_2 can be trapped and retained in natural reservoirs.

ULTimateCO_2 will enable operators, regulators and other stakeholders to understand how different processes, particularly trapping mechanisms, secure CO_2. The guidance produced from the research is designed to meet the requirements of the European Directive on geological storage of CO_2 (2009/31/EC) which has established a legal framework for the environmentally safe geological storage of CO_2. www.nationalcoalcouncil.org/studies/2015/Leveling-the-Playing-Field-for-Low-Carbon-Coal-Fall-2015.pdf ●

Press Release: National Coal Council Releases New Report for U.S. Secretary of Energy: "Leveling the Playing Field for CCS Technology"

The National Coal Council (NCC) has released a new report that calls for creating a level playing field to deploy CCS used for coal, natural gas and industrial sectors at commercial scale.

The white paper offers recommendations to create "policy parity" for CCS to achieve diverse energy policy objectives and examines the state of play for clean energy development including coal. Authors have provided a gap analysis defining the difference between the current trajectory of CCS and what is needed to propel its progress.

The white paper was requested by U.S. Secretary of Energy Ernest Moniz in advance of the U.N. Conference of Parties in Paris late this month. The NCC was chartered in 1984 under the Federal Advisory Committee Act (FACA) to advise, inform and make recommendations to the U.S. Secretary of Energy on matters related to coal policy and technology.

"Coal will continue to be a major source of electricity in the United States and globally for decades to come," said NCC Chair Jeff Wallace, retired Vice President of Fuel Services for Southern

Company. "The world needs CCS to achieve its environmental goals, and CCS offers the greatest opportunity to capture, use and store significant volumes of carbon dioxide from fossil fuels."

Some 87% of global energy is supplied by fossil fuels, and coal is by far the most abundant fossil fuel by reserves. Coal provides 44 percent of the world's electricity. Coal will remain the dominant fuel for power in 2035, accounting for approximately one-third of electricity, according to the BP Energy Outlook 2035. Currently there are more than 2,200 coal units in construction and planned globally.

NCC Report Chair Glenn Kellow, Peabody Energy's President and Chief Executive Officer, explained that the U.S. Department of Energy has stewarded a successful research and development program to spur early development of CCS technologies, though greater support is needed to bring CCS to commercial scale.

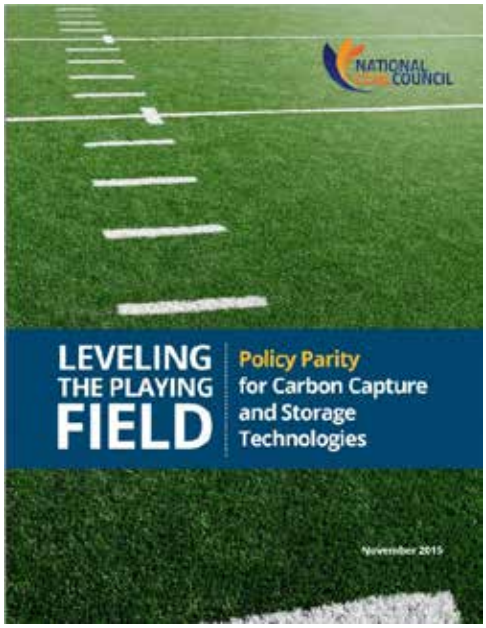
"We believe the recommendations in this report will bring much needed advances to commercialize this vital technology and will help guide decisions on global facilities that will operate for years to come," said Kellow. "This report addresses the path to near-zero emissions, which is recognised by global leaders as essential to carbon goals," Kellow said.

Principle report recommendations include:

1. Financial Incentives: Financial incentives for CCS must be substantially increased and broadened to include incentives available to other clean energy sources. Incentives should be emphasised and designed recognizing, as with wind and solar in the 1990s, that CCS is an immature technology with upfront risks and high capital costs. Risk to capital must be reduced, and operating incentives are important to assure a steady long-term revenue stream and lessen direct costs to consumers.
2. Regulatory Improvements: A first-of-its-kind regulatory blueprint is needed to remove barriers to construction and development of CCS projects. This blueprint would be applicable to power plants and carbon capture facilities and would apply to transportation and injection.
3. Research, Development and Demonstration: The U.S. Department of Energy must be a catalyst for additional commercial-scale demonstration projects, and such projects must commence immediately. The NCC believes that the United States should set a goal of bringing online 5 to 10 gigawatts of commercial-scale projects by 2025, and development must begin now.
4. Communication and Collaboration: The U.S. Department of Energy must assure U.S. and global policymakers and other stakeholders that fossil fuels will be used in coming decades to a greater extent than today, and there is a resulting need for CCS. The U.S. Department of Energy should initiate international collaboration to support the prompt deployment of 5 to 10 GW of commercial scale demonstrations in addition to U.S. projects.

In assessing policy parity for CCS, the NCC noted U.S. renewables received 12 times the federal subsidies compared with coal in 2013 even though fossil fuels produced 79 percent of U.S. energy, and renewables 11 percent.

NCC Executive Vice President and Chief Operating Officer Janet Gellici noted that the NCC has a long history of developing studies and reports supporting deployment of CCS technologies to achieve the world's ambitious environmental goals.



The NCC's Leveling the Playing Field white paper is the tenth report the Council has prepared for the U.S. Secretary of Energy on carbon management policy and technologies since 2000, Gellici said. The NCC Technical Report Chair and lead author was Fred Eames, Hunton & Williams, with Janet Gellici as a contributing author.

Council members are appointed by the U.S. Secretary of Energy and serve at no compensation. A list of Council members is available from the NCC office at info@NCC1.org or 202-756-4524.

To download the full report, please follow this link: www.nationalcoalcouncil.org/studies/2015/Leveling-the-Playing-Field-for-Low-Carbon-Coal-Fall-2015.pdf

Design and Costing of 1000 MWth Boiler for Chemical-Looping Combustion, by Anders Lyngfelt, Chalmers Tekniska Högskola

Chemical-looping combustion (CLC) is a novel principle of combustion where CO_2 is produced in a separate stream as a result of the process itself. This is possible without any gas separation process in contrast to normal CO_2 capture technologies like post-combustion or oxy-fuel, where you need to process around 10,000 cubic meter of gas for every tonne of fuel, in order to produce either a CO_2 stream or an oxygen stream. These gas separation processes are associated with inevitable costs of equipment and energy penalties. In CLC it is possible to avoid the gas separation step because fuel and combustion air are never mixed. Instead the oxygen is transferred from air to fuel by means of a metal oxide particles called the oxygen-carrier, which circulates between two fluidized beds, the air reactor and the fuel reactor. The gas leaving the fuel reactor is ideally pure CO_2 and H_2O, the latter easily removed by condensation.

A key question is if this process really works in practice, but more than 7000 h of operation in 24 pilots with more than 50 different oxygen carrier materials clearly indicate that this is the case. In particular the results with solid fuels, e.g. successful operation of a 100 kW pilot, are important because of the potentially low costs for CO_2 capture. Although cost estimations for solid-fuel CLC in the range 10-25.7 €/tonne CO_2 have previously been published, essentially no data to support these results have become public.

With respect to technology, there are large similarities between CLC and conventional combustion of solid fuels in circulating fluidized bed (CFB). In order to achieve a better understanding of technology differences, development needs and key costs, a detailed comparison between a 1000 MWth CFB boiler and a CLC system was made. The study analyses a possible CLC boiler design in terms of mass and heat balances, flows, solids inventories, boiler dimensions, expected performance and added costs compared to the reference CFB. Major costs are associated with CO_2 compression, oxygen production for "oxy-polishing", oxygen carrier, added boiler cost and steam/CO_2 fluidization of the fuel reactor. In total the cost was estimated at 20 €/tonne CO_2 captured, with a range from 16-26 €/tonne CO_2 avoided. The energy penalty was found to be 3.9%.

The basis for the design is well explained and cost calculations are given in detail. Thus, the cost calculations are transparent and easy to verify or improve.

Lyngfelt, A., and Leckner, B., A 1000 MWth Boiler for Chemical-Looping Combustion of Solid Fuels - Discussion of Design and Costs, Applied Energy 157 (2015) 475-487 (Available in Open Access: www.sciencedirect.com/science/article/pii/S030626191500519X) ●

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

The 6th High Temperature Solid Looping Cycles Network Meeting took place from 1st to 2nd of September 2015 and was jointly organised by IEAGHG and 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.

Day 1 started with Carlos Abanades (INCAR-CSIS) who brought everyone up-to-date on the progress in calcium looping post-combustion technologies, before the agenda went on to provide the latest research and advances in calcium and chemical looping pilot plant testing, solid carrier fundamentals and process integration. On the second day, Tobias Mattisson (Chalmers University) provided delegates with review on the progress in chemical looping technologies, analogous to Carlos' presentation on the day before. The following technical 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. The meeting 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 August 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 again for contributing to this excellent meeting and hope to see you in about two years' time in Sweden.

The presentations of the meeting will be available soon for download in the members' area of the HTSLCN and we will also produce a summary report about the meeting.

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

Midwest Regional Carbon Sequestration (MRCSP) – 2015 Annual Meeting Recap,

by Lydia Cumming and Neeraj Gupta, Battelle

The Midwestern Regional Carbon Sequestration Partnership (MRCSP, www.mrcsp.org) held its annual partner and stakeholder meeting at Battelle in Columbus, Ohio. Led by Battelle (www.Battelle.org), the MRCSP is one of seven regional partnerships established by the U.S. Department of Energy to study and develop carbon storage options across the USA. MRCSP is now well into the 10-year Development Phase of the research. The MRCSP is conducting a large-volume CO_2 injection test in Michigan, USA. The goal is to inject and monitor one million metric tons of CO_2 into depleted oil and gas reservoirs during a span of several years. The source of CO_2 for the test is the by-product of natural gas processing from shale gas production in shallower formations. The testing is being carried out across multiple carbonate reef oil fields in different stages of the oil production life cycle: late-stage fields that have already undergone significant CO_2-EOR, active CO_2-EOR operations, and a new CO_2 flood. MRCSP is testing the effectiveness and cost of various tools for measuring, monitoring, and modeling the CO_2 behavior in these closed reservoirs. Ultimately, the data collected will help to accurately predict how much CO_2 can be stored and how such projects can be designed to be safe, environmentally friendly, and cost-effective. Since monitoring operations began in February 2013, more than 430,000 tons of net CO_2 has been injected. Historically, the cumulative net CO_2 retention in the EOR fields exceeds 1.5 million tons.

More than 80 research partners, project supporters, and other interested stakeholders participated in the 2015 meeting. The group met to review MRCSP's accomplishments and discuss how they relate to the current policy context and future challenges for CCS. The group also reviewed several other emerging research developments and heard from the U.S. Department of Energy about the overall carbon storage program.

Battelle Principal Investigator Dr. Neeraj Gupta highlighted recent progress in the field, efforts to further improve the geologic characterization of the ten-state MRCSP region, joint "piggyback" research being conducted in third-party well bores, research to further characterize the potential CO_2 storage resources, and the role of enhance oil recovery with CO_2 storage to mitigate climate change. There is enormous potential to store CO_2 in the region," said Gupta. "Research on assessing storage capacity, characterizing geologic formations, CO_2 accounting, monitoring, and reservoir modeling are yielding results which demonstrate that CO_2 can be safely injected and monitored." Plans for the coming year to monitor new fields with advanced technologies were presented to the audience.

Other theme sessions for the meeting included CCS policy context, risk assessment and mitigation, and related technologies such as brine disposal from shale gas operations. U.S. EPA's Clean Power Plan and the role of CCS in its implementation were discussed in a keynote speech by Dina Kruger, the former Director of USEPA Climate Change Division. The discussion touched on GHG limits for

new and existing electricity generating units and a federal implementation plan and model rule for emissions trading under the program. An update to the Coal Technology R&D Roadmap issued jointly by the Electric Power Research Institute (EPRI) and the Coal Utilization Research Council (CURC) was presented. Additional presentations on policy included role of CCS in international climate negotiations and the federal incentives available to encourage CO_2 storage and CO_2-EOR development. Other presentations focused on topical issues for CCS including: risk assessment, monitoring technologies, wellbore integrity, interplay between brine disposal and CO_2 storage, induced seismicity, and exploration strategies for mapping storage potential. Reports on brine disposal and well integrity are scheduled to be issued this fall – look to MRCSP Website for announcements later in the fall.

The annual meeting is an important opportunity for those involved in CCS in the region to meet, share information, and further working relationships to help build a core competency in the region. Information on overall MRCSP activities, including project updates and past reports, is available at www.mrcsp.org.

Polish Post-Combustion CO_2 Capture Pilot Programme has Been Successfully Accomplished, by Adam Tatarczuk, IChPW

The Institute for Chemical Processing of Coal (IChPW) in cooperation with TAURON Group, the second largest producer of electricity in Poland, developed 1,2 CO_2 TPD mobile pilot plant for post-combustion carbon capture. Since 2013 the pilot plant has been operated for more than 2200 h and successfully demonstrated reliable operation during the removal of almost 100 tons of CO_2 from flue gases using advanced amine scrubbing process with the reboiler heat duty below 3 MJ/kgCO_2.

The process maturity and simplicity of incorporation into existing power plants are main advantages of post combustion amine based carbon capture technology. The latter is especially important for countries like Poland where more than 80% of electricity is produced from coal. The main disadvantage of the amine based process is the energy penalty. There are mainly two ways of reducing the energy demand of the amine based carbon capture: solvent developments and process flow sheet modifications. That two paths were investigated by a team of scientist during the largest polish research project focused on the post combustion carbon capture.

The objective of the Strategic Research Program-Advanced technologies for energy generation: Development of a technologya for highly efficient zero-emission coal-fired power units integrated with CO_2 capture, co-financed by the National Centre of Research and Development was to develop technological solutions which will contribute to the achievement of 3 x 20 strategy (reduce greenhouse gas emissions by 20%, reduce energy use by 20%, achieve 20% of renewable energy in energy supply).

Putting the mobile pilot plant into operation in 2013 at TAURON's Power Plant in Łaziska Górne was one of the breakthrough moments of the programme.

First campaigns were focused on gaining operational experience using baseline solvent monoethanolamine (MEA) solution and testing of the novel construction of the stripper. First 550 hours proved efficiency of the pilot plant. Initial results showed the reduction in the reboiler heat duty for modified process by 8 to 11 % and the increase of the CO_2 recovery by 8 to 12% comparing to standard flow sheet.

In 2014, the pilot plant was transported and connected to the hard coal fired, fluidized bed boiler where overall, 850 hours of

Mobile pilot plant at Łaziska Power Plant -2013

tests were conducted. Thanks to flexible technological design, numerous process flow sheet modifications were tested. Using split flow and multi absorber feed processes together with advanced solvent, allowed decreasing the reboiler heat duty below 3 MJ/kgCO_2 during tests at the TAURON's Power Plant in Jaworzno.

IChPW post-combustion CO_2 capture research team

During third year of the research which was conducted again at Łaziska Górne Power Plant, research team focused on testing novel solvents. Together with power efficiency research, emission and degradation tests were carried out. Acquired data allows CO_2 capture units optimization and will be useful for scaling-up amine scrubbing CO_2 capture plants. The pilot plant is now being upgraded for CCU project which will be focused on chemical utilisation of the CO_2 captured using the mobile pilot plant. Simultaneously the plant could be used for commercial solvent testing for capture process.

TAURON Group and The Institute for Chemical Processing of Coal were awarded the Golden Laurel of Innovation for amine-based carbon capture mobile pilot plant by the decision of Polish federation of Engineering Associations.

If you are interested in having more details about polish programme, please don't hesitate to contact research team: **tatarczuk@ichpw.pl**. ●

CO_2 Stored - the UK CO_2 Storage Evaluation Database (hosted and under development by the British Geological Survey (BGS) and The Crown Estate)

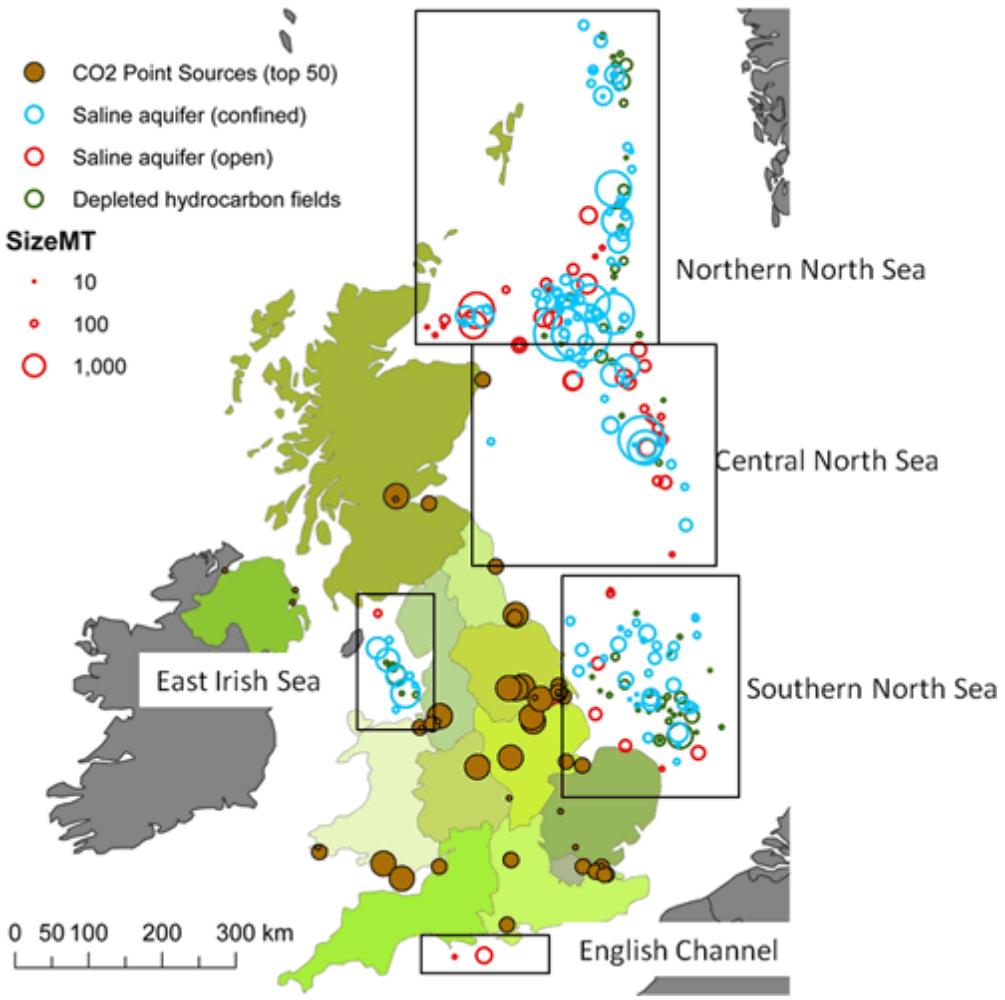
The original data in CO_2 Stored was developed by the UK Storage Appraisal Project (UKSAP), which was commissioned and funded by the Energy Technologies Institute (ETI) .

CO_2 Stored provides an overview of CO_2 storage data for over 500 potential CO_2 storage sites around offshore UK.

Between 2013 and 2018, The Crown Estate and The British Geological Survey will develop and update CO_2Stored improving the data and functionality of the original database according to the needs of the sector.

For more information on CO_2 Stored including the methodology and data held within it, the following article is available for download from ScienceDirect: CO_2 STORage Evaluation Database (CO_2 Stored). The UK's online storage atlas (www.sciencedirect.com/science/article/pii/S1876610214023558)

The figure to the right shows major offshore areas covered by CO_2 Stored (© Energy Technologies Insititute) ●



IEAGHG Member CCS Activities - Norway

Alstom pursues parallel commitments in Norway

Together with partners in Norway and Switzerland, Alstom Norway is developing a technology that will dramatically reduce energy consumption compared with traditional CO_2 capture technology.

Alstom became known as a serious CCS (carbon capture and storage) player when the company built a test plant for CO_2 capture at the Technology Centre Mongstad (TCM). The test plant captures CO_2 from flue gas using a chilled ammonia process. The tests at TCM, which have now been concluded, confirmed that the technology can be sold on a commercial basis, but there is room for improvement.

New tests at TCM?

Alstom is processing data from the tests along with Sintef in the CHIPPER Phase 1 project, which is funded by the CLIMIT programme. The project will improve factors such as energy efficiency, cost, equipment for measuring process parameters and operational safety. The project includes tests at Sintef's CO_2 laboratory at Tiller in Trondheim. When the project results are ready in early 2016, Alstom will decide whether to proceed with regard to modification and new tests at TCM in 2017.

"The reason Alstom started to seriously invest in CCS technology in 2006 was that we deliver coal, oil and gas-fired power plants, and we wanted to be able to offer our customers these power plants with low CO_2 emissions. We h a v e

brought several technologies up to a commercial status: amine, chilled ammonia and oxy-combustion," says Arne Ellestad, head of CCS in Alstom Norway.

The power plant customers have yet to engage. Alstom is therefore also examining solutions for combined plants for CO_2 capture and use of the CO_2, either for industrial production (urea, methanol, etc.) or for improved oil recovery.

Reducing energy consumption up to 90 per cent.

Alstom is also working on entirely new technologies that could be ready for a market after 2020. The company has looked at several so-called second-generation technologies. One of the most exciting is a carbonate cycle that does not need externally supplied energy. The project is called Fully Integrated Regenerative Carbonate Cycle (FIRCC).

The main principle is a carbonate cycle with two reactors. The CO_2 in the flue gas binds to calcium oxide and converts into calcium carbonate in one reactor, the carbonate is moved over to a calcination reactor where CO_2 is released for further compression and storage, while the calcium oxide is transported back to the first reactor for re-use. This takes place in a continuous process.

In order to get the energy to release the CO_2, the common concept for this technology is to combust fossil fuel in pure oxygen. Producing oxygen from air is a very energy-intensive process. Alstom and its partners (Tel-Tek, Telemark University College, IFE and ETH/Zurich) want to cut out this step by instead calcinating using indirect heat transfer from the flue gas and also exploiting high-quality energy that is released at approx. 600 degrees in the first reactor when CO_2 binds to calcium oxide.

If they succeed, energy loss will be drastically cut – up to 90 per cent. This major reduction is because the operator no longer needs to produce oxygen for the calcination and due to recovery of released energy at high temperature.

Coal, the Next 40 Years – it Will Happen,

by Debo Adams, IEACCC

IEA Clean Coal Centre Executive Committee and staff, Windsor UK, 22 October 2015

Experts from around the world met in Windsor, UK, on 22nd October 2015 to discuss the future of coal. The event was part of the celebrations to mark the 40th anniversary of the IEA Clean Coal Centre.

Visions of the future of coal were presented from a range of perspectives - China, India, Japan, the USA and the EC as well as the IEA. Despite the diversity of the speakers, they were all of the opinion that coal will continue to supply a large proportion of global energy. For example, the IEA expects that 44% of energy needs will be met by fossil fuels in 2050 so high efficiency low emissions (HELE) technologies and carbon capture and storage (CCS) are vital if climate change is to be limited to an average increase of 2˚C.

Currently, ultra-supercritical (USC) coal power plants emit almost 20% less CO_2 per unit output than traditional subcritical ones. USC units operate in more than ten countries including China, Germany, India, Japan, Korea, and the USA. Developments in advanced ultra-supercritical (AUSC) plant mean that a plant operating at 51% efficiency (net LHV basis) would emit up to 28% less CO_2 than a subcritical plant.

Since 1993, all coal-fired units installed in Japan have been USC and operate at about 45% efficiency. Japan aims to build an AUSC plant and has a technology roadmap to 2030 to increase efficiency of coal-fired plant and develop CO_2 capture.

In China, in 2014, 67% of total power generated was supplied by coal. The policy of closing small old inefficient coal-fired power plants and replacing them with large efficient ones is significantly improving the average efficiency of coal use. The first USC unit was commissioned in China in 2006. By 2017, USC capacity in China will be over 208,000 MWe.

Coal consumption and coal imports to India will continue to grow, as will its demand for energy. India has a national programme for AUSC plant, with a target efficiency of 49% (LHV). There is a huge market in India for clean coal technologies. But extensive research is required to match CCT to Indian coal, which typically have a high ash content.

In the EU coal will remain important for the foreseeable future. Currently, coal supplies more than 26% of electricity generated. It is on a par with nuclear and renewables.

Although coal power may decline further the USA will continue to be the second largest user of coal after China. There is a substantial clean coal R&D programme underway in the USA with some focus on developing AUSC plant and establishing CCS. The USA is funding an advanced combustion programme, and investing in pressurised oxy-combustion research for carbon capture as part of a drive to establish second generation coal based CCS schemes with lower efficiencies penalties and reduced capital costs.

Closing comments

Coal will continue to make a vital contribution to the energy mix until 2050 at least, across most of the world. Any growth in coal use is not consistent with current climate policies, unless high efficiency low emission (HELE) technologies and carbon capture and storage (CCS) are included. HELE technologies are a vital preliminary step to the introduction of CCS on coal-fired plant. The IEA Clean Coal Centre has an important role to play in analysing and disseminating information and knowledge on these practical ways to improve efficiency and reduce emissions from fossil fuel-fired plant.

Find out more about the IEA Clean Coal Centre at **www.iea-coal.org** ●

Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2016. Full details will be posted on the networks and meetings pages of our website at www.ieaghg.org.

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

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

10th IEAGHG International Interdisciplinary Summer School

Dates TBC, July 2015, Saskatchwan, Canada

Combined Monitoring / Modelling Network Meeting

5th - 8th July (TBC) 2015, Edinburgh, UK

GHGT-13

14th - 18th November 2016, Lausanne, Switzerland

Greenhouse News
ISSN 2047-2218 (Online)

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

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