IEAGHG 2013 Peer Review of US RCSP Phase III Projects

Public Summary Report:

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IEAGHG 2013 PEER REVIEW OF US RCSP PHASE III PROJECTS

Summary Report

Executive Summary

The United States Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs) Initiative in the USA is now approximately half way through its third phase of operation. This phase involves large-scale (0.25 – 1 Mt) injection of CO_2 into geological formations at eight sites across the United States. The DOE, through the National Energy Technologies Laboratory (NETL), manages the RCSP Initiative. The NETL required a third independent peer review of the Initiative in 2013. Two previous independent peer reviews, by international experts, were completed in 2008 and 2011. The panel was chaired by the IEAGHG.

The 2013 international independent expert review of the RCSP had the following aims:

1. To follow up progress in addressing the recommendations of the second review in 2011 of the RCSP Initiative and their Phase III projects.

2. To assess the progress on the individual Phase III projects and consider whether the proposed technical work program for each project achieves the individual projects goals and those of the overall RCSPs. Inherent in this assessment will be the identification of any gaps or modifications that are necessary to the individual work program to address both the projects and the overall RCSP goals.

3. To assess results and key findings from the Phase III tests across the RCSP Initiative as they relate to the DOE/NETL Program goals.

4. To assess the overall technical integration of the RCSP Initiative, address the synergies between the eight Phase III projects and how they complement each other and how collectively they will provide a technical basis for future commercial scale projects in the USA.

5. To assess how the RCSP compares/compliments/contrasts with similar projects underway worldwide and how the information from these projects contributes to an international knowledge base on CO_2 capture and storage.

The review meeting was held in Arlington, Virginia in November 2013. Each partnership presented a summary of their project's progress and key findings since the inception of Phase III.

Most of the test sites consist of fluvial or fluvial deltaic sandstones. There is one near-shore strand plain depositional environment and two carbonate reservoirs. The variety of reservoir types, and their occurrence at depths down to 3,000m, provides a range of pressure and temperature (P/T)

conditions for developing and testing new monitoring techniques including Electrical Resistance Tomography, pulsed neutron logs and fibre optic thermal sensory systems. Each team has used a series of monitoring, verification and accounting (MVA) methods to interpret reservoir characteristics which has enable them to determine reservoir properties and the level of risks. Mitigation strategies have been developed based on the suite of monitoring data and integrated modelling. The development of monitoring techniques has also enabled different teams to track the progress and build-up of CO_2 in different reservoirs.

The partnerships have collectively demonstrated the positive benefits of close collaboration between industry partners, academic researchers and state geological surveys. These partnerships have had to handle complex commercial relationships between CO_2 suppliers, pipeline operators and reservoir engineers as well as technical challenges. Each partnership has also developed creative solutions to public outreach programs to avoid potential disputes and convey key information to communities in close proximity to test sites.

The review panel also made a series of general recommendations relative to the Phase III projects and overall RCSP Initiative.

From an international perspective there was unanimous agreement that the RCSP Initiative is a world leading initiative, generating valuable results and experience.

IEAGHG 2013 PEER REVIEW OF US RCSP PHASE III PROJECTS

Results and Recommendations Report

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1. Introduction

The United States Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs) Initiative in the USA is now approximately half way through its third phase of operation. This phase involves large-scale (0.25 – 1 Mt) injections of CO_2 into geological formations at eight sites across the United States. The DOE, through the National Energy Technologies Laboratory (NETL), manages the RCSP Initiative. The NETL required a third independent peer review of the Initiative in 2013. Two previous independent peer reviews, by international experts, were organised by IEAGHG in 2008 and 2011.

The RCSP Initiative comprises seven regional partnerships:

- Midwest Geological Sequestration Consortium (MGSC)
- Southeast Regional Carbon Sequestration Partnership (SECARB)
- Big Sky Carbon Sequestration Partnership (BSCSP)
- Southwest Regional Partnership on Carbon Sequestration (SWP)
- Midwest Regional Carbon Sequestration Partnership (MRCSP)
- The Plains CO_2 Reduction Partnership Program (PCOR)
- West Coast Regional Carbon Sequestration Partnership (WESTCARB)

The IEA Greenhouse Gas R&D Programme (IEAGHG) is an international programme that evaluates mitigation options for greenhouse gas reduction and has specialised in CO_2 capture and storage (CCS). IEAGHG also has extensive experience of CO_2 injection projects worldwide through its direct involvement in projects such as Saline Aquifer CO_2 Storage (SACS), the Weyburn monitoring project and CO_2 Storage into a Saline Aquifer at Ketzin (CO_2SINK). IEAGHG provides its membership with independent technical advice on options to reduce greenhouse gas emissions. In addition, IEAGHG has also organised a number of independent expert reviews on projects and programmes relevant to the Partnerships Initiative. These have included:

- Chairmanship of the annual expert review of Battelle's Carbon Management Initiative (2001 - 2004), USA.
- Organisation and management of IEAGHG Weyburn Monitoring Project First Phase - Expert review of final project results, 2003, Canada.

- Organisation of IEAGHG Weyburn – Midale Monitoring Project Final Phase -Expert review of proposed work programme, 2006, Canada.
- Organisation and chairmanship of the Australian Otway Basin Pilot Plant Project expert reviews held in 2006 and 2009.
- Organisation of the peer review for the U.S. Environmental Protection Agency (EPA) Vulnerability Evaluation Framework, 2008.
- Organisation of the 2008 and 2011 Peer Reviews of the US RCSP projects.

On November 11th – 15th 2013, IEAGHG, as the Independent Professional Organisation (IPO), convened a panel of seven academic, industry, and regulatory experts from organisations around the world to conduct a technical peer review of this initiative. The review was held at the Westin Hotel in Arlington, Virginia, USA. This report contains a summary of the project reviews and recommendations suitable for public release.

Proposed Goals of the Expert Review

The 2013 international independent expert review of the RCSP Initiative had the following aims:

1. To follow up progress in addressing the recommendations of the second review in 2011 of the RCSP Initiative and their Phase III projects.
2. To assess the progress on the individual Phase III projects and consider whether the proposed technical work programme for each project achieves its goals and those of the overall RCSP. Inherent in this assessment is the identification of any gaps or modifications that are necessary to the individual work programme to address both the projects and the overall RCSP goals.
3. To assess results and key findings from the Phase III tests across the RCSP Initiative, as they relate to the DOE/NETL Program goals.
4. To assess the overall technical integration of the RCSP Initiative, address the synergies between the eight Phase III projects and how they complement each other and how collectively they will provide a technical basis for future commercial scale projects in the USA.
5. To assess how the RCSP Initiative compares/compliments/contrasts with similar projects underway worldwide and how the information these projects should provide will help build an international knowledge base on CO_2 capture and storage.

The WESTCARB consortium did not take part in this review.

Expert Review Process

IEAGHG organised the expert review process in co-ordination with NETL. Close co-ordination between both groups ensured that the review process was successfully completed and met the U. S. Office of Management and Budget (OMB) requirements.

IEAGHG invited eight recognised international technical experts to assist in the review process, drawn from organisations not directly involved in the RCSP Initiative. The technical experts all have direct experience with CO_2 injection projects worldwide; several were involved in the IPCC Special Report on CO_2 Capture and Storage or the IPCC Inventories Report 2006. The review panel was chaired by the IEAGHG who also acted as the facilitator for the review discussions.

Regional Carbon Sequestration Partnership Expert Review Projects

The RCSP Phase III (Development) projects are currently in various stages of implementation that include: Site Characterisation/Operations; Injection Operations; and Post-Injection Operations. The Site Characterisation/Operations Stage includes at least one to three years of site characterisation to validate the site and determine whether it can safely and permanently store CO_2, complete US Environmental Protection Agency (EPA) compliance, and develop infrastructure. The Injection Operations stage includes CO_2 procurement, transportation, injection, and monitoring for two to four years. Finally, the Post-Injection stage includes site closure, as well as several years of post-injection monitoring, verification and accounting (MVA), depending on the project. Results obtained from Phase III, coupled with results and key findings from Phase II (Validation), will provide a firm foundation for the future commercialisation of large-volume CCS projects across North America. The RCSP Phase III research projects reviewed by the Expert Panel are summarised in Table 1.

Table 1 US RCSP Phase III Projects

Regional Partnership	Site	Storage Type	Reservoir Type	Scheduled / Initial Injection	Total Planned Injection (Mt CO_2)*	CO_2 Source
MGSC	Decatur, IL	DSF★	Fluvial sandstone	Nov 2011	1.0	Ethanol Plant
SECARB – Early Test	Cranfield, MS	CO_2-EOR# / DSF	Fluvial sandstone / conglomerate	2009	4.0	Natural CO_2 reservoir
SECARB – Anthropogenic Test	Citronelle, AL	DSF	Fluvial sandstone	Aug 2012	0.1 – 0.3	Coal Fired Plant
BSCSP	Kevin Dome, MT	DSF	Dolomite	Jan 2015	1.0	Natural CO_2 reservoir
SWP	Farnsworth Unit, Ochitree, TX	CO_2-EOR	Fluvial / deltaic sandstone	Oct 2013	1.0	Ethanol & fertilizer Plants
MRCSP	Chester, Otsego County, MI	Depleted EOR	Carbonate Pinnacle Reef	Feb 2013	1.0	Natural gas processing plant – CO_2 stripped from gas stream.
PCOR	Bell Creek, MT	CO_2-EOR	Near shore / strand plain sandstones	May 2013	1.0	Natural gas processing plant – CO_2 stripped from gas stream

*Note: Total planned injection over the lifetime of each RCSP research project

★DSF = Deep Saline Formation, #EOR = Enhanced Oil Recovery

Review

DOE/NETL provided the review panellists with detailed information on each of the projects ahead of the meeting.

- Opening presentations were made by IEAGHG on the review process and agenda. DOE/NETL outlined the aim of the RCSP Initiative including an overview of the program structure, timescales, overall goals and expected achievements from the Phase III Initiative.
- Over the next three days there were a series of seven presentations from the partnerships on the Phase III projects. Each presentation included a summary of the project structure, program, budget timescales, overall goals, status and expected outcomes.
- Representatives from each partnership were then questioned by the review panel, followed by a closed panel session without the project representatives present.
- Finally, the expert panel held a closed discussion on how the RCSP projects fit into the international context for the development of CCS.

The panel discussed the interim status of each project and proposed initiatives that could benefit all the partnerships.

2. Phase III Project Review Findings

The Phase III RCSP field projects are now providing valuable data on comparatively large scale injections of up to 4 Mt of CO_2 into a variety of different reservoir types. Recent progress has also revealed the effectiveness of innovative monitoring techniques, strong multiparty partnerships and constructive public outreach activities.

The range of reservoirs includes deep saline aquifers in a variety of clastic depositional environments including fluvial, fluvial-deltaic and near shore sandstones. It also includes carbonate reservoirs. Some partnerships are collaborative arrangements with oil industry operators to develop CO_2 storage using depleted fields. In contrast other partnerships are injecting into deep saline aquifers (DSAs) with no residual hydrocarbons. These formations extend over wide areas and could offer significant CO_2 storage potential in North America and many other parts of the world. By using a variety of monitoring techniques, for example seismic, different partnership teams have been able to successfully track the progress of CO_2 plumes in a variety of sandstone formations.

The Partnership Initiative also includes good examples of natural analogues in carbonate reservoirs which have pre-existing accumulations of CO_2. These analogues could be valuable for other potential carbonate reservoirs with natural CO_2 accumulations that have storage potential. The presence of existing CO_2 within a carbonate reservoir, and the potential interactions with injected CO_2, provides the basis for valuable scientific observation and understanding.

Geotechnical as well as geochemical interactions are also being investigated. The presence of a closed (compartmentalised) reservoir within a carbonate pinnacle reef at one location allows one of the teams to investigate pressure effects within the reservoir.

The broad spectrum of reservoirs have provided a variety of conditions including comparatively deep formations of depths down to 3,000m which can provide a valuable testing ground to monitor high P/T conditions. Project teams have developed innovative down-hole modular assemblies to monitor reservoir conditions often in these relatively high pressure / temperature environments. One team has developed a multiple modular system capable of monitoring several parameters simultaneously thereby reducing costs. Some Partnerships have developed other innovative monitoring techniques including Electrical Resistance Tomography (ERT) analysis. Other partnerships have applied a new light detection and ranging (LIDAR) dataset over project areas and completed 3D surface seismic and 3D vertical seismic profiles (VSPs). The use of fibre optic sensory systems to detect thermal variations and acoustic monitoring pulsed neutron logs (PNL) have also been applied. Other teams analysed former wells, in one case up to 700 wells, as part of reservoir assessments for CO_2 storage in depleted oil and gas fields. Each team used a series of monitoring, verification and accounting (MVA) methods to interpret reservoir characteristics and determine the level of risks, such as wellbore integrity. Mitigation strategies could then be developed based on the suite of monitoring data and integrated modelling.

Microseismicity has also been successfully monitored following test injections in some of the reservoirs. Using special monitoring equipment, the pattern of these very small seismic events can be tracked and linked to specific pre-existing subsurface fractures within these reservoirs. As projects progress more work is planned in this area.

All the partnerships are now generating detailed data from each demonstration site which is providing a valuable pool of information on CO_2 storage into a variety of reservoirs. One partnership has established a Technical Advisory Board to provide scientific and operational guidance which has aided the project.

Public outreach has been a positive feature across the partnerships for example public meetings with communities close to test sites. They have all produced publicity to clearly explain different activities. In one case an interactive database of land ownership and mineral rights has been compiled to avoid potential disputes and alleviate public concerns.

Good co-operation between multiple parties in the public and private sectors, and between different private entities, is a common feature of the RCSP program. Strong partnerships have been established between industry, state geological surveys and CO_2 suppliers. In one case the partnership includes a power plant operator, pipeline operator and the storage team. This strong multi-party collaboration has meant that project teams have had to handle complex commercial arrangements to co-ordinate a fully integrated CCS chain – a feature which may become commonplace as CCS becomes more established. Another feature of industry-development team

collaboration is that it enables the project teams to influence the field monitoring programs where CO_2 storage is linked to EOR operations. This type of relationship also means that project teams can have complete access to essential oil field data and they can control the rate of injection for research objectives. In addition, these projects offer potential for detailed history matching and a comprehensive modelling approach.

Phase III projects are now at an interim stage. Further monitoring and modelling continues and will help to refine predicted patterns of CO_2 behaviour and storage capacity. The publication record of the partnerships is good with the expectation of more high quality papers, and other material appearing in the public domain, as these projects progress.

3. General Comments and Recommendations

The panel made a number of recommendations to further enhance the quality and management of the RCSP projects. These include:

- Periodic reviews of the projects should be completed to identify progress, developments and challenges. There would be benefit in sharing the positive experiences from those projects that make good progress across the full range of project goals with those projects which encounter more challenges. Collaboration on specific topics or issues, for example innovative analytical techniques, could be discussed within small dedicated meetings. A recommendation for one area to consider is the detection limits of specific techniques and related data processing.
- There is scope for further detailed analysis of results, although interpretation also needs to reflect the early stages which projects have reached.
- Monitoring techniques and their application have further potential to be linked to risk assessment.
- The relative effectiveness of different monitoring techniques in different settings, including cost-benefit analysis, could be further explored and shared.

4. Review Panel Discussion on the RCSP Initiative in the Context of International CCS Developments

The panellists outlined the progress with the development of other CO_2 storage projects in Australia, Canada, Norway, Japan and Germany. Some of these countries have bilateral agreements with the USA or collaborate through joint projects as in the case of Canada. Some panellists expressed the view that, owing to the commercial nature of some other CCS projects where there is less information that can be currently placed in the public domain, the ability to

share information from US DOE-funded RCSP projects is a real strength and benefit of the RCSP Initiative.

There was a general consensus that the US RCSP Initiative generates valuable scientific and technical information which can be applied to key projects elsewhere. This would be of benefit to other countries if the RCSP Initiative could provide useful technology transfer from techniques that are being developed and tested at the different sites. This could be highly beneficial as many countries do not fully appreciate how the suite of MVA techniques is being applied.

Experience from the RCSP Initiative has also shown the importance of different approaches to site characterisation. Some of the sites are highly relevant because they are examples of large scale CO_2 injections into deep saline aquifers in fluvial sandstone systems. There are similarities, for example, with sites in Europe such as Ketzin, which also helps with international scientific collaboration. Two of the current RCSP projects are investigating the use of carbonate reservoirs for storage which should add value to the diversity of storage options in other regions of the world.

Some panel members commented that there is growing interest in CCS in areas such as the Gulf States of the Middle East, Malaysia and Indonesia. It is likely that CO_2-EOR will be the initial stimulus for investment, which is an area that the RCSP Initiative is directly engaged in. There was a general consensus that the RCSP teams are producing very useful data and results and have valuable experience to share via publications and international conferences.

5. Conclusions

In 2013 a third IEAGHG peer review was completed on seven Phase III RCSP projects. The panel consisted of seven international experts. Each RCSP team outlined the technical and non-technical scope of its project and presented interim results. The panel discussed the merits and challenges of each project in view of objectives and goals and then made a series of recommendations to improve and enhance each work program.

All of the projects reviewed have provided, and continue to generate, significant developments in CO_2 storage.

The review panel also made a series of general recommendations that could be applied to all the projects.

From an international perspective there was unanimous agreement that the RCSP Initiative is a world leading initiative that is generating valuable results and experience. The scientific and technical advances, as well as public outreach activities, should be communicated to a wider audience via dedicated publications, journal publications, conferences and existing bilateral agreements.