

## "Geological Storage as a Carbon Mitigation Option"

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Anthropogenic emissions of CO<sub>2</sub> have increased atmospheric concentration of CO<sub>2</sub> by about 35 percent during the past 200 years. The current concentration, at about 385 ppm, represents the highest CO<sub>2</sub> concentration in the last 500,000 years. Projected future emissions will lead to doubling of preindustrial CO<sub>2</sub> concentration within the next 50 years. If this relentless increase of atmospheric CO<sub>2</sub> is to be reduced, or reversed, technological solutions must be implemented on a massive scale. While many options are being considered, one attractive approach is carbon capture and storage, or CCS.

The "geological storage" version of CCS involves capture of CO<sub>2</sub> before it is emitted into the atmosphere and subsequent injection of the CO<sub>2</sub> into deep geological formations. Injection of CO<sub>2</sub> into deep formations leads to a multiphase flow problem that may involve important mass exchange between phases, nonisothermal effects, and complex geochemical reactions. In addition, because enormous quantities of CO<sub>2</sub> must be injected to have any significant impact on the atmospheric carbon problem, the spatial scale of the problem becomes very large.

Broad questions involving the fate of the injected CO<sub>2</sub>, including possible leakage of CO<sub>2</sub> out of the formation, as well as the fate of displaced fluids like resident brines, lead to very challenging modeling and analysis problems.

Because important leakage pathways can be very localized, and their properties can be highly uncertain, an overall analysis of the system requires resolution of multiple length scales in the context of a probabilistic approach. These requirements render standard numerical simulators ineffective due to excessive computational demands. A series of simplifying assumptions may be proposed to provide more efficient numerical calculations, even to the point of allowing for analytical or semianalytical solutions. Such simplifications, while restrictive in their assumptions, allow for large-scale analysis of leakage in a probabilistic framework while capturing much of the essential physics of the problem. Example calculations illustrate the utility of these methods, and show the current state of leakage estimation. They also lead to a proposal for specific field experiments that can reduce the uncertainty associated with potential leakage pathways.