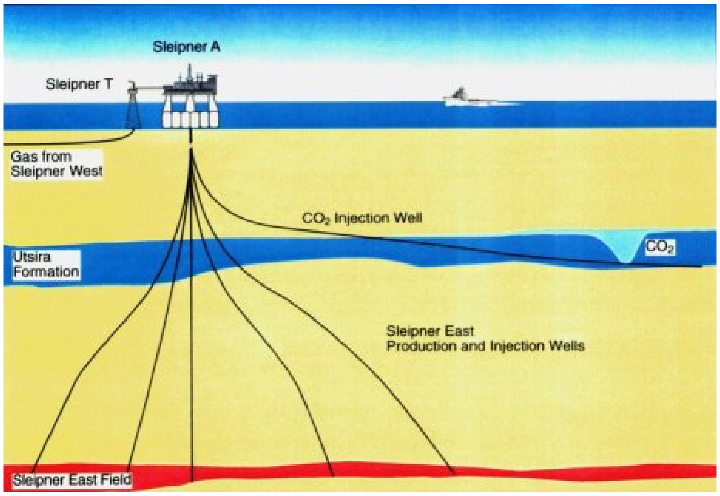
3.1.2 CO_2 STORAGE IN GEOLOGIC FORMATIONS

Technology Description

Sleipner North Sea Project



Large amounts of CO_2 (about a billion tons per year) may need to be stored as a part of a future global atmospheric stabilization strategy. CO_2 can be injected into depleting oil fields, gas fields, and unmineable coal-bearing formations to enhance resource recovery. A portion of the CO_2 remains underground, although current industry practices are geared strongly toward minimizing the CO_2 left underground – and little or no attention is paid to the CO_2 that is not recovered. R&D is focused on revamping conventional enhanced oil recovery, gas recovery, and enhanced coalbed methane processes so that they can serve a dual purpose: resource recovery and CO_2 storage. Other high permeability formations filled with brine, organic-rich shale beds, and other nonconventional geologic structures have potentially enormous CO_2 storage capacities. Research is focused on learning more about these formations and developing the capabilities needed to use them as CO_2 repositories.

System Concepts

- CO_2 is captured from a large anthropogenic point source, and transported and injected into a depleting oil field, unmineable coal seam, saline formation, depleting gas field, shale, or other geologic structure amenable to CO_2 storage. There are five different mechanisms that can trap CO_2 in geologic formations:
    - Structural trapping: A layer or "cap" of impermeable rock that overlies the formation of porous rock into which the CO_2 is injected prevents upward flow of CO_2. This is the mechanism that caused natural deposits of crude oil, natural gas, and CO_2.
    - Capillary trapping: The surface of sandstone and other rocks preferentially adheres to saline water versus CO_2. If there is enough saline water within a pore (75-90% of the pore volume), it will form a capillary plug that traps the residual CO_2 within the pore space.
    - Dissolution in saline water: CO_2 is soluble in saline water, and will dissolve in solution on contact.
    - Mineralization: Over longer periods of time, dissolved CO_2 can react with minerals in the formation to form solid carbonates. There may be ways to enhance this reaction.
    - Adsorption: Coal and other organically rich formations will preferentially absorb CO_2 onto carbon surface as a function of reservoir pressure. In some cases, such as coal beds, CO_2 displaces methane, which can be recovered to enhance economics.
- In an oil field, the CO_2 displaces the oil in place and also dissolves in the oil, decreasing the oil viscosity and enabling more of it to be recovered. A portion of the injected CO_2 remains stored in a reservoir as a free gas, in brine or oil solution, or in carbonate minerals.
- Leakage of sequestered CO_2 back to the surface may occur through faults, active or abandoned wells, and microseepage.

Representative Technologies

- Natural gas storage fields provide experience of injecting significant quantities of gas into geologic formations.
- Technologies will borrow extensively from the petroleum industry in the areas of drilling simulation; completion of injection wells; processing, compression, and pipeline transport of gases, including acid gases; operational experience of CO_2 injection for enhanced oil recovery and natural gas storage; and subsurface reservoir engineering and characterization.
- Enhanced coal bed methane recovery using nitrogen.

Technology Status/Applications

- The Mount Simon reservoir underlying Illinois, Indiana, Michigan, Kentucky, and Pennsylvania has been approved for industrial waste disposal and underlies a region with numerous fossil energy power plants.
- Industry has experience with more than 400 wells for injecting industrial wastes into saline formations.
- The petroleum technology is readily adaptable to subsurface CO_2 storage.

Current Research, Development, and Demonstration

RD&D Goals

- Develop domestic CO_2 underground storage repositories capable of accepting around a billion tons of CO_2 per year.
- Demonstrate that CO_2 storage underground is safe and environmentally acceptable, and an acceptable GHG mitigation approach.
- Demonstrate an effective business model for CO_2 enhanced oil recovery and enhanced coalbed methane, where significantly more CO_2 is permanently stored than under current practices.
- Develop cost-effective methods to survey large land areas and locate zones of potential CO_2 leakage.
- Provide monitoring techniques that can reliably evaluate the stability, capacity, rate of leakage, and permanence of carbon dioxide stored in geologic formations.
- Develop publicly accepted monitoring protocols.

RD&D Challenges

- Develop the capability to inject CO_2 into saline formations with low permeability.
- Harness geochemical reactions to enhance containment.
- Develop injection practices that preserve cap integrity.
- Develop an understanding of the properties of shales and other unconventional hydrocarbon-bearing formations that determine how they will react to CO_2 injection.
- Develop the ability to track CO_2 transport.
- Develop field practices that optimize CO_2 storage and resource recovery.
- Develop the ability to predict the CO_2 storage capacity and potential resource recovery of a particular formation.
- Develop models that are able to simulate the fate and transport of CO_2 in geologic formations and along potential migration pathways.
- Develop the ability to track the fate and transport of injected CO_2.
- Develop methods to locate well bores, with and without casing, that might potentially leak.
- Develop surface and near-surface monitoring technologies that will allow public demonstration of the safety of CO_2 storage.
- Develop a better understanding of the chemistry of coal and CO_2, and conduct comprehensive R&D program on all physical and chemical aspects of CO_2 interactions with reservoir phases.

RD&D Activities

- Study geochemical reactions involving CO_2 in a laboratory.
- Study the natural analogs of geochemical CO_2 conversion. Study rock samples from CO_2 bearing geologic formations to better understand in situ geochemical/geobiological reactions.
- Develop CO_2 tracking technology, e.g., sonic, chemical tracers.
- Study CO_2 transport in the Sleipner Vest gas field, via the International Energy Agency's Greenhouse Gas Programme.

- Assessment of techniques for finding abandoned wells near a potential sequestration site.
- Develop models to simulate migration of CO_2 through multiple subsurface formations.
- Novel injection techniques to increase CO_2 storage in saline formations.
- CO_2 storage in coal beds. Laboratory measurements of CO_2/CH_4 sorption and coal swelling under confined and unconfined conditions, ARI and industry consortium, commercial-scale field demonstration in the San Juan Basin; Consol – horizontal drilling, Alabama geologic survey, screening model for Black Warrior.
- Apply surface and near-surface monitoring techniques such as surface CO_2 flux, injection tracers in soil-gas, and changes in shallow aquifer chemistry for CO_2 leakage.
- Study chemical reactions involving CO_2 and cement from new or existing wells as a possible source of leakage.
- CO_2 storage in oil reservoirs. Weyburn, reservoir mapping, West Pearl Queen, CO_2 monitoring and simulation.
- Airborne reconnaissance of a 38,000-acre EOR/sequestration site to locate wells, faults, and other potential CO_2 leakage zones.
- Other RD&D activities in DOE, Australia, the European Union, Japan, etc.

Recent Progress

- Major saline formations underlying the United States have been identified.
- Initiated a pilot-scale test of CO_2 storage in a depleted oil reservoir.
- Completed pilot-scale injection of CO_2 into the Frio deep saline aquifer and field tested near-surface monitoring techniques.
- Initiated several field tests with key industrial companies participating and providing cost-share: Consol Inc. CBM,-Appalachia ARI, CBM-San Juan Basin; Strata Production C. – Permian Basin; Pan Canadian Resources EOR-Canada.

Commercialization and Deployment Activities

- Since 1999, Statoil has been injecting CO_2 at a rate of 1 Mt/yr into the Sleipner Vest gas field in a sandstone aquifer 1,000m beneath the North Sea.
- About 70 oil fields worldwide use CO_2 for enhanced oil recovery.
- Another project uses CO_2 from Dakota Gasification for enhanced oil recovery in the Weyburn field in Canada. CO_2 is transported via pipeline.
- The pipeline enables extensive use of CO_2 for enhanced coal bed methane recovery in the San Juan basin.
- There are plans for using CO_2 for enhanced oil recovery in Kansas, using CO_2 from ethanol production.
- Planned test in Kansas using landfill gas for enhanced coal bed methane recovery.

Market Context

- Development of approaches for economically decarbonizing fossil fuels will allow the carbon-free production of electricity and hydrogen, and will take advantage of an existing fossil fuel infrastructure that accounts for more than 80% of the energy consumed in the United States and internationally.