Research in Saline Formations Paves the Way for Long-Term CO_2 Storage

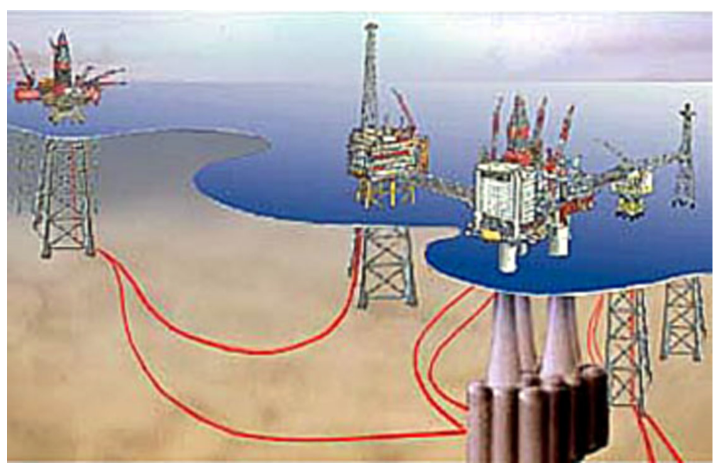
By Eileen Fitzpatrick

CO_2 enhanced oil recovery projects, such as Weyburn, currently inject 32 million tonnes of CO_2 annually into depleted oil and gas reservoirs. This research furthers the progress of long-term CO_2 storage in another geologic formation: deep saline/sandstone reservoirs. SACS, Scripps, Battelle and AEP, and the University of Texas at Austin are among the U.S. DOE project partners advancing our knowledge of geologic storage sites, improving sequestration technology, and essentially paving the way for long-term storage. This research represents a worldwide commitment to reducing the threat of global climate change.

Geologic carbon sequestration is the concept of storing CO_2 underground in deep saline reservoirs, unmineable coal seams, or depleted oil and gas wells. These underground formations, which can be found all over the world, have the necessary structure, porosity, and other properties that make them ideal storage sites. They are more than ideal—they have already stored crude oil, natural gas, brine, and naturally occurring CO_2 for millions of years.

Sleipner West and Carbon Sequestration

Sleipner is a series of platforms off the coast of the Norwegian North Sea, where five wellheads, a treatment facility, and transportation pipelines produce and distribute about 650,000 barrels of crude oil and condensate per day. Sleipner West is a gas field that contains about 9% CO_2, which must be removed before the gas can be marketed.



A cross section of the Sleipner platforms and underwater pipelines. Statoil takes advantage of retrofit technology, using energy created during the CO_2 capture and compression process to run two 3-MW generators that supply power to the platform. Drawing courtesy of Statoil ASA.

Statoil ASA, the company that manages operations at Sleipner, collaborated with BP Amoco, Mobil, Norsk Hydro, Saga, Vattenfall, and IEA GHG R&D Programme on a first-of-its-kind research project directly aimed at greenhouse gas mitigation as part of their operations.

Prompted by the CO_2 tax imposed by the Norwegian Petroleum Directorate, in 1995 Statoil installed a treatment platform with CO_2 capture technology, and used horizontal drilling techniques to install a well for transporting the separated CO_2 into the Utsira formation.

The Utsira formation is a sand, shale, and clay formation of about 11,500 square miles in extent and 250 meters in thickness, situated about 1,000 meters (3,280 feet) below the Sleipner platforms in the North Sea.

Separation and storage of CO_2 began in October 1996, with the injection of about 1 million tonnes of CO_2 into the Utsira formation annually. This is a drop in the bucket, though, according to scientists and geologists, who predict that the North Sea has the potential to store some 800 billion tonnes of CO_2—more than all the carbon emissions from Europe's power stations for the next 800 years.

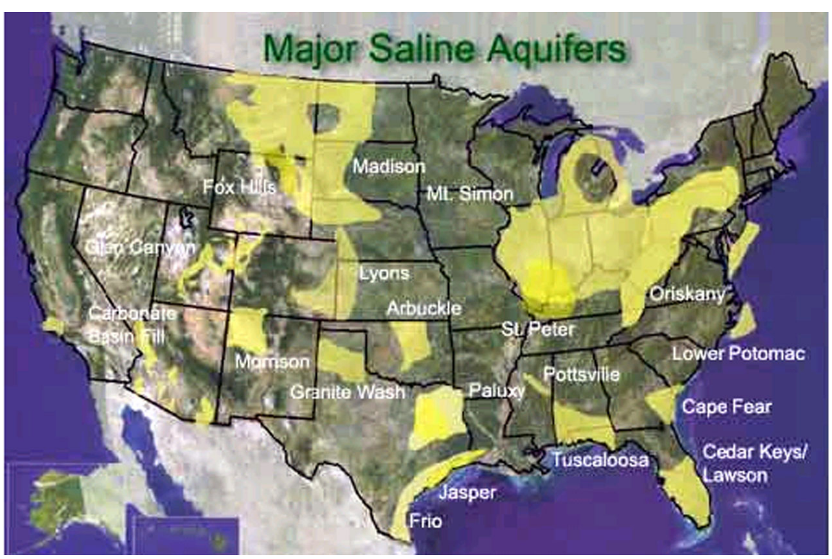
The SACS Project

The Saline Aquifer CO_2 Storage (SACS) research project was formed to monitor the behavior of CO_2 in the Utsira formation. Statoil and the IEA GHG R&D Programme coordinate the SACS project to provide project information to those interested in developing similar CO_2 storage projects.

The SACS project began with a thorough geophysical study of the formation and expected behavior of the CO_2 in the reservoir to determine both storage capacity and how well the formation could hold the carbon in place.

This research spawned the world's first method of monitoring CO_2. Geophysicists had debated whether it was possible to see the injected CO_2 in the reservoir, given the small difference in density between water and liquid CO_2. But results of the SACS project have shown conclusively that the position and movement of CO_2 "bubbles" can be monitored using 3D seismic surveys. This is a huge step forward in confirming the viability of deep saline reservoirs for CO_2 storage.

The SACS report also confirms previous estimates that the Utsira formation can store 600 to 700 billion tonnes of CO_2, most of the estimated potential capacity of the North Sea. This is not surprising, since the Utsira formation is larger in area than Maryland and Washington DC combined.



Because saline formations are typically 3,000 to 12,000 feet below the surface, they are not expected to disturb drinking water aquifers, which lie 10 to 200 feet below the surface. Geologists believe the distance between the saline formations and the drinking water aquifers is great enough, and the intervening rock layers are so impervious to the upward movement of carbon dioxide, that the proposed carbon sequestration should not be a hazard to drinking water supplies.

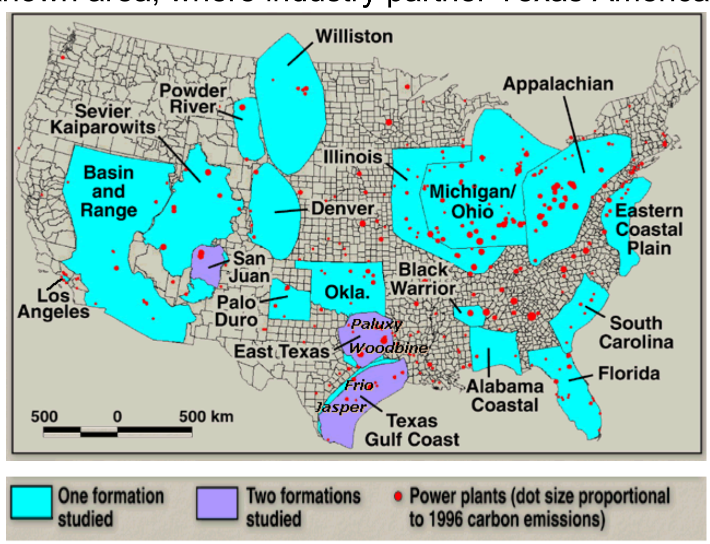
CO_2 Monitoring Technology Demonstration in the North Sea

Until recently, the United States has not been directly involved in project activities at Sleipner. But in August 2002, U.S. DOE awarded $225,000 to Scripps Institute of Oceanography at the University of California, San Diego to survey the Utsira formation, to demonstrate the ability of their high-precision gravitational techniques to identify and monitor CO_2 changes in the reservoir. Results of this study are expected to improve technology for monitoring and predicting the behavior of CO_2 stored underground, and to ultimately bridge the gap between scientific theory and practice of deep saline reservoir storage.

Environmental-Scale Field Test in Texas

This fall, the Bureau of Economic Geology (BEG) at the University of Texas at Austin will put this storage theory into practice by injecting 3,750 tons of CO_2 into a saline formation in the Texas Gulf Coast Basin.

BEG researchers conducted extensive research and modeling to identify areas where point sources of CO_2 are close to potential geologic sequestration sites. The test site was selected in a geologically well-known area, where industry partner Texas American Resources Company has provided logs and information dating back to the 1950s, as well as a recent 3-D seismic survey and access to idle wells.



The bureau's website contains information on all of the formations and basins shown, as well as capabilities for matching power plants with the closest possible storage reservoirs. Drawing courtesy of Bureau of Economic Geology at the University of Texas at Austin.

Researchers from BEG and from the Geo-Seq project led by Lawrence Berkeley National Laboratory have conducted numerical and hydrogeologic analyses of the injection target interval, which have provided clear expectations of CO_2 behavior. Once injected down the well, the CO_2 will move out along the permeable sandstone a few hundred meters. This movement will be limited to a small subsurface compartment by shale seals on top of the sandstone, and by lateral fault seals. Modeling predicts that the CO_2 will be trapped by capillary forces. Simply put, geologic sequestration is expected to use the same process of physics that traps residual oil in reservoirs.

Rather than use a depleted reservoir, where residual oil may make the CO_2 difficult to model and monitor, BEG and Geo-Seq researchers plan to inject into geochemically simpler, nonproductive sandstone. Subsurface movement of CO_2 will be monitored using VSP and cross-well seismic techniques, wireline logging, tilt meters, pressure, temperature, stable isotopic geochemistry and introduced tracers at the injection well and a nearby idle production well.

In addition to monitoring movement, the measured concentrations of CO_2 in the formation will be used as the basis for estimating a CO_2 residual saturation formula for calculating storage capacity. This experiment will demonstrate the feasibility of subsurface storage in the Gulf Coast. The team calculates that in the Frio Formation alone, more than 200 billion metric tons of CO_2 can be sequestered.

With funding of $3.2 million from the U.S. DOE, the BEG has been working toward this field test since 1998 by compiling extensive information on 19 formations in 21 basins in the United States. This research has provided the first comprehensive data bank of saline reservoirs and formations in the U.S. for the purpose of geologic carbon sequestration. This online data bank contains digitized structure maps, permeability analyses, porosity, mineralogy, and other geological characteristics—up to 18 for each formation studied—to determine suitability for CO_2 storage. Though research continues, this database—accessible through the BEG website—allows researchers and industry personnel to view, as well as manipulate, this vital information for their own modeling and simulation efforts.

With an environmental assessment under way and community support behind them, BEG researchers are confident of successfully proving geologic sequestration as a viable tool for reducing greenhouse gas emissions.

Researching Storage Options in the Ohio River Valley

The U.S. DOE, National Energy Technology Laboratory recently awarded funding of $3.2 million to American Electric Power (AEP) and Battelle Laboratories to study one of these U.S. saline formations as a potential carbon sequestration site.

The planned research site, AEP Mountaineer Plant in New Haven, WV, is situated along the Ohio-West Virginia border, and is considered an ideal candidate for CO_2 storage, in part because of the geology of the region, and in part because of its proximity to a ready supply of CO_2—the Ohio River Valley is home to one of the largest concentrations of fossil fuel-powered plants in the United States .

The Mountaineer Power Plant in New Haven, West Virginia. Photo courtesy of American Electric Power.

Over the course of this 18-month project, Battelle and AEP researchers will conduct seismic surveys of the Mt. Simon underground rock formation within a 5 to 10-mile radius of the plant to determine its geologic environment, test the nature of the potential injection zones and caprock formations in a 10,000-ft deep borehole, and conduct simulations and analyses based on these tests. Researchers will also develop monitoring plans for future CO_2 storage in the formation. CO_2 injection activities are not planned as part of this study, and will not occur until the results of the study have been thoroughly evaluated.

Target formations, such as the Mt. Simon and other deep sandstone formations in the midwestern region of the United States, are believed to be suitable for CO_2 sequestration. However, the lack of pre-existing deep well data in the Ohio-West

Virginia region has sparked the question of storage suitability, and the need for research in this area.

This project is being supported with significant cash and in-kind contributions from AEP, Battelle, BP, and Schlumberger, and technical support is being provided by the Ohio Geological Survey, Pacific Northwest National Laboratory, West Virginia University, and the Ohio Coal Development Office of the Ohio Department of Development.

The Big Picture

Worldwide, scientists estimate that the capacity of storage in saline formations is between 400 and 10,000 billion tons. Even if only a fraction of these sites prove suitable for storage, we could store centuries of emissions from power plants. In the United States, deep underground reservoirs have been identified beneath 35 states as possible CO_2 storage facilities. Given worldwide estimates, the carbon storage capacity of these saline formations makes them a viable long-term solution to greenhouse gas mitigation.

However, the biggest barrier to geologic carbon sequestration isn't where to store CO_2, but rather how to make CO_2 capture technology affordable. The cost of carbon capture technology can be as much as 2/3 the cost of retrofitting a power generation facility—the main reason it isn't already enjoying widespread use. By combining a reduction in the cost of carbon capture technology with convenient saline reservoirs for CO_2 storage, carbon sequestration can become an effective pathway to a worldwide reduction in greenhouse gas emissions.

Project Partners and Support

The Department of Energy's National Energy Technology Laboratory is providing a total of $6.7 million to these projects directly supporting the Bush administration's Global Climate Change Initiative and expanding research in carbon sequestration, as a promising approach to countering the threat of global climate change.