



IEAGHG **Technical** Review
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IEAGHG 2017 Peer Review of
US RCSP Phase III Projects

IEA GREENHOUSE GAS R&D PROGRAMME

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IEAGHG 2017 PEER REVIEW OF US RCSP PHASE III PROJECTS

Results and Recommendations Report

Executive Summary

The Regional Carbon Sequestration Partnerships Program (RCSP) in the USA has been engaged in its third phase of operation since 2008. This phase has involved large scale (0.25 to 1 Mt/y) injection of CO₂ into six geological formations across North America since 2013. The DOE, through the National Energy Technologies Laboratory (NETL), manages the RCSP Initiative. The NETL required a fourth independent peer review of the Initiative in 2017. Three previous independent peer reviews, by international experts, were completed in 2008, 2011 and 2013.

The 2017 international independent expert review of the RCSP had the following aims:

1. To follow up progress in addressing the recommendations of the third review in 2013, both in terms of the overall RCSP and individual regional partnerships and their Phase III projects;
2. To assess the progress on the individual Phase III projects (7) and consider whether the proposed technical work program for each project has achieved its goals and those of the overall RCSP. Each project was expected to respond to the recommendations made in the previous review in 2013 and whether any subsequent modifications to project plans had achieved their desired effect;
3. To assess results and key findings from the Phase III tests across the RCSP;
4. To assess the overall technical program of the RCSP, address the synergies between the 7 Phase III projects and how they complement each other and how collectively they can provide a technical basis for future commercial scale projects in the USA;
5. To assess how the RCSP compares, complements and contrasts with similar projects underway worldwide and how the information from these projects can help build an international knowledge base on CO₂ capture and storage.

The review meeting was held in Pittsburgh, USA in January 2017. Each partnership presented a summary of their project's progress and key findings since the inception of Phase III.

From an international perspective there was unanimous agreement that the RCSP program is a world leading initiative, generating valuable results and experience. This program will benefit US companies and organizations, including the coal industry, in the scale-up and cost-reduction of CCS projects. There has already been a transfer of technology and practices from the SECARB



Cranfield project to the large-scale integrated CCS projects at Port Arthur and Petra Nova in Texas. These projects are generating intellectual property for the US and have global potential.

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 CO₂ suppliers, pipeline operators and reservoir engineers as well as technical challenges. Projects have also published key findings in peer-reviewed Journals supporting the global development of technology in the field. 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 scientific and technical output from this partnership program provides stakeholders in the USA and the international community with new knowledge, information and data that are valuable for future projects in the USA and elsewhere.



IEAGHG 2017 PEER REVIEW OF US RCSP PHASE III PROJECTS

Results and Recommendations Report

TABLE OF CONTENTS

1. Introduction.....	4
Proposed Goals of the Expert Review	5
Expert Review Process	6
Regional Carbon Sequestration Partnership Expert Review Projects	6
Review	8
2. Phase III Project Review Findings	8
3. General Comments and Recommendations	9
4. Review Panel Discussion on the RCSP Initiative in the Context of International CCS Developments	10
5. Conclusions	11



1. Introduction

The United States Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs) Initiative in the USA has been engaged in its third phase of operation since 2008. This phase has involved large-scale (0.25 – 1 Mt) injections of CO₂ into geological formations at six of the seven designated sites across the United States. There were two test injection sites within Southeast Regional Carbon Sequestration Partnership. The proposed test injection planned for Kevin Dome within the Big Sky Carbon Sequestration Partnership did not take place. The West Coast Regional Partnership did not include any planned injection. The DOE, through the National Energy Technologies Laboratory (NETL), manages the RCSP Initiative. The NETL required a fourth independent peer review of the Initiative in 2017. Three previous independent peer reviews, by international experts, were organized by IEAGHG in 2008, 2011 and 2013.

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 CO₂ Reduction Partnership Program (PCOR)
- West Coast Regional Carbon Sequestration Partnership (WESTCARB)

The IEA Greenhouse Gas R&D Program (IEAGHG) is an international program that evaluates mitigation options for greenhouse gas reduction and has specialized on CO₂ capture and storage (CCS). IEAGHG also has extensive experience of CO₂ injection projects worldwide through its direct involvement in projects such as SACS/CO₂STORE, RECOPOL, the Weyburn Monitoring Project and CO₂SINK. IEAGHG provides its membership with independent technical advice on options to reduce greenhouse gas emissions. IEAGHG organized the previous three peer reviews of the US RCSP in 2008, 2011 and 2013. In addition, IEAGHG has organized a number of independent technical reviews on projects and programs relevant to the Partnerships Program. These have included:

1. Chairmanship of the annual technical review of Battelle's Carbon Management Initiative (2001 - 2004), USA.
2. Organization and management of IEAGHG Weyburn Monitoring Project First Phase -



- Technical review of final project results, 2003, Canada.
3. Chairmanship of RECOPOL Project Technical review of proposed CO₂ injection work program, 2005, Netherlands.
 4. Organization of IEAGHG Weyburn - Midale Monitoring Project Final Phase - Technical review of proposed work program, 2006, Canada.
 5. Organization and chairmanship of the Australian Otway Basin Pilot Plant Project technical reviews held in 2006 and 2009.
 6. Organization of the peer review for the US EPA Vulnerability Evaluation Framework, 2008.
 7. Organization of the US DOE Storage Program's project peer review in 2015.

IEAGHG was, therefore, well placed to organize a forth independent review of the RCSP using internationally recognized experts.

Between January 23rd – 27th 2017, IEAGHG, as the Independent Professional Organization (IPO), convened a panel of seven academic, industry, and regulatory experts from organizations around the world to conduct a technical peer review of this initiative. The review was held at the Sheraton Hotel, Station Square, in Pittsburgh, USA. This report contains a summary of the project reviews and recommendations

Proposed Goals of the Expert Review

The 2017 international independent expert review of the RCSP Initiative had the following aims:

1. To follow up progress in addressing the recommendations of the third review in 2013, both in terms of the overall RCSP and individual regional partnerships and their Phase III projects;
2. To assess the progress on the individual Phase III projects (7) and consider whether the proposed technical work program for each project has achieved its goals and those of the overall RCSP. Each project was expected to respond to the recommendations made in the previous review in 2013 and whether any subsequent modifications to project plans achieved their desired effect;
3. To assess results and key findings from the Phase III tests across the RCSP;
4. To assess the overall technical program of the RCSP, address the synergies between the 7 Phase III projects and how they complement each other and how collectively they can provide a technical basis for future commercial scale projects in the USA;
5. To assess how the RCSP compares, complements and contrasts with similar projects underway worldwide and how the information from these projects can help build an international knowledge base on CO₂ capture and storage.



The WESTCARB partnership did not take part in this review

Expert Review Process

IEAGHG organized 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 US Office of Management and Budget (OMB) requirements.

IEAGHG invited seven recognized international technical experts to assist in the review process, drawn from organizations not directly involved in the RCSP Initiative. The technical experts all have direct experience with CO₂ injection projects worldwide; several were involved in the IPCC Special Report on CO₂ Capture and Storage. Most of the panel have participated in previous RCSP reviews adding beneficial continuity. 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. These projects have included: Site Characterization/Operations; Injection Operations; and Post-Injection Operations. The Site Characterization/Operations Stage included at least one to three years of site characterization to validate the site and determine whether it can safely and permanently store CO₂, complete US Environmental Protection Agency (EPA) compliance, and develop infrastructure. The Injection Operations stage includes CO₂ procurement, transportation, injection, and monitoring for two to four years. Finally, the Post-Injection stage includes site closure, as well as 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 commercialization of large-volume CCS projects across USA and around the world. The RCSP Phase III research projects reviewed by the Expert Panel are summarized in Table 1.



Table 1 US RCSP Phase III Projects

Regional Partnership	Site	Storage Type	Reservoir Type	Initial Injection/ End of operations	Total /Planned* Injection (Mt CO₂)*	CO₂ Source
MGSC	Decatur, IL	DSF★	Fluvial sandstone	Nov 2011 / Nov 2014	1.0	Bio-ethanol Plant
SECARB Early Test	Cranfield, MS	CO ₂ -EOR# / DSF	Fluvial sandstone / conglomerate	Dec 2009 / April 2015 (end of field activities, commercial activities have continued)	4.3	Natural CO ₂ reservoir
SECARB Anthropogenic Test	Citronelle, AL	DSF	Fluvial sandstone	Aug 2012/ September 2017	0.114	Coal Fired Power Plant
BSCSP	Kevin Dome, MT	DSF	Dolomite	N/A	0	Natural CO ₂ reservoir
SWP	Farnsworth Unit Ochitree, TX	CO ₂ -EOR	Fluvial / deltaic sandstone	Oct 2013 / July 2018	1.0*	Bio-ethanol & fertilizer Plants
MRCSP	Chester Otsego County, MI	Depleted EOR	Carbonate Pinnacle Reef	April 2013 / Dec 2019	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 / Dec 2018	4.86	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 Recover



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 providing valuable data on comparatively large scale injections of up to approximately 5 Mt of CO₂ 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 Partnership Initiative allowed an extensive comparison of monitoring techniques to be made, for example one site used both Baker Hughes and Schlumberger technologies allowing a direct comparison to be made which is not thought to have occurred at any other site. A strong relationship between the research teams and commercial operator's has also been established at numerous sites which has been highly beneficial to the RCSP initiative and the wider community as it has allowed the development of public outreach and information dissemination. Public outreach had been very active within the projects and a variety of high quality publication materials have been produced as a result.

Four 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 (ERT), pulsed neutron logs (PNL) and fiber optic thermal and acoustic sensory systems. Each team has used a variety of monitoring, verification and accounting (MVA) methods to interpret reservoir characteristics, which has enabled 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 each team to track the evolution of CO₂ and pressure build up in different reservoirs.

Microseismicity has also been successfully monitored following test injections in some of the reservoirs. One project developed a uniquely integrated microseismicity and pressure dataset which has been considered a valuable asset to the project. All the partnerships are now generating datasets from each demonstration site which is providing a valuable pool of information on CO₂ storage into a variety of reservoir types. More material will be published and made publically available as more projects reach the end of their lifecycles. One partnership has established a successful Technical Advisory Board to provide scientific and operational guidance which has been seen to significantly aid the project.

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 enabled the project teams to influence the field monitoring programs where CO₂ storage is linked to EOR operations. This has allowed major successes where projects have been able to develop strong integrated management processes with an adaptive management approach to risk. For some projects this has provided robust direction to monitoring and decision making.

One site allowed a full life-cycle project to develop from capture to storage and now closure, the site was able to overcome numerous challenges through improved project management and developing pragmatic monitoring plan. This is considered highly beneficial for the wider CCS community with future public dissemination of this research planned in the near future.

Phase III projects are now reaching their final stages. Further monitoring and modelling continues and will help to refine predicted patterns of CO₂ behaviour and storage capacity. The publication record of the partnerships was considered good.

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:

- Although the projects are aligned with DOE goals, the project summaries could better explain how the projects are integrated within the larger program and their achievements coincide with the specific program goals.



- Further analysis of seismic results would be beneficial for most projects and further geomechanical analysis and characterization.
- Monitoring techniques and their application need to be more directly linked to risk assessment.
- The relative effectiveness of different monitoring techniques and technologies in different settings needs to be further explored and shared, including costs associated and a value-benefit analysis.

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

The panelists expressed the view that the commercial nature of some other CCS projects restricts the amount of information that can be placed in the public domain. The ability to share information from US DOE-funded RCSP projects is consequently a real strength and benefit of the RCSP Initiative. The importance of information sharing using various means was emphasized, e.g., through the CO₂ Storage Data Consortium (CSDC) (a US-Norway led initiative). Information sharing on value-benefit analysis, particularly for MVA technologies, could be highly beneficial as many countries do not fully appreciate how the suite of MVA techniques is being applied.

There was a general consensus that the US RCSP Initiative generates valuable scientific and technical information which can be applied to key projects elsewhere. In particular, US companies and organizations have gained the knowledge and capability to apply expertise to larger-scale projects. This has already happened in the case of MMV learnings from the SECARB Cranfield project that have been applied to the larger-scale integrated projects at Port Arthur and Petra Nova, Texas. The Canadian Quest project has also benefited from RCSP input into the risk assessment process. Networking at RCSP meetings and at project sites has instigated and facilitated knowledge transfer from the RCSP program. As the initiator and major funder of the RCSP program, the DOE enhances its credibility and the international value of these projects.

The dissemination of lessons learnt from these projects has been a major strength of the RCSP initiative. The Best Practice Manuals have been highly beneficial and regularly utilized within the international CCS community. From this, the panel highlighted that a Best Practice Manual on large-scale CCS project management aspects of these projects (e.g. stakeholder engagement and risk management) would be useful given the wealth of information available. Also, selecting key representatives from these projects to advise on comparable international storage projects would be an effective means of technology transfer. To further disseminate knowledge, a virtual IJGGC special issue would be highly valued.



Other beneficial documents the US DOE could produce include summary books on different projects (aimed at a broader audience including industry and the general public) but cross referenced to published scientific papers. The Cranfield project would be a good candidate for the first publication. A summary review of RCSP projects as a compendium in a standard format was also suggested by the review panel. Interim versions could be produced as annual summaries of projects.

5. Conclusions

In 2017 a fourth IEAGHG peer review was completed on seven Phase III RCSP projects. The panel consisted of eight 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 CO₂ 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.



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