2022-IP11 - Carbon Management Project Review Meeting, Pittsburgh Part II August 15th – 19th 2022

This is the second of two IP's that cover the annual review meeting of all the US DOE funded projects in CO_2 capture, storage, transportation and utilisation, held in Pittsburgh in August. This IP will cover the CarbonSAFE III projects, offshore Gulf of Mexico, stress monitoring technologies, data resources and an update on NRAP. The previous IP covered the morning plenary sessions, the SRMS workshop and an update on Regional Programs.

CarbonSAFE Phase III: includes the detailed site characterisation of five projects that had completed Phase I & II. To be undertaken in 3 years it is to include UIC Class VI permit to construct, CO_2 capture assessment and NEPA approvals. The five projects gave updates – Kemper County, Mississippi; Illinois storage corridor; San Juan Basin; North Dakota and Dry Fork, Wyoming.

The **ECO_2S CarbonSAFE Phase III** project in Kemper County, Mississippi has established a 'world class' storage hub that could serve additional CO_2 sources in the region. They have built a foundation of positive community outreach and education, and improved understanding of carbon capture costs at Plant Ratcliffe from adaptation of the FEED study conducted at Mississippi Power's Plant Daniel and Alabama Power's Plant Barry for storage site development. The project has highlighted the importance of retaining access to pore space and surface easements in future property transactions. It's provided a catalyst for evaluating large-scale future Infrastructure Bill funded DOE/NETL projects such as Direct Air Capture (DAC), Hydrogen Hubs, and Integrated Capture and Storage Pilots and Demonstrations. It has helped clarify future power generation and decarbonization strategies in the Southeast with CCUS related source-sink matching driven by regulatory/policy changes or enhanced 45Q tax credits. It has motivated continued discussions with large landowners for access to pore space and surface property. The overall objectives are to demonstrate that the subsurface at Kemper can safely and securely store commercial volumes of CO_2 and evaluate commercial prospects post combustion coal- and gas-fired capture, transportation and storage in the southeastern US. Data acquired includes: six characterisation/monitoring wells to test and characterise geologic properties; 290ft of core from reservoirs and confining units; well logging; reservoir fluid sampling and injection tests; and 92 line-miles of 2D seismic. The scope of the project requires Class VI well construction permits capable of 50MMt of storage in 30 years. Two wells have been planned and the first permit application submitted in August 2022. In SRMS terms the Paluxy reservoir will have progressed from Prospective Storage Resource at the beginning of CarbonSAFE Phase III to Capacity at the beginning of Phase IV. Two CO_2 capture assessments, one at Plant Millar (coal) and one at Plant Radcliffe (gas) are being completed. The Plant Daniel FEED was completed in June 2022.

The San Juan Basin CarbonSAFE PHASE III runs from 2020 to September 2023. The overall objectives are to perform a comprehensive commercial-scale site characterisation of a storage complex within the basin to accelerate the deployment of integrated carbon capture and storage (CCS) technology at the San Juan Generating Station (SJGS). This includes reservoir and caprock characterisation, geological modelling and simulation, Underground Injection Control (UIC) Class VI Permit Application, Impacts and considerations (environmental, social and economic justice), benefit versus cost assessment, and outreach and engagement. Plans are to retrofit the San Juan Generating Station with 6-7 MMT/yr CO_2 capture technology and store CO_2 in the San Juan Basin (17 miles away). 100 $miles^2$ of 3D seismic has been purchased, 3D VSP is being acquired; and in addition to laboratory experiments and numerical modelling, a characterisation well is being drilled and injectivity tests performed. The stratigraphic well will be completed to Class VI standards and a fibre optic line attached with downhole gauges to monitor stress, pressure and temperature profiles. The average storage capacity of three reservoir units is 9,259 million metric tons of CO_2.

North Dakota's CarbonSAFE Phase III goal is to perform commercial-scale site characterisation and permitting for the geological storage of nearly 4 million metric tons (Mt) of CO_2 per year captured from the Milton R. Young Power Station. Areas of interest are adjacent and 5 miles from the power station, with two potential saline reservoir units. 18 miles^2 of seismic and 2,551 feet of core has been collected and a step rate injection test undertaken. The area of review assumes a risk-based approach for the over-pressured Broom Creek formation. Pore space access includes 50 individual parcels of land with 60 different landowners; so far >95% have enrolled voluntarily. Engaging with the public is vital to gain support, and at a public hearing over 7 hours of testimony were given along with response to public comments. The storage facility permits were approved January 2022. The MRV plan was approved in April 2022. EIV has been submitted and verbally approved, and the Environmental Assessment is being prepared. Plans are now moving forward to install injection wells and monitoring wells and then to file for a permit to inject once CO_2 is available.

Wyoming CarbonSAFE Phase III is accelerating CCUS commercialisation and deployment at Dry Fork Station (DFS) and the Wyoming Integrated Test Centre. The site has been selected due the location of a modern coal plant with 50+ year life span which produces ~3.3 million tons of CO_2/year, and due to the adjacent Wyoming Integrated Test Centre (WY-ITC), which tests CO_2 capture and CCUS technologies and includes the Membrane Technology Research (MTR) Large-Scale Capture Pilot. The project objectives include finalising surface and subsurface characterisation activities at DFS, conduct NEPA environmental analysis, integrate MTR's CO_2 FEED capture assessment, complete Class VI permits to construct the storage hub, and advance commerciality within the storage hub. The site has an experienced carbon workforce, multiple utilisation industries, multiple point sources, and transportation infrastructure. Wyoming is well placed with: CO_2 management legislative and government framework; Class VI primacy; a long-term CCUS liability fund; educated and supportive public; and geologic capacity. There are seven sites within the storage hub with the focus to date on: the Dry Fork Station, 2 wells to optimize stacked storage and reservoir testing, wells completed to Class VI standards, risk assessment and MVA plans, which are being finalised. The storage site characterisation is nearly complete, the environmental/baseline monitoring is complete, model agreements have been developed and submitted, outreach is underway, and the economic model has been updated. Future work includes updating and integration of the commercialisation plan for the Wyoming CarbonSAFE storage hub by finalising permitting, developing the monitoring network, building four additional injection sites, building the transportation network for the storage hub, and classifying resources with the SMRS system.

Offshore Gulf of Mexico:

Four presentations focussed on the offshore, three on the Gulf of Mexico (GoM) and one on the Offshore CO_2 Saline Storage Methodology and Calculator, which also used the Gulf of Mexico as a case example. The GoM is highly prospective for CO_2 storage with large point-source emissions, abundant data, proven reservoirs and seals, and potentially re-usable infrastructure. The offshore is attractive as it has one landowner, relatively few wells, few competing uses, is away from population centres, has multiple stacked reservoirs and some modern infrastructure. Some of the challenges include economics and an uncertainty in regulatory framework.

Ben Wernette (Southern States Energy Board) opened with an update on **SECARB-Offshore project** (Southeast Regional Carbon Storage Partnership) which covers the eastern part of the Gulf of Mexico. Initiated in 2018, its activities over the past couple of years includes hosting joint partnership meetings with the GoMCarb project (the western Gulf), report on representative storage opportunities, white paper outlining optimum commercial strategies, hosting a regulator workshop, evaluating commercial risks, and developing dynamic models for opportunities. Characterisation work has identified >4 Gt of storage resources in depleted reservoirs and >400 Gt in saline reservoirs. High level screening of sands included pressure, temperature, porosity, and permeability. Three sites (saline reservoirs) have been identified in Louisiana state waters and reservoir modelling conducted, in addition to modelling of

Horn Mountain oil field. A risk registry has been established and existing infrastructure has been evaluated and screened. Additional activities focus on developing legal and regulatory workflows for project developers, developing infrastructure, and modelling how the CO_2 pressure plume might interact with local structural features (e.g., salt diapirs).

The **GoMCarb** area covers the western Gulf. Updates were presented by the team from the Gulf Coast Carbon Centre, Bureau of Economic Geology, which has funding for 5 years. Some of the main takeaway messages were an evaluation of the potential to inject CO_2 into structural lows rather than highs (which are commonly hydrocarbon traps), the rational being that there would be few well penetrations, it may be an area that has accumulated thick sands, and CO_2 will migrate and be trapped by capillary processes. A study on the dissolution and dispersion of CO_2 in marine waters was made. Also, an evaluation was made of dry wells in the Miocene and why they failed and whether this would have implications for seal risk. Infrastructure re-use in Texas State waters has been evaluated, and there is a general urgency to identify assets before abandonment. Lastly, they presented on critical pressure analysis of the offshore vs the onshore and presented plans for future testing, development and commercialisation – it's recognised that the scale-up potential is large, and GoMCarb's learnings are being used to support multiple, in-progress commercial projects.

Lastly, Nur Wijaya of NETL presented on Site Selection and Cost Estimation of Pilot-Scale CO_2 Saline Storage Study in the Gulf of Mexico. Looking at two case studies in Federal and Texas State waters, both scenarios were run through QUE$TOR an O&G project cost estimator software which generates OPEX, CAPEX and forecasts for operations and decommissioning. The lowest cost option is Texas State waters with re-use of infrastructure (projects were evaluated with and without re-use).

Stress technologies:

'Development of Thermal Breakout Technology for Determining In Situ Stress' by Sam Voegeli of Respec. An accurate measurement of in-situ stress state is critical for designing successful CO_2 injection, particularly to understand acceptable injection pressures and volumes, maintain caprock integrity and avoid induced seismicity. Current in-situ stress technologies are limited especially for the maximum horizontal stress. As the result of a previous R&D project, Respect observed that inducing heat in a downhole tool caused fractures to form that appeared related to the maximum horizontal stress acting on the borehole – these observations led to the development of an in-situ stress measurement method. The project workflow (2019-2023) moves from modelling, bench scale laboratory testing, small-scale field testing through to large-scale field testing. Lab testing has proved the concept that thermally-induced borehole breakouts show a correlation between temperature and in situ stress. The small-scale field testing was performed in an abandoned gold mine now converted to a laboratory as Sanford Underground Research Facility (SURF), located in Lead, South Dakota. It has the advantage of providing an easy and cost-effective access to deep (>1500m) rock formations for in situ testing and the stress state has already been measured and other data is available. Some delays to this testing occurred due to Covid, and the next step is the large-scale field demonstration for which instrumentation (near-commercial prototype tool) is currently being built – this tool will be tested in the small-scale field test before demonstration at a large-scale. Once the project is complete (2023), plans are to partner with geophysical service providers to commercialise and deploy the tool to industry.

Data Resources:

SimCCS3.0 Open-source toolset for regional CCS Infrastructure decision support was presented by Bailian Chen, Los Alamos National Laboratory. SimCCS is a US based network model and optimisation engine that can help determine optimal, regional transport networks between CO_2 sources and CO_2 sinks that meet desired CCS goals. It incorporates three models: $NICO_2LE$, geodatabase of source locations, CO_2 streams and capture costs; SCO_2T, rapidly calculate realistic injection, number of wells, storage capacity costs; and CostMAP, which identifies likely corridors and develop candidate pipeline routes. It is being utilised by the Los Alamos National Laboratory to support infrastructure modelling

on a range of projects including national-scale CCS pipeline network modeling, three regional CCUS initiatives, and an energy transition initiative (I-WEST). It can generate pipeline buildout scenarios and CCTS costs. Notably the model can take into consideration areas of disadvantaged communities and tribal lands as per Justice40, incorporating both environmental and social impacts in pipeline modelling. They presented I-WEST as an example of a 4-phased CCS infrastructure buildout to meet net zero by 2050, avoiding disadvantaged communities and taking into account 45Q tax credits at $50/ton. Also presented are a series of case studies to demonstrate what is required to meet Net Zero GHG emissions by 2050, utilizing the 671 regional point sources and the 314 saline storage resources – three scenarios are envisaged which include crossing or not crossing disadvantages communities and an additional case where existing pipelines are utilised (up to 2050). The outputs include mapped pipelines, costings, length and diameter of pipeline required and captured CO_2. 28,000 miles of new pipelines will be needed to be constructed to capture and store the emissions, of which 93-95% will be needed by 2035. ~271 miles of existing CO_2 pipeline can be potentially reused.

Several talks focussed on the Energy Data eXchange (EDX), including updates and information regarding this vast resource (initiated in 2011): for example 'Updating NATCARB and Carbon Storage Geospatial Resource via EDX Cloud' – Paige Morkner and 'The DisCO2ver Platform, Building a Virtual Carbon Storage Data Library and Infrastructure for the Future' – Kelly Rose.

NRAP: Robert Dilmore of NETL presented on Thursday morning on the National Risk Assessment Partnership: Phase II Accomplishments and Phase III introduction. NRAP has evolved from the initial phase (2010-2016) of risk assessment and uncertainty quantification and is about to wrap up phase II (2017-2022) looking at risk management and uncertainty reduction, before embarking on phase III (2022-2027) supporting CCS deployment. This comes at a critical moment in time as the need for CCUS to meet climate goals is greater than ever. The main learnings from Phase I & II were presented that included delivering methods and computational tools to assess and manage risks. Two of these tools include: Open Source Integrated Assessment Model (OpenIAM) – new beta release, this tool simulates and outputs leakage risk profiles and can support decisions in delineating the area of review, post-injection site care period and conformance evaluation. And Designs for Risk Evaluation and Management (DREAM 3.0) is due for release Fall 2022. Also discussed were research, protocols and workflows (e.g., induced seismicity risk management and leakage risk management and containment assurance), and insights. Lawrence Livermore National Laboratory researcher Joshua White's follow-on presentation discussed tools and recommended practices for induced seismicity. NRAP Phase III (2022-2027) supporting CCS deployment, is one of three planned DOE FECM complementary applied research projects to enable and accelerate CCS deployment – the others are SMART (real-time visualization, forecasting and virtual learning for decision makers), and EDX 4CCS (a virtual data infrastructure to enable CCS). For further reference there were six presentations on the SMART project. Five main tasks of NRAPs Phase III include: refining and operationalizing workflows to support environmentally protective and efficient permitting; managing site-scale risks, including assessing the risks of Class II to Class VI transition; maturing an integrated risk-based monitoring design (using OpenIAM); quantifying long-term risk and liability (OpenIAM + Storage Cost Model); and assessing the risks of rapid basin-scale deployment and how are they best managed.

In summary, the diversity of projects covered by this year's review meeting, clearly reflects the US ambition to scale-up and broaden CO_2 storage across the country and extend offshore. The announcement of the Inflation Reduction Act just prior to the meeting no doubt help buoy morale and make the work to do ever more urgent. All the presentations are available to view at https://netl.doe.gov/22CM-CTS-proceedings.

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16th September 2022