Development of a Stacked Storage Complex in the Northern Michigan Basin, USA

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The Northern Michigan Basin CarbonSAFE Integrated Pre-Feasibility Project is a part of the U.S. Department of Energy’s Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative. The U.S. Department of Energy (DOE) is funding early-stage projects to develop integrated carbon dioxide capture and storage (CCS) complexes with an expected start date in the 2025 timeframe. These projects will facilitate the permitting, construction and long-term operation of storage locations capable of storing 50 million tonnes of carbon dioxide (CO₂) over a 20- to 30-year time frame.

The objective of the Michigan Basin CarbonSAFE program is to develop an integrated commercial-scale CO₂ storage site for deep geologic intervals in the Northern Michigan Basin. This region of the country has several promising deep saline intervals for storage. In addition, CO₂-Enhanced Oil Recovery (EOR) operations provide a model for safe CO₂ handling, injection, and a value-added option for CO₂ storage. In fact, as part of the Midwestern Regional Carbon Sequestration Partnership (MRCSP), the area has already hosted a 60,000 tonnes storage test in saline formations and a 1-million tonnes scale assessment of associated storage with EOR operations. These projects have also created significant geologic and operational information, which will be useful for the CarbonSAFE program. The project will largely focus on an area in the upper four tiers of counties in the Northern Michigan Basin. A major emphasis of the work is to develop an effective team capable of addressing the technical, economic, legal, engineering, surface, and public acceptance factors related to implementation of a real-world CO₂ storage project in the Northern Michigan Basin. The Phase I effort is focused on four main activities, discussed below.

**Carbon Source Evaluation:** Rapid changes are occurring in Michigan’s electricity generation resources due to changes in natural-gas prices, coal-based power plant retirements, renewables, and new more efficient power plants being built. A review of current and upcoming CO₂ sources was conducted to evaluate the need for CCUS in Michigan and identify key potential emission sources. Combined, these sources have the potential to emit over 170 million tonnes of CO₂ per year. A total of ten existing and potential CO₂ sources were determined to be the most attractive candidates for the establishment of a regional CCS hub based on total and potential future CO₂ emissions, location, and industry-specific characteristics. These sites span multiple industrial categories including electricity generation, cement production, and steel production. Overall, there are sufficient CO₂ sources to meet the goal of 50 million tonnes of storage over a 20 to 30 years period.

**Sub-basinal Geologic Storage Assessment:** Geologic storage pre-feasibility was assessed at sub-basinal scale to effectively portray the subsurface impact of a CCUS complex in northern Michigan.
and identify potential risks. Three formations were identified which included the Bass Islands Dolomite, Brown Niagaran oil-bearing reef complexes, and St. Peter Sandstone. The Bass Islands Dolomite and St. Peter Sandstone were evaluated following standard petrophysical workflows to characterize changes in lithology, porosity, permeability, thicknesses, and depths. Results were used as input to calculate CO$_2$ resources and construct static earth models. As a value-added option, over 800 depleted Niagaran reefs were characterized by constructing a catalog of information which included reef location, name, cumulative production of all recorded fluids, number of wells, status of reef and wells, and current reef operator. The reef catalog information was used to calculate CO$_2$ resources across the northern reef trend, identify key reefs for future storage, and the potential for CO$_2$-EOR. Ten of these depleted oil fields are already under active EOR program using CO$_2$ from natural gas processing. Confining units for each complex were also evaluated to describe continuity of the seal, thickness, and rock characteristics. A risk assessment was conducted to determine number of well penetrations in each confining unit and the quality of the wells were ranked based on public well records. Overall, the confining unit assessment indicated high quality seals with low risk of leakage.

**Project Definition and Integration:** Land ownership data was acquired for northern Michigan and compared to geologic sweet spots to identify potential sites which have favorable geology and state-owned land/single land ownership. Each site was evaluated by clipping the static earth model to run a dynamic simulation. Dynamic simulations provided information on CO$_2$ and pressure plume sizes, and number of wells required to meet the 50 million tonnes of storage. Results from static and dynamic models were used as input for cost estimates for each site and for more detailed risk assessment using NRAP tools. The study region has a history of responsible use of State lands for oil and gas activities. Furthermore, Michigan also has a robust gas storage industry, which provides a parallel for CO$_2$ storage.

A comprehensive cost and financial analysis has been performed to evaluate the likely business scenarios applicable to the Storage Complex. These include a detailed development of cradle-to-grave storage costs, review of pipeline requirements, models for site ownership and related financial mechanisms, and financial assurance mechanisms. Economic scenarios included comparing single source and sink, multi-source and sink, and a mix of EOR and saline storage. Additionally, storage regulations, pore space and mineral rights, and land ownerships rights were evaluated to determine regulatory limitations to CCUS in northern Michigan. Public acceptance factors were also identified and evaluated for all counties in northern Michigan.

**Team Building and Path Forward:** Overall, the Northern Michigan Basin has significant potential to develop a successful CCUS complex due to strong geology, numerous CO$_2$ sources, and public acceptance due to a long history of oil and gas production. The future effort will lead towards a more detailed site characterization using seismic data and drilling of a test well to validate the geologic assumptions. In parallel with this, the analysis of the CO$_2$ source, regulatory and policy aspects, financing mechanisms, and stakeholder interactions will continue to help qualify and eventually develop the large-scale site in the region.

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