Carbon Sequestration leadership forum
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PROJECTS INTERACTION AND REVIEW TEAM

Engagement of CSLF-recognized Projects

Background

At the London meeting in June 2016, there was consensus by the CSLF Projects Interaction and Review Team (PIRT) to find ways to improve its interactions with CSLF-recognized projects. To that end, the CSLF Secretariat, along with Dr. Sallie Greenberg (representing the CSLF-recognized Illinois Basin – Decatur Project), developed a new format for projects to report their status. As an initial trial, PIRT delegates from Australia, Canada, and the United States used this new reporting format to engage several projects located in each of their countries.

This summary, prepared by the CSLF Secretariat, is a collection of reports received from ten CSLF-recognized projects:

Australia

- CarbonNet Project
- Gorgon CO_2 Injection Project
- The South West Hub Project

Canada

- The Alberta Carbon Trunk Line
- The Boundary Dam Integrated CCS Project
- CANMET Energy Technology Centre (CETC) R&D Oxyfuel Combustion for CO_2 Capture
- Quest Project

United States

- Illinois Basin – Decatur Project
- Illinois Industrial CCS Project
- Michigan Basin Development Phase Project

Action Requested

The PIRT is requested to review the information received from the projects.

Project Name: CarbonNet

Brief non-technical description:
The CarbonNet Project is investigating the potential for establishing a commercial scale CCS hub network, bringing together multiple CO_2 capture projects in the Latrobe Valley, Victoria Australia, transporting CO_2 via a common-use pipeline and injecting it deep into offshore underground storage sites in the Gippsland region. The project is jointly funded by the Commonwealth and Victorian governments.

Is the project still active? *Yes*

If still active, what have been the important factors in its continued progress, and why?
The project is fortunate in that the Gippsland region in Victoria offers considerable potential for CCS. The nearby Latrobe Valley contains the second largest deposit of brown coal (lignite) in the world and is home to significant existing and potential future industry. The offshore Gippsland Basin is located close to these brown coal reserves and is well suited for geological carbon storage. The National Carbon Taskforce report (September 2009) considered the Gippsland Basin as having the highest technical ranking of 25 major basins across Australia and the largest storage potential of any east coast basin.

As a hub based concept to support multiple potential sources of CO_2, CarbonNet has sought to meet the needs of potential coal-to-products processes (urea, hydrogen etc), as well as the power sector. This has enabled the project to progress despite challenging market conditions in the power sector (falling demand, mandated renewables targets). Support from the Federal and State governments has been critical in maintaining continued progress of the project. CarbonNet have worked closely with the government to progress CCS within existing policy settings, identifying deficiencies and presenting solution for both its own and future CCS projects.

Please briefly describe the overall project timeline (with emphasis on next six months):
CarbonNet, as a government funded and lead project, has focused on increasing the storage certainty to de risk subsequent investment decisions for the rest of the

CCS value chain. This has involved work that goes beyond the typical pre commercial / pre competitive data acquisition undertaken by government organisations such as Geoscience Australia. CarbonNet's storage characterisation and site selection process has intentionally adopted a portfolio approach to provide robustness and optionality should geological data for one site be found lacking, or other needs/constraints require an alternate site to be prioritised.

The project is finalising a plan to progress to the next stage of development, involving appraisal of its prioritised storage site. The project aims to obtain a Declaration of Storage and then progress towards obtaining a CO_2 Injection License by 2020 at which time the project will be transitioned into the commercial sector.

What kinds of sharable information have been produced?

CarbonNet has an agreement with the Global CCS Institute to produce knowledge share reports available on the Website. There are multiple reports available including:

3 whole of project reports:

- *A Historical Perspective – Which explores the history of CCS in Victoria from 2003 and the initial phase of CarbonNet from 2009 to 2014.*
- *Developing a business model for a CCS hub network*
- *GCCSI Regulatory Test toolkit for Victoria*

5 reports on storage:

- *Site Characterisation for Carbon Storage in the near shore Gippsland Basin*
- *CarbonNet storage site selection and certification: challenges and successes Gippsland Basin*
- *Integrity of wells in the near shore Gippsland Basin Victoria*
- *3D mapping and correlation of intraformational seals within the Latrobe Group in the nearshore Gippsland Basin*
- *GipNet – baseline environmental monitoring and technology validation for near shore carbon storage*

2 reports on transport:

- *Dispersion modelling techniques for CO_2 pipelines in Australia – Report produced for BCIA, with support from CarbonNet, ANLEC R&D, GCCSI*
- *Development of a CO_2 specification for a CCS hub network*

Please describe any interesting outcomes or gains in knowledge.

There are significant opportunities for CarbonNet to establish a foundation CCS network around coal-to-products proponents in the urea and hydrogen sectors

where total life cycle costs for CCS have been assessed at less than $50 per tonne of CO_2. A large scale and a high utilisation rate of the network is important to realise low costs in the transport and storage components of the network to minimise total costs for individual CO_2 sources. This will provide opportunities for CCS in the power sector in the medium to longer term.

While Australia and Victoria have in place legislative and regulatory frameworks for CO_2 storage, the pathway has been untested and therefore regulators have been particularly cautious in the application. An outcome of this project is a deep understanding of Australia's regulatory approval schedule and opportunities to expedited the process to meet the needs of private sector proponents. . Of particular interest in the future will be whether the established long term liability regimes under Australian and Victorian legislation represent an impediment to private sector investment in the development of storage sites.

Who is the project's main point-of-contact for the CSLF?

Ian Filby – Project Director
Ian.filby@ecodev.vic.gov.au

Project Name: Gorgon Carbon Dioxide Injection Project

Brief non-technical description:
The Gorgon Carbon Dioxide Injection Project will safely dispose of over 100 million tonnes by underground injection into the Dupuy Formation two kilometres below Barrow Island, off the northwest coast of Australia.

The project is an integral component of the larger Gorgon Project which involves the initial development of the Gorgon and Jansz gas fields, the processing of that gas into liquefied natural gas for export and domestic gas for consumption in Western Australia. The reservoir carbon dioxide that is routinely extracted during the gas processing operations is to be injected at a rate of between 3.5 to 4 million tonnes per year. There is an extensive integrated monitoring plan, and the objective of the project is to demonstrate the safe commercial-scale application of greenhouse gas storage technologies at a scale not previously attempted.

Is the project still active? *Yes.*

Construction of the Gorgon Project commenced in 2009. Commissioning operations, which will occur over a period of several years, commenced in 2015 and the first liquefied natural gas cargo was exported in 2016. The Carbon Dioxide Injection component of the project will be commissioned in 2017 once there are significant volumes of reservoir carbon dioxide being produced from the gas processing facility.

The Gorgon Carbon Dioxide Injection Project is the largest greenhouse mitigation project to be undertaken by industry globally.

Apart from some minor government funding ($60 million contribution to the capital cost of the Injection Project under the Australian Government's Low Emissions) it is not dependent on any other form of government policy support.

Please briefly describe the overall project timeline (with emphasis on next six months):
The continuation of construction and commissioning of the overall Gorgon Project. The Gorgon Project is a huge and highly compact undertaking and will take several years to

bring to full production. The Injection Project is scheduled to commence injection towards the end of that process.

What kinds of sharable information have been produced?
Chevron as operator of the Gorgon Project has provided updates to groups such as the CSLF and the IEA once significant milestones have been passed.

Please describe any interesting outcomes or gains in knowledge.
There is no technical, legal or regulatory barrier preventing such projects from moving forward. They are however costly and until the question of how to fund future projects is addressed, large scale deployment of similar greenhouse mitigation projects will remain problematical.

Who is the project's main point-of-contact for the CSLF?

John Torkington
Manager - Climate Change Team
Chevron Australia Pty Ltd

250 St Georges Terrace
Perth, WA 6000
Tel +61 8 9216 4025
Mobile 0408 947 130
John.Torkington@chevron.com

Project Name: The South West Hub Project

Brief non-technical description:
The South West Hub (SW Hub) project is a pre-feasibility investigation into the potential for commercial scale CO_2 storage in the South West of Western Australia (WA). The project is currently managed by the WA Government through the Department of Mines and Petroleum (DMP). The project is non-conventional in that it relies on the concept of "migration assisted trapping" (MAT) or residual trapping for CO_2 containment in the proposed storage aquifer.

Is the project still active? *Yes*

If still active, what have been the important factors in its continued progress, and why?
The most important factors have been:

- *Funding support from the Commonwealth and State Governments. The funding support has provided a level of certainty and demonstrated a commitment by both governments to investigate potential CO_2 storage options for future industry development;*
- *Collaborations with industry and research partners. The collaborations have led to increased technical understanding of the potential reservoir and commercial drivers for development. The collaborations have increased industry and research capabilities in CCS; and*
- *A general level of community acceptance of the project. This acceptance will be a key factor in determining whether a commercial project is a viable option.*

Please briefly describe the overall project timeline (with emphasis on next six months):
Preliminary (desktop) investigations commenced in 2007. This was followed by a data acquisition process that has included 2D and 3D seismic surveys and the drilling of 4 stratigraphic wells. Information from the data acquisition process has been incorporated into static and dynamic modelling to establish confidence levels for injection rates, well count and CO_2 containment. The modelling outcomes will be released in September 2016.

The program of activity for the next six - twelve months will be to conduct additional laboratory and desktop analysis. The results of this process will be utilised to create additional modelling scenarios to further reduce identified uncertainties. The results of this process will inform an investment decision for potential future field data collection (drilling) activity.

What kinds of sharable information have been produced?
Numerous technical reports along with raw data and summaries of community engagement activity are made freely available on the DMP website at: www.dmp.wa.gov.au/ccs (general reports) and www.dmp.wa.gov.au/wapims (raw data)

Please describe any interesting outcomes or gains in knowledge.
As highlighted above, the SW Hub project relies on the concept of MAT or residual trapping rather than a conventional impenetrable formation layer acting as a seal. The recent modelling conducted for the SW Hub project indicates that commercial quantities of CO_2 could be contained through residual trapping in the identified area.

Who is the project's main point-of-contact for the CSLF?
Dominique Van Gent, Project Coordinator, Department of Mines and Petroleum
Dominique.vangent@dmp.wa.gov.au
+61 8 9791 2040
Martin Burke, Project Manager, Department of Mines and Petroleum
Martin.burke@dmp.wa.gov.au
+61 8 9222 3464

Project Name: The Alberta Carbon Trunk Line

Brief non-technical description:
The Alberta Carbon Trunk Line (ACTL) is a fully integrated carbon capture and storage system that will have the potential to compress, transport and store 14.6 million tonnes of CO_2 per year at full capacity. Pioneered in Alberta, Canada by Enhance Energy Inc., the ACTL is the first large-scale Enhanced Oil Recovery (EOR) and storage project in Alberta, utilizing Alberta's wealth of innovative, exportable, and local expertise to create thousands of new jobs while decreasing Canada's carbon footprint.

The ACTL will initially capture and compress CO_2 from two industrial sources: The Agrium Redwater Fertilizer Plant and the North West Redwater Partnership's Sturgeon Refinery. The Sturgeon Refinery is the first greenfield refinery to be built in Canada since 1984. It is also the world's first bitumen refinery which will combine the already proven processes of gasification technology with an integrated carbon capture and storage solution. The process is optimized to minimize the environmental footprint of the facility and make bitumen refining sustainable in Alberta. The refinery is set to be operational at the end of 2017.

The ACTL consists of a 240-kilometre pipeline that will create the CO_2 gathering and distribution infrastructure required for the cost-effective management of CO_2 emissions from facilities in Alberta's Industrial Heartland and throughout central Alberta. To add to this environmental advantage, the stored CO_2 will be injected into depleted oil reservoirs for enhanced oil recovery. These oilfields will see significant increases in production as CO_2 is permanently stored in the reservoir, which will provide the economic stimulus of additional jobs in construction, manufacturing, research and a host of other industries. Alberta will also benefit from the incremental royalties and taxes it will generate through EOR.

Is the project still active? *Yes.*

If still active, what have been the important factors in its continued progress, and why?
The Project is still active, but not yet operational. Both the ACTL and the Sturgeon Refinery are under construction and set to be operational at the end of 2017. Timing delays for the ACTL were mostly due to the construction timing of the $8.5B Sturgeon Refinery. The ACTL timeline needed to align

with the timing of the CO_2 availability. Continued support from both the provincial and federal governments have been important factors in allowing the Project's continued progress.

Please briefly describe the overall project timeline (with emphasis on next six months):
THE ACTL is in its final phase of project financing and is targeting full construction to occur over the coming 12-18 months for project completion near the end of 2017. The main CO_2 supply for the ACTL will come from the North West Redwater Partnership's Sturgeon Refinery. The Refinery is currently at peak construction and will begin commissioning in 2017.

What kinds of sharable information have been produced?
http://www.enhanceenergy.com/video/Enhance_EOR.mp4

Please describe any interesting outcomes or gains in knowledge.
The project team hopes to have outcomes and gains in knowledge to share after the project is complete and in operations mode.

Who is the project's main point-of-contact for the CSLF?
Alyssa Haunholter
Vice President Government Relations
Enhance Energy
ahaunholter@enhanceenergy.com
+1 780-504-2623

Project Name: The Boundary Dam Integrated Carbon Capture and Storage Project

Brief non-technical description:

The Boundary Dam Integrated Carbon Capture and Storage Project is SaskPower's flagship CCS initiative. Through the development of the world's first and largest commercial-scale CCS project of its kind, SaskPower is making a viable technical, environmental and economic case for the continued use of coal.

The Boundary Dam CCS Project rebuilt a coal-fired generation unit with carbon capture technology, resulting in low-emission power generation. In the fall of 2014, the project came online.

This project transformed the aging Unit #3 at Boundary Dam Power Station near Estevan, Saskatchewan into a reliable, long-term producer of more than 110 megawatts (MW) of base-load electricity, capable of reducing greenhouse gas emissions by up to one million tonnes of carbon dioxide (CO_2) each year, the equivalent of taking more than 250,000 cars off Saskatchewan roads annually.

The captured CO_2 is sold and transported by pipeline to nearby oil fields in southern Saskatchewan where it will be used for enhanced oil recovery. CO_2 not used for enhanced oil recovery will be stored, permanently and safely more than two miles underground in the Aquistore Project.

In addition to CO_2, SaskPower will sell other byproducts captured from the project. Sulphur dioxide (SO_2) is captured, converted to sulphuric acid and sold for industrial use. Fly ash, another byproduct of coal combustion, is also sold for use in ready-mix concrete, pre-cast structures and concrete products.

Is the project still active? *Yes*

If still active, what have been the important factors in its continued progress, and why?

The plant is nearing two full years of operation. For the period of October 2014 to the end of August 2016 the plant has captured just over one million tonnes. SaskPower's goal is to capture 800,000 tonnes of CO_2 in 2016, which meets the needs of its offtaker and exceeds federal emission regulations.

Please briefly describe the overall project timeline (with emphasis on next six months):

What kinds of sharable information have been produced?

SaskPower releases a monthly progress update on the operation of the carbon capture facility. Through a partnership with BHP Billiton, SaskPower has launched The International CCS Knowledge Centre. This entity is building relationships around the world by sharing lessons learned at the Boundary Dam CCS Project. Its mission is to help the development and adoption of CCS technologies worldwide.

Please describe any interesting outcomes or gains in knowledge.

Through SaskPower's unique experience in applying CCS technology to the production of coal-fired electricity on a commercial scale, it has identified significant lessons learned that will allow it to reduce costs by up to 30% on future CCS retrofits.

Who is the project's main point-of-contact for the CSLF?

Michael J. Monea
President & Chief Executive Officer
The International CCS Knowledge Centre
an initiative of BHP Billiton and SaskPower

Project Name: CANMET Energy Technology Centre (CETC) R&D Oxyfuel Combustion for CO_2 Capture

Brief non-technical description:
This is a pilot-scale project, located in Ontario, Canada, that will demonstrate oxy-fuel combustion technology with CO_2 capture. The goal of the project is to develop energy-efficient integrated multi-pollutant control, waste management and CO_2 capture technologies for combustion-based applications and to provide information for the scale-up, design and operation of large-scale industrial and utility plants based on the oxy-fuel concept.

Is the project still active? *No.*

If not, when did it end, and why?
It was ended in December 2009 upon completion of the Work Program of Phase 9 of this multi-phase project. Further pilot-scale research on the 1st generation oxy-fuel combustion systems was deemed unnecessary by the project's consortium members, due to the fact that the technology had reached the level of maturity ready for pre-commercial field demonstration by that time (as evidenced by a few oxy-fuel demonstration projects such as Vattenfall's Schwarze Pumpe 30 MW pilot plant in Germany that achieved nearly 100% CO_2 capture by November 2009).

If still active, what have been the important factors in its continued progress, and why?
While the project is not active, but the research work on the new generation of oxy-fuel combustion systems is ongoing at CanmetENERGY in Ottawa, with focus on high pressure oxy-fuel combustion processes and their integration with advanced power cycles (e.g., supercritical CO_2 cycles).

Please briefly describe the overall project timeline (with emphasis on next six months):
This was a multi-year, multi-phase project that was started in 1996 and completed in 2009.

What kinds of sharable information have been produced?
The project produced significant amount of information and data that were recorded in confidential reports over the years. However, some of the results related to processes for oxy-combustion and CO2 capture systems as well as data obtained from pilot-scale experiments, were presented in several international conferences and subsequently published in their proceedings.

Please describe any interesting outcomes or gains in knowledge.
Over the years, this project generated valuable knowledge and interesting results in the area of oxy-fuel combustion systems with CO2 capture. This includes unique data from pilot-scale combustion experiments, development of new burners, demonstration of hydro-oxy fuel combustion with coal, processes for pollutant control in oxy-fuel systems, proprietary CO2 capture processes and proof-of-concept pilot-scale test facilities, several patents and many confidential technical reports. The learning from this project persuaded a few members to further consider this technology for commercial scale deployment and conducting several feed studies for utility scale oxy-fuel power plants with CO2 capture.

Who is the project's main point-of-contact for the CSLF?
The Project Leader and point-of-contact was Dr. Kourosh Zanganeh (Kourosh.zanganeh@canada.ca) of Natural Resources Canada's CanmetENERGY in Ottawa.

Project Name: Quest

Brief non-technical description:
Quest is a large-scale, fully integrated CCS project, located at Fort Saskatchewan, Alberta, Canada, including capture, transportation, storage, and monitoring, which will capture and store up to 1.2 million ton CO_2 per year from an oil sands upgrading unit. The CO_2 will be transported via pipeline and stored in a deep saline aquifer in the Western Sedimentary Basin in Alberta, Canada.

Is the project still active? *Yes*

If still active, what have been the important factors in its continued progress, and why?

- *Continued financial support from the provincial and federal governments*
- *Operational success – everything is working as well as or better than expected*

Please briefly describe the overall project timeline (with emphasis on next six months):
Quest is currently in commercial operations and has already captured and injected more than one million tonnes of CO_2 in the past year. Over the next six months we expect to continue capture and injection at current levels, and to continue collecting MMV data. We also plan to update our reservoir model and to revise our plume predictions to take into account our recent learnings.

What kinds of sharable information have been produced?
Information sharing was a condition of our agreement with the Alberta provincial government. As a result, much of the information gathered and created during the Quest project development is freely available on the government website, including virtually all engineering and subsurface details:
http://www.energy.alberta.ca/CCS/3848.asp

Please describe any interesting outcomes or gains in knowledge.
A key outcome has been the overall success of the full integrated project over the first year of operation, with all aspects of Quest meeting or exceeding the plan.

Both capture efficiency and reservoir performance have been better than expected, leading to fairly significant reductions in operating costs.

A variety of MMV technologies have been deployed, including a new laser-based atmospheric monitoring system at each of the three well sites. The lack of locatable microseismic events has confirmed the expectation that CO_2 injection in the BCS would not generate a significant microseismic response.

Who is the project's main point-of-contact for the CSLF?

Simon O'Brien
Simon.Obrien@shell.com

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Project Name: Illinois Basin – Decatur Project

Brief non-technical description:

The Midwest Geological Sequestration Consortium (MGSC) large-scale CO_2 storage demonstration project, the Illinois Basin – Decatur Project (IBDP), has stored one million tonnes of CO_2 in a deep saline reservoir in the central portion of the United States. Carbon dioxide at IBDP was captured from ethanol production at Archer Daniels Midland and stored more than 2,000m beneath the surface. The IBDP began in 2007 and is being conducted over three phases – pre-injection, injection, and post-injection. The project is currently in a three to five-year post-injection phase monitoring the stored volume of CO_2 at the site.

Is the project still active? *Yes. Currently in post-injection phase.*

If not, when did it end, and why?

If still active, what have been the important factors in its continued progress, and why?

Important factors toward continued progress include a very supportive and collaborative industrial partner (ADM), detailed site characterization prior to and during injection, thoroughness on the part of the US DOE and project team to ensure goals and objectives are being met, stakeholder engagement incorporated into project management, and strong technical leadership.

Please briefly describe the overall project timeline (with emphasis on next six months):

The IBDP was funded in 2007 and is conducted over three periods – pre-injection (2007-2011), injection (2011-2014), and post-injection (2014-2017(9)). IBDP is currently in the post-injection monitoring phase and is conducting continuous pressure/temperature monitoring in the reservoir, annual fluid sampling in the storage zone and above the primary seal, and conducting annual logging to ensure well integrity and plume monitoring. The next six months will be heavily focused on the analysis of plume location, microseismic results from injection, and the reworking of the deep monitoring well to improve performance and long-term integrity.

What kinds of sharable information have been produced?
IBDP has a wide-variety of communication materials available, a website www.sequestration.org, and is currently working with partners in Norway to establish data sets that can be shared among researchers globally.

Please describe any interesting outcomes or gains in knowledge.
There are many interesting outcomes and gains in knowledge from IBDP. The one most researchers find unique is our microsesimic data set which is one of the most comprehensive data sets of geomechancial and geophysical data related to the injection of CO_2 in a deep saline reservoir. We are presently actively working to understand the connection between the geomechanical reservoir response and plume migration.

Who is the project's main point-of-contact for the CSLF?
Sallie E. Greenberg, Ph.D.
Associate Director – Energy Research and Development
Illinois State Geological Survey
University of Illinois at Urbana-Champaign
615 East Peabody Drive
Champaign, IL 61821
sallieg@illinois.edu
+1 217 244 4068

Project Name: Illinois Industrial Carbon Capture and Storage Project

Brief non-technical description:
This project, located in Decatur, Illinois, will be demonstrating an integrated system for capturing approximately 1.0 million tons/yr of carbon dioxide from an industrial source (ethanol production) and geologically storing it in the Mount Simon Sandstone, a saline reservoir, which covers portions of the Midwest including central and southern Illinois. This will be the first project operating with the U.S. Environmental Protection Agency's Class VI injection well permit for geological storage of carbon dioxide.

Is the project still active? *Yes*

If still active, what have been the important factors in its continued progress, and why?

The main attributes that allowed the project to move forward were:

1) *Large source of CO_2 that was cost effective to capture (i.e. low capital and operational expense).*
2) *The site is located on a geologic formation that has the potential to safely store billions of tons of CO_2 (reduction in transportation cost – local storage).*
3) *Front end loading of public funds to reduce project risk (i.e. using public funding to offset most of the capital expense and allowing the operator to take on the operational cost.)*
4) *Availability of CO_2 storage tax credits (45Q) to reduce operational expense.*

Please briefly describe the overall project timeline (with emphasis on next six months):
2009 – Q3: Feasibility Study
2010 – Q3: Project Engineering
2011 – Q3: Began Construction and Environmental Permitting
2012 – Construction, Drilled and Cased 2 Monitoring Wells
2013 - Substantially Completed Construction except Injection Well.

2014 – Began limited commissioning activities, completed all facility construction (i.e. compression, dehydration, electrical substation, and transmission pipeline). Q4 2014 USEPA issued final UIC Class VI permit allowing the construction of the injection well.
2015 – Injection Well Construction and Final Completion of Monitoring Wells.
2016 – Full Unit Commissioning and EPA review of well completion documentation
2017 – Q1: Start –up of injection operation

What kinds of sharable information have been produced?
The project has not started operation, therefore the sharable information is related to:

1) *Site Characterization, (i.e. methods applied and site geologic information)*
2) *Engineering and Construction (i.e. construction cost, equipment selection, engineering, system integration, site monitoring methods, and instrumentation.)*
3) *UIC Class VI Permitting Experience.*

Please describe any interesting outcomes or gains in knowledge.
Interesting experiences and achievements are related to the project development, design, construction, permitting, and operational commissioning.

Who is the project's main point-of-contact for the CSLF?
Scott McDONALD
Biofuels Development Director
Project Director, IL-ICCS Project
Archer Daniels Midland Company
1001 N. Brush College Rd.
Decatur, IL 62521 USA
+1 217 451-5142: Direct
+1 217 451-2457: Fax
scott.mcdonald@adm.com

Project Name: Michigan Basin Development Phase Project

Brief non-technical description:

The Midwest Regional Carbon Sequestration Partnership (MRCSP), established and led by Battelle with funding from the United States Department of Energy (DOE) and others, is assessing the technical potential, economic viability, and public acceptability of CCS/CCUS within its region. MRCSP is now well into the 10-year Phase III, or Development Phase, of the research. This phase entails implementing a large volume CO_2 injection test in Michigan, continuing regional geologic characterization activities, participating in several smaller scale research activities, and communicating results with stakeholders.

The Michigan Basin Development Phase project is designed to inject and monitor approximately one million metric tons of CO_2 in depleted oil and gas fields undergoing enhanced oil recovery (EOR) operations. The source of the CO_2 for the test is man-made (natural gas processing) and the site has existing surface and well infrastructure. In cooperation with the site host, Core Energy LLC, CO_2 is being injected into about ten small oil fields in different stages of the oil production life cycle: late-stage, active CO_2-EOR, and new CO_2 flood. The individual fields are part of the Silurian-aged pinnacle reefs with containment provided by many layers and thousands of feet of low-permeability carbonate and evaporites. Substantial quantities of oil and gas have been produced from these ancient reefs since the 1960's. Today many of the reefs are at or near their economic limit for primary production of oil and gas. Combined, such reefs could store several hundred million metric tons of CO_2 and, when combined with EOR, could provide economic benefit through incremental oil production.

Data is being collected to help develop strategies for optimizing future CO_2 EOR and storage projects. The project team developed a conceptual geologic model of the injection site using historical data to provide insight into the impact of geologic heterogeneity and hydrocarbon production history on CO_2 storage potential. The geologic model was used as the basis for the numerical models that simulate reservoir behavior in response to CO_2 injection and provide estimates of key parameters such as injectivity and capacity. Monitoring data is being used to evaluate reservoir properties via pressure data analysis, to calibrate models, to evaluate the usefulness of monitoring technologies, and to account for net CO_2

stored in the reefs. The practical experience and knowledge gained from these tests will provide data for improving injectivity and capacity estimates, and demonstrate storage capacity within a regionally significant potential storage resource.

Is the project still active? ***Yes***

If still active, what have been the important factors in its continued progress, and why?

- *Availability of an appropriate host site and the host company's willingness and flexibility in working with the MRCSP team to address key technical challenges.*
- *Consistent source of federal funding and significant existing infrastructure available for the project has been an important factor in continued progress. In general, public-private partnerships provide a way to bridge barriers when economic and policy incentives are insufficient to drive technology development.*
- *Ability to build on success of the Phase II program. Three small-scale field tests, including one in the Michigan Basin, resulted in an experienced research and industry project team capable of developing and implementing the Phase III Project within budget and schedule.*
- *Other enabling factors included sufficient data to select, design, operate and monitor the site, a workable regulatory framework, existing infrastructure and CO_2 source, and public acceptance.*

Please briefly describe the overall project timeline (with emphasis on next six months):
Tasks to be completed in the next six months (and beyond) include:

- *Regional geologic characterization: An update to the initial regional source-sink analysis performed circa 2005 will be completed to reflect current status and trends for large-point CO_2 sources. The MRCSP Geoteam will continue to progress on preparing topical reports that describe regional characteristics relevant to CCS/CCUS. A prospective storage estimate of the Appalachian Basin region in eastern Ohio will be completed. Work will also continue on offshore CO_2 storage assessment in the Baltimore Canyon Trough area in the Atlantic offshore region.*
- *Public Education and Outreach: The website is being transferred to a mobile friendly platform. Project results will be presented at professional meetings, e.g., American Association of Professional Geologists (AAPG), Society of Professional Engineers (SPE) and Greenhouse Gas Control Technologies*

(GHGT) conference. MRCSP/Battelle will also host the 2017 meeting of IEAGHG Monitoring Network meeting in Traverse City, Michigan.

- *Late-Stage Reef Post Injection Monitoring: Post injection monitoring activities including vertical seismic profile survey, microseismic monitoring analysis, borehole gravity meter survey, and pulsed neutron capture (PNC) logging will be completed. A new characterization well will be drilled in the reef to evaluate post-injection changes and improve reservoir models. Resulting information will be used to update the static and dynamic models and evaluate containment.*
- *Active EOR reef Monitoring and Accounting: Continue monitoring in eight active EOR reefs and analyzing pressure data. The metering system at the central processing facility is being upgraded to reduce margin of error in the CO_2 accounting system. One new well be drilled, which will be used for additional characterization data and to evaluate oil production and CO_2 recycling in a new EOR flood.*
- *New CO_2 Flood Planning: Field work planning and preparation to drill two new characterization wells in a new EOR flood. One well will be used for injection and the other for monitoring, with advanced monitoring options being considered.*
- *Project Management: The next annual MRCSP meeting for industry and research partners, as well as for other project stakeholders and collaborators, will be held in November.*

What kinds of sharable information have been produced?

The project information is shared via the MRCSP Website (www.mrcsp.org); technical reports; papers; and presentations.

Please describe any interesting outcomes or gains in knowledge.

Key takeaways include:

- *The Michigan Basin test is nearly 60% completed (>575,000 net metric tons CO_2) and CO_2 accounting framework has been established for CO_2 retained in reservoirs during and after active EOR operations.*
- *In implementing CCS programs in depleted fields, ability to work with existing infrastructure and existing data, which may at times be incomplete, is crucial. The verification framework for CO_2 retained from past operations must be flexible to incorporate uncertainties in older operational data.*

- *In some cases, baseline monitoring will not be possible, if CO_2 flooding started prior to CCS evaluation. Accounting for the pre-existing CO_2 in the reservoirs in the monitoring program can be a challenge.*
- *Even in a relatively small area of study for the group of reefs undergoing CO_2-EOR, there is a range of geologic complexity and each reef requires a site-specific geologic model.*
- *In the depleted fields CO_2 changed phase from gas, to liquid, to super-critical as the pressure increased. Furthermore, there was a sustained decline of 2 to 4 psi/day over the 18 months post-injection period.*
- *Modeling of all these transitions across all phases of injection and decline was not possible with analytical codes. The numerical models are being used to simulate these changes. The use of synthetic models to better understand reservoir processes has been useful. It also shows the differences in reservoir response in the near-field conditions dominated by CO_2 and far-field conditions dominated by oil phase.*
- *Satellite monitoring (INSAR), combined with geomechanical modeling shows that within the margin of error, there was not perceptible change in surface elevation as reservoir pressure increased from highly depleted to above discovery pressure.*
- *Pulse Neutron Capture (PNC) logging evaluation is complicated due to presence of multiple phases (oil, gas, CO_2, brine) in the oil/gas fields and new log interpretation workflows were developed to effectively analyze these data.*
- *Fiber optic based microseismic sensor system was used to monitoring microseismic activity at lower pressure during early injection and near the end of injection, when the reef was above discovery pressure. The results are under analysis currently.*
- *Both monitoring and modeling are essential for understanding performance – imperative to be able to do much with limited data*
- *Regional characterization is helping identify new storage zones and estimate storage resources – setting stage for CCUS implementation in parts of MRCSP, outside of the large-scale test area.*
- *Results contributing to developing standards and best practices, National Risk Assessment Program (NRAP) tools, CO_2 capacity estimate tools*

Who is the project's main point-of-contact for the CSLF?

Dr. Neeraj Gupta, Principal Investigator, gupta@battelle.org, +1 614 424-3820