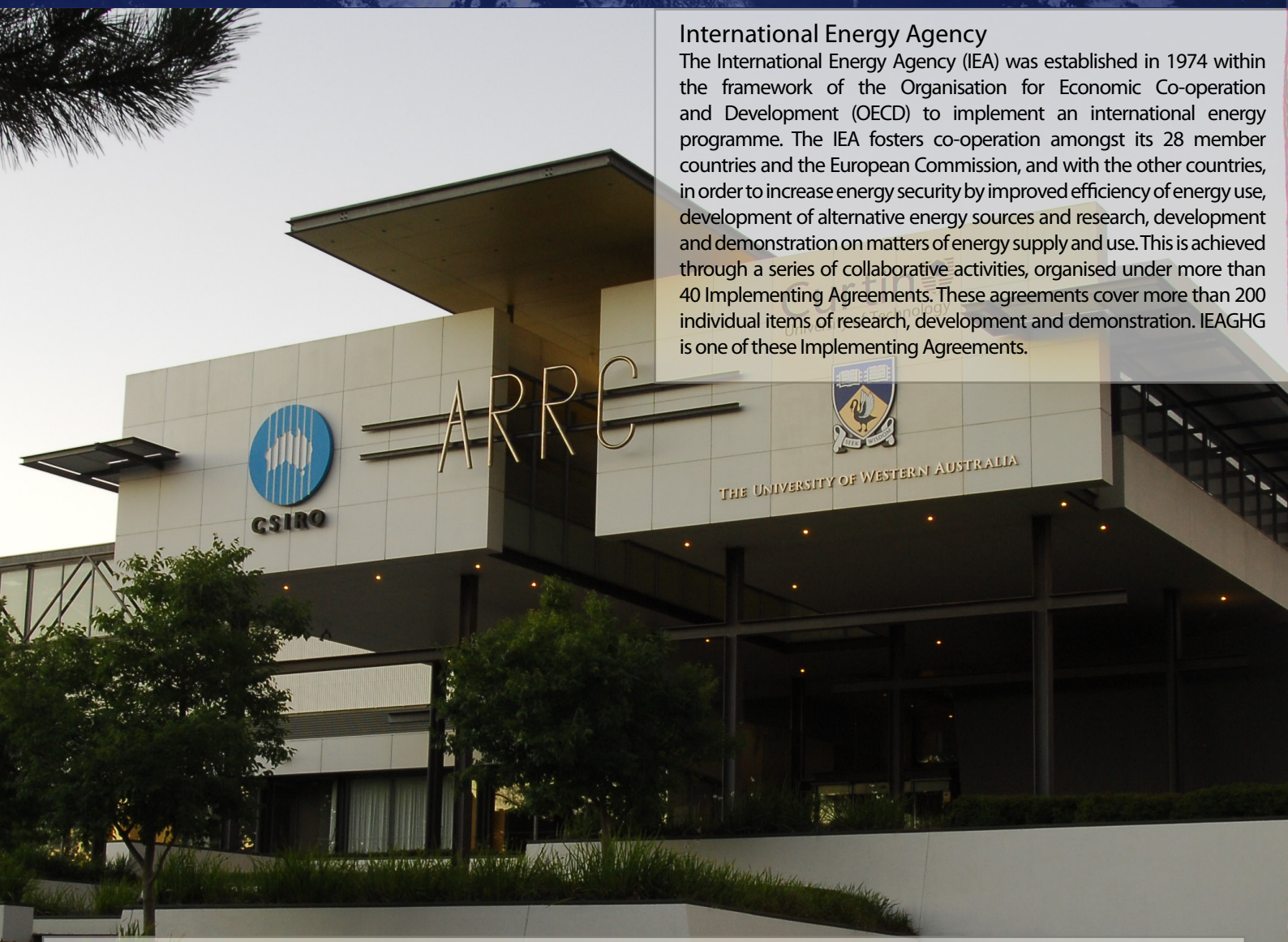
Evaluating technology options to mitigate greenhouse gas emissions

combinedmodelling wellboreintegrity networkmeeting

27th-29thapril2011

IEA GREENHOUSE GAS R&D PROGRAMME



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The report should be cited in literature as follows:

'IEAGHG, "Combined Modelling Wellbore Integrity Network Meeting", 2011/13, October, 2011.'

Further information or copies of the report can be obtained by contacting IEAGHG at:

IEAGHG, Orchard Business Centre, Stoke Orchard, Cheltenham, GLOS., GL52 7RZ, UK

Tel: +44(0) 1242 680753 Fax: +44 (0)1242 680758

E-mail: mail@ieaghg.org

Internet: www.ieaghg.org

Date Published: October 2011, Review compiled by Samantha Neades, design and layout by Toby Aiken and Becky Kemp.

Front & back cover images: ARRC Building, Sleipner A Platform, North Sea, Schematic of Snøhvit project, Pumpjack near Weyburn, and field trip to Collie Southwest CO_2 Hub

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Meeting delegates on field trip / Field visit to the potential site of the Collie Southwest CO_2 Hub, Western Australia

Introduction

This combined meeting of the IEAGHG Modelling and Wellbore Integrity networks was held from the 27th to the 29th of April 2011, in Perth, Australia, hosted by Curtin University and the University of Western Australia and sponsored by Shell, Chevron, Curtin University, the University of Western Australia and the Government of Western Australia Department of Mines and Petroleum. Seventy five delegates attended the meeting, representing 9 different countries.

The three day event looked at the complexity of models, real projects (local and international), geomechanics and wellbore integrity, followed by a field visit to the site of the planned Collie Southwest CO_2 Hub. The agenda and presentations from the meeting are available in the network members' area of the IEAGHG website (www.ieaghg.org). Previous meetings of both the Modelling and Wellbore Integrity networks are also detailed on this website.

Australian Resources Research Centre (ARRC), Venue for the Network Meeting

Session 1: Complexity of Models

Sleipner Benchmark Model
- Andrew Cavanagh, Permedia -

Statoil has released a benchmark dataset from the Sleipner site, available to Modelling Network members through the IEAGHG website. The presentation introduced the dataset and modelling undertaken by Statoil and Permedia, testing numerical simulators against the monitoring data. Modelling successfully matched the general morphology of the underground setting at Sleipner, but predicts faster migration than the observed plume and movement – the next challenge for the modelling team will be matching the two layers of the CO_2 plume.

Sleipner A Platform, North Sea. Courtesy of Statoil.

Sim-SEQ: A Model Comparison Study Using Results from CO_2 Field Tests
– Sumit Mukhopadhyay, LBNL -

Facilitated by Lawrence Berkeley National Laboratory (LBNL), Sim-SEQ provides a forum for discussion, interaction, cooperation and learning among modelling groups. This initiative aims to emphasise the common goal of improving model prediction and demonstrate to stakeholders that the geological storage of CO_2 can be safe. The Sim-SEQ website can be found at: **https://gs3.pnl.gov/simseq/wiki/index.php/Sim-SEQ_Home**.

The Effects of Impurities
- Dave Ryan, NRCan -

A recent study for IEAGHG considered both physical and chemical potential effects on storage from impurities and showed that reduction in storage capacity could be most significant. Other adverse physical effects relate to decreased injectivity and increased buoyancy. Potential chemical effects may be negated by both the 'dry out' zones around injections and the buffering capacity of reservoir and caprock mineralogy. However, potential corrosion of wellbore materials during water encroachment (post-injection) could be significant.

Long term fate of CO_2, Fluid-Rock Interactions
– Pascal Audigane, BRGM -

When looking at the long-term fate of CO_2 fluid rock interactions, researchers found uncertainties in long-term SDRM (Structural, Dissolution, Residual, Mineral) trapping estimate using coupled models. Focusing on geochemical processes, models predictions remain limited with increasing salinity which requires specific formalism (Pitzer) and constant update of thermodynamic databases. Difficulties also reside in the integration of high level of reservoir heterogeneity and complex geological architecture (dip, fluvial deposition, faults).

Model Complexity for the Geological Storage of CO_2
– Mike Celia, Princeton University -

The presentation described levels of complexity in models, options for simplification, considerations of length and time scales and toward guidelines for model choice. Modelling considerations that should be recognised include the time scale for buoyant segregation, heterogeneity and its inclusion in models. Proper model choice requires analysis of space and time scales.

CCS in the Clean Development Mechanism (CDM) – Relevance of Modelling

A presentation by IEAGHG explained that at the 2010 United Nations Climate Change Conference, the 16th session of the Conference of the Parties (COP16) meeting in Cancun had, for the first time, approved the principle of CCS projects being incorporated into the CDM. This was subject to the resolution of certain issues, including the ability of CO_2 storage predictive modelling to guide monitoring programmes and give confidence to regulators.

Delegates were asked to complete a questionnaire on this topic; results are presented in Appendix A. The responses were generally positive that modelling can be used with an appropriate degree of confidence to inform regulator decisions, but data is required from further large scale projects to verify and refine the science. Development of risk mitigation plans was also recognised by delegates as a key priority for CCS projects.

Session 2: Real Projects

Reservoir & Risk Modelling at the ZeroGen project – Andrew Garnett, ZeroGen Pty Ltd -

Engineering and geotechnical models of potential storage sites drive the uncertainties of a CCS project. It is essential that a line-of-sight is created between these models, the inputs and uncertainties of which come from exploration and appraisal activities, and final financial predictions. In order to guide decisions at investment stage-gates, techno-economic decision criteria need to be developed for storage in advance. This presentation discussed these criteria and the geotechnical modelling which informed them.

Impact of Thermal Effects on CO_2 Injectivity – Qingjun Yang, Chevron -

The injection of cold CO_2 into a hot reservoir will affect injectivity by increasing viscosity (which will have a negative effect) and increasing density (positive effect). CO_2 simulations show that the net effect is likely to be positive, yet small, and that density effects dominate over viscosity effects. The modelled thermal effects were consistent between two different simulators.

CO_2 Sequestration/EGR feasibility in Western Australia – Eric May, Shell, UWA and CSIRO -

This presentation looked at model reliability and parameter requirements, simulating field-scale dispersion and risk management considerations in enhanced gas recovery (EGR). A key issue is the size of the mixing zone. This needs to be modelled in relation to dispersion - the combined effect of diffusion and convection - which governs flow.

Quest Project – Hongmei Huang, Shell -

This fully-integrated CCS project had four generations of modelling carried out with the key objectives of creating pressure and CO_2 plume models. Modelling activities are decision-driven and evolve when necessary; utilising multi scale models fulfils the purposes of each targeted investigation.

USRP – Phase 3 Fort Nelson – Charles Gorecki, PCOR -

The PCOR Fort Nelson site has shown that an integrated approach to site characterisation, modelling and risk assessment can lead to an effective monitoring strategy, identify any gaps in site characterisation and can increase the likelihood of project success by identifying and mitigating potential risks. This site has excellent potential – but still requires more characterisation data to ensure project success.

History Matching at Ketzin - Michael Kühn, GFZ -

The Ketzin project in Germany has demonstrated successful history matching for the arrival time of the CO_2 at the first observation well, although at another well (202) the prediction was inaccurate – due to the impact of heterogeneity. GFZ want to improve their monitoring set up with a revised static model and are working on well integrity with a new approach.

Ketzin injection site, Germany

Phase 2 modelling activities at Otway – Mark Bunch, CO2CRC -

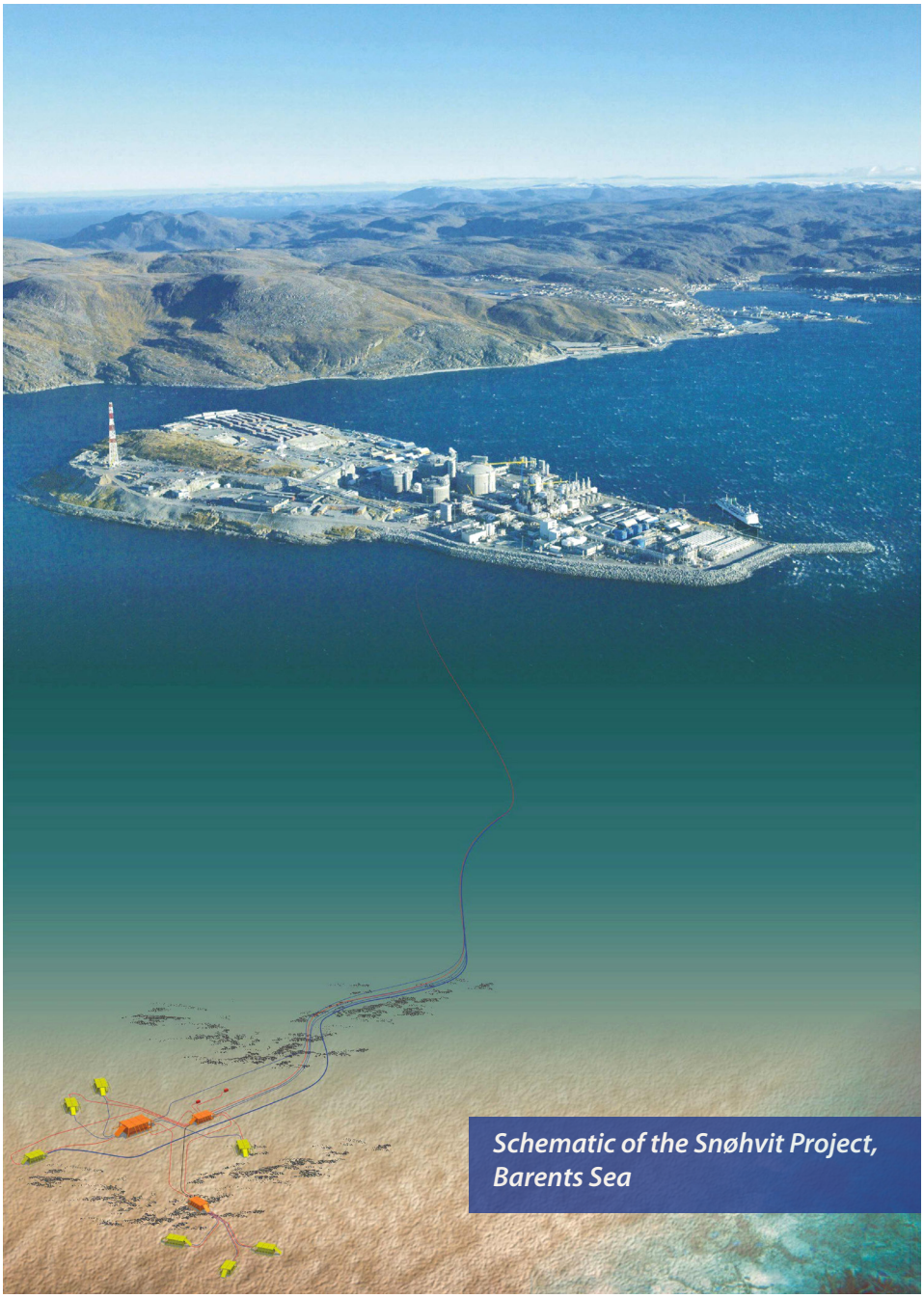
CO2CRC are looking to quantify residual trapping mechanisms in two stages, recognising key uncertainties in modelling (and associated risks), such as sparse well data, facies prediction, non-calibrated well logs and the unknown lateral flow and pressure boundary conditions.

Lessons Learnt from CO_2 Storage Projects at Snøvhit – Martin Iding, Statoil -

At Sleipner and Snøhvit, surface geophysical and well pressure monitoring data give rich information on the storage behaviour – so dynamic modelling is better constrained (yet still challenging). Plume development has been strongly controlled by geological factors which were learned about during injection. Detailed site characterisation, reservoir monitoring/modelling and well solutions have allowed quantification of storage capacity and field performance, which could give a good basis for scoping and optimising future project.

Real Projects: Discussion

All recognised the trust issue between operators, regulators and the public. Modelling needs to be put into a better context – it doesn't necessarily represent reality but it can help with solutions for the future. There is an issue because most people are biased by their backgrounds (i.e. oil or hydrogeology), but the CO_2 problem doesn't fit exclusively into either of these approaches. Much more focus should be put on the caprock properties. Modelling needs to be approached on a site-specific basis and parameters (i.e. injectivity, capacity) must be looked at separately. A key parameter is the tensile strength of the rock – stresses (thermal and other) can lead to fracturing, and the original rock system and fracture profile needs to be taken into consideration.



Schematic of the Snøhvit Project, Barents Sea

Session 3: Geomechanics (& Coupling With Other Processes)

Interpretation of Induced Surface Deformation over KB-502 at Krebcha (In Salah) – Eric Davis, Pinnacle -

Surface deformation monitoring, measured using InSAR, has proven to be one of the more useful of a wide array monitoring methods deployed here. The results of this analysis indicate strain sources far shallower than the injection horizon, coincide well with formation properties determined from logs and 3D seismic surveys. The implications of fluid intrusion into depths far shallower than the injection interval, even if that fluid is displaced formation water rather than CO_2, are significant for the operators.

Caprocks Systems for the Geological Storage of CO_2 – John Kaldi, CO2CRC -

This recent study for IEAGHG recognised that the assessment of caprock systems is highly site-specific and identified several key knowledge gaps, including the hydrodynamic effects on membrane seal capacity, the role of faults/fractures in the system, characterisation of regional geomechanical properties (which is problematic), and the direct monitoring of the caprock. Modelling here shows that when CO_2 is injected, intraformational shales, or 'baffles', increase the length of the migration path before increasing the amount of residual trapping.

The In Salah project, Krechba, Algeria

Geomechanics at Weyburn, Redwater and Zama – Chris Hawkes, University of Saskatchewan -

The modelling carried out at the three sites aims to be an assessment of primary seal integrity, ground surface deformation, sensitivity to mechanical properties and intends to look at the capabilities and limitations of semi-analytical models and the effects of cool CO_2 injection. Fluid production and injection induces stress change within and around the reservoir, so historical withdrawal of fluids at EOR operations (for example the projects presented here), may have affected geomechanical properties.

CCS and Geomechanics: A Review of Workflows and Technical Challenges – Mark Davison, Shell -

Geomechanics is crucial in understanding the containment of a storage complex and a workflow has been developed to ensure geomechanical tasks are aligned with project deliverables at stages throughout the project. Technical gaps identified at the Shell UK Goldeneye project include fault leakage prediction (the risk of reactivation or shear failure is important), thermal response (the possible cooling of the reservoir that

may result from injection could lead to tensile failure or shear fracture), reservoir stress paths (there is a lack of data on what happens with injection), and the alteration of rock minerals with time (the changes alter temporally).

Subsidence Profiles (In Salah – Reservoir engineering and then..?) – Bert van der Meer, TNO -

Following modelling at In Salah, TNO found that the initial movement was too small to use from the history match and there was non-linearity between the surface movement and the history-matched reservoir pressures. The surface movement depression seems too narrow to be explained by a fracture at reservoir depth. Better geological characterisation is needed of the reservoir and overburden and more realisations should be made with simulation solutions.

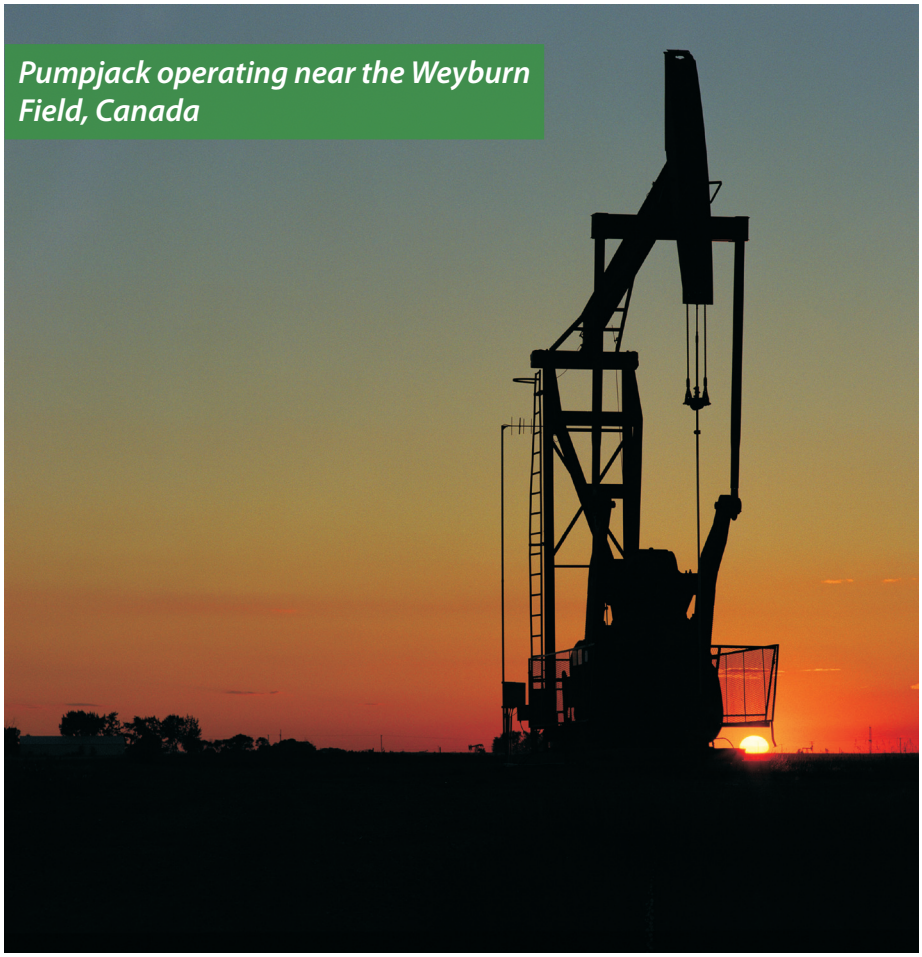
Fluid production and injection induces stress change within and around the reservoir, so historical withdrawal of fluids at EOR projects (for example the HARP project, the Weyburn project etc.), may have affected geomechanical properties.

Geomechanics and Coupling With Other Processes): Discussion

When looking at thermal effects, an issue with just injecting CO_2 at a higher temperature may be the trade-off between raising the temperature and associated costs. In some onshore operations, the temperature of the CO_2 is higher at injection but the risk associated with this procedure in an offshore environment is difficult to quantify.

Calculations for entry pressure into caprocks typically assume the rock is filled with an aqueous phase. There are concerns whether this is a valid assumption – but this can be adjusted for in site-specific calculations. Modellers need to ascertain what fraction of materials (caprocks) are filled with brine.

At Sleipner, the working model is multiple shale layers with a single injection point. The CO_2 then permeates the shale layers; current thinking on how CO_2 propagates through multiple shale lenses to the caprock is mainly by spill points and seal capacity,– perhaps the CO_2 can exceed the entry pressures of the shale layers. More research is therefore needed on plumes and column heights at demonstration sites.



Pumpjack operating near the Weyburn Field, Canada

Session 4: Wellbore Integrity

CO2WELLS JIP & Guideline: A Status Report – Mike Carpenter, DNV -

To create these guidelines, DNV looked at various milestone/ project decisions and a number of case studies (including projects in Norway and Canada). Emphasis on monitoring is a feature of the guidelines. Modelling is required to identify wells/areas that could be affected by CO_2. The guideline will be published in June (available on the DNV and GCCSI websites). DNV are looking at combining this report with the CO2QUALSTORE guidelines that are already out, this could be potentially published in 2012.

Well Engineering Issues at the ZeroGen Project – Andre Mol, ZeroGen Pty Ltd -

CCS wells are risky and complex and this complexity is increasing – managing the uncertainties and the associated risk is key. The tools developed by ZeroGen were updated every day to give accurate risk curves and cost profiles were then built from the bottom up. This tool will also be used for the abandonment campaign.

Wellbore Integrity at Weyburn – Rick Chalaturnyk, University of Alberta -

The presentation described wellbore integrity studies within the IEAGHG Weyburn-Midale Monitoring Project, with particular emphasis on field studies at a recently abandoned well within the CO_2-flood area, including the development of a specialised sampling tool. Valuable data has been acquired on wellbore integrity and cement condition/permeability.

CO_2 Effects on Cement & Comparison with CO_2-Resistant Cements – Jean-Benoît Laudet, TOTAL -

TOTAL looked to assess well integrity issues due to chemical actions on neat G class cement associated with acid gas injection and to test the efficiency of cements designed to resist CO_2 attack. It was found that neat G class cement does chemically react with CO_2, but it is not necessarily detrimental to the integrity. Specifically-designed cements have, however, proven more efficient at 90 or 140°C than the normal cements. There are ongoing tests to validate and confirm these preliminary results.

Modelling of CO_2 leakage rates coupled to wellbore cement reactivity – Bruno Huet, Schlumberger -

The Schlumberger models explain large differences in the rates of Portland cement reactivity, which are due to three main mechanisms – calcium leaching, carbonate ingress and pore clogging. The new cement matrices show that these carbonation rates will be much slower and the degree of carbonation much less. Schlumberger has recognised there is a need for further 1D and 2D experiments with pressure, temperature and flow control.

Cementing Strategies for Effective Zonal Isolation of CO_2 Wells – Andreas Brandl, Baker Hughes -

Baker Hughes have focused on strategies to improve the wellbore cementing quality (initial cement bonding and its durability towards degradation in CO_2 environment), in addition to the recommended good cement practices. A cement spacer system has been evaluated which forms an effective seal along formations to improve cementing success. Lab tests revealed that this spacer does not only minimize losses and filtrates to fragile and highly permeable formations, but also has potential to provide a protective layer between the cement and corrosive fluids. Different samples of Portland cement were also analysed, along with a new Portland cement design.

USRCSP Best Practice Guidelines, - Brian Dressel, NETL-

The US Regional Carbon Sequestration Partnerships have brought together best practice guidelines for drilling, well installation, operations and closure for the geological storage of CO_2 and these are an important output for the programme. These guidelines look in detail at well construction and operation, site development plans, site preparation, drilling and construction, injection operations and post-injection operations.

Meeting Conclusions

A key point recognised during the meeting was that modelling is site-specific and should be done on a project-to-project basis. Simplified models can be useful as they allow exploration of a wide range of scenarios on a short time-scale – but this may not improve the overall understanding of the reservoir. The assessment of caprock systems is highly site-specific and has many knowledge gaps in which further research is needed. There is also a noticeable lack of data on reservoir stress paths – again, an important issue when looking at injection and geomechanics, and there is a need for further 1D and 2D pressure, temperature and flow control experiments when modelling leakage rates.

There is a trust issue between regulators, operators and the public – more needs to be done in bridging the gaps between all stakeholders, public or otherwise. Modelling should be put into a better context to perhaps help with this communication issue – modelling doesn't necessarily represent reality but is crucial to guide monitoring and risk management strategies. Mitigation is a crucial component of risk management strategies that requires early consideration in project planning.

Research into wellbore integrity issues continues to improve our understanding of the performance of cements and other well materials in the presence of CO_2, and highlights the importance of field data from projects such as Weyburn-Midale to calibrate theoretical and laboratory studies.

A crucial point that was raised at many points throughout the meeting is the ongoing need for further, large scale storage demonstration projects to calibrate modelling science and further inform wellbore integrity issues.

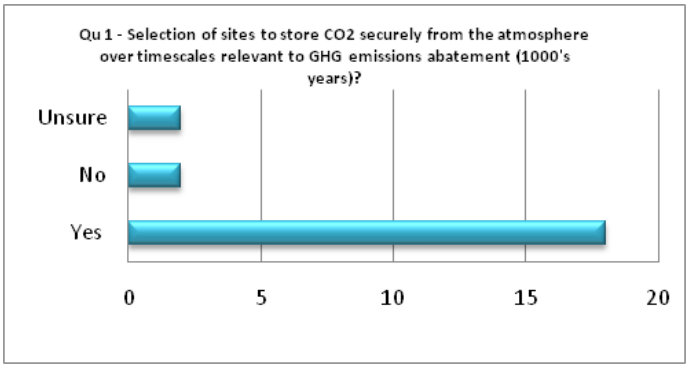
Presentations given can be found on the modelling and welbore integrity pages of the IEAGHG website: **http://www.ieaghg.org/index.php?/20110125241/1st-combined-network-meeting-on-modelling-and-wellbore-integrity.html**

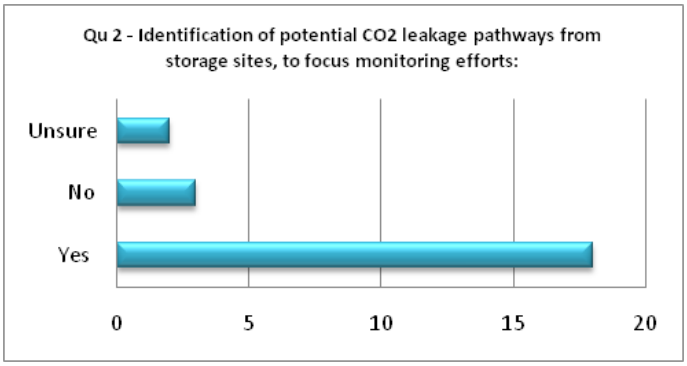
Delegates on Field Trip to the Collie Southwest CO_2 Hub

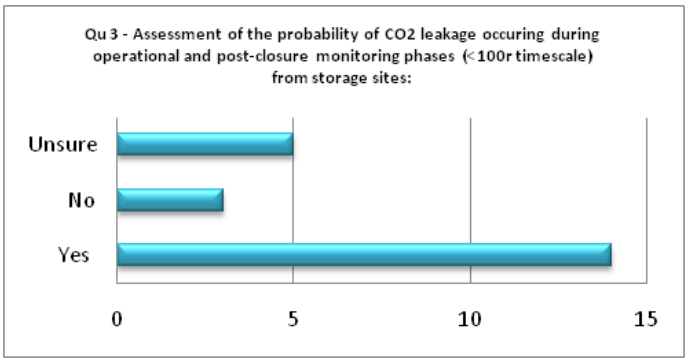
Delegates During Session 3 Presentation

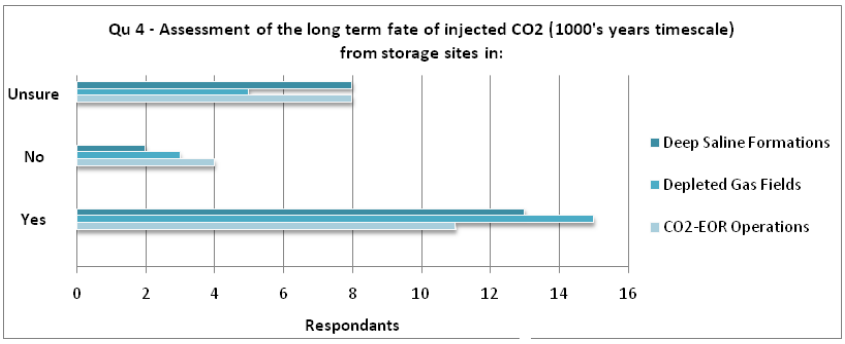
Appendix A – Results from the delegates' questionnaire on CCS in the CDM, session 1

Assuming selection, characterisation and predictive modelling of CO_2 geological storage sites is undertaken according to relevant best practice guidance (e.g. US DOE/NETL manuals), do you consider that current characterisation and modelling techniques can provide sufficient confidence to regulators and policymakers in assessment of the following:









Comments received in the delegates' questionnaire:

Need more investment in demo projects and funds to cover mitigation to ensure positive outcomes prior to commercial implementations. Need to benchmark tools used for site characterisation. Regulators need also education to understand uncertainties and management plans to allow early transition from operator liability to country regulation. Leak mitigation is difficult and I struggle to understand what we can do if fault leakage occurs. Well leakage is more manageable due to oil and gas experience.

I found the talks which discussed real projects (Demo Field Projects), either active or in planning, most useful. I would like to see more work on modelling at different scales, to answer specific questions at these real projects (basin, reservoir, near wellbore, etc.). On the questionnaire, it is difficult to answer questions 1 & 4 since we have no history on the 1000's of years timescale. I do not believe we can guarantee 100% containment on this timescale, however I do believe we can predict a range of potential outcomes on real projects, if there is sufficient CO2 injection to match with adequate monitoring techniques.

For CCS in the CDM to be effective, it is important that host countries develop effective CCS regulatory regimes to ensure appropriate monitoring of CCS projects. There should be more clarity regarding decision making processes in relation to the eligibility of CCS projects to be considered under CDM.

Finding enough suitable large scale storage capacity. There seems to be a general idea that large scale onshore storage will be difficult due to negative public perception. A move offshore could increase cost to unacceptable levels for both transport and storage. A low permeability (<200md) could need a lot of wells in combination with high offshore well cost could push up the cost above acceptable levels.

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Orchard Business Centre, Stoke Orchard,
Cheltenham, Glos. GL52 7RZ, UK

Tel: +44 1242 680753 mail@ieaghg.org
Fax: +44 1242 680758 www.ieaghg.org