Geologic Storage and Monitoring of CO2:
A UK Research Strategy

Executive Summary

The UK is on the threshold of demonstrating that CO_2 emissions can be captured from power plants and stored in geologic formations. The UK government, industry and research councils have invested heavily in advancing the state of knowledge in CCS, and as a result the UK is becoming well placed to lead in this field. Academic research has played a key role in establishing the UK's CCS prominence at the demonstration scale; however continued support in several strategic areas can build upon our existing substantial knowledge base and ensure our investments thus far can continue propelling us on a trajectory towards full-scale deployment. This document identifies some of the most urgent research needs and priorities for geologic storage and monitoring as recognised by scientific leaders working on CCS.

Document development

Over fifty of the country's leading carbon capture and storage scientists and other CCS stakeholders attended a meeting on 7 July 2010 at the University of Edinburgh to develop a UK academic research strategy for the geologic storage and monitoring of CO_2. Participants heard from a panel of international experts involved in CO_2 injection projects and UK research funding organisations before splitting up into working groups tasked with developing various strands of this research strategy document. The meeting was organised by the UK Carbon Capture and Storage Community Network, which is funded by a grant from the Research Councils UK, Energy Programme.

Key recommendations

While each group discussed different topics within the field of geologic storage and monitoring of CO_2, two clear needs underpinned the discussions from nearly each group. 1) It is imperative that UK scientists undertake research at actual CO_2 injection sites. Other leading CCS countries (USA, Canada, Norway, Australia and Germany) have research injection sites, or commercial/research partnerships established that facilitate hands on learning and allow cutting edge science to take place. However, the UK is the only CCS leading country without such a facility. The UK should work towards developing a research program on pilot and full scale research injection sites, with the possibility that one or more of these may not be located in the UK. 2) New and more refined technologies need to be developed which will enable scientists to better monitor and observe the subsurface. More definitive predictive and observational information will be required to give government, industry and the public the level of certainty needed to undertake long-term geologic storage of CO_2 at the commercial scale. There are a host of more specific research needs identified within the storage and monitoring field, and they are discussed below in greater detail. However, without greater support, the need for scientific access at injection sites and more robust monitoring technologies will continue to hamper overall research efforts in the UK.

Key themes presented in this document are grouped by topic as broken out in the workshop discussion groups and are as follows:

Storage types and capacity
Research characterising the type and capacity of potential CO_2 reservoirs has resulted in the identification of significant UK subsurface assets. However, UK and global understanding of very large geological stores suitable for commercial-scale CO_2 storage lags well behind that of CO_2 capture technology. Key areas for further research include assessment of overlapping storage site (as present in the North Sea) interactions, refinement and harmony of storage capacity calculations and characterisation of heavy metals and naturally occurring radioactive material (NORM) in produced / disposed water.

Prediction: modelling the lifetime behaviour of CO_2 storage sites
Predicting the behaviour of CO_2 storage sites based on observations before, during and post injection will be vital for estimating reservoir capacity and satisfying risk assessment and regulation. The physical complexities of storage reservoirs, the difficulty of predicting reservoir-scale physical properties from measurements on small drill samples and the sensitivity of multiphase flow mean that it will always be important to test and refine modelling of CO_2 storage sites based on observed behaviour. Academic access to real-time injection experiments, both full-scale injection and small-scale pilot schemes is paramount to improve our predicative modelling efforts.

Baseline measurements and requirements
Understanding the baseline requirements for geologic injection of CO_2 and obtaining precise and well thought out baseline measurements is crucial before injection activities commence. Without proper baseline measurements that are consistent with current and future measurement techniques, future modelling and analysis reservoirs may be called into question. In the UK context, all foreseeable storage will be offshore, which greatly adds to the complexity of applying many standard subsurface monitoring techniques and increases their costs significantly. The UK urgently requires real-world experience in applying monitoring technology to the offshore environment. Further research into more cost effective instrumentation particularly with offshore capabilities is also required.

Verification of CO_2 behaviour during and post injection
Verifying, calibrating and interpreting long-term monitoring tools are essential to determine the effectiveness of CO_2 stores throughout their lifetime. Developing a portfolio of technologies that can be deployed and trialled at research injection sites would help ensure proper monitoring takes place during and post injection at future commercial sites. A wide variety of tools (e.g. 4D seismic, electromagnetic methods, InSAR, micro-seismic, gravity etc.) need to be developed and deployed in the short-term at test sites so that optimal techniques can be selected and recommended for reliable use at future industrial storage sites.

Managing risk in carbon storage projects
Regulatory risk assessments required for CCS deployment will need to demonstrate an understanding of the potential risks, their possible magnitudes and appropriate remediation plans for the lifecycle of the project. Quantitative risk management tools are needed to predict the likelihood of potential leakage rates from the storage sites particularly through the caprock and the well. Effective risk management will be the cornerstone to public acceptance and commercial-scale operation successes in CCS.

Each of the themes listed above were considered in more detail during working groups at the 7 July 2010 meeting. Each group met simultaneously, so many of the recommendations presented are repeated in this document. Summaries from each of these groups with elaboration on specific research priorities are presented below.

1.0 Findings from working group on baseline requirements

Understanding the baseline requirements for geologic injection of CO_2 and obtaining the right set of baseline measurements is imperative before injection activities commence. All future predictive modelling and our understanding of storage-induced changes in the subsurface will rely on both careful and complete baseline measurements. The measurements of baseline reservoir characteristics will also aid in planning optimal injection specifications, assist in the verification phase to ensure CO_2 migration is occurring as planned and will be applied to the remediation of leakage, should this occur. Without proper baseline measurements that are consistent with current and future measurement techniques, future modelling and analysis of the reservoir may be called into question. At this early stage in the development of CCS, a thorough suite of baseline measurements is also needed to compare different monitoring methods and approaches, which could reduce costs for subsequent projects. It is therefore of particular importance that initial injection activities include comprehensive baseline measurements to ensure that early projects provide adequate learning opportunities for subsurface monitoring , to provide reassurance to the regulators and the public that the technology is safe and effective.

1.1 Recommendations and research needs

In the UK context, all foreseeable storage will be offshore. The group agreed that offshore operation adds to the complexity of applying many standard subsurface monitoring techniques and increases their costs significantly, though some techniques are significantly easier and cheaper offshore e.g. seismic surveying. It is therefore felt that further research into more cost effective instrumentation particularly with offshore capabilities is required. For example, the use of automated underwater vehicles might be used to assist both with subsurface baseline measurements and with ecological baseline measurements of the ocean floor.

The principle recommendation of the group is that the UK urgently requires real-world experience in applying monitoring (including baseline surveying) techniques / technology to the offshore environment, where the vast majority of UK storage lies. This can only be achieved through 'learning by doing'. UK research at existing and future injection sites is required to establish well understood baseline conditions of the reservoirs. Refinement of subsurface characterisation instrumentation is needed to facilitate application in the marine environment and to define and then lower costs. Again, this can only be achieved by hands-on experience at a real test-scale or industrial-scale injection site.

1.2 Barriers to research and opportunities for the UK

- The offshore nature of UK CO_2 stores is the main barrier to establishing comprehensive baseline measurements, due to the high costs of offshore operations that exceed the funding available through 'ordinary' academic channels.

- However, some measurement techniques, such as seismic surveys are easier and cheaper in offshore environments, and these have been well tested elsewhere though perhaps not at the depths of burial that might be anticipated for typical UK storage sites.
- A potential barrier is industry consent to perform detailed measurements on their assets, and publish the results. As the North Sea is one of the most heavily explored offshore regions of the world, there is a wealth of pre-existing or "legacy" data obtained by oil companies. However access to this data is often difficult due to confidentiality issues. Additionally this data may not be of high enough quality, or correctly focussed, to make robust baseline determinations.
- Negotiating IPR issues can be a significant barrier to overcome and is important for researchers to address.
- A key opportunity for the UK is that all wireline logs of wells drilled on the UK continental shelf are available in digital format and available to researchers, and that core is collected and maintained by the UK Government.

2.0 Findings from working group on prediction: modelling the lifetime behaviour of CO_2 storage sites.

Predicting the behaviour of CO_2 storage sites based on storage site characterisation prior to injection, from observations during injection, and after injection ceases, will be vital for estimating reservoir capacity and satisfying risk assessment and regulation. Prediction will be dependant on storage site characterisation coupled with our ability to model the fate of the CO_2 over the required 10^2 to 10^5 year reservoir lifetimes. The physical complexities of storage reservoirs resulting from geological heterogeneities on all scales, the difficulty of predicting reservoir-scale physical properties from measurements on small drill samples and the sensitivity of multiphase flow to multiple properties of the reservoirs means that it will always be important to test and refine modelling of CO_2 storage sites based on the observed behaviour during injection. For this reason development of techniques for imaging sub-surface CO_2 flows will form an important part of prediction. Research related to prediction will therefore need prioritisation based on our ability to image stored CO_2, model flow of multiphase fluids and acquire data on the reservoir parameters that control this, investigate the chemical reactivity of fluid in the reservoirs, better understand geo-mechanical issues and extend models to cover the whole storage site and far-field fluid flows.

2.1 Recommendations and research needs

Like other groups, this group felt the overarching need is for research is the access to real-time injection experiments, both full scale injection schemes and small-scale pilot schemes where sampling of fluids is possible. Planned CO_2 sequestration schemes in the UK and abroad offer important opportunities for research, and it is vital that this is planned in advance of injection so that opportunities are not lost. However the full scale schemes injecting into reservoirs under the oceans are unlikely to allow direct sampling, and it is vital that UK scientists have access to smaller scale land-based schemes that allow down-hole sampling and geophysical measurements. This work is essential to understand the critical multi-phase flow phenomena, caprock and reservoir integrity issues and calibrate imaging. Ideally UK scientists should be able to fund participation in collaboration with international groups to work on the most suitable sites for such experiments (not limited to areas within the UK).

The group agreed that research encompassing a range of theoretical modelling, laboratory experimental and analytical facilities and field imaging experiments are essential to develop robust modelling of CO_2 storage. Development of a multi-disciplinary research base is necessary for the volume of work needed and for training the future knowledge-based workforce. Care must be taken to support all aspects of the research and participation in field injection and monitoring experiments. Specific research priorities were discussed in the following fields:

Remote imaging of CO_2 reservoirs: A range of methods including seismic reflection, passive seismics, electro-magnetic techniques, gravity and INSAR contribute in different settings. None of these has the resolution to fully image likely reservoir accumulations and further research, particularly on seismic techniques will be important. It will be essential that pre-injection surveys of sites are planned to the same specifications as post-injection surveys and observational techniques are optimised. Observation wells would be expensive, carry some additional risk but might provide information on the behaviour of CO_2 in reservoirs not available from remote methods.

Modelling multi-phase flow: It was agreed that solubility trapping and porosity trapping are two of the most important processes which will make CO_2 storage secure but model predictions of their efficiency remain very uncertain. Ideally we would like a proper physical description of multiphase flow but such a solution has remained elusive, possibly because the multiple controls on multi-phase flow in porous media are inherently complex. For this reason we need to carry out field experiments in which we can observe the extents of solubility and porosity trapping on reservoir scales, observe CO_2 saturation states and observe the impact of reservoir heterogeneity on these processes. This work needs to be complemented by more laboratory studies of relative permeabilities involving brines and CO_2 fluids in appropriate reservoir rocks.

Chemical reactivity: The interaction of wet or dry CO_2 with mudrocks and reservoir minerals is little studied. CO_2-charged brines may react with reservoir minerals to precipitate a significant fraction of the reservoir CO_2 permanently in carbonate minerals over the lifetime of the reservoirs. The CO_2-charged brines may also react with cap-rocks and faults, although whether these reactions will be self-sealing or corrode leakage pathways is controversial. Better data on mineral thermodynamics (especially clays and phyllosilicates) and particularly mineral reaction rate kinetics in field settings is needed to test model predictions.

Geo-mechanics: Opinions were divided on how serious an issue this is and whether existing failure criteria are adequate. CO_2 injection sites at Sleipner (Norway), Ketzin (Germany) and Cranfield (USA) show no significant injection pressure increases over time but contained reservoirs may be more problematic. More work is needed on coupling failure models to multiphase flow models.

Whole site modelling: Unlike oil exploration, carbon storage will require characterisation and modelling of the whole storage site, both to characterise the overburden into which CO_2 may escape and be trapped, and to model the far-field fluid flows which may result from of injection. The geochemical pollution consequences of CO_2 escape into potable aquifers need to be determined. The large scale of storage sites presents special problems relating to the amount of data needed for characterisation and the length scales over which flow needs to be modelled. Modelling is needed over long time periods.

Modelling – analytical and numerical models: It is important to understand the physics (i.e. which physics is important and which can be ignored) controlling CO_2 injection and migration in the subsurface. Modelling needs to cope with geological heterogeneity, especially important with low-viscosity CO_2 injection with consequent fingering. Analytical modelling will be essential to understand the controlling physics and interpret images of CO_2 storage. Improved understanding of how to better parameterise complex near-well and regional-scale, fully coupled, thermal-hydraulic-mechanical-chemical (THMC) models is essential for the predictions of reservoir performance on which regulation and risk assessments will be based. Models must be tested against observations from CO_2 injection sites.

2.2 Barriers to research and opportunities for UK

- Need to organise and apply multi-disciplinary techniques on a scale which is challenging to small department-based research groups.
- Costs: Adequate imaging of reservoirs, facilities for sufficient laboratory measurement of reservoir rock properties, investment in people.
- Need to combine theoretical and applied research. The UK has research strengths across the range of specialities needed but these need to be integrated – sufficient resources must be put into data collection and sufficient into modelling and data interpretation.
- Need for training of a workforce (on scale of oil industry) if CCS is to be applied commercially on scale required.
- Data from field scale CO_2 injection is essential for research and development. Such experiments are expensive and managing access and data collection from such experiments needs careful oversight.
- Although many excellent commercial software packages for exploring the issues above are available, academic licence agreements (for the more user friendly end of the software market) can be overly challenging to obtain and commercial software tariffs can be prohibitively expensive (primarily due to original oil and gas motivations). Relationships between leading software providers and the wider UK research community could be greatly improved.

3.0 Findings from working group on storage types and capacity

Geological storage of CO_2 is anticipated to be within depleted oil and gas fields for pilot and demonstration projects whereas the greatest potential capacity for storage in the longer-term is within strata containing salt water (saline aquifers). UK and global understanding of very large geological stores suitable for commercial-scale CO_2 storage lags well behind that of CO_2 capture technology. This position threatens the UK's potential for commercial CCS projects despite laudable UK-led ingenuity in capture technology. To most profitably advance this state of the art we outline here key R&D priorities in UK research on storage types and capacity with specific attention further given to barriers to be avoided and enablers to be fostered.

3.1 Recommendations and research needs

The key recommendation of this group is that the UK research community must "understand by doing." Academics should undertake full appraisal of storage sites by requiring academic assessment of saline aquifers as part of a commercial demonstration project licences, establishing a method to assess the 'risk' of an aquifer store, and by taking part in a virtual storage licence application (dummy run) e.g. Scottish Government 'dry-run' licence application project. The research community must investigate the long-term implications of CO_2 storage to storage sites by studying injectivity over several decades. Interdisciplinary research should be encouraged across the many fields of study (geological and environmental science, technology, economics, etc) to extend our knowledge base within the wider context of implementation for CCS. Below are more specific areas of research needs identified by this working group:

Saline aquifer storage: Saline aquifers, both UK-wide and globally hold the greatest long-term potential for storing large quantities of CO_2 in the subsurface. It is therefore imperative to establish greater understanding of saline aquifers as potential storage sites.

Multiple saline aquifer storage sites: A key knowledge gap is the interaction of adjacent CO_2 storage sites in large aquifers that overlap in extent, as present within the UK North Sea. In particular, the interaction of multiple injection projects within a relatively small area. Case studies simulating the interaction of the hydrodynamic regimes and CO_2 pressure footprints would inform the projected performance of adjacent saline aquifer storage sites and how their response changes over time. Although the outcome of this research will be relevant to multiple CCS injection projects within the national waters of individual countries the results will inform possible interaction across political boundaries because of the wide extent of aquifer formations.

Storage capacity estimations: There is more than one method presently employed to estimate the capacity of geological CO_2 stores with significant variations to their calculated values. Storage factors or efficiency factors are used to quantify reservoir capacity. However, values for storage or efficiency factors that are suitable for basin-scale assessment may not be appropriate for site-specific structural traps. Comparison of these methods and their results is needed to reduce the uncertainty associated with estimating long term geologic storage capacity of CO_2.

A key milestone is to better characterise the naturally dynamic behaviour of CO_2 for legislative confidence in how to use dynamic storage (as opposed to static) criteria in both capacity estimates and regulation of the sub surface storage. An acute danger exists of legislation proceeding knowledge; research is urgently needed into "open" aquifers where water naturally migrates out of the reservoir stores as well as Risk associated with a change in the phase of the CO_2 in post-injection migration and the implications for storage.

Managing storage capacity*:* A pivotal R&D area in the creation and management of storage capacity is the impact of water control, metal content and naturally occurring radioactive material (NORM) in produced water. Cases of the (commercial) need to govern & lower CO_2 injection or plume pressure are anticipated. This may be via water production or predictive modelling of displacement of existing water from an open aquifer. A knowledge gap exists presently into how water management and attendant regulations differ from the oil and gas sector. R&D focus should include characterising (heavy) metal content and NORM in produced / disposed water.

3.2 Barriers to research and opportunities for UK

- There is insufficient funding to licence regional seismic data sets acquired for hydrocarbon exploration to allow research assessment of saline aquifers as CO_2 storage sites. The data are made available at costs much less than for commercial purposes, but a licence to access such data is still too costly for research projects. Additionally, acquisition of new data specifically to appraise storage sites is beyond the resources available for research.
- Agreement of Intellectual Property Rights (IPR) permitting access to costly and commercially sensitive data for genuine academic study and publication is fraught with legal difficulties and associated negotiation can be protracted and seen as a barrier to research.
- The considerable cost and uncertainty of (unproven) commercial-scale CCS projects causes reluctance to invest by industry and their funding for research of storage site appraisal even where matched by research programme funding.
- The creation of a NERC, EPSRC or other data repository or centre to hold data for academic study that accordingly opens up research opportunities across UK higher education institutions would significantly facilitate further storage research.
- The UK SAP (Storage Appraisal Project) should have a delivered database that is able to be upgraded as new critical parameters for storage are found. The database architecture should either be extensible or there should be a new geospatial appraisal of the UK storage resources.

4.0 Findings of working group on verification of CO_2 behaviour during and post injection

Verifying, calibrating and interpreting long-term monitoring tools will help ensure that we can determine how CO_2 is behaving both during and post injection. Industry, government and the public will have many questions about long term storage of CO_2, and further research is need to provide confident answers to pressing and pertinent questions. The main questions about CO_2 behaviour that need to be answered are:

- *Where is the CO_2 plume, and what does it look like?*
- *What is the best way to quantify CO_2 saturation and with which tools?*
- *How will CO_2 behave over 20-30 years? 100 years? 1000+ years?*

Answering these questions will require an interdisciplinary approach alongside in-depth discipline-specific research with ample knowledge sharing between academia, industry and public sectors.

4.1 Recommendations and research needs

Two key recommendations came out of this group. UK researchers need access to an actual injection site and a portfolio of monitoring instrumentation and technologies must be developed and trialled at this site.

A common injection field site for UK (and partner) interdisciplinary research would greatly build our research capacity. It could allow for deployment and trialling of various monitoring techniques, such as installation of a permanent seismic grid, monitoring wells and tracer analyses. This test site would allow much needed baseline data to be collected (geological model, passive active seismic, geochemical survey, etc). Having easy academic access to such a site is crucial for well-documented scientific advancement in this field. At the moment, UK researchers must develop individual collaborations in the US, Germany or Canada to learn from actual CO_2 injection sites. The UK needs a field site where researchers can maximise science return, and this may or may not be in the UK.

The key priority is the development of a portfolio of monitoring instrumentation and technologies that can be deployed readily and cheaply at future storage sites. A wide variety of tools need to be developed and deployed at test sites so that the best technology can be selected and recommended for reliable use at future commercial storage sites. Current tools that need further development include: chemical (e.g. isotopes or noble gases) tracers, 4D seismic, E-M methods, InSAR, micro-seismic, gravity and others as this is not an exhaustive list.

Whilst the two overarching recommendations are stated above, there is a number of pressing research questions that exist. In order to answer industry, government and the public questioning about CO_2 behaviour scientists much first address many of the unknowns listed below:

Subsurface chemistry:
- What effect does dissolution of the CO_2 have on its reaction with reservoir rock?
- What effects do chemical reactions have on rheology and dual/multiple porosity?
- What are the reaction rates of geochemical processes?
- How can tracers, isotopes and noble gases be effectively used for monitoring?

Supercritical CO_2 behaviour:
- What are the effects of supercritical CO_2 as a solvent?
- Need for an improved thermodynamic database for supercritical CO_2 systems.

Pathways for flow:
- What are the pathways out of reservoirs and how could these fast pathways (e.g. fractures) be imaged?
- How do these fast pathways evolve over time?
- Investigating natural analogues (i.e. natural CO_2 seeps) and leaky (or failed) CO_2 injection sites will also provide much needed insight into how CO_2 behaves in the subsurface.

Faulting:

- How can we determine if faults are sealing or not?
- How do fault sealing properties change through time?

Modelling needs:

- How can accurate geo-mechanical model and constitutive models be constructed?
- How can we model multiphase flow in reactive deformable media?
- How do we accurately couple thermodynamic, hydrologic and geomechanical models? These coupled models should be informed by observations.
- How do you verify models, particularly given the sparse subsurface datasets?
- Researchers need better sample recovery of reservoir fluids (formation water and water produced from the reservoir) from both baseline and during CO_2 injection in order to evaluate geochemical and geomechanical models.

Geophysics and imaging:

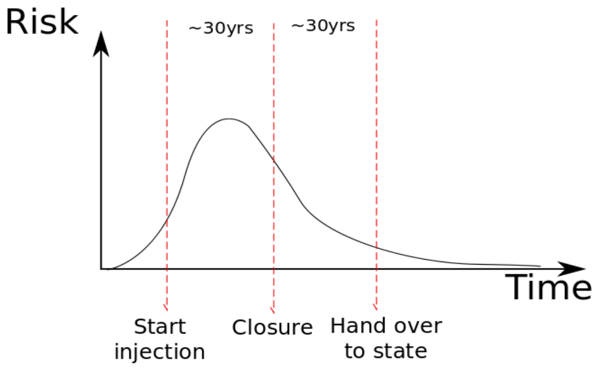
- How does seismic velocity change in CO_2 saturated rock?
- How can we image the effects of injection on the pressure and effective stress fields in and around the reservoir?
- What are the geophysical properties of the "overburden", "side burden", "underburden"?

4.2 Barriers to research and opportunities for UK

- Commercial and intellectual property issues hamper access to data and publication of results. Resolving these conflicts is paramount to getting more academic involvement in commercial injection sites.
- There has been a lack of CCS expertise in reviewers of some proposals, which is not helpful for a field that wishes to grow.
- The CCS community, both industry and academic have shown good links. And there is a good relationship established which can help overcome issues around commercial and intellectual property.
- The UKCCSC Network is fairly established, meaning there is a critical mass of good teams that are already communicating with each other. This group should help foster better academic collegiality amongst the CCS community.
- The UK has strength in technology development particularly with miniaturisation of monitoring equipment and operating in hostile environments from space and offshore industries. This experience and technological research capacity can support efforts to develop less costly and more reliable technologies that can characterise the subsurface for CCS.
- There are many lessons that can be learned from failed sites including natural analogues and leaky injection sites.

5.0 Findings of working group on managing risk in carbon storage projects

Managing risk at CO_2 storage sites will be vital for assurance of safety and for acquiring public and private support of CCS. The success of future CO_2 storage projects will rely on the scientific and technological assessments of the sites with effective communication of the opportunities and risks to the public and policy makers. The risks associated with storage projects evolve over the lifecycle of the project.



5.1 Recommendations and research needs

The CCS community (including government, industry and academia) needs to define a consistent and transparent risk management approach prior to large scale roll out of CCS. This development can only be realistically achieved through application to actual injection sites, both immanent UK demonstration projects and existing injection sites elsewhere, with evolving risk. This need for “real world” experience is a potential barrier to progress. However, data from injection sites particularly any failure incident data should be made transparently available to the research community, within the limits of commercial confidentiality if applicable.

Engineered remediation/natural remediation: Research needs to be undertaken to quantify the performance of the engineered leakage mitigation techniques (e.g. changing the injection strategy or drilling more wells) and natural remediation (e.g. the ability of the overburden to retain CO_2 from an unintended migration out of the storage area) taking into account the wide range of phase behaviour of CO_2 including the impact of impurities through the subsurface. This helps define the long term risks.

Quantitative hazard assessment tools: Better quantitative hazard assessment tools need to be developed. These tools should predict potential leakage rates from the storage sites particularly through the caprock and the well. In order to constrain the evolving risk profile over the lifecycle of a storage project, we require a better understanding of several key areas:

- The impacts of impurities on CO_2 phase behaviour enveloping the supercritical region
- Diffusion and reactivity of CO_2 in the presence of impurities
- Fluid-rock interactions
- The role of hydrate formation in preventing leakage to surface
- Modelling sudden pressure release, for example through the caprock
- Quantification of the magnitude and rates of trapping throughout the subsurface region are required to estimate the proportion of CO_2 that is

permanently locked in the subsurface and to evaluate the proportion of free CO_2 that poses a leakage risk
- Research needs to be undertaken to quantify the geophysically measurable quantities of CO_2 that could first be observed outwith the storage zone for continuous and staged surveys

5.2 Barriers to research and opportunities for the UK
- A significant opportunity is the ample data that exists for potential offshore UK storage sites due to the oil and gas industry. We should remain open to reprocessing existing datasets to optimise the information content for CO_2 storage projects.
- Fundamental differences exist in the requirements and assurances delivered in exploration projects compared to storage projects. We need to ensure that the tools used to assess storage security are optimised for CO_2 storage assessment rather than oil and gas exploration and production.
- We desire the ability to measure subsurface CO_2 migration rates but can only estimate CO_2 saturation and measure the earth's geomechanical response.
- The single greatest barrier to research is the lack of access to "real world" injection data or sites.
- The group felt that there is a strong argument for incorporating research activities into planned CCS demonstration projects and other research-led injection projects. The integration of research and data sharing into real injection projects might refine a risk management strategy for future storage projects.
- The need for confidentiality in commercially sensitive data is a real and recognised barrier, but this could be balanced by evidence based risk management and regulation that requires learning on all early projects if future efforts are to be fit for purpose.

Conclusion

Key recommendations

As stated in the executive summary, each of the groups reached agreement in the main research needs for geologic storage of carbon. Greater support is needed for scientific access at injection sites and for the development of robust monitoring technologies and CO_2 migration modelling techniques. UK researchers need to conduct work at actual storage injection sites. If the UK is to compete with other leading CCS countries (USA, Norway and Germany) our scientists will need a parity of resources and access to real injection sites and data. There is also a strong need for more specialised subsurface monitoring technology that can be deployed both cheaply and readily in the offshore environment. Our understanding of subsurface processes and CO2 behaviour during and after injection is dependant upon our measurements in the field. Technology can enhance our understanding of geologic storage for CO2 and should be developed with this goal.

Appendix: Meeting Participants

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