AN OVERVIEW OF THE IEA GREENHOUSE GAS R&D PROGRAMME REGIONAL GEOLOGIC STORAGE CAPACITY STUDIES

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Regional mapping of CO_2 geological storage resources provides an important element in the planning of widespread CO_2 capture and storage (CCS) deployment. The IEA Technology Roadmap for CCS suggests that by 2050 alone, up to 150 Gt of CO_2 will need to have been captured and stored if CCS is to make the required contribution toward the targeted reduction in emissions of greenhouse gases. Recent studies by the IEA Greenhouse Gas R&D Programme (IEA GHG) have estimated the realistic global capacity that could be available in depleted gas and oil fields to be 130 and 65 Gt, respectively. Given that other geological storage scenarios such as coal seams and basaltic formations remain essentially unproven, the importance to CCS of storage in deep saline formations (DSF) becomes clear.

While high-level estimates of storage resources in depleted hydrocarbon fields can be made on a mass balance basis by consideration of ultimately recoverable oil and gas reserves, comparable estimates for DSF require an analytical approach that considers the fraction of pore space in storage formations that could be occupied by injected CO_2. At this time, two basic types of methodologies are proposed to estimate CO_2 storage capacity in DSFs; these are based on the premise that the DSFs are either open or closed systems. Methodologies to estimate storage resources in open systems have been developed by the U.S. Department of Energy (DOE) and the Carbon Sequestration Leadership Forum (CSLF), and these have been found to be computationally equivalent (Carbon Sequestration Leadership Forum, 2008, Comparison between methodologies recommended for estimation of CO_2 storage capacity in geologic media – Phase III report: April 21, 2008). The only significant difference in approach is conceptual, whereby the DOE methodology considers storage potential in an entire formation and whereas the CSLF method advocates consideration only of structural traps. An alternative approach is one that considers the storage formation as a closed system in which fluids cannot leave the system or leave the system so slowly that the system acts as though it is closed, creating a pressure buildup that does not subside as injection operations continue.

In both the CSLF and DOE open-system methodologies and the closed-system compressibility methodology, a storage coefficient, E (or efficiency factor), is used as part of their analytical equations to derive resource estimates. The E coefficient in the open-system methods is a multiplicative factor which converts the theoretical pore space that could be available into an effective capacity (CSLF) or storage resource (DOE) according to the respective classification schemes associated with the two methods. In a closed system, or perceived closed system, the potential storage resource is limited to the pore volume of the storage formation multiplied by a storage coefficient equal to the difference in pressure between the maximum injection pressure and the initial pressure multiplied by the total compressibility (the formation compressibility plus the fluid compressibility). As part of these effective capacity or storage resource calculations, in both open and closed systems, the E coefficient takes into account various geological and technical factors that could restrict the amount of pore space available for storage but does not take into account economic, regulatory, and source–sink-matching considerations. It must be emphasised that the main use of these methodologies is for the estimation of regional storage resources; the analytical approaches described are not a substitute for the detailed investigation, modeling, and assessment required for individual storage sites.

IEA GHG and DOE commissioned a study by the Energy & Environmental Research Center (EERC) at the University of North Dakota to improve the accuracy of the storage coefficients for estimation of storage resources in DSF. Although the work examined CO_2 storage in both open- and closed-system DSFs, the focus of the study was on the open-system methodologies. As there was insufficient real-world CO_2 injection data to derive a representative range of coefficients, an alternative numerical modeling approach was employed, with geological input parameters derived from global hydrocarbon reservoirs as a proxy for DSF. The modeling work showed the relative influence of various parameters on the efficiency of storage and allowed the derivation of probabilistic ranges of storage coefficients for calculation of effective capacities/storage resources at both site-specific and formation levels for clastic, carbonate, and dolomite lithologies. The overall mean value of E for all lithologies was calculated as 2.6% at the formation level. The report has provided a series of storage coefficients that can be used for assessment of CO_2 storage resources in deep saline formations in association with the published methodologies of DOE and CSLF. The study also addresses the closed-system methodology by estimating the storage resource of a single formation using both open- and closed-system methodologies. The resulting storage coefficient or storage efficiency was nearly an order of magnitude larger using the open-system methodologies than the closed-system methodology; however, this is very dependent on how consolidated the formation is, with unconsolidated formations having much higher storage coefficients using the closed-system methodology.

A key assumption when estimating storage resource in DSFs, with either the CSLF or DOE methodology, is that the DSFs will predominantly act as “open” systems, whereby pressure and displaced formation fluids can be safely dissipated through the wider storage formation and adjacent strata. When estimating storage resource with a closed-system methodology, the formation fluids cannot be displaced, and the pressure in the storage reservoir will build up and not dissipate after injection ends. The fundamental assumptions made in both of the open- and closed-system methodologies have attracted widespread debate in recent years, with several authors claiming that the open-system assumption leads to considerable overestimation of storage resources and the closed-system assumption leads to a considerable underestimation. While detailed consideration of this problem was beyond the scope of the EERC study, IEA GHG has commissioned a separate study to examine this particular concern.