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Greenhouse News

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GHGT-13: Summary of Conference Learnings and Outcomes, by Kelly Thambimuthu

ghgt-13

Greenhouse Gas Control Technologies 13th International Conference on

General

Thomas Stocker's communication of the IPCC findings leaves us in no doubt about the importance and scale of the challenges we face in meeting the 2°C and below targets. CCS and negative emissions from Bio-CCS are key elements of the mitigation portfolio

IEA's publication has tracked the substantial progress that has been made with CCS technologies in marking 20 years since the initiation of the Sleipner project in Norway. The message also reinforces the role of CCS and Bio-CCS and highlights the significance of CCS in industry with limited alternatives for mitigating GHG emissions. The importance of CCS for industry has been highlighted in the presentation by Gassnova of the 3 projects currently under consideration for funding in Norway. And by the way, Happy Birthday Sleipner, 20 years is indeed a milestone!

The Boundary Dam CCS power project has announced the launch of the International Knowledge Centre to share knowledge for the purpose of accelerating the roll out of CCS.

The Quest project has seen a year's operation – a highly successful demonstration project not just technically but in terms of its approach to outreach and communication to the local community.

Value of CCS

Modelling of integration of CCS into power systems clearly shows the value of

In this issue

The Interior of the SwissTech Convention Centre; Venue for the GHGT-13 Conference

the technology, going far beyond that implied by traditional levelized cost of electricity metrics (LCOE). The biggest benefit in this regard comes from the abatement of other air pollutants hugely important to several developing countries. The challenge is to communicate this long-term value to key decision makers who are accustomed to seeing only LCOE metrics. Potential for negative emissions via CCS can be enhanced by improved conversion technology and policy that credits negative emissions.

EOR

Really good advances are being made in the area of CO_2-EOR for storage. Good work out of Europe better quantifies the supply curves for CO_2-EOR and make the prospects look less daunting than in the past. There is a growing consensus that it is possible to deliver emissions reductions from CCS+CO_2-EOR; however, more work is needed to go from carbon-accounting to true life-cycle assessment.

Drivers for CCS

In the current energy scenario, renewable energies are not sufficiently developed to provide enough energy supply, which could be comparable to the one obtained through the use of fossil fuels. Therefore, CCS represents not only an option but a real and urgent necessity in the near future to reduce CO_2 emissions. The CCS community has received a call to strongly promote safe CCS technologies. Several studies have shown how CCS has a strong potential to complement the implementation and use of renewable energies.

The benefits of fossil energy with CCS from an emissions reduction standpoint are clear to the community, but have yet to galvanise policy action – and clouds have appeared on the political horizon; given that we have no time to lose, the community must be creative in looking for niches that can drive the technology forward in the near term, while continuing to push for policy action. CCS can unlock 'unburnable carbon'.

Content

A large group of new young researchers got involved this year, which is a very good sign. The conference organisation and even scientific content has improved a lot as compared to the last one in Austin

A more detailed summary of the findings and outcomes of the conference will be released by the IEA GHG program around February next year. ●

GHGT-13 Statistics

Interested in Becoming a Peer-Reviewer?

At GHGT-13 we received an overwhelming number of questions about how to become a peer reviewer for academic journals, such as the International Journal of Greenhouse Gas Control. Editor in Chief, John Gale, and Elsevier Publisher, Katherine Eve, are pleased to share resources to support budding peer-reviewers.

There are some guidelines available at Elsevier.com to help you understand what reviewing involves, how to review, and how reviewers are recognised for their efforts:
www.elsevier.com/reviewers/becoming-a-reviewer-how-and-why

In addition there are a number of online lectures available at Elsevier's Publishing Campus:
www.publishingcampus.elsevier.com/pages/69/Colleges/College-of-Skills-Training/Peer-review.html.

If you would like to register your interest in becoming a reviewer for the ***International Journal of Greenhouse Gas Control***, please contact the editor using the form here: **www.journals.elsevier.com/international-journal-of-greenhouse-gas-control/editorial-board/john-j-gale** ●

IEAGHG 50th ExCo, by Becky Kemp, IEAGHG

The 50th bi-annual IEAGHG ExCo meeting was held in the beautiful Swiss city of Lausanne.

The two day IEAGHG Executive Committee meeting began on Saturday 12th November and was held in the excellent Hôtel de la Paix. This regular meeting is held twice yearly, at different locations across the world each time, and gives IEAGHG an opportunity to provide our Members and Sponsors with programme progress, an update of recently completed and on-going activities and to approve any future work to be undertaken. It also gives our Members a chance to report back to the Programme on their activities over the last 6 months and any activities planned for the near future.

The Programme's ExCo Members were given an overview of recent activities such as feedback from the Monitoring and Modelling Networks meeting along with feedback from the 2016 Summer School which was held in Regina, Canada. Tim Dixon eagerly presented on COP22, in Marrakech, as IEAGHG held yet another successful side event at this conference. There were also presentations on reports which are on-going and also proposals given for potential new studies for IEAGHG to carry out.

Members agreed to take forward 5 new studies this year (two as technical reviews) – so do stay tuned to see the progress in these various areas; more details will come soon.

The ExCo dinner at this meeting was held in the elegant restaurant of the Hôtel de la Paix. Members were all very eager to discuss the outcomes of the first day and to have a chance to relax and enjoy the picturesque Lausanne setting.

New IEAGHG Technical Report: 2016-11-Regional Assessments of the Economic Barriers to CO_2 Enhanced Oil Recovery in the North Sea, Russia and GCC States, by James Craig, IEAGHG

The use of CO_2 for enhanced oil recovery (EOR) is a well established commercial practice in the United States where it has been used for over 40 years. There is widespread potential for CO_2-EOR in other mature petroleum producing regions. If CO_2-EOR could be implemented it would offer an economic stimulus to develop CO_2 storage. There are, however, a number of barriers, not least the installation of infrastructure and modifications that would be necessary to supply CO_2 and inject it into target reservoirs.

This study has looked at the challenges faced by the prospect of CO_2-EOR in three regions: the North Sea; Russia; and the Gulf Cooperation Council (GCC) states which is a regional political organisation comprising Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. In addition to the technical challenges the study included two hypothetical examples, one based on the North Sea and the other in a GCC state, to explore what economic conditions would be necessary for CO_2-EOR to be implemented. The most significant factor that influences of CO_2-EOR uptake is the prevailing price of oil. The injection rate, capital expenditure (CAPEX), operational costs (OPEX) and tax incentives are of secondary importance. Despite the challenges posed by this form of EOR there is growing interest in its use in Saudi Arabia where Saudi Aramco launched the Uthmaniyah CO_2-EOR demonstration project in July 2015. There are also plans for CO_2-EOR in China for a potential project offshore Guangdong Province.

Key Messages

- Approximately 95% of all CO_2-EOR activity takes place in the U.S., and in 2010, CO_2-EOR projects were producing approximately 300,000 barrels of oil per day, close to 4% of total U.S. oil production. To achieve this quantity of oil, approximately 60Mt of CO_2, is injected annually into oil fields.
- Investment in CO_2-EOR is highly constrained by the volatility of the price of oil. For EOR projects to remain profitable over their operational life the cost of supplied CO_2 needs to fluctuate.
- Offshore production relies on fewer deviated wells with less spatial coverage of producing areas which is less advantageous for CO_2-EOR compared with onshore 5 or 9 spot closely-spaced injection and production well configurations commonly used in North America. This configuration provides a higher density and control for EOR operations.
- Experience with CO_2-EOR shows that the projected incremental recovery ranges from 7% to 23% of Original Oil in Place (OOIP). Estimates for CO_2-EOR recovery rates for the North Sea range from 4 – 18%.
- Based on previous estimates of suitable fields, and a 3 barrel/tonne of CO_2 recovery rate, the estimated incremental oil potential for the Norwegian sector could be 3,535M barrels that would require 1,180M tonnes of CO_2. In the UK sector an additional 2,520M barrels could be recovered with 840M tonnes of CO_2.
- The main factors that currently inhibit investment in offshore CO_2-EOR are the upfront investment costs, loss of oil production during work-overs and lack of significant CO_2 volumes. ●

New IEAGHG Technical Report 2016-13: Fault Permability, by James Craig, IEAGHG

Fault zones are widely recognised as being important to the secure long term storage of CO_2 as they could provide a migration pathway out of the target reservoir. Fault characterisation within reservoirs, especially where they extend into caprock, and other overlying formations, needs to be thoroughly understood as part of any risk assessment for CO_2 storage. The aim of this study is to review what is known about the permeability of fault zones in order to highlight under what circumstances faults may impact overall storage integrity.

The behaviour of fault zones in relation to sub-surface fluid migration is important to many industries and consequently has been comprehensively documented in the literature. CO_2 operations involve the injection and pressurisation o f reservoirs usually resulting in changes to the state of in-situ stresses which may modify fault properties. Instability could lead to slippage along pre-existing faults or fracture systems, which may be associated with seismicity. In addition, the movement of faults, and the generation of factures within the damage zone adjacent to the core, may create conduits that lead to the leakage of fluids to the surrounding overburden or even to the surface.

In 2015 IEAGHG published a study reviewing the geomechanical stability of faults during pressure build up which provided a helpful background to the behaviour of faults in stress regimes relevant to CO_2 storage. This study is designed to build upon the previous work and provide a significantly broader review of the current state of fault zone permeability and also to investigate what mitigation options may be available to CO_2 storage operations if leakage was to occur.

Key Messages

- CCS requires the secure retention of CO_2 in geological formations over 1000's of years. To achieve this, characterisation of target injection formations, and their structural features including faults, is essential to ensure leakage does not occur.
- Faults can either act as barriers to fluids, or as conduits for migration. Consequently, the properties of faults that dissect or form a boundary with potential CO_2 reservoirs, need to be determined.
- The significance of faults has long been recognised in the petroleum, mining and geothermal industries, but CO_2 storage is less mature and more experience and research related to faults would be beneficial.
- The objective of this study was to review recent research on the permeability (a measure of the ability of rocks to transmit fluids) of faults in CO_2 storage, particularly how different geological processes can either cause faults to help retain fluids within a reservoir, or lead to migration along or across faults. It builds upon an earlier study which looked at the role of geomechanical stress on faults.
- There is widespread experience of working with faults and fractures and provided there is sufficient characterisation of their properties they should not restrict storage development.
- If fault zones are present they need to be carefully characterised to ensure the development of an effective containment assessment and to inform the development of operational constraints and monitoring plans.
- A number of mitigation measures have been proposed to counter potential leakage. These include hydraulic barriers, biofilms and reactive cement grout. Changing subsurface pressure has been seen to be effective: there is strong evidence of the reduction in flow of a natural hydrocarbon seep caused by depletion of an offshore oil reservoir hydraulically linked to the seeps.

New IEAGHG Technical Review 2016-TR6- National CO_2 Storage Assessment Guidance,

by James Craig, IEAGHG

The effectiveness of CCS as a global solution to carbon emission abatement will depend on widespread deployment in both established industrialised and developing economies. One of the key stages for any country is the identification of a national CO_2 storage resource. To help understand the challenges faced by different countries that have either conducted, or are planning such a resource assessment, a survey was commissioned by the UK and Korean governments. The responses to this survey have generated a useful foundation that can aid governments and other organisations who are less advanced in planning CO_2 storage assessments. IEAGHG has now produced a guide based on the survey's findings. It is designed to help government bodies and policy makers with limited CCS experience to identify and select information on assessment methodologies. The guide provides information on where to find the material required to undertake initial national scale storage assessments. The guidance also includes definitions of technical terminology, proposed steps to establishing a national storage assessment and recent up to date case studies from a variety of countries focussing on Africa and Asia. A variety of methods for capacity estimation have been used and this guide provides explanations of where to find these studies and sources of information including websites, papers and organisations. Most companies and organisations engaged in CCS development have stated their ambition to share knowledge and experience; and they actively collaborate at an international level to aid future projects. This guide provides a link with current expertise in CO_2 storage to help facilitate new CCS projects especially in developing countries.

It should be stressed that many detailed storage assessments have been conducted and published in the past decade. A wide variety of techniques and technologies have been used to complete them given the varying nature of each country and individual sites. Although a standardised method has yet to be established, this guide aims to provide links to the most developed methodologies providing a direction on the most suitable approach to adopt.

At the conclusion of this guide there is a nine point summary of the key stages that are recommended for the establishment of a national CO_2 storage assessment.

20 Years of Carbon Capture and Storage: A new IEA report highlights progress but stresses the need to redouble efforts, by Juho Lipponen, IEA

Year 2016 marked a significant milestone with two decades of successful CCS operations at the Sleipner project in Norway since 1996, resulting in permanent storage of some 17 million tonnes of CO_2. Sleipner is significant not because it was the first large-scale CO_2 capture and injection project – three projects had already been capturing CO_2 for enhanced oil recovery (EOR) in the United States – but because Sleipner was the first project to have permanent, dedicated CO_2 storage with associated CO_2 monitoring as its main objective. The start of Sleipner very much signified the birth of large-scale CCS.

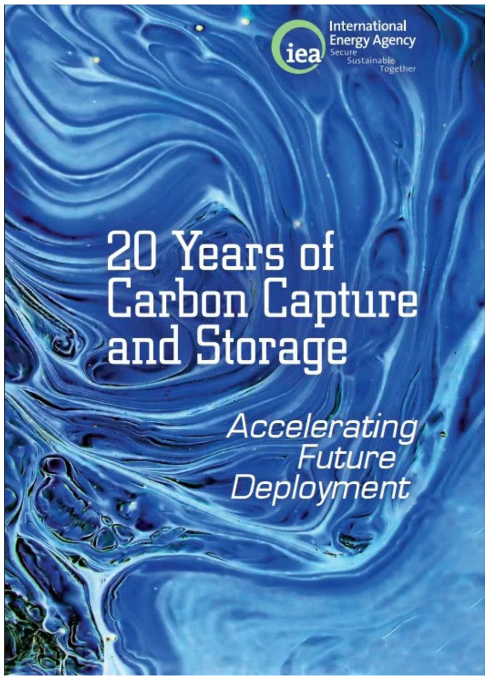
To take stock of these first 20 years of CCS, IEA has published a report looking at experience gained in CCS across the globe. The report, targeted at policy-makers and non-expert readers, highlights the fact that despite slow progress, we do have more CCS now than we did back in 1996. The number of large-scale CCS projects in operation has expanded to 15, with six more expected to come online within the next two years in various sectors. The size of capture and dedicated CO_2 storage projects is also growing, soon reaching the 3 $MtCO_2$ per year milestone. Very importantly, the experience with CCS projects to date underscores the reality that CCS is not just a "clean coal technology", but a family of technologies offering CO_2 reduction solutions to a wide range of industries and feedstocks. In addition to the first industrial-scale projects, more than 20 years of dedicated CCS research and development have delivered significant technical advances across capture, transport and storage of CO_2.

Despite technical advances, wide CCS deployment has been hampered by fluctuating policy and financial support. Following the release of the 2005 IPCC Special Report on CCS and in the lead-up to the 2009 Copenhagen climate negotiations (COP15) there was a period of considerable momentum in CCS. More than USD 30 billion in public funding announcements were made and G8 leaders pledged to build 20 new large-scale CCS demonstration projects. However, this momentum was not maintained as early CCS deployment proved to be more complex, expensive and politically challenging than anticipated. Of the USD 30 billion in public funding announcements, less than 10% was actually invested in large-scale CCS projects between 2007 and 2014.

CCS is not optional in a climate-friendly energy future

After a review of progress, the report discusses the role that CCS can play in the accelerating energy transition. The global community agreed in Paris last year to a more ambitious temperature target of "well below 2°C", to pursue efforts towards 1.5°C, and to balance emissions during the second half of this century. This commitment provided a step-change in the level of shared ambition and will require rapid and extensive deployment of all low-emissions technologies, including CCS.

In the IEA 2°C scenario (2DS), CCS delivers 94 gigatonnes (Gt) of CO_2 emissions reductions in the period through 2050. This amounts to 12% of the cumulative emissions reduction task in the energy sector. Around



56%, or 52 Gt, of total CO_2 captured is from the power sector, predominantly from coal-fired power generation (80%); 31% or 29 Gt is captured from industrial processes; and 14% or 13 Gt is captured from fuel transformation. The 29 $GtCO_2$ captured in industry in the 2DS represents around 20% of the cumulative emissions reductions from these sectors. This may sound like a relatively small contribution, however it is a critical one. If CCS were not available, much of the 29 $GtCO_2$ reductions achieved by CCS would need to be offset by efforts in other sectors.

While the power sector could be decarbonised without CCS, this would have significant cost implications. Without CCS, the transformation of the power sector would be at least USD 3.5 trillion more expensive. In a "no CCS in power" scenario variant of the 2DS, deployment of renewable technologies would need to be expanded by an additional 1 900 GW by 2050 over and above the 2DS requirements. This is equivalent to around four times the total wind and solar PV capacity additions achieved in the last decade. In parallel, such scenario would require a virtual elimination of all coal-fired power generation, with significant stranding of assets, as well as considerable challenges for existing energy networks.

Faster deployment of CCS could support the shift from 2°C to the Paris Agreement target of well below 2°C. Greater penetration of CCS could help to reduce the remaining 7 GtCO_2 of industrial emissions in 2050, and bridge the gap between a 2°C target and well below 2°C. Furthermore, faster deployment of CCS on coal-fired power generation could reduce cumulative emissions by 35 GtCO_2 through 2050 and on gas-fired power by an additional 10 GtCO_2.

The higher the ambition, the more role negative emissions will have to play. It is noteworthy that of the 94 GtCO_2 captured in the IEA 2DS, BECCS delivers around 14 Gt of "negative emissions" over the period through 2050, primarily from biofuel production. These negative emissions are able to compensate for higher emissions elsewhere in the energy sector. Going below 2 degrees, the role of negative emissions will significantly increase.

Accelerating the pace of CCS deployment: The next 20 years

Accelerating the pace of CCS during the next 20 years will require significant political commitment from governments – and from industry. The introduction of financial incentives and the identification and characterisation of CO_2 storage resources are critical in paving the way for CCS deployment. In addition, the report lists a number of areas where increased emphasis would be particularly relevant:

- **Focus on retrofitting:** CCS is needed to reconcile today's reality of more than 1 950 GW of existing coal-fired power plants and a 2°C, or below, pathway. Coal currently generates around 40% of global electricity and the ability to retrofit CCS to coal power plants can help reverse the "lock-in" of emissions while limiting the economic and social cost associated with the premature closure of these plants.
- **Revive BECCS:** negative emissions will take on increased importance as the world seeks to achieve a net balance of emissions in the second half of the century. BECCS is the most mature of the negative emission technology options. However, widespread deployment will require that associated technical, economic and social challenges are addressed, particularly the availability of sustainable biomass and access to CO_2 storage sites.
- **Encourage low-carbon "clean industrial products":** Chemicals, steel and cement all have significant carbon footprints, and CCS is a key technology to achieve deep cuts in the associated carbon emissions. A combination of market "push" and "pull" levers, such as regulations, incentive mechanisms, and stimulating consumer interest, can help create the demand for "clean industrial products", and to incentivise the investment in CO_2 capture in various industrial processes.
- **Drive transition towards "EOR+":** novel EOR practices that include monitored CO_2 storage can produce verifiable, net emissions reductions. The volume of CO_2 injected and stored can significantly outweigh the emissions from the additional oil produced. Commercial interest in EOR+ could also encourage further investment in CCS deployment.
- **Disaggregate the CCS value chain:** the development of CO_2 storage resources remains critical for widespread deployment of CCS. Separating out CO_2 storage development as a distinct business, partially insulated from the different operational and risk profiles of capture and transport, could present an attractive investment proposal for entities with subsurface expertise.

The future for CCS will ultimately depend on a significant strengthening and expansion of the global climate response. As stated by the IEA Executive Director Dr Fatih Birol in the foreword of the report, "Deployment of CCS will not be optional in implementing the Paris Agreement." The Paris Agreement marked an important and historic milestone with increased ambition, however a significant gap exists between the national pledges ("NDCs") and a well below 2-degree outcome. Bridging this gap will require high levels of political commitment on national level. The required mid-century national strategies can provide a significant opportunity to ensure the positioning of CCS in countries' low-carbon energy landscape. The pace and intensity with which governments now enact ambitious national climate and energy policy will ultimately determine the future of CCS deployment.

The IEA secretariat thanks IEAGHG for excellent contributions made to the report! The report is available at: www.iea.org/topics/ccs/ ●

NRAP Releases Phase I Tools, by Grant Bromhal, US Department of Energy

The National Risk Assessment Partnership (NRAP) recently released a set of Phase I Tools useful to help address leakage and induced seismicity risks associated with geologic carbon storage. These tools are designed to find broad application in the international geologic carbon storage (GCS) community; foster robust, objective, and science-based communication and decision making with respect to large-scale application of GCS; and accelerate the adoption of GCS technologies.

NRAP is a multi-national lab team focused on developing tools and technologies to overcome risk-related barriers to full scale deployment of carbon storage. NRAP is led by the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL), leveraging broad technical capabilities from across the DOE, involving Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Pacific Northwest National Laboratory.

NRAP focus is shifting from risk assessment to risk management, as its Phase II activities begin this year. In a culmination of its Phase I efforts, a suite of ten (10) simulation tools were developed to help evaluate risk and quantify uncertainties for candidate CO_2 storage sites. These tools have been applied to evaluate critical performance of several components of the carbon storage subsurface containment system (e.g., reservoirs, seals, and legacy wells), as they relate to two major types of environmental risks: leakage and induced seismicity.

National Risk Assessment Partnership

The tools are:

- Integrated Assessment Model for Carbon Storage (NRAP-IAM-CS)
- Wellbore Leakage Analysis Tool (WLAT)
- NRAP Seal Barrier Reduced-Order Model (NSealR) Tool
- Reservoir Evaluation & Visualization (REV) Tool
- Reservoir Reduced-Order Model Generator (RROM-Gen) Tool
- Aquifer Impact Model (AIM) Tool
- Multiple Source Leakage Reduced-Order Model (MSLR) Tool
- Short-Term Seismic Forecasting (STSF) Tool
- Ground Motion Prediction applications to potential Induced Seismicity (GMPIS) Tool
- Designs for Risk Evaluation and Management (DREAM) Tool

These tools can be accessed on the NRAP website: https://edx.netl.doe.gov/nrap.

The tools were distributed widely last year, within the U.S. and internationally, including the Regional Carbon Sequestration Partnerships (RCSPs), as part of a beta testing program to demonstrate that they perform as designed for several types of subsurface conditions. The NRAP research team has actively engaged with the international CCS research, development and deployment community, and particularly the IEA Greenhouse Gas Programme and the ANLEC R&D group, to gather feedback used to revise and improve the tools. NRAP has and will continue to work closely with operators, regulators, and researchers to extend the types of storage fields, seals, and operational conditions to which they may appropriately be applied.

Press Release: National Energy Technology Laboratory Releases an R&D 100 Award-Winning Computational Toolset Designed to Accelerate Development of CCS Technologies

The Carbon Capture Simulation Initiative (CCSI) Toolset developed by the United States Department of Energy's National Energy technology Laboratory received a 2016 R&D 100 Award on November 3rd in Oxon Hill, MD. The R&D 100 Awards, known in the research community as the "Oscars of Invention," identify and celebrate some of the best, game-changing technologies developed over the past year.

The award-winning CCSI Toolset gives the power industry a way of dramatically speeding up and reducing the risk of carbon capture technology development for application in power plants and industrial sources of CO_2. The Toolset is the only suite of computational tools and models specifically tailored to help maximize learning and reduce risk during the scale-up process for carbon-capture technologies. By maximizing the learning during all stages of development, the CCSI Toolset can help reduce the timeline and cost of commercialization and enable greater investment confidence.

The CCSI Toolset provides a simulation-based workflow with interconnected modules for integrating multi-scale, multi-physics models with advanced optimization, uncertainty quantification (UQ), and surrogate modeling techniques. These capabilities cover the full spectrum of technology development from guiding experimental data generation, to systems-level control and optimization. Each CCSI module is specifically tailored to properly guide experimental and pilot-scale testing in the acquisition of important data; to assess the sources and effects of model and parameter uncertainty at all levels of analysis; to identify promising device configurations; to promote the rapid synthesis of complete, optimized processes; to model and assess dynamic process behavior; to ensure process designs exhibit nimble dynamic system response to changing plant conditions and disturbances; and to deploy advanced process control techniques that ensure optimal, on-spec operation of CCS systems.

Key features of the CCSI Toolset include:

- Particle- and Device-Scale Modeling
- Process Synthesis, Design, and Optimization
- Process Dynamics and Control
- Risk Management
- Model Scale-Bridging

The CCSI tools are designed to work in conjunction with models implemented in commercial process simulators and extend their capabilities. As a result, technology transfer is more flexible as the CCSI Toolset can be integrated with pre-existing modelling platforms already commonly in use by engineers.
For more information on the Toolset and for licensing options, please visit: www.acceleratecarboncapture.org or contact Michael Matuszewski, Associate Technical Director of CCSI2 at: michael.matuszewski@netl.doe.gov

Pilot testing of Bio-CLC technology at VTT,

by Sebastian Teir & Toni Pikkarainen

VTT Technical Research Centre of Finland Ltd is developing carbon capture technologies suitable for power and heat production plants. Initial work with a 20 kW test unit indicates that chemical looping could be an efficient technology for combusting biomass and capturing CO_2.

Finland is well on its way to achieving the 2020 climate goals, but it is already clear that the goals for 2050 are impossible to attain without major changes in energy production and other industries. VTT has calculated that CCS could cost-effectively cover one third of the needed reduction in greenhouse gas emissions in Finland by 2050. Of this share, more than 80% would be captured during biomass combustion or refining, while the rest would be captured from coal-intensive industry.

Chemical Looping Combustion (CLC) is a new combustion technology requiring much less energy for capturing CO_2 than other technologies. The first experiments with combusting biomass have been carried out this year using a 20 kWth test rig at VTT's Bioruukki pilot centre in Espoo, Finland. The fuels used were untreated and heat-treated wood pellets, and the oxygen carrier used was

The 20 kWth bio-CLC test rig at VTT's Bioruukki pilot centre

ilmenite, a natural material mainly containing titanium-iron oxide. The results have been promising, proving the functionality of CLC as a biomass combustion method.

In addition, CLC could enable higher power generation efficiencies from biomass. When using current combustion technologies, chlorine compounds in biomass cause an elevated high-temperature corrosion risk. For this reason, the steam temperature must be kept low, which reduces the efficiency. Bio-CLC technology allows the use of higher steam temperatures, leading to a higher power generation efficiency. In the initial pilot experiments, no signs of any risk of corrosion were detected. However, further work is required to verify this.

This work was carried out in the Finnish Carbon Capture and Storage R&D Program (CCSP, 2011-2016) and continues the Nordic Negative CO_2 project (2015-2019).

- **http://ccspfinalreport.fi/**
- **www.nordicenergy.org/flagship/negative-co2/**

Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2017. 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.

Monitoring Network
13th - 15th June, Battelle, Michigan, USA

High Temperature Solid Looping Network
4th - 5th September, SWEREA MEFOS, Sweden

4th Post Combustion Capture Conference
5th - 8th September, Birmingham, Alabama, USA

IEAGHG Costs Network Workshop (By Invitation Only)
13th - 14th September, London, UK

IEAGHG Summer School
Date and Location To be Confirmed

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