
# Greenhouse News

• the official newsletter of IEAGHG and its members •

*September 2015 • Issue 119*


## GHGT-13, by Siân Twinning, IEAGHG

# ghgt-13

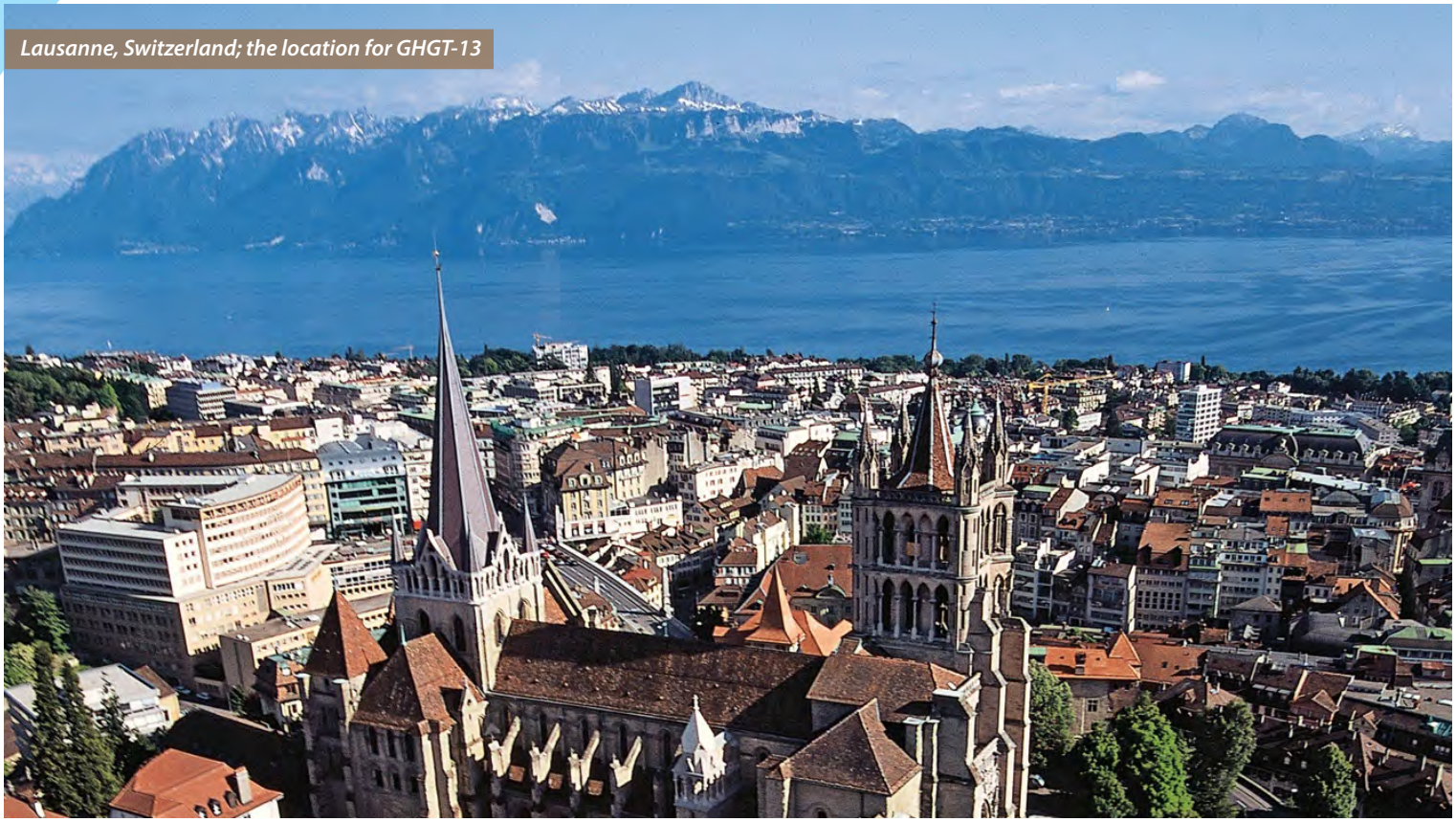
**It may only seem like yesterday that we were in Austin, Texas at GHGT-12 but it is once again time to open the doors on another GHGT conference by inviting the submission of abstracts. With each GHGT conference, we are humbled by the response to the call for papers. GHGT is a major part of our lives here at IEAGHG, from the work involved to the technical learning experience and the friends we make on route. Of course, each GHGT event is not something we do on our own; for GHGT-13 our hosts are École Polytechnique Fédérale de Lausanne (EPFL) and much of the organisational work will fall on their shoulders.**

The first GHGT in its current format was held in Interlaken, 1998 and we are very much looking forward to returning to Switzerland, this time to Lausanne, 18 years after that inaugural event. For IEAGHG, it has been a privilege to hold the guardianship of what has become the most recognised and successful technical $CO_2$ Capture and Storage (CCS) conference globally.

Despite the effort put into organising the event, the conferences' success is a direct result of the papers we receive. We do not kid ourselves that it is anything other than the high technical content that makes the CCS community attend time after time and we recognise the authors' major role in the global impact of the conference.

The task of selecting the technical programme is undertaken by the Technical Programme Committee (TPC). For the past few conferences, we have been very lucky to

## In this issue



*Lausanne, Switzerland; the location for GHGT-13*

have a core of experts prepared to assist with this role. GHGT-13 will see some new faces but before introducing these, we would like to extend our gratitude to members of the TPC who have decided to move on; Howard Herzog (MIT, USA), Olav Bolland (NTNU, Norway) and Peta Ashworth (University of Queensland, Australia) for the many hours they have dedicated to the TPC over the past years.

The new faces for GHGT-13 will include Lyesse Laloui (EPFL, Switzerland), Carlos Abanades (CISC, Spain), Mohammad Abu Zahra (Masdar Institute of Science and Technology, UAE), Sean McCoy (IEA, France), Susan Hovorka (The Bureau of Economic Geology at The University of Texas at Austin, USA) and Gary Rochelle (The University of Texas at Austin, USA).

*Science Direct; this is the website for the GHGT Proceedings*

These will join Tim Dixon (IEAGHG, UK) Chris Hendriks (Ecofys, Netherlands) and Sally Benson (Stanford University, USA) to complete the team.

The TPC, have put together a 'wish list' of topics to be presented during the conference but will be guided by the papers submitted. For a full list of themes, please visit our website **www.ghgt.info**

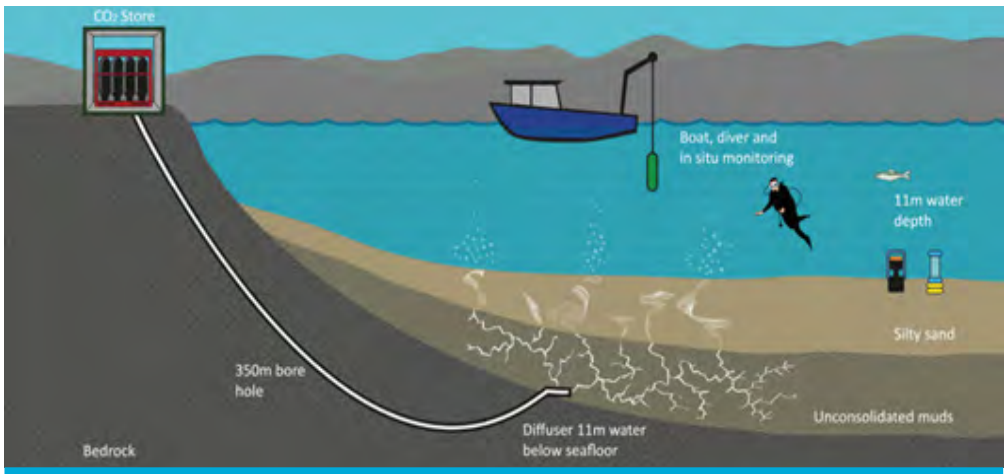
With a redesigned website aimed at streamlining the author experience, we very much hope that you will consider GHGT-13 (14th - 18th November 2016) as a worthy place to present your research. As with past conferences, we will produce a proceedings to be published online with Elsevier's' Energy Procedia. The papers published will be indexed with Scopus and Web of Science and on a selective basis by Thompson Reuters' Conference Proceedings Citation Index℠ to assist with getting your work shared and recognised within the wider community.

For those of you who have not yet had the pleasure of visiting Lausanne, it is a beautiful city sat on the banks of Lake Geneva and it proudly holds the title of Olympic Capital. There is much to see and do from the stunning scenery to the numerous museums, city tours, restaurants and vinyards as well as a thriving nightlife (should you have anything left after the rigours of the conference!) that adding a few extra days should be considered. The Swiss rail network is exceptional and with this you can gain easy access to the villages of the Swiss and French Alps - an experience not to be missed!

# New IEAGHG Report: 2015-05 Review of Offshore Monitoring for CCS Projects, by James Craig, IEAGHG

**Many regions of the world with offshore continental shelf areas offer significant potential for large-scale $CO_2$ storage. These regions often have depleted oil and gas fields, deep saline aquifers or other permeable formations which are suitable for injected $CO_2$. The gas must be safely stored and retained within predefined reservoirs but should any seepages occur they need to be detected so that mitigation measures can be implemented. It is also important to be able to verify the pattern of $CO_2$ migration within reservoirs by comparison with predictive models. IEAGHG contracted a consortium of leading UK research institutes, led by the British Geological Survey, to review monitoring techniques currently available for $CO_2$ geological storage. The National Oceanography Centre, Plymouth Marine Laboratory, and the University of Southampton added their expertise to the study.**

A range of monitoring techniques are available for $CO_2$ geological storage offshore, both deep-focussed (providing surveillance of the reservoir and deeper overburden) and shallow-focussed (providing surveillance of the near seabed, seabed and water-column). Deep-focussed operational monitoring systems have been deployed for a number of years at the offshore Norwegian storage sites Sleipner and Snøhvit. The efficacy of key technologies are starting to emerge. Research based on 3D seismic surveys have been highly effective for tracking $CO_2$ plume development in the Sleipner and Snøhvit reservoirs. In the Snøhvit field a combination of 3D seismic and downhole pressure/temperature measurement has demonstrated the benefit of complementary techniques. This monitoring programme led to a switch in the injection strategy into an alternative reservoir. Assessment of the results from both deep-focussed and shallow-focussed monitoring activities from Sleipner and Snøhvit indicates that many elements of the European storage requirements have been met at these large-scale sites which were both initiated before the CCS Directive was introduced.

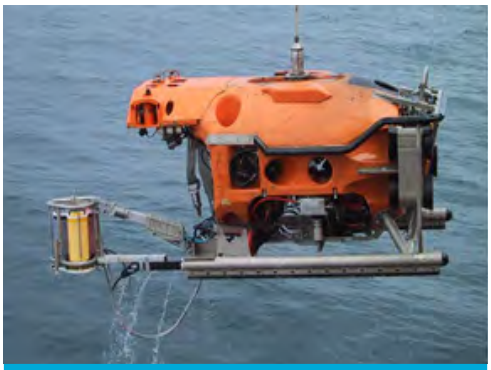



*Schematic of the QICS experiment (copyright Plymouth Marine Laboratory)*

Shallow-focussed monitoring systems are being developed and demonstrated. New marine sensor and existing underwater platform technology such as Automated Underwater Vehicles (AUVs) and mini-Remotely Operated Vehicles (Mini-ROVs) enable deployment and observation over large areas at potentially relatively low cost. Seafloor and ocean monitoring technologies can detect both dissolved phase $CO_2$ and precursor fluids (using chemical analysis) and gas phase $CO_2$.

Controlled release experimental sites such as QICS (Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage) have proved to be useful test-beds for shallow seismic techniques and acoustic detection systems. They can also reveal how $CO_2$ migrates through, and is partially retained by, unconsolidated sediments.

Developments in geophysical techniques, such as the P-Cable seismic system, have generated higher resolution 3D images of the overburden. Successful integration of these shallow subsurface technologies, with the seabed monitoring data, can help to build a better understanding of shallow migration processes. Search areas could be narrowed down by the integration of information from deeper-focussed monitoring such as 3D seismics, which can identify migration pathways, with shallow surface monitoring such as acoustic detection.



*Remotely operated underwater vehicle (ROV) (courtesy of Statoil ASA)*

There has been significant progress in demonstrating monitoring of offshore $CO_2$ geological storage sites, and this report compiles and reviews the developments to-date. The report reference is, **"Review of Offshore Monitoring for CCS Project, 2015/05, July, 2015".**

# Post Combustion Capture Experts Flock to Regina, by Siân Twinning, IEAGHG

**We are fortunate enough to be able to facilitate the gathering of the world's experts in post Combustion Capture (PCC) through our PCC conference series (PCCC) which is held every two years. The last few days has seen the latest instalment – PCCC3.**

Having had Technology Centre Mongstad (TCM) present their results after one years' operation at the previous conference, expectations were high when we announced a partnership with SaskPower to reveal their results and findings from building and operating the world's first integrated carbon capture and storage power plant.

We were humbled to have 190 delegates make the effort to travel to Regina, Canada to attend, present and knowledge share their knowledge.

The first two days of the conference set the scene with highly technical presentations providing the background to the development of the technology now in use at Boundary Dam. It was a packed programme, with 3 parallel sessions allowing 77 presentations and a dedicated poster session with a further 33 posters. The final two sessions provided results from demonstration and pilot scale projects which led us very nicely to the handover from the IEAGHG PCCC3 conference to SaskPower for their CCS Symposium.

Expectation was high and SaskPower did not disappoint, presenting the business case for CCS at Boundary Dam in the morning, and results and learnings in the afternoon. The presenters were grilled by the audience, all keen to learn as much as possible form SaskPower's experience, with the questioning going on well into tea breaks and the evening dinner.

A special report was presented to the audience, commissioned by IEAGHG and funded by US DOE. The author, Carolyn Preston, was given access to the Boundary Dam team and has produced the report outlining the journey from decision to operation.

SaskPower also used the Symposium to make a special announcement of the signing of a Memorandum of Understanding with BHP Billiton to share information from Boundary Dam.

All in all, a very busy exciting three days were enjoyed by attendees and, to round it all off, 150 delegates also toured Boundary Dam. It must be said, a very successful event was held!

# IEAGHG 5th Social Research Network Meeting,

## by Sam Neades, IEAGHG

**The most recent meeting of the IEAGHG Social Research Network (SRN) was held in Cambridge, UK. Hosted by the University of Cambridge at the beautiful St Catharine's College, and sponsored by the UK CCS Research Centre, this one day meeting on Monday 6th July 2015 was packed with captivating talks from all aspects of the topic of social research and science in relation to CCS and energy technologies.**

The meeting – 'Energy Transformations and the Role of Social Sciences' – kicked off with a wonderful dinner in the Senior Combination Room at St Catharine's, where attendees were addressed by Lord R. Oxburgh, member of the House of Lords and also President of the Carbon Capture and Storage Association (CCSA), who gave a brief welcome talk on energy transitions and the importance of CCS.

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

*Discussions ongoing at the SRN meeting in Cambridge, UK back in July 2015*

*St Catharine's College at the University of Cambridge (UK), the venue of the 5th IEAGHG SRN meeting*

*The delegates of the 2015 SRN meeting at Trinity Hall, the University of Cambridge, UK*

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

On Tuesday the 7th July, the UKCCSRC held a related workshop on the issues in governance and ethics of CCS. For more information on this please see the UK CCS Research Centre's website (**https://ukccsrc.ac.uk**). The report from the 5th IEAGHG SRN meeting will be available soon to Members of the Programme.

For more information about the IEAGHG Social Research Network or for a copy of the previous meeting reports, please contact **tim.dixon@ieaghg.org**.

# Peterhead Project Prioritises CCS Education,

## by Natalie Ghazi, Shell


*Geo walk participants, hosts and organisers come together to celebrate the successful event*

**Through the Peterhead CCS Project, Shell is proposing to bring a 'world first' to the doorstep of the Peterhead community, putting the town on the map of world leaders in this important low-carbon technology.**

As this is a pioneering development – the world's first industrial-scale CCS project on a gas-fired power station – the project has a responsibility to inform and educate the community on the technology and to explain the opportunities associated with having this innovative venture in their back garden. Since the earliest stages, the project team has embraced this responsibility, proactively consulting and engaging with the community through a variety of events, learning sessions and workshops. Through these myriad activities, they have reached a wide range of different stakeholders in the local community and those surrounding it.

Building on the success of the three-phased public consultations which took place from late 2013 to February 2015, in April 2015 Shell sought a secondee to support their ongoing outreach and communications activities. I came through the interview process successfully and have been working in this role since the start of May.

In that time I have been involved in hosting or supporting a plethora of external events, whose primary focus has been building relationships with key stakeholders in an interactive and educational way, while also raising awareness of CCS.

The first event was a 2-day CCS workshop for 8 primary schools in the Peterhead area, which

*Pupils generating energy on the static bikes at the Peterhead School Workshop*

*Pupils from Peterhead Schools learning how to capture $CO_2$ at the School Workshops in May*

*Natalie at Peterhead Scottish Week, back in July, with members of local community group, Theatre Modo*

over 220 pupils attended. These action-packed workshops, hosted in conjunction with the Global CCS Institute's $CO_2$ Degrees programme, used fun experiments, creative challenges and interactive presentations to build on the pupils' knowledge of energy while introducing them to the proposed CCS project on their doorstep. GeoBus – a

*In front of the Peterhead Power Station, participants of the Geological Walk learn more about the rocks that make up the Goldeneye Reservoir*

mobile team of science educators who 'bus' to schools all over Scotland and run geology-based education modules – were also involved, helping to bring the geology of the Goldeneye reservoir (where $CO_2$ from the Peterhead project will be stored) to life.

Following this, we participated in a series of established community events in and around the Peterhead area. Having a presence at these events allowed us to integrate with the community and reach many stakeholders we had not previously engaged with. Each event had a fun, family-friendly atmosphere, while also delivering educational value. Information was tailored to suit different groups and was presented in the form of simple experiments for visitors to try and a variety of written materials – some on display, others to take away. Performance-based CCS activities also featured, led by local community group Theatre Modo.

The most recent community event hosted by the project – in collaboration with the Global CCS Institute and GeoBus – was a 2.5 km Geological Walk in Boddam, the village closest to the Peterhead Power Station (where the CCS project is being developed). This walk took participants on a 145-million-year journey through the geological history of the Goldeneye reservoir, which lies 2.5 kilometres below the North Sea seabed. Led by geologists, the event traced the make-up and history of the multiple layers of rock that lie over the depleted Goldeneye gas reservoir. There were nine stops along the walk, each

*Members of the Geological Walk exploring and learning about the core of the Gooldeneye Reserviour*

focusing on a different theme and rock sample, with an associated experiment and activity explaining why the reservoir is an optimal location to store $CO_2$ from the Peterhead Power Station.

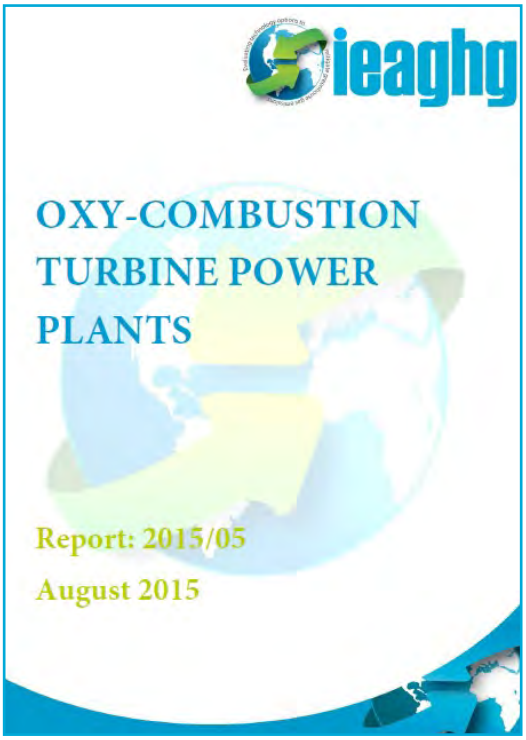
In addition to hosting events, we have also been involved in recent months in supporting the development of CCS module for schools, as part of the very popular GeoBus educational programme, in collaboration with The Crown Estate, the Global CCS Institute and SCCS. The module is being developed to raise awareness of the technology and geology associated with CCS and it is aimed to roll it out to schools across the UK from next year.

Educating the leaders of tomorrow and the ones who will ultimately reap the long-term benefits of CCS as a low-carbon energy technology is a priority of the Peterhead project. Should the project go ahead, the team has committed to leaving a legacy in the community, and educating young people is recognised as one of the most effective ways of doing this. This priority has underpinned almost all of the community events the project has hosted or supported to date. The aim is to build on these pilot initiatives as the project progresses so that the young people of Peterhead and surrounding areas have an opportunity to be the first generation of CCS ambassadors.

Natalie Ghazi is Outreach and Communications Advisor for the Peterhead CCS Project. A native of Glasgow, she worked as a primary school teacher for eight years, in Scotland and Nigeria, before undertaking a Masters in CSR in Energy at Robert Gordon University in Aberdeen in 2014.

# New IEAGHG Report 2015-05: Oxy-Combustion Turbine Power Plants, by John Davison, IEAGHG

**IEAGHG undertakes studies on the performance and costs of plants incorporating various $CO_2$ capture technologies. A technology which has been receiving increasing attention lately, including from some major industrial companies, is oxy-combustion turbine power cycles. These involve burning gaseous fuel in high purity oxygen to heat high pressure $CO_2$ and/or $H_2O$, which is then expanded in a turbine. Various oxy-combustion turbine cycles have been proposed, some of which are still academic concepts but others are the subject of industrial development activities.**




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

The main highlights of the study are:

- The predicted thermal efficiencies of the cycles assessed in this study range from 55% (LHV basis) for the NET Power cycle to around 49% for the other base case cycles. For comparison, a recent IEAGHG study (2012-08: $CO_2$ Capture at Gas Fired Power Plants) predicted an efficiency of 52% for a natural gas combined cycle plant with post combustion capture using a proprietary solvent.
- There was shown to be scope for improving the thermal efficiencies in future for example by making use of materials capable of withstanding higher temperatures. Proprietary improvements by process developers may also result in higher efficiencies.
- The levelised cost of electricity (LCOE) of base-load plants using natural gas at 8 €/GJ are estimated to be 84-95 €/MWh, including $CO_2$ transport and storage costs. The lowest cost oxy-combustion plant (NET Power) has a slightly lower LCOE than a conventional gas turbine combined cycle with post combustion capture using a proprietary solvent.
- The cost of $CO_2$ emission avoidance of the various cycles compared to a reference conventional natural gas combined cycle plant is 68-106 €/t $CO_2$ avoided.
- The base case percentage capture of $CO_2$ in this study was set at 90% but it was determined that it could be increased to 98% without increasing the cost per tonne of $CO_2$ avoided, or essentially 100% if lower purity $CO_2$ was acceptable.
- The water formed by combustion is condensed in oxy-combustion turbine cycles which would mean that if air cooling was used, the power plants could be net producers of water, which could be an advantage in places where water is scarce, although air cooling would reduce the thermal efficiency.
- Oxy-combustion cycles could have advantages at compact sites. The total area of an oxy-combustion combined cycle plant is estimated to be slightly less than that of a conventional combined cycle with post combustion capture. The ASU could be located off-site if required to further reduce the power plant area. In addition, regenerative oxy-combustion cycles are significantly more compact than combined cycles.
- Oxy-combustion turbines could be combined with coal gasification. The predicted thermal efficiency of a coal gasification plant with a SCOC-CC is 34% (LHV basis), which is similar to that of more conventional CCS technologies (IGCC with pre-combustion capture and supercritical pulverised coal with post combustion amine scrubbing) but the estimated capital cost and cost of electricity of the oxy-combustion turbine plant are significantly higher.

Technical Report 2012-08 is available to download open source via: **www.ieaghg.org/publications/technical-reports**

Technical report 2015-05 will be available open source to the public in April 2016. Companies and individuals from member countries can request the report from IEAGHG by contacting Becky Kemp at **becky.kemp@ieaghg.org**

# The Special Report on CCS -10 years on,

## by John Gale, Editor in Chief

**The IPCC Special Report on CCS (SRCCS), published in 2005, was a major definer for the acceptance of CCS as a mitigation tool for greenhouse gas management. Before the SRCCS, CCS was parked in the "under research and not really taken seriously" category under IPCC. However, after the publication of the SRCCS, thankfully all that changed, and CCS was accepted. It took its place alongside the other low carbon technology options and became part of the portfolio of options that was needed to be deployed to fight climate change.**

Whilst many like me who had been through the IPCC SRCCS process, had remarked "never again", there was a need to update the 10 years of extensive work that has been undertaken since the SRCCS was published. The concept of a Special Issue of the International Journal of Greenhouse Gas Control (IJGGC) as a vehicle to update the IPCC SRCCS was first suggested by my co-editor, Carlos Abanades – also an ex SRCCS author. The challenge this special issue presented was then naively taken up by the Editors of IJGGC as something we should champion. The naivety, of course, stemmed from the fact that we thought we could get reviews undertaken on key development areas on CCS easily, as ever you forget that people have day jobs and nothing is ever easy when it comes to writing multi-authored, peer-reviewed papers. Nevertheless we stuck at our task, as did the authors, and we are very proud of the result. The authors and reviewers involved should also be commended for their efforts. The journal, of course, was the ideal place to launch this new initiative since it was conceived after the SRCCS as a home for peer – reviewed papers on CCS that could be utilised for IPCC Assessment Reports post SRCCS, a vacuum I am pleased to say it has filled.

The Special Issue of IJGGC commemorating ten years since the SRCSS (Vol. 40) can be found at www.sciencedirect.com/science/journal/17505836/42 . All papers will be free to download until December 31st 2015, so I recommend you take advantage of that "once in a lifetime" opportunity.

The Special Issue presents to the CCS community, and to the wider stakeholder community, a collection of 17 review papers covering areas in which significant progress has been made in the 10 years since the publication of the IPCC SRCCS. Just over 100 authors participated in this exercise, who referenced nearly 3000 publications to support their work, including peer reviewed scientific and technical documents as well as grey literature. The list of papers and authors is given in Table 1 (overleaf).

The Editorial, which we worked on and put together, provides a nice summary of what was included in the Special Issue. We got 14 successively-improved versions before we finally finalised the Editorial content. I understand Carlos still hates me because I removed from version 2 a diagram he had carefully drawn. Editorial "love" all round and once again I was quoted as saying "never again".

If we summarise the results of this Special Issue the take away message is: "We can be certain that the science and the technologies supporting CCS as a climate change mitigation tool have experienced a great advance in the last 10 years, consolidating and


expanding the knowledge base to estimate more accurately the impacts, risks and cost associated with large CCS projects"

As much as what we included there were aspects covered in the SRCCS we left out of this review. For instance we did not cover aspects of System Economic Analysis and Emission Accounting as these were considered to be covered elsewhere – IPCC Assessment Report 5 in the first case and the IPCC Guidelines for Emissions Accounting, 2006 for the latter. Research in the area of Ocean Storage has largely been curtailed following the decision by the London Convention to ban ocean storage in 2007. The Editorial team decided to exclude "Ex-situ" mineral carbonation processes which have evolved little except in some niche applications. We also decided to exclude $CO_2$ utilisation for the reasons expounded in the Editorial. I am sure we will get lots of responses to both these decisions. But I would throw out a challenge to the advocates of these technology options; write some papers and prove us wrong. There are some areas we did not cover because a couple of papers did not get written due to author time constraints, or pass the peer review process. Whilst in some areas the research currently published was too limited at the time we took the decision to start this exercise well over a year ago.

One such area that has now been covered since we started on this project is Wellbore Integrity, Stefan Bachu, another ex SRCCS author and co-editor, in his final duty for IJGGC has completed the Virtual Issue (VI) that covers 32 papers submitted to IJGGC on this topic. Obviously the VI is not as broad a review of the literature as the reviews in the Special Issue themselves because it only covers papers published in IJGGC. However, the VI does outline the status of the topic as we know it and, in truth, I hardly think we are way off the mark as IJGGC captures some of the best research articles on CCS.

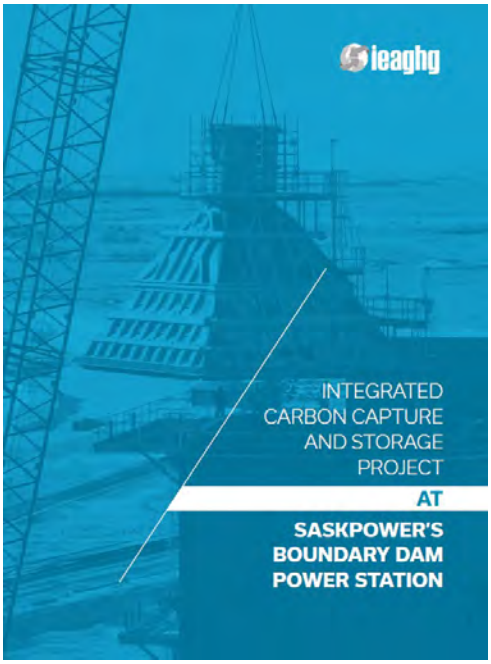
We also recognise that here are also some topics where the literature is now building, such as: capture at industrial facilities, $CO_2$ pipeline design/safety and the development of transport infrastructure, which will themselves warrant reviews in due course. The Editors of IJGGC are open to ideas and suggestions by author teams for future Review papers. We are open to the idea of a Virtual Special Issue in a couple of years' time to cover gap areas. Did I say "never again"?

I would like to thank one and all that made this happen; my fellow editors, the authors, the reviewers and the production team at Elsevier. I hope you enjoy reading the papers in the Special Issue and you find value in the publications presented.

| Paper Title | Authors |
|---|---|
| Editorial | John Gale, Carlos Abanades, Stefan Bachu, Charles Jenkins |
| Practical Implementation and Demonstration of Post-Combustion $CO_2$ Capture Technology Using Reactive Solvents - Recent Successes, Challenges and Future Directions: State of the Art - 10 years on from IPCC/SRCCS | Raphael Idem, Teeradet Supap, Huancong Shi,; Don Gelowitz, Max Ball, Colin Campbell, Paitoon Tontiwachwuthikul |
| Recent progress and new developments in post-combustion carbon-capture technology with reactive solvents | Zhiwu (Henry) Liang, Kaiyun Fu, Hongxia Gao, Helei Liu, Cao Fan, Wichitpan Rongwong, Teerawat Sema, Amr Henni, Kazi, Sumon, Huancong Shi, Teeradet Supap, Christine W. Chan, Qing Zhou, Don Gelowitz; Chintana Saiwan, Abdelbaki Benamor,, Malcolm Wilson; Raphael Idem, Paitoon Tontiwachwuthikul, |
| Oxyfuel Combustion of Coal and Gas Fired Power Plants with $CO_2$ Capture and Storage - Review of the Current State-of-the-Art | Rohan Stanger; Terry Wall; Reinhold Spörl; Manoj Paneru; Simon Grathwohl; Günter Scheffknecht; Max Weidmann; Denny McDonald; Kari Myöhänen; Jouni Ritvanen; Sirpa Rahiala; Timo Hyppänen; Jan Mletzko; Alfons Kather; Stanley Santos |
| Emerging $CO_2$ capture systems | Juan Carlos Abanades, Borja Arias,; Anders Lyngfelt, Tobias Mattisson, Dianne Wiley, H. Li, M.T. Ho, E. Mangano, S. Brandani |
| Precombustion $CO_2$ capture systems for CO2 capture | Daan Jansen, Giampaolo Manzolini, ,Matteo Gazzani, Michiel Carbo, Eric Dijk |
| Review of $CO_2$ Storage Efficiency in Deep Saline Aquifers | Stefan Bachu |
| $CO_2$ Migration and Pressure Evolution in Deep Saline Aquifers | Jens Birkholzer; Curtis M Oldenburg, Quanlin Zhou, |
| Capillary trapping for geologic carbon dioxide storage – From pore scale physics to field scale implications | Samuel Krevor, Martin Blunt, Sally Benson, Christopher Pentland, Catriona Reynolds, Ali Al-Menhali, Ben Niu |
| Convective dissolution of $CO_2$ in saline aquifers: Progress in modelling and experiments | Hamid Emami-Meybodi; Hassan Hassanzadeh, Christopher P Green, Jonathan Ennis-King, |
| Subsurface geochemical fate and effects of impurities contained in a $CO_2$ stream injected into a deep saline aquifer: What is known? | Stephen Talman |
| Recent Advances in Risk Assessment and Risk Management of Geologic $CO_2$ Storage | Rajesh J Pawar, Grant Bromhal, Bill Carey, Bill Foxall, Anna Korre, Philip Ringrose, Owain Tucker, Max Watson, Joshua White |
| The state of the art in monitoring and verification - ten years on | Charles Jenkins; Andy Chadwick; Susan Hovorka |
| Developments in understanding potential environmental impacts of $CO_2$ leakage from geological storage since 2005 | David Jones, Stanley E Beaubien, Jerry C Blackford, Edwin M Foekema, Julie Lions, Cinzia De Vittor, Julia M West, Stephen Widdicombe, Chris Hauton, Ana M Queirós |
| The Cost of Carbon capture and storage | Ed Rubin, John Davison, Howard Herzog |
| Biomass and carbon dioxide capture and storage - A review | Jasmin Kemper |
| Legal and regulatory developments on CCS | Sean, McCoy, Tim Dixon, Ian Havercroft |
| Developments in Public Communications on CCS | Peta Ashworth, Sarah Wade, David Reiner, Xi Liang |

# New IEAGHG Report 2015-06: 'Integrated CCS Project at SaskPower's Boundary Dam Power Station'

**On October 2nd 2014, the first-ever, commercial-scale, coal-fired power plant incorporating amine solvent absorption carbon capture began operation near Estevan, Saskatchewan, Canada at the Boundary Dam Power Station, Unit 3 (BD3). This was a global landmark event. Although carbon capture technologies had been pilot tested prior to this, a commercial-scale power plant now exists that has demonstrated a number of high-risk technology and business issues have been overcome.**




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

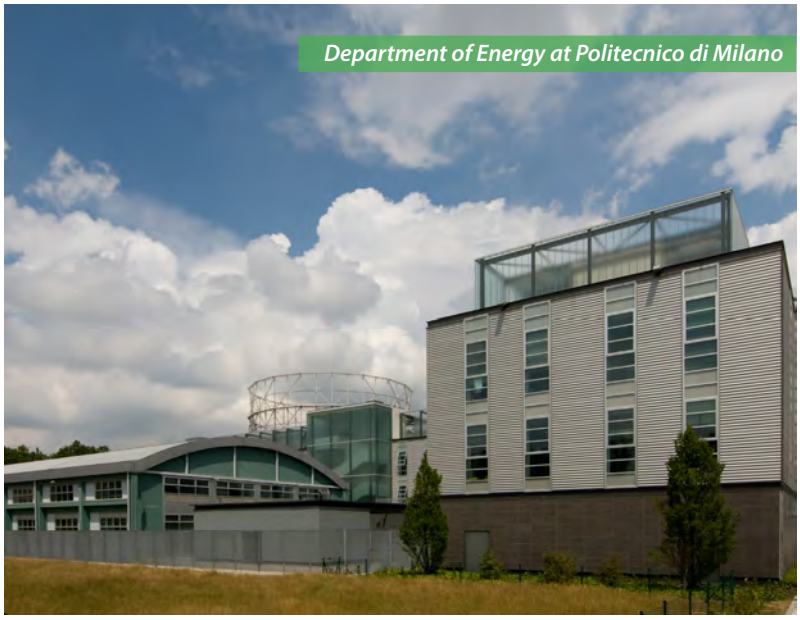
This report, released by IEAGHG on August 31st, 2015 summarises the experience and learnings of SaskPower to provide some insights to other clean-coal initiatives on a wide variety of issues during the design, construction, and first year of operation of BD3.

This report is publically available to download from: www.ieaghg.org/publications/technical-reports/2015-technical-reports or contact Becky Kemp at becky.kemp@ieaghg to request a copy. ●

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

## by Jasmin Kemper, IEAGHG

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


*Department of Energy at Politecnico di Milano*

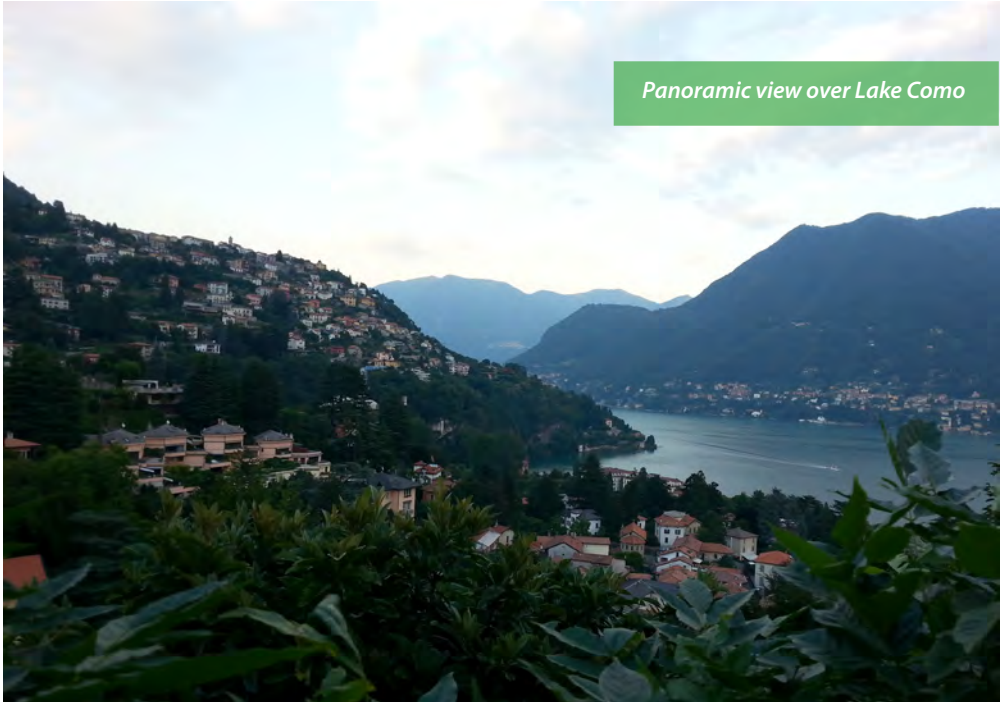
This year's meeting was jointly organised by Politecnico di Milano and IEAGHG.

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

*Delegates of the 6th HTSLCN Meeting during Prof Shimizu's presentation*

testing, solid carrier fundamentals and process integration.

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



*Panoramic view over Lake Como*

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

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

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

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

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

# Challenges of Deploying CCS in Energy Intensive Industries, by Stanley Santos, IEAGHG

**IEAGHG undertakes 10 - 12 technical studies annually covering various areas on how technology could deeply reduce greenhouse gas emissions from fossil fuel use in the power sector and industry. Recently, our members changed our report retention policy to make our reports free to all, rather than keep them to our members only. The aim being to promote knowledge transfer amongst the CCS technical community and related stakeholders. In keeping with our members desire to openly share our technical information, we have also launched the webinar series to expand our communications portfolio and share the results of our study to reach the wider community.**


The first webinar was held on the 29th June (14.00 BST). I had the pleasure and honour of giving the inaugural presentation. My presentation covered my views of the issues pertaining to CCS implementation in the energy intensive industries based on the experience gained from the studies we have done in this area to date.

My presentation, highlighted the following points:

- The importance of CCS in the reduction of $CO_2$ emissions from energy intensive industries to meet the 450ppm or 2DS scenario.
- Increasing the process efficiency is essential for CCS deployment.
- Early deployment of CCS in industry is now on-going enabled by the assistance of government support.
- Future growth in CCS in industry needs to consider and address the market competitiveness concerns of industry.
- $CO_2$ capture and utilisation or CCU is emerging as a key topic. It is ought to be recognised that there are pros and cons in relation to CCS deployment. We need to be critical in assessing how CCU could play a role in the future GHG mitigation strategy.

To view the recording of the webinar, you can visit the IEAGHG website or follow the link as follows:
**www.youtube.com/watch?v=QBhceE5Vafc**

We were very pleased by the number of registrants we received for the first airing of our work in this manner and we received a number of questions that we have responded to online. Quite a lot of comments focused on the issue of $CO_2$ recycle so it seems appropriate for IEAGHG to suggest to its members a study or review on this topic.

# IEAGHG Webinar on Biomass with Carbon Capture and Storage (Bio-CCS/BECCS), by Jasmin Kemper, IEAGHG

**IEAGHG's webinar on biomass with carbon capture and storage (Bio-CCS) provided an overview of the global status of Bio-CCS with a focus on the surrounding sustainability issues rather than technical challenges. It started off with the rationale for Bio-CCS, i.e. its ability to achieve net removal of $CO_2$ from the atmosphere (so-called negative emissions), which both the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) acknowledge. Bio-CCS shows significant potential to achieve this reduction at a cost that is comparable with other mitigation options, while at the same time providing versatility, valuable temporary flexibility and an approach for sectors, where reductions are much harder to achieve.**


Several studies, including assessments by IEAGHG, estimate the global Bio-CCS potential to be ~10 $GtCO_2$/yr in 2050 (based on a bioenergy potential of ~100 EJ/yr). However, the

technically and economically exploitable potential will probably be smaller due to uncertainties, e.g. availability of sustainable biomass, crop yields, land availability, price structures and lack of a standard methodology. A brief conclusion regarding the global status of Bio-CCS projects was that a number of commercial-scale projects exist but many more will be necessary to build up and strengthen confidence in the technology. Many of these operational projects focus on ethanol as the $CO_2$ source and enhanced oil recovery (EOR) as the sink, thus deployment in other applications will be necessary.

Costs of Bio-CCS are likely to be in the same order as Fossil-CCS and a review of estimates published in literature gives a ballpark range of 60 – 250 $/t$CO_2$. Another issue is that currently many policies and accounting frameworks do not adequately recognise and reward Bio-CCS. For example, the EU Emissions Trading Scheme (EU ETS), the largest existing carbon market at present, does not include Bio-CCS. Bio-CCS is, however, inside the remit of United Nations Framework Convention on Climate (UNFCCC) Clean Development Mechanism (CDM) and in some jurisdictions discussions are underway on how to include CCS, Bio-CCS, negative emissions and lifecycle emissions into the schemes. Due to the gaps, there is currently no incentive for operators to achieve negative emissions from Bio-CCS over just zero emissions from biomass combustion without CCS or Fossil-CCS.

The public perception of Bio-CCS specifically remains unclear as a whole, as research is very limited, with contradicting results. The only conclusions so far is that it will be highly dependent on the socio-cultural context of the stakeholders.

Besides the issues discussed so far, it is evident that deployment of Bio-CCS will require an integrative approach addressing the inextricable links within the so-called food-water-energy-climate nexus. Although the overall impacts remain uncertain due to the diversity of Bio-CCS pathways and complexity of the interactions, some of the main concerns in this regard include:

- Competition between food and bioenergy crops for land and impact on local land rents and food prices (especially in developing countries)
- Shift of GHG/$CO_2$ emissions from one sector to another ("carbon leakage")
- Impact of large-scale biomass infrastructure, trade, and supply chains
- Impact of climate change on crop yields
- Water footprint of Bio-CCS systems, competition for water resources and impact of climate change on water availability
- Effects of increased fertiliser use on economics of Bio-CCS and lifecycle GHG emissions
- Land availability and lock-in
- Land use change (LUC )and its impacts on lifecycle emissions, biodiversity, carbon debts
- Availability of sustainable biomass

The webinar concluded that sustainable Bio-CCS deployment will hinge on a number of case-specific details, with the availability of sustainable biomass likely to be the linchpin. In addition, results and implications that apply to one region or system will not be easily transferable to another. Uncertainties regarding potential, costs, sustainability, and policies need to be resolved in order for Bio-CCS to become a viable mitigation option.

You can view the Webinar on the IEAGHG website or click here: **www.youtube.com/watch?v=cVtumabrz3s** ●

# News From the IEA Clean Coal Centre,

## by Debo Adams, IEACCC

### What are the prospects for coal in Italy?

Italy is a leading economy, ranked 11th in the world. The industrial sector drives the economy; it employs more than 30% of the working population and accounts for 25% of GDP. But, it faces challenges of poor economic growth and restricted competitiveness – partly due to high electricity costs.

The government wants the industrial and manufacturing sector to maintain a central role in the Italian economy. Sustainable growth will only happen if the competitiveness of the economic system improves.

In his latest report for the IEA Clean Coal Centre, **Prospects for coal and clean coal technologies in Italy**, Dr Stephen Mills identified various factors that help keep the price of Italy's electricity high and hinder its economic competitiveness:

- The energy mix for electricity is based mainly on imported natural gas and renewables. There is no nuclear power and a modest amount of coal, so it's significantly different to the average EU mix

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• Average wholesale gas prices are high and many Italian power plants are fired on imported gas, which is reflected in the price of electricity

• Some generators are operating in difficult economic conditions or are facing market transition; in particular, there is over-capacity in the CCGT (combined cycle gas turbine) sector

• Italy has the highest incentives in Europe for renewables production which amount to >€10 billion/y, and make up ~20% of the average consumers' energy bill.

Italy is one of Europe's biggest energy importers, importing much of its oil, natural gas, coal and electricity. This is expensive and makes the country vulnerable in terms of security of supply. Energy import costs reached a new high of €65 billion in 2012. Energy import dependency is >80%, whereas the EU 28 average is 53%.

The energy sector is crucial if Italy is to resume sustainable growth. The National Energy Strategy (NES), launched by the Italian government, aims to achieve a more secure, less expensive, and environmentally sustainable energy supply. It concentrates on the greater use of natural gas and renewables for electricity generation. Both are likely to keep electricity costs high.

According to Steve Mills: "Recent years have seen the cancellation of several important proposed major clean coal-based power projects. These would have operated cleanly and efficiently and provided secure, lower cost electricity".

Reducing reliance on imported gas by increasing the use of coal for power generation could provide significant economic benefits as well as broaden the energy mix. The current coal-fired fleet has a combined capacity of ~9.7 GW and most plants use modern technology to achieve high levels of efficiency. Average fleet efficiency is ~40% which compares well with the overall European average of 35%.

Various Clean Coal Technologies (CCTs) are in use or active development in Italy. These include:

- the commercial scale application of circulating fluidized bed combustion (CFBC) technology
- the deployment of modern emission control systems
- the co-combustion of coal and biomass/wastes
- the use of advanced supercritical steam conditions in pulverised coal combustion (PCC) power plants.

Italy relies on imports to meet most of its coal demand – consumption is between 20 - 27 Mt/y. Italy is the 3rd largest coal importer in the EU after Germany and the UK. The Carbosulcis mine at Sulcis (Sardinia) is the country's last working coal mine. There are proposals for this to be revamped as a combined mining and carbon capture site, linked with a coal-fired power plant equipped with carbon capture and storage (CCS) technology.

The establishment of the $CO_2$ Technology Centre Sulcis, located at Sotacarbo's research centre in Sardinia is an important new development. A programme focused on a number of CCT- and CCS-related areas is now underway. CCS is a research priority for the NES. Italian organisations continue to engage in activities focused on the three main routes for $CO_2$ capture (pre- and post-combustion capture, and oxyfuel combustion). Significant technological advances have been achieved via a number of projects that have ranged from small-scale RD&D to technology demonstration. Italy intends to continue R&D in this field, and to monitor closely associated advances made elsewhere.

The report **Prospects for coal and clean coal technologies in Italy** by Dr Stephen Mills CCC/254, June 2015 is available for download from the IEA Clean Coal Centre Bookshop **http://bookshop.iea-coal.org.uk/site/uk/clean-coal-technology-research-reports**. Residents of member countries and employees of sponsoring organisations can download the report at no charge after a one-off registration.

Other new reports from the IEA CCC include:

- Operating experience of low grade fuels in CFBC, CCC/253 by Dr Ian Barnes
- Advanced sensors and smart controls for coal-fired power plants, CCC/251 by Toby Lockwood

Visit our website **www.iea-coal.org** and follow us on twitter **@IEACCC**

# Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2015/2016. Full details will be posted on the networks and meetings pages of our website at www.ieaghg.org.

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

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

### 4th Conference on $CO_2$ as Feedstock for Chemistry and Polymers
29th - 30th September 2015, Haus der Technik, Essen, Germany

### 5th Oxyfuel Network Meeting
27th - 30th October 2015, Wuhan, China

### Risk Management Network & Environmental Research Network Combined Meeting
29th September - 2nd October 2015, Southampton, UK

### LCA in CCUS Workshop
12th - 13th November 2015, London, UK

### International CCS Conference (organised by the OCTAVIUS Project)
17th - 19th November 2015, Rueil-Malmaison, France

### 9th IEAGHG International Interdisciplinary Summer School
6th - 12th December 2015, Perth, Australia

### GHGT-13
14th - 18th November 2016, Lausanne, Switzerland

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