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Greenhouse News

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IEA calls for strong actions on CCS in this decade, by Ellina Levina, IEA

On July 2nd IEA launched a new Roadmap for CCS. More than 100 people attended the launch webinar and around 600 people downloaded the publication from our website on the day of the launch.

If this interest cannot yet be taken as an indication of the increasing importance of CCS in energy and climate policy-making, it shows a serious attention of stakeholders to CCS. The time is ripe to accelerate the deployment of CCS and put it on track for playing a significant role in cutting energy sector CO_2 emissions.

"After many years of research, development, and valuable but rather limited practical experience, we now need to shift to a higher gear in developing CCS into a true energy option, to be deployed in large scale", our Executive Director Maria van der Hoeven says in her foreword to the Roadmap.

This view is shared by many stakeholders from governments, industry, NGOs, research and finance communities, who provided valuable inputs to the process and helped us develop the updated CCS Roadmap. We hope that the CCS Roadmap will serve as a guiding document for these important players and facilitate their various contributions to building the foundation for large scale CCS deployment as did the first edition issued in 2009.

This Roadmap is an update of the 2009 IEA CCS Technology Roadmap. It takes into account recent developments in the energy sector in general and in CCS in particular and provides a revised vision for CCS deployment that is based on ETP-2012 scenarios but is mindful of conditions and challenges that the energy sector faces today. The Roadmap emphasises that the ultimate goal is to develop by 2050 a CCS industry at a scale comparable to today's oil and gas production industries combined. By 2050 7 Gt of CO_2 may need to be captured, transported and stored annually, and cumulatively 120 $GtCO_2$ may be stored around the world to meet the 2°C climate target.

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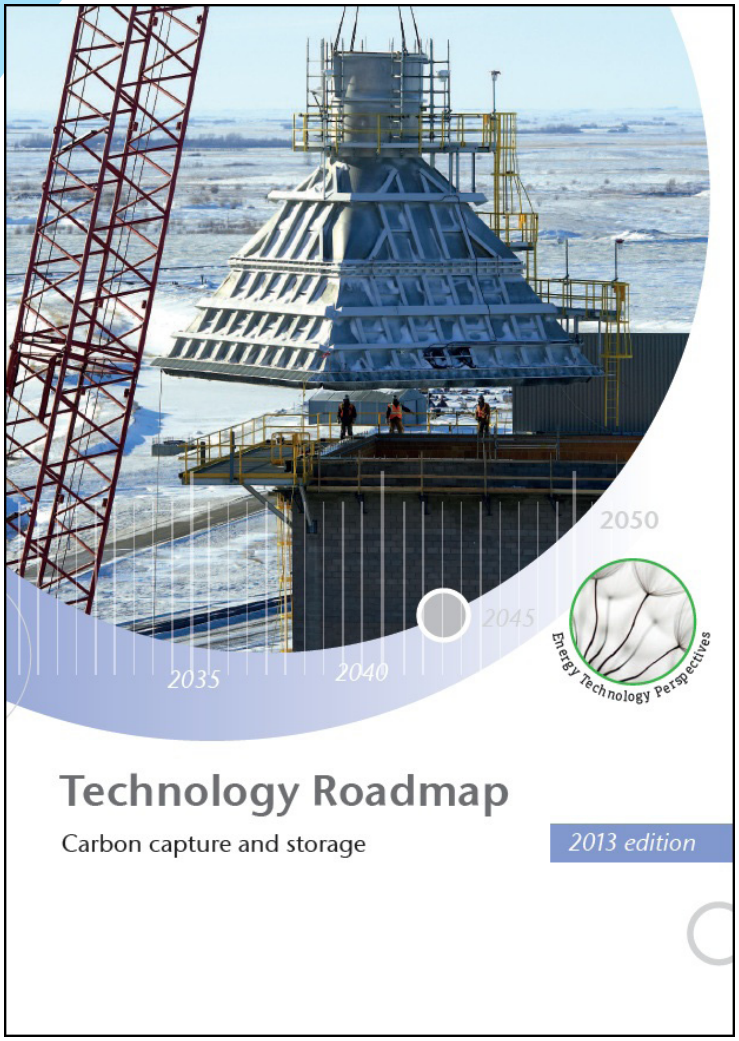
In this issue



However, the Roadmap also stresses that, most importantly, some positive movement is needed during the next seven years. The next seven years, until 2020, are less about actual emission reductions, and much more about technical learning and policy development. First of all, governments and industry must ensure that the incentive and regulatory frameworks are in place to deliver upwards of 30 operating CCS projects by 2020 across a range of processes and industrial sectors. This would be equivalent to all projects in advanced stages of planning today reaching operation by that time.

Technology Roadmap: Carbon Capture and Storage notes that governments need to show leadership in formulating and implementing supportive policy frameworks. Industry must enhance pilot and demonstration efforts to prove capture on various processes and in various industries and increase research and development to reduce the cost of electricity from CCS-equipped power plants. Governments and industry need to mobilise their resources to implement by 2020 the following seven actions:

1. Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects,
2. Implement policies that encourage storage exploration, characterisation and development for CCS projects,
3. Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready,
4. Prove capture systems at pilot scale in industrial applications where CO_2 capture has not yet been demonstrate,
5. Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment,
6. Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles,
7. Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

Each of these actions is underpinned by discussion and description in the Roadmap.

Given their rapid growth in energy demand, the largest deployment of CCS will need to occur in non-Organisation for Economic Co-operation and Development (OECD) countries. By 2050, non-OECD countries will need to account for 70% of the total cumulative mass of captured CO_2, with China alone accounting for one-third of the global total of captured CO_2 between 2015 and 2050. OECD governments and multilateral development banks must work together with non-OECD countries to ensure that support mechanisms are established to drive deployment of CCS in non-OECD countries in the coming decades.

Carbon capture and storage will be a critical component in a portfolio of low-carbon energy technologies. Under our scenario analysis, CCS contributes one-sixth of total CO_2 emission reductions required in 2050, and 14% of the cumulative emissions reductions between 2015 and 2050. Actions during this decade will be crucial in defining the CCS's role in a low-carbon future.

We believe that 17 actions that we list in the Roadmap offer an opportunity for further collaboration among various stakeholders and also between the IEA and the IEAGHG. The Roadmap also identifies areas where the technical work of the IEAGHG could facilitate progress. We are grateful to the IEAGHG experts and the IEAGHG ExCo members for their contribution and support during the process of the CCS Roadmap development.

Induced Seismicity and its Implications for CO_2 Storage Risk, by Millie Basava-Reddi, IEAGHG

IEAGHG have published a study considering the potential for induced seismicity at CO_2 geological storage sites and the associated risks. This study was carried out by CO2CRC and led by GNS Science.

There are relatively few examples of induced seismicity at CO_2 geological storage sites (<100/yr) and where there has been microseismicity it have been of a very small magnitude (M<1). Given the paucity of induced seismicity data for CO_2 storage sites, it is necessary to consider induced seismicity produced by water injection. Despite differences in the properties of water and supercritical CO_2, it is now accepted that they probably produce comparable induced seismicity magnitudes and productivity. Industrial analogues were considered in the study from the fields of petroleum production and stimulation, hydrothermal and petrothermal enhanced geothermal systems and waste fluid disposal.

Observations from case studies and compilation of empirical data in this study indicates several potential relationships such as maximum magnitude of induced events may increase with total volume of fluid injected/extracted and the injection rate. The volume-maximum magnitude relationship may arise because larger volumes of injection fluid have the potential to modify the stresses in larger volumes of crust and to encounter larger faults. However, when considering empirical relationships, it is important to note the bias in the data and that the majority of sites do not produce induced seismicity to any significant degree. There are also a number of other controlling factors which will be specific to the site in question, but were not documented in enough detail to apply them to this study.

A particular challenge in developing robust statistical and physical models to forecast induced earthquakes will be to test that they produce expected, unbiased and reproducible, and, ultimately, informative results, which can be used as part of the risk assessment. The risks associated with induced seismicity at CCS sites can be reduced and mitigated using a systematic and structured risk management programme.

Risks to CCS projects associated with induced seismicity may include:

1. Loss of public support due to concern about potential seismicity or from actual observed events;
2. Ground shaking causing damage to property or injury;
3. Loss of integrity of the reservoir though fracturing of the reservoir or of the seal.

The risks associated with induced seismicity at CCS sites can be reduced and mitigated using a systematic and structured risk management programme. While precise forecasts of the expected induced seismicity may never be possible, a thorough risk management procedure will include some level of knowledge of the possible behaviour of induced seismicity. Risk management will require estimates of the expected magnitude, number, location and timing of potential induced earthquakes. Such forecasts should utilise site specific observations together with physical and statistical models that are optimised for the site. Statistical models presently show the most promise for forecasting induced seismicity after injection has commenced, however, with further development physical models could become key predictive tools that are informative prior to injection. Combining forecasts with real-time monitoring of induced seismicity will be necessary to maintain an accurate picture of the seismicity and to allow for mitigation of the associated risks as they evolve. Site performance and management guidelines should be established prior to injection to facilitate:

1. Definition of the acceptable levels and impacts of induced seismicity,
2. Optimisation of the monitoring and mitigation programmes, and
3. The establishing of key control measures. Such guidelines have been developed for Enhanced Geothermal Systems and should provide the starting point for a management strategy of induced seismicity at CCS sites.

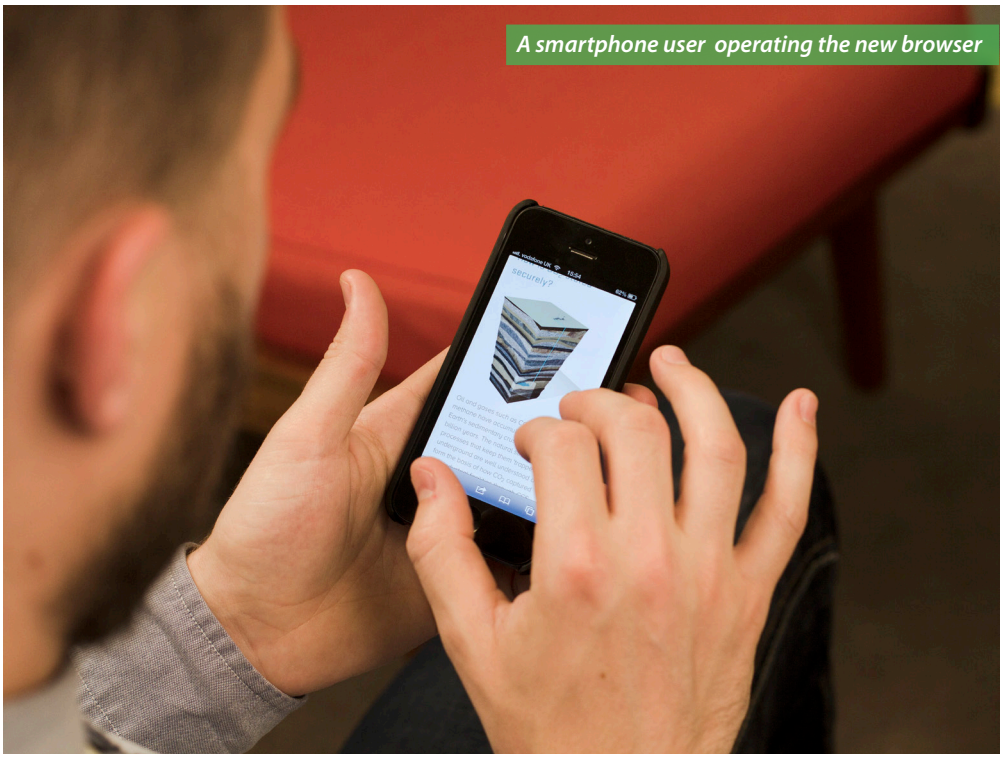
A number of information and knowledge gaps have been identified for induced seismicity in the study and include the need for more systematic studies and increasing available induced seismicity catalogues. ●

For a copy of the report: 2013-09 titled "Induced Sesmicity and its Implications for CO_2 Storage Risk" please contact Becky Kemp (becky.kemp@ieaghg.org),

Press Release: CCS Browser Launched To Help Public Explore CO_2 Capture And Storage

CO_2 Capture Project®

The CCP has launched a dedicated multi-format digital resource, the CCS Browser (www.ccsbrowser.com), to help the public learn more about CO_2 capture and storage.



A smartphone user operating the new browser

Available on tablet, PC and mobile, the CCS Browser has been designed to allow people to explore the topic in the way best suited to them – by watching animations, listening to audio clips and by interacting with maps and diagrams. The site also acts as a portal to other sources to allow people to explore topics in even greater depth if needed.

The main focus of the CCS Browser is on storage, with detailed animations used to explain areas such as geological trapping, porosity and containment, as well as storage site operation and CO_2 monitoring. Dan Kieke, Chevron subsurface consultant explains: "How CO_2 stays securely underground is one of the biggest public concerns regarding CCS. Storage had to be the focus for the site. We felt that animations would help bring these quite technical areas to life for the non-technical audience and provide an insight into the scientific processes at work. We also wanted to demonstrate how our industry uses its experience with subsurface conditions to safely store CO_2."

Mark Crombie, Program Manager and Communications Team Lead comments: "The CCS Browser is one of the most significant pieces of communications work the CCP has undertaken. We have brought together a team of digital designers, capture, subsurface and communication experts to create one of the first dedicated, interactive websites to explain CCS to a non-technical audience. We want this to be a resource for the whole CCS industry to use – so get in touch to tell us what you think."

Please visit www.ccsbrowser.com ●

Press Release: State of play on geological storage of CO_2 in 28 European countries

The European Commission recently took the first step towards developing a 2030 framework for EU climate change and energy policies. The Commission also published a Consultative Communication on the future of CO_2 capture and storage (CCS) in Europe, aimed at initiating a debate on the options available to ensure its timely development. In parallel, The European Parliament is preparing a report on developing and applying CCS Technology in Europe.

In this context, the report "State of play on CO_2 geological storage in 28 European countries", published in the framework of the Pan-European Coordination Action on CO_2 Geological Storage (FP7 CGS Europe project), reflects the current situation and achievements regarding geological storage of CO_2 in the 28 European countries covered by CGS Europe.

The report gives a brief overview of the CO_2 storage options, potentials and capacities in Europe. It summarises information on research activities and organization of research funding related to CO_2 storage in each of the CGS Europe countries. Information on a national level is complemented by an overview of activities on a regional and European level. Current pilot, demo and test sites in the CGS

Europe countries are listed, followed by an overview of the state of transposition of the EU Directive on the geological storage of CO_2 and the level of public awareness in the individual countries.

For a Europe-wide comparison, a ranking is provided assessing the overall national achievements regarding CO_2 storage in the 28 European countries. The current level of CCS activities in European Countries varies widely between well advanced countries, such as Norway, and CCS-rejecting countries that have not even transposed the EU CCS Directive into national law. CGS Europe exchanges geo-technical knowledge between advanced and following countries in order to level the playing field and pave the way for the future deployment of CO_2 storage pilot and demonstration projects in Europe.

This report is a valuable information pool for the current debate on the future CO_2 Capture and Storage in Europe. The CO_2GeoNet Association, the European network of excellence on CO_2 geological storage, in close connection with the CGS Europe FP7 project, here expresses the views of a pan-European consortium involving 34 research institutes from 24 EU Member States and 4 Associated Countries. As such representing the European scientific community on CO_2 Geological Storage (CGS), CO_2GeoNet and CGS Europe wish to share their expert input for the debate on taking CCS forward in Europe.

The report is available at: **www.cgseurope.net/NewsData.aspx?IdNews=87&ViewType=Actual&IdType=478**
Press Contacts: CO_2GeoNet Secretariat – Sergio Persoglia: +39 329 26 07 303 email: **info@co2geonet.com**

OCC3 and the 3rd Oxy-FBC Workshop,

by Stanley Santos, IEAGHG

IEA Greenhouse in partnership with Ciudad de la Energia (CIUDEN) and Foster Wheeler (FW) would like to highlight the programme of the OCC3 and the 3rd Oxy-FBC Workshop.

This event includes keynote presentations by Arto Hotta (Foster Wheeler) and Pedro Otero (CIUDEN) discussing the development of Oxy-CFB combustion and their experiences in operating the largest oxy-CFB pilot plant in world; Ken Humphreys (FutureGen Alliance) presenting the activities of FutureGen2 leading the demonstration of Oxy-PC combustion; Prof. Chuguang Zheng (HUST) discussing about the large scale oxyfuel combustion pilot demonstration activities in China; Dominique Copin (TOTAL) presenting the storage dimension of the Lacq and Rousse Project; and Monica Lupion (MIT/CIUDEN) discussing the importance of public acceptance.

There will be 2 Plenary Sessions, 2 Workshops on High Temperature Corrosion and Oxy-FBC Combustion, 1 special session on industry application of oxyfuel combustion with CCS, and 22 technical sessions covering all aspects of R&D activities in the development of oxyfuel combustion technology.

A total of 125 oral and 50 poster presentations will be delivered over the three days in 4 different parallel sessions. The meeting will be concluded by a closing panel of distinguished experts. Finally, an opportunity to visit the Technology Development Platform of CIUDEN demonstrating the various facilities covering 20MWth oxy-PC, 30MWth oxy-CFB, 3 MWth gasifier and transport rig.

The organising committee would like to thank the sponsors - Vattenfall, Alstom and Air Liquide for their generous support and contribution to the success of this event.

With more than 260 participants registered - don't miss out to the world's largest gathering of Oxyfuel Combustion Community!

9th - 13th September OCC3
www.ieaghg.org/index.php?/20120814317/3rd-oxyfuel-combustion-conference.html

7th IEAGHG International CCS Summer School,

by Samantha Neades, IEAGHG

Interactive Working Drawing of the CCS Chain
Photo Courtesy of Lori Gauvreau, Schlumberger

This year's IEAGHG International CCS Summer School was held in Nottingham, UK, from the 21st to the 26th of July 2013. The 7th annual School was held in partnership with the Engineering Doctorate Centre in Efficient Fossil Energy Technologies at Nottingham University and jam-packed with lectures and events throughout the week.

From the 137 applications received, 60 students were selected, from 26 countries. The week-long programme covered all aspects of CCS – from capture to storage, regulations to technical writing and followed a project logic structure. New to this year included presentations on advanced fossil power generation, unconventional gas and CCS project closure. The field trip day included a visit to the British Geological Survey, E.ON Ratcliffe Technology Centre, the UK CCS Research Centre's PACT facilities and the UK Health & Safety Laboratory.

Not only was the programme full to the brim with lectures, students were split into 6 groups and assigned a topic to work on throughout the week and present on the Friday. This year's group winner was Group 6, whose topic was: 'Should CCS be mandatory in the developed world? What are the pros and cons?'. This year's Most Outstanding Students, as decided by the Expert Mentors, were Rebecca Allen from King Abdullah University of Science and Technology (Saudi Arabia) and Navdeep Singh Kahlon from Nottingham University (UK). IEAGHG wish to congratulate them both again on this achievement, chosen on overall performance, enthusiasm and participation throughout the week. The prize for the Most Outstanding Students is to attend the 8th IEAGHG Summer School as Student Mentors, which will be held at the University of Austin, in 2014.

The students were taught and mentored by 36 experts and 2 Student Mentors – Niels Berghout (Utrecht University) and Viviane Romeiro (University of Sao Paulo). The hard work of the Mentors ensured this was a again hugely educational and enjoyable event – many staying up until the early hours of most mornings to assist the dedicated students in their group work!

The 2013 School was sponsored by the Global CCS Institute, Alstom, CIUDEN, CO2CRC, UK DECC, Gassnova, Schlumberger Carbon Services, Shell, Statoil and Elsevier (the School's on-going Series Sponsors), along with local sponsors – the University of Nottingham, UK CCS RC, the KTN EGS, APGTF, Schlumberger, Doosan Power Systems, E.ON, HSL, BGS and the PACT facilities. IEAGHG would like to thank all sponsors, Local Organising Committee members, International Steering Committee members and particularly the fantastic Mentors for their enthusiasm during and their input prior to the School.

We'd also like to thank the students from this year's School for ensuring, as always, that the 2013 IEAGHG Summer School was a success – your enthusiasm and hard work throughout the week was great to see and we wish you all the best for your future endeavours.

The 2014 IEAGHG International CCS Summer School will be held in Austin, Texas. Keep an eye on our website for announcements regarding the Summer School in the coming months, as students are invited to apply for the next School from early January 2014.

For more information, please visit: www.ieaghg.org.

The winning group of the 2013 Summer School
Photo Courtesy of Lori Gauvreau, Schlumberger

The Most Outstanding Students
Photo Courtesy of Lori Gauvreau, Schlumberger

Students and Mentors of the 2013 Summer School
Photo Courtesy of Lori Gauvreau, Schlumberger

Mineralisation for CO_2 sequestration?

by Steve Goldthorpe, IEAGHG-SGEA

The natural process of weathering of igneous rocks absorbs CO_2 from the atmosphere and locks it up in materials that would become sedimentary rocks. Mimicking and accelerating that natural process as a CO_2 sequestration method has long exercised the minds of researchers. A 2005 IEAGHG review of mineralisation as means of CO_2 sequestration concluded "Significant breakthroughs are needed but obstacles to be overcome are considerable". A recent revisiting of the issues (IEAGHG 2013-TR6) confirms that view and concludes that recent research initiatives are unlikely to lead to technically and economically viable industrial CO_2 sequestration processes.

A major barrier is the scale of mineral handling that would be required for CO_2 absorption by a mineral at a coal-fired power station. The amount of igneous mineral material to be mined, processed and returned to the ground would involve materials handling an order of magnitude greater in scale than the scale of the coal mining operation that provided the fuel that is burned to produce the CO_2. That would result in significant environmental consequences and life-cycle energy demands.

Natural carbonation of minerals is a very slow process that would need to be greatly accelerated to provide a useful industrial process. Recent research initiatives have focussed on complex ways to speed up the mineralisation process, involving staged conversion at high temperature and high pressure conditions or catalysis under acidic conditions. However. technically viable concepts have not yet been defined, so these ideas have not advanced to the stage of assessment of economic viability.

An alternative mineralisation concept is the spreading of alkaline

minerals on the ground for the purpose of drawing down CO_2 from the atmosphere via enhanced mineralisation. There is a divergence of views on the optimum particle size for material to perform that function. This geo-engineering approach to addressing climate change is probably limited to situations where it is a beneficial side-effect of an infrastructure project.

In summary, no technology breakthrough is on the horizon that would mimic and accelerate natural mineralisation to become a viable industrial CO_2 sequestration method. ●

Press Release: Aquistore: Listening Closely and Leading the World

Regina - Below the surface of south-eastern Saskatchewan, someone or something is listening.

Six-hundred-and-thirty somethings to be exact.

Outside Estevan, Saskatchewan lays one of the most extensive permanent seismic arrays to be used for tracking carbon dioxide (CO_2) movement in the subsurface. As part of the Aquistore project, this permanent seismic array is the first in the world to be used for CO_2 monitoring. Aquistore is an independent research project which is demonstrating the storage of carbon dioxide 3.4 km deep underground. By storing liquid CO_2 in a saline sandstone formation, Aquistore will demonstrate the scientific and economic feasibility of reducing greenhouse gases through dedicated CO_2 storage.

As spring oh-so-slowly arrives on the Canadian prairies, Aquistore is warming up for what will certainly be another busy summer. The project's 2012 operations were focused on the drilling and evaluation of two heavily instrumented wells, the two deepest in Saskatchewan: an injection and observation well. As interest grew, over 250 international visitors came to Saskatchewan to visit this unique, world-class project. The implementation of a monitoring, measurement, and verification program was also undertaken, of which the permanent seismic array is a critical component.

ptrc

Petroleum Technology Research Centre

To build this permanent seismic array, six-hundred-and-thirty geophones were installed around the project site. But what exactly is a geophone?

"Geophones," says Aquistore's top research scientist Dr. Don White (Natural Resources Canada), "are very sensitive listening tools. They measure ground vibrations which are used to image the Earth's structure in a manner similar to medical ultrasound imaging." While geophones and seismic surveys have been used for decades to define and illustrate the subsurface of our planet, Aquistore is the first project to implement seismic monitoring of this kind aimed at tracking and observing the movement of CO_2.

Installation of this innovative sparse array took place in March of 2012 on a 2.5 x 2.5 km grid. The six-hundred-and-thirty geophones were installed at a depth of 20 m. This installation will serve as both an active and passive source of monitoring and can be activated using various man-made sources of vibrations to monitor activity. Of all available remote monitoring systems, the use of sequential seismic imaging at the Aquistore site will provide the highest definition of CO_2 in the subsurface.

This permanent array is already collecting data for Aquistore, allowing the project to establish monitoring baselines before CO_2 injection and to track any minute movements of the subsurface. Following the initial installation, a baseline test survey was conducted. Data from each of the six-hundred-and-thirty geophones has been harvested, and the Aquistore team continues to process and analyze its results.

As 2013 continues, Aquistore moves closer to its goal of injecting CO_2, which will be captured at the nearby SaskPower Boundary Dam Power Station and transported via pipeline to the Aquistore site. Once CO_2 injection begins, the permanent seismic array and its 630 geophones

will listen and observe the CO_2 3.4 km below the ground surface. Aquistore's permanent seismic array is anticipated to provide the clearest and most accurate information possible on the subsurface movement of CO_2.

Aquistore and Natural Resources Canada have been working collaboratively, to take advantage of this remarkable technology. Dr. White and his team have been out in the field again. In the past month, aided by snowmobiles, the seismic team conducted additional baseline field-work outside Estevan. In one test, a group of geophones was lowered to the bottom of the injection well, while a 'sound source' was lowered into the observation well. This source produced sound waves which were then picked up by the geophones in the injection well. This allows for a detailed image which shows the geology within the reservoir and the cap rock which seals the injection zone.

A second test of the permanent seismic array was hindered by – what else – the snow. This baseline survey will now take place later in May. These seismic tests are regular occurrence says Dr. White although the schedule will depend on the CO_2 injection schedule: "In general the surveys are repeated after time intervals in which the cumulative amounts of injected CO_2 have increased significantly. We anticipate repeating the surveys every 12 months for the first years of monitoring".

While these geophones continue to listen, the world watches. Aquistore's seismic program is the first of its kind. As monitoring work continues, Aquistore is attracting interest from research partners, internationally. International visits are beginning again in the coming month. The demonstration of deep saline CO_2 storage, economics, and monitoring requirements developed by the Aquistore project are of global interest and applicability.

As Canada and the world work towards reducing greenhouse gas emissions, projects like Aquistore are more necessary than ever. Aquistore is helping Saskatchewan reduce greenhouse gas emissions and leading the way for CO_2 geological storage in Canada and the world.

Press Release: Livermore scientists develop CO_2 sequestration technique that produces 'supergreen' hydrogen fuel, offsets ocean acidification

The Great Barrier Reef in Australia already has been affected by ocean warming and acidification

Lawrence Livermore scientists have discovered and demonstrated a new technique to remove and store atmospheric carbon dioxide while generating carbon-negative hydrogen and producing alkalinity, which can be used to offset ocean acidification.

The team demonstrated, at a laboratory scale, a system that uses the acidity normally produced in saline water electrolysis to accelerate silicate mineral dissolution while producing hydrogen fuel and other gases. The resulting electrolyte solution was shown to be significantly elevated in hydroxide concentration that in turn proved strongly absorptive and retentive of atmospheric CO_2.

Further, the researchers suggest that the carbonate and bicarbonate produced in the process could be used to mitigate ongoing ocean acidification, similar to how an Alka Seltzer neutralizes excess acid in the stomach.

"We not only found a way to remove and store carbon dioxide from the atmosphere while producing valuable H_2, we also suggest that we can help save marine ecosystems with this new technique," said Greg Rau, an LLNL visiting scientist, senior scientist at UC Santa Cruz and lead author of a paper appearing this week (May 27th) in the Proceedings of the National Academy of Sciences.

When carbon dioxide is released into the atmosphere, a significant fraction is passively taken up by the ocean forming carbonic acid that makes the ocean more acidic. This acidification has been shown

to be harmful to many species of marine life, especially corals and shellfish. By the middle of this century, the globe will likely warm by at least 2°C and the oceans will experience a more than 60 percent increase in acidity relative to pre-industrial levels. The alkaline solution generated by the new process could be added to the ocean to help neutralize this acid and help offset its effects on marine biota. However, further research is needed, the authors said.

"When powered by renewable electricity and consuming globally abundant minerals and saline solutions, such systems at scale might provide a relatively efficient, high-capacity means to consume and store excess atmospheric CO_2 as environmentally beneficial seawater bicarbonate or carbonate," Rau said. "But the process also would produce a carbon-negative 'super green' fuel or chemical feedstock in the form of hydrogen."

Most previously described chemical methods of atmospheric carbon dioxide capture and storage are costly, using thermal/mechanical procedures to concentrate molecular CO_2 from the air while recycling reagents, a process that is cumbersome, inefficient and expensive.

"Our process avoids most of these issues by not requiring CO_2 to be concentrated from air and stored in a molecular form, pointing the way to more cost-effective, environmentally beneficial, and safer air CO_2 management with added benefits of renewable hydrogen fuel production and ocean alkalinity addition," Rau said.

The team concluded that further research is needed to determine optimum designs and operating procedures, cost-effectiveness, and the net environmental impact/benefit of electrochemically mediated air CO_2 capture and H_2 production using base minerals.

Other Livermore researchers include Susan Carroll, William Bourcier, Michael Singleton, Megan Smith and Roger Aines.

www.llnl.gov/news/newsreleases/2013/May/NR-13-05-07.html

Norcem CO_2 Capture Project, by Liv Bjerge, Norcem CO_2 Project

Norcem and its parent company HeidelbergCement in cooperation with the European Cement Research Academy (ECRA) have joint forces in establishing a test centre for demonstration of post-combustion CO_2 capturing technologies on cement flue gases.

Figure 1: Norcem Brevik Plant

In May 2013 Gassnova through the Climit program awarded the project 75% funding for construction of the test centre which will be established at Norcem's cement plant in Brevik, Norway. Total project budget is 11.7 MEUR where Norcem and its partners contribute with 25% of the budget.

The CO_2 capture test centre at Norcem Brevik will be the first demo-scale installation on a cement industrial process and will constitute a unique basis for CO_2 capture R&D in the cement industry and for the progress of CCS in general.

The project mandate involves testing of more mature post-combustion capture technologies initially developed for power applications as well as small scale technologies at an early stage of development.

The demo testing will be basis for assessment of CO_2 capture technologies and an evaluation of establishing future full-scale capture plants and commercial possibilities.

Norcem Brevik is equipped with both SO_x- and NO_x-scrubbing installations which makes it possible to simulate other cement industrial emissions sources on this test site. The CO_2 concentration in the flue gas is between 17 and 20%.

The cement industry acceptance of a CO_2 capture technology as a realistic measure for reduced CO_2-emissions is dependent on successful testing on exhaust gases from actual cement plants. Long term technical, environmental and economic performance will be basis criteria in the commercial scale qualification process.

Carbon capture is energy demanding and one of the essential

criterions for qualification of technology will be the energy use per ton CO_2 captured (avoided). At Norcem a considerably quantity of waste heat can be made available, therefore the capture technology's capability of utilising this waste heat is of special interest.

NORCEM
HEIDELBERGCEMENT Group

Capture Technologies
In this first test step the following technologies will be investigated:

1. Aker Solutions (former Aker Clean Carbon) for demonstration of advanced amine technology which is a first generation technology at demo scale.
2. The consortium DNV KEMA/ NTNU & Yodfat Engineers for testing of membrane technology which is a small scale upcoming technology at a lab-/ pilot scale.
3. RTI (Research Triangle Institute – US) for testing and development of a solid sorbent technology which is a small scale upcoming technology at a lab-/ pilot scale.
4. Alstom for de-risking study of a regenerative calcium cycle technology (RCC). The study will be done in co-operation with the University in Darmstadt, Germany which has a 1 MW test pilot.

Project schedule
Project duration is from May 2013 until March 2017. Refer to plan, RTI and the Membrane Consortium will start their testing at the end of 2013 and Aker Solutions in May 2014.

ECRA
The international perspective of the project is important in the context of dissemination of project results. ECRA hold and important role in sharing know-how from the project with the European cement industry.

Understanding the Techno-Economics of Deploying CO_2 Capture Technologies in an Integrated Steel Mill,

by Stanley Santos, IEAGHG

This report presents a reference document illustrating the techno-economic evaluation of deploying CO_2 capture technologies in an integrated steel mill. This study defines the mass and energy balances, the direct CO_2 emissions of individual processes, and their CAPEX and OPEX for a conceptual integrated steel mill without and with CO_2 capture situated in the coastal region of Western Europe producing 4 million tonnes/year (MTPY) of hot rolled coil (HRC).

The study evaluates the performance and the techno-economic analysis of the following cases:

- **Case 1:** REFERENCE Steel Mill without CO_2 capture
- **Case 2:** Integrated Steel Mill with Post-Combustion CO_2 Capture using MEA Solvent (i.e. this involves the capture of CO_2 from flue gases from the different stacks of the steam generation plant, hot stoves, coke oven underfire heaters and lime kilns)
- **Case 3:** Integrated Steel Mill equipped with Oxy-Blast Furnace (OBF) and capture of CO_2 from the top gas using MDEA/Pz Solvent.

The report has summarised in detail the major modifications to the processes and equipment when CO_2 capture technologies has been deployed to an integrated steel mill. For Case 2, most of the changes involved the addition of the CO_2 capture plant and modification on how steam and electricity are supplied to the steel mill. For Case 3, this involves significant changes to the hot metal production, gas distribution network, the addition of CO_2 capture plant and low purity oxygen supply, and the modification on how steam and electricity are supplied to the steel mill.

This study has established a clear methodology to evaluate the cost of deploying the CO_2 capture plant in an integrated steel mill; it should be noted that cost of steel production could be very site specific.

The study reported the overall breakdown of the direct CO_2 emissions of the integrated steel mill which are summarised as follows:

- **Case 1**: REFERENCE Steel Mill, the annual direct CO_2 emissions was estimated at 2090 kg CO_2/t HRC.
- **Case 2A**: For integrated steel mill capturing CO_2 from the flue gases of hot stoves and steam generation plant (achieving 50% CO_2 avoided), the annual direct CO_2 emissions was estimated at 1042 kg CO_2/t HRC. For this case, the total CO_2 captured was 1243kg/t HRC.
- **Case 2B**: For integrated steel mill capturing CO_2 from the flue gases of hot stoves, steam

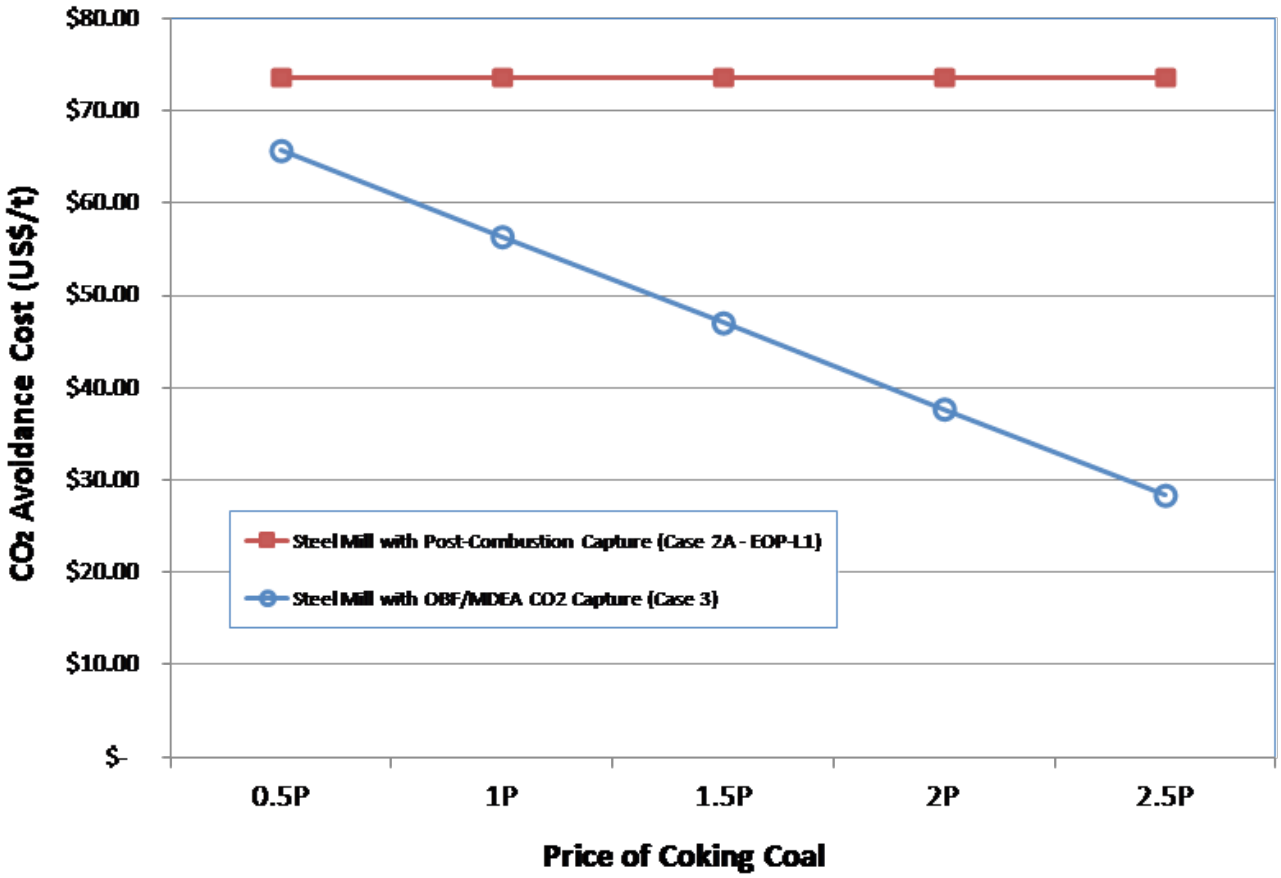


Figure 6: Sensitivity of the CO_2 Avoidance Cost to Coking Coal Price
F(@ 1P -> hard coking coal = US$220/t & semi-soft coking coal = US$160/t)

generation plant, coke oven underfire heaters and lime kiln (achieving 60% avoided), the annual direct CO_2 emissions was estimated at 828 kg CO_2/t HRC. For this case, the total CO_2 captured was 1533 kg/t HRC.

- **Case 3:** For the steel mill with OBF and capturing CO_2 from raw top gas (achieving 47% CO_2 avoided), the annual direct CO_2 emissions was estimated at 1115 kg CO_2/t HRC and the total CO_2 captured was 860 kg CO_2/t HRC.

The levelised cost of HRC (ex-works) or its breakeven price was evaluated; and the following results are summarised:

- **Case 1:** REFERENCE Steel Mill (without CO_2 capture), the levelised cost of the HRC (ex-works) produced was estimated at US$575/tonne.
- **Case 2A:** Steel mill with Post-Combustion CO_2 capture (achieving 50% CO_2 avoidance), the levelised cost of HRC produced was estimated at US$652/tonne.
- **Case 2B:** Steel mill with Post-Combustion CO_2 capture (achieving 60% CO_2 avoidance), the levelised cost of HRC produced was estimated at US$678/tonne.
- **Case 3:** Steel mill with OBF and CO_2 capture from raw top gas, the levelised cost of HRC produced was estimated at US$630/tonne.

The study has demonstrated that the cost of CO_2 avoidance for a steel mill with OBF and MDEA CO_2 capture is strongly linked to the price of the coking coal (i.e. as coking coal price increase, the CO_2 avoidance cost decreases – as shown in Figure 6). This relationship is attributed to the decrease in coke consumption by the blast furnace when equipped with OBF and top gas recycle.

The study concluded that post-combustion CO_2 capture (i.e. capture of CO_2 from different flue gases of the different combustion processes) in an integrated steel mill could be cost prohibitive for the following reasons:

- It significantly increases the energy demand of the steel mill. It requires a larger amount of captured CO_2 to achieve similar level of CO_2 avoidance as compared to the OBF case. Consequently, this will also results in a larger amount of CO_2 to be transported and stored.
- It does not gain any upside cost benefit of an increasing coking coal price.

It should be noted that this study only presents the cost of deploying CO_2 capture technology from an average performing integrated steel mill. It is essential that future studies should establish the cost of CO_2 capture deployment from one of the best performing integrated steel mills to demonstrate the site specific sensitivity of the reported CO_2 avoidance cost.

The study recommended the following for future studies:

- Evaluation of other versions of ULCOS BF. This should

demonstrate the sensitivity of the CO_2 avoidance cost to the different reduction levels of coke consumption of the blast furnace. Furthermore, this should also evaluate other CO_2 capture technologies such as the use of PSA/VPSA or cryogenic separation.

- Assessment of other chemical absorption technologies capturing CO_2 from top gas of conventional blast furnaces. This represents part of the activities undertaken by the Japanese (Course 50) and South Korean (POSCO/RIST) R&D programmes. Key to this assessment is the potential coke reduction that could be achieved when cleaned BFG (i.e. after CO_2 has been removed) are recycled back to the blast furnace. Additionally, this activity should also include assessment of the use of novel waste heat recovery (i.e. heat recovery from slag).
- Assessment of other novel CO_2 capture options. This includes: Air Products' BF plus technology, Linde's or LanzaTech technology involving alcohol production from off-gases, and Praxair's technology involving hydrogen injection to the blast furnace.
- Assessment of integrated steel mill with DRI production unit and in combination with CO_2 capture. This option should open up several other opportunities for additional coke consumption reduction and at the same time achieving higher level CO_2 avoidance.

[1] For this study, the OBF case has demonstrated a reduced coke consumption of ~24%. It should be noted that ULCOS has reported up to 30% reduction of coke consumption by the blast furnace.

[2] Case 2A (steel mill with post-combustion CO2 capture) would require an extra ~3.37 GJ/t HRC to achieve 50% CO2 avoidance as compared to Case 3 (steel mill with OBF) which would only require an extra ~0.55 GJ/t HRC to achieve 47% CO2 avoidance.

[3] Case 2A would need to capture 1243 kg CO2/t HRC to achieve 50% CO2 avoidance as compared to Case 3 which would only need to capture 860 kg CO2/t HRC to achieve 47% CO2 avoidance.

[4] See Figure 6

Brainstorming Day on the long-term fate of geologically stored CO_2, by Laura-Mae Macadré, (Bureau Veritas, PANACEA project)

The first Brainstorming Day on the long-term fate of geologically stored CO_2 was successfully held in Trondheim (Norway) on 3rd June, 2013. This event was attended by 50 specialists from the CCS community.

The workshop, hosted by STATOIL, was presented by speakers from five different European-funded (FP7) research projects about CO_2 storage: MUSTANG, ULTIMATECO_2, CO_2CARE, CARBFIX and PANACEA.

The meeting was divided in six sessions dedicated to transverse topics shared by the different research projects as:

- Processes affecting stabilization of CO_2: Peter Frykman (GEUS, CO_2CARE/ULTimateCO_2), Nicolas Maurand (IFP EN, ULTimateCO_2), Sigurdur R. Gislason (University of Iceland, CarbFix)
- Mechanical impacts and induced seismicity: Gerco Hoedeman (TNO, ULTimateCO_2), Jeremy Rohmer (BRGM, ULTimateCO_2), Jean-Pierre Deflandre (IFP EN, CO_2CARE)
- Monitoring technologies: Stefan Lüth (GFZ, CO_2CARE), Philippe Pezard (CNRS, PANACEA/MUSTANG)
- Modeling: Philippe Gouze (CNRS, MUSTANG/PANACEA), Christopher McDermott (Univ. of Edinburgh, MUSTANG/PANACEA)
- Leakage: Jens Birkholzer (LBNL, MUSTANG), Auli Niemi (University of Uppsala, MUSTANG/PANACEA), Jesus Carrera (CSIC, MUSTANG/PANACEA), Thomas Kempka (GFZ, CO2CARE) Risk assessment: Ton Wildenborg (TNO, CO_2CARE), Thomas Le Guenan (BRGM, ULTimateCO_2)
- Wrap-up: Philip Ringrose (STATOIL, PANACEA), Chin-Fu Tsang (LBNL/University of Uppsala, MUSTANG)

Members, as well as non-members, of the EU projects were welcome to contribute to this debate. A large number of key points were raised during the free discussion sessions as: importance of modeling coupled processes, role of heterogeneities, uncertainties quantification, active management of underground CO_2), liability and transfer of responsibility, communication and public perception.

Proceedings are now available at: www.bsdt2013.org

Contact: contact@bsdt2013.org or Laura-Mae Macadré (Bureau Veritas, PANACEA project) - laura-mae.macadre@bureauveritas.com

2013 NETL CO_2 Capture Technology Meeting, 8th – 11th July 2013, Pittsburgh, by by Jasmin Kemper, IEAGHG

The annual meeting of the US DOE's National Energy Technology Laboratory (NETL) concerning the R&D on CO_2 capture technologies was held from 8th to 11th July at the Sheraton Station Square Hotel in Pittsburgh, PA. The meeting, which was attended by 210 participants, offered a full 4-day programme comprising of 60 oral presentations and 10 posters.

The main objective of the meeting is to provide a forum for the US DOE funded projects to present their status of and accomplishments made in CO_2 capture technology development. At the moment the NETL R&D programme is pursuing the demonstration of 1st generation CCS technologies in new as well as existing power plants and industrial facilities. Because cost effectiveness of CCS is a main issue, all projects are required to achieve the following performance goals.

- *1st generation technologies:*
  CO_2 capture rate of at least 90% with less than 35% increase in COE for post- and oxy-combustion, resp. 10% for pre-combustion
- *2nd generation technologies:*
  Commercial demonstration in 2025, cost less than \$40/tCO_2 (\$45/tCO_2 for retrofits)
- *Transformational technologies:*
  Commercial demonstration in 2035, cost less than \$10/tCO_2 (\$30/tCO_2 for retrofits)

This year's meeting covered a wide range of topics. In the post-combustion capture sessions progress made in liquid solvents, solid sorbents as well as membranes was presented. Also, the advances in the projects related to pre-combustion and oxy-combustion (including chemical looping) were discussed. Further sessions dealt with system studies and modelling, CO_2 compression and the ARPA-E projects. ARPA-E investigates high-potential, high-impact energy technologies that are considered too early for private sector investment. The IMPACCT programme under ARPA-E aims at minimising the CO_2 capture costs by developing materials and processes that have not been considered for this application before.

The presentations from the meeting are available on the NETL website:
http://netl.doe.gov/publications/proceedings/13/co2capture/index.html

NETL also published a very comprehensive report tracking the progress of DOE/NETL CO_2 capture related technology developments. For each project the report contains a description of the project goals, technical content, technology advantages, R&D challenges and the accomplishments and results to date. This handbook is updated bi-annually.

The latest edition (May 2013) can be obtained through the following link:
www.netl.doe.gov/technologies/coalpower/ewr/pubs/CO2Handbook/

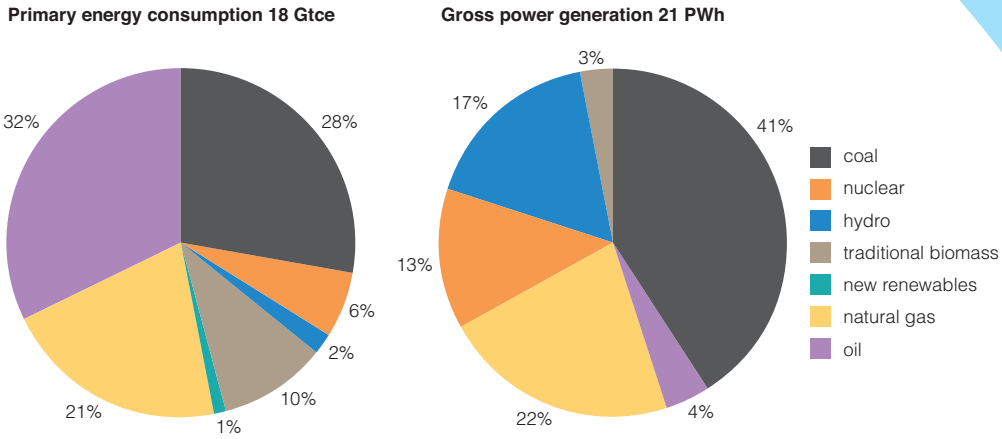
News from the IEA Clean Coal Centre, by Debo Adams, IEA CCC

Coal and gas competition in global markets, CCC/220 by Herminé Nalbandian and Nigel Dong is the latest report from the IEA Clean Coal Centre. IEA CCC reports can be downloaded from the website www.iea-coal.org at no charge, after a one-off registration by residents of member countries and employees of sponsoring organisations. Visit our Bookshop for details and to register http://bookshop.iea-coal.org.uk

Report summary

Global consumption of commercial energy totalled 18 Gt of coal equivalent in 2010. With a 28% share, coal ranked second after oil as one of the major sources of primary energy and natural gas (at 21%) ranked third. Gross power generation with coal was approximately 41% and gas 22%. Natural gas as a global commodity is growing rapidly with the advent of unconventional sources such as shale gas. Recently, gas has become the fuel of choice for new power generating plants in some countries. Overall production of coal has increased in the same time-frame. The share of coal in electricity production was constant in Europe from early 2000 but recently increased. This was due to the high cost of gas in Europe and a low emissions penalty levied by the regulator, making coal currently more competitive in Europe compared to gas. Coal utilisation continues to increase in Asia but is facing serious competition with gas in the USA, where the share of electricity generated with coal dropped in 2012. However, natural gas used to generate electricity in early 2013 was below the high level seen during the comparable 2012 period, when

low natural gas prices led to significant displacement of coal by natural gas for power generation. The current consensus in the USA is that while coal may recover ground in the short term, it loses in the long term as coal plants are retired. The discovery, production and availability of significant amounts of gas have implications for not only the price of natural gas but also the price of coal as well as supply and demand, and utilisation of both fuels internationally. The interaction between coal and gas in the global markets today is investigated in this review and the near-term outlook and impact on both fuels is presented. In this report, reserves, production and trade, supply and demand, pricing, utilisation and consumption, public attitudes and finally near/short to medium-term prospects are discussed for both coal and gas.



Wednesday webinar

Each month one of our authors presents a webinar on the subject of their latest research. IEA CCC webinars are free to view, but a one-off registration is required. They are usually held on the second Wednesday of the month at midday (UK time) but can be viewed at any time. Forthcoming webinars include Toby Lockwood on 4th September presenting on Techno-economic analysis of PC versus CFB technology and Kyle Nicol on 9th October. Kyle's subject is Status of advanced ultra-supercritical power plant.

Visit out webinar page www.iea-coal.org/site/2010/news/webinars?LanguageId=0

Press Release: MRCSP Begins Field Tests in Michigan
Part of national effort to develop methods for carbon storage

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

Battelle
The Business of Innovation

Battelle has announced the beginning of a large-scale carbon dioxide (CO_2) injection by the Midwest Regional Carbon Sequestration Partnership (MRCSP) program in the oil fields of Michigan's Northern Reef Trend.

The MRCSP is one of seven Regional Carbon Sequestration Partnerships in the United States established by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL). This multi-year research program (led by Battelle) will identify, test, and further develop the best approaches to CO_2 utilisation and storage in the nine-state region in the Midwest and Northeast U.S. encompassed by MRCSP. This significant milestone builds on the work completed by MRCSP's industry and research members during earlier phases of the program that included smaller-scale testing and mapping of geologic formations across the region.

The current project in Michigan is designed to inject and monitor at least one million metric tons of CO_2 into a series of oil fields that are in different stages of their production life-cycles. The first test in the series will inject up to 500,000 metric tons of CO_2 into a depressurized, late-stage oil field that has undergone primary production and enhanced oil recovery (EOR) for several years and is now near the end of its productive life. Such late-stage fields are ideal for conducting research on monitoring and modeling of CO_2 storage and evaluating incremental production of residual oil still trapped in the pore spaces.

Continued over the page.

During the last year, Battelle's MRCSP team has worked with Core Energy, LLC, the owner and operator of the oil fields, to conduct baseline geologic characterization and advanced monitoring and to prepare the wells for the injection phase. These fields already are permitted for injection as part of the routine EOR operations. In this first leg of the field test, MRCSP expects injection rates of approximately 1,000 metric tons of CO_2 per day.

MRCSP will be using state-of-the-art techniques to track the CO_2 and quantify the amount that is retained in the formation after the oil is removed - during and after the active injection phase. The CO_2 will be injected into the geologic structures known as the northern Niagaran pinnacle reef trend. These oil fields comprise closely spaced but highly-compartmentalised ancient coral reefs buried about 6,000 feet below the ground surface. This reef trend formed millions of years ago when the area was under an ocean in a setting similar to what is now observed in the Great Barrier Reef.

One way to combat global climate change is to limit greenhouse gas (such as CO_2) emissions from large-scale emitters such as coal burning power plants. Carbon capture, utilization and storage seeks to capture CO_2 as it goes up smokestacks, pressurize and dry it, then inject it deep beneath the ground (in this case, 6,000 feet), in formations known to hold hydrocarbons for millions of years. Carbon capture, utilization and storage is an important class of technologies and represent means for a secure energy future. The knowledge gained from this research will be of broad value to the regional economy and its industrial base.

About Battelle

Every day, the people of Battelle apply science and technology to solving what matters most. At major technology centers and national laboratories around the world, Battelle conducts research and development, designs and manufactures products, and delivers critical services for government and commercial customers. Headquartered in Columbus, Ohio since its founding in 1929, Battelle serves the national security, health and life sciences, and energy and environmental industries. For more information, visit: **www.battelle.org**

About Core Energy, LLC

Core Energy, LLC is actively involved in innovative oil and gas exploration and production technologies throughout Michigan. Core was the first company in Michigan to utilise carbon dioxide on a commercial scale to produce oil that would otherwise be stranded from existing oil fields. The company is also using modern techniques to explore for new reserves located near existing oil fields. Core Energy is headquartered in Traverse City, MI. More information about the company is available on the Internet at: **www.coreenergyholdings.com.**

Contact T.R. Massey on (614) 424-5544 or **masseytr@battelle.org** for more information.

Member Update: Norway

What new CCS activities have been undertaken this month?

Gassnova appoints new head for technology area

Hans Jörg Fell has been appointed as the new head of the Department of Technology and Expertise in Gassnova. Fell has extensive experience in research and development, technology product development and technology commercialisation. Fell has a master's and doctorate in materials science and he is 47 years old. He took up his post as head of the Department of Technology and Expertise in August 2013.

What new CCS research has been carried out this month?

First cement factory in Europe to capture CO_2

CLIMIT has granted NOK 70 million to support the establishment of a pilot plant at Heidelberg Cement's plant at Norcem in Brevik, Norway. This is the first cement factory in the world to test carbon capture and storage (CCS).

"This is an important milestone for CCS," says Tore Amundsen, CEO of Gassnova.

Several technologies can be tested in parallel at the Norcem plant. The composition of flue gas from the cement plant can also be varied, which in turn will provide results that are relevant to new as well as older cement factories. The project starts now and a total of four technologies are to be piloted in Brevik, where testing will continue until 2017. This will determine which technology is best suited to capturing CO_2 from the cement factory. The results of the project will also be transferred to Europe via the European Cement & Research Academy (ECRA). "Norcem has been interested in studying CO_2 capture for a long time, and with this commitment they show that they take climate change seriously. We look forward to seeing the results as they come in," says Amundsen in closing.

And opening seminar for the Norcem CO_2 capture project will take place September 3rd.

Schlumberger

The Illinois Basin – Decatur Project (IBDP) is a collaboration between Midwest Geological Sequestration Consortium, the Archer Daniels Midland Company, Schlumberger Carbon Services, and other subcontractors to inject 1 million metric tons of anthropogenic carbon dioxide into the Mount Simon Sandstone at a site in Decatur, Illinois, USA.

In early June a major milestone was reached as the injected volume reached the 500,000 metric ton mark. To date, the injection has proceeded as planned with the receiving reservoir readily taking the injected volume of 1,000 metric tons per day. Capacity, injectivity, and containment have all met pre-injection expectations and researchers continue to focus on validating the project's environmental framework, understanding the carbon dioxide distribution in the subsurface, and improvements in operations and monitoring well equipment. Pressure readings from an observation well 1,000 from the injection well suggest that the injected CO_2 has not reached the middle of the 1,500 foot thick Mount Simon reservoir. Models that project the movement of the CO_2 plume over 100 years suggest that the CO_2 will remain below this level. Data from a 3D vertical seismic profile acquired in early April 2013 are expected to further define the position of the plume.

The IBDP has attracted international attention as one of the few onshore projects in the world to successfully reach the demonstration stage, and numerous international guests have visited the site. Countries represented include Norway, China, Taiwan, South Korea, Spain, Japan, Brazil, and others. Worldwide interest in the project continues and lessons learned to date will be detailed in an invited seminar for European researches to be held in Oslo, Norway in October 2013. ●

Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2013/2014. 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.

5th High Temperature Solid Looping Network Meeting
2nd - 3rd September; University of Cambridge, UK

OCC3
9th - 13th September; Leon, Spain

PCC2
17th - 19th September; Bergen, Norway

Wellbore Integrity Conference
16th - 17th October; Denver, USA

4th Social Research Network Meeting
14th - 15th January 2014; University of Calgary, Canada

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

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