FOUR-SITE CASE STUDY OF WATER EXTRACTION FROM CO_2 STORAGE RESERVOIRS

Guoxiang Liu,[1] Charles D. Gorecki,[1] Jordan M. Bremer,[1] Ryan J. Klapperich,[1] Robert M. Cowan,[1] Yevhen I. Holubnyak,[1] Damion J. Knudsen,[1] Dayanand Saini[1]

[1]Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Deep saline formations (DSFs) constitute the largest potential global resource for the geological storage of carbon dioxide (CO_2). While several small-scale and large-scale DSF CO_2 storage projects are under way, uncertainties remain relating to the capacity and injectivity of DSFs, with particular concern relating to the management of pressure and potential displacement of formation fluids. Extraction of saline waters from storage formations is a potential method to improve reservoir storage volume, manage CO_2 plume migration, reduce cap rock exposure to CO_2, and/or manage storage reservoir pressure. It may also lead to the generation of a new source of water that can be treated and applied to a variety of surface uses. Furthermore, sale of the extracted water may provide cost offsets for formation water extraction that ultimately reduces the cost of CO_2 storage.

With funding support by IEAGHG and the U.S. Department of Energy, the Energy & Environmental Research Center conducted an international project to investigate water extraction from CO_2 storage reservoirs. In the present study, a total of four CO_2 storage sites were selected to demonstrate the potential rates of water extraction in conjunction with CO_2 injection: the Ketzin project site in Germany, the Zama oil field in Canada, the Gorgon project site in Australia, and the Teapot Dome oil field in the United States. These sites represent offshore and onshore cases with pilot- and commercial-scale plans and differing formation water qualities, injectivities, climates, and beneficial water use opportunities.

Heterogeneous, 3-D geologic models were developed for each of the study sites and were populated with data related to porosity, permeability, structure, lithology, formation water quality, temperature, and pressure by using Schlumberger's Petrel™ software. The Ketzin and Gorgon sites were modeled following published methodologies for the two sites, which included a combination of object modeling and truncated Gaussian simulation processes. Teapot Dome utilized over 1200 well tops from the field, which were used to identify and model the behavior of different horizons. Heterogeneities of these sites were assigned according to variogram ranges attributed to depositional environments from the Average Global Database. The Zama Field pinnacle reefs contain complex internal geometry and variable structure. These systems were modeled using a combination of object modeling and multipoint statistics using an interpreted reef structural diagram as a training image. The facies model was populated with site-specific heterogeneity and properties developed through the Plains CO_2 Reduction Partnership characterization activities.

The dynamic modeling and simulation started with analysis of boundary condition scenarios with which to determine the efficiency of storage–extraction models under closed, semiclosed, or open conditions. Generalized Equation-of-State Model Compositional Reservoir Simulator by the Computer Modelling Group was utilized for all simulation scenarios. Moreover, with cost-effective planning, the maximum capacity of CO_2 storage and expected rates of water extraction were optimized based on the designed CO_2 injection rates and the number and location of wells for CO_2 injection and water extraction. Site-specific factors such as geological structure, porosity, permeability, and heterogeneity were also assessed for the four test sites. The injection scenarios were designed for pure CO_2 injections and also for CO_2-saturated fluid injections in order to compare the maximum CO_2 storage and formation fluid extraction rates as well as cost differences among the cases. In addition, CO_2 plume and pressure management strategies in response to the CO_2 injection and water extraction were investigated to analyze the potential decrease in risk by controlling the CO_2 plume and decreasing reservoir pressure associated with CO_2 storage.

The results show that CO_2 storage capacity increased with formation fluid extraction for all test sites; however, this was greatly influenced by the site's boundary conditions. The CO_2 storage capacity increased from 4% to 1300% depending on the case study site. At the Zama site, where boundary conditions are closed, the CO_2 storage capacity could be increased by 1300% while maintaining a near 1:1 ratio of extracted water to injected CO_2. In the open systems (Ketzin, Gorgon, and Teapot Dome), storage capacity increases with water extraction were generally on the order of 10% to 50%, while also requiring greater than a 1:1 ratio to achieve increased storage capacity.

CO_2 plume and pressure management strategies were found to be heavily influenced by the geological structure of the site, primarily due to the density differences between the injected CO_2 and in situ fluids. In the case of the Ketzin site (dome-shaped structure), water extraction did not appear to affect dome-shaped CO_2 movement. Inversely, in the case of a relatively flat structure reservoir (Gorgon and Teapot Dome sites), CO_2 plume and pressure management results were significantly affected by water extraction. At the Gorgon and Teapot Dome sites, CO_2 injection coupled with fluid extraction increased storage capacity by 50% with only 10% increase in plume size in several scenarios. In other scenarios, fluid extraction resulted in a 10% to 20% reduction in reservoir pressure with only 5% increase in plume size. Results of this study also indicate that, in sites with little structural control, water extraction coupled with CO_2 injection could be effective in steering the CO_2 plume and in general were effective in reducing the overall reservoir pressures.

All results will be presented along with recommendations for the implementation of formation water extraction as part of future carbon capture and storage projects.