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Geologic Sequestration of Carbon Dioxide—An Energy Resource Perspective

Most energy used to meet human needs is derived from the combustion of fossil fuels (natural gas, oil, and coal), which releases carbon to the atmosphere, primarily as carbon dioxide (CO_2). The atmospheric concentration of CO_2, a greenhouse gas, is increasing, raising concerns that solar heat will be trapped and the average surficial temperature of the Earth will rise in response. Global warming studies predict that climate changes resulting from increases in atmospheric CO_2 will adversely affect life on Earth.

In the 200 years since the industrial revolution, the world's population has grown from about 800 million to over 6 billion people and the CO_2 content of the atmosphere has risen from about 280 to about 360 parts per million by volume, a 30 percent increase (fig. 1). International concern about potential global climate change has spurred discussions about limiting the amount of CO_2 and other greenhouse gases released to the atmosphere.

Although there is no U.S. Government policy concerning CO_2 emissions, multinational corporations will face CO_2 regulations in countries that have resolved to reduce emissions. Furthermore, the Clear Skies Act of 2003 was introduced in the U.S. House of Representatives as House bill HR 999 and the Senate as Senate bill S. 485 on February 27, 2003. The act proposes a voluntary CO_2 emissions reduction plan (http://www.epa.gov/clearskies/). To evaluate all options for reducing CO_2 emissions, we need to study the potential of geologic reservoirs and geologic processes to store CO_2 (fig. 2).

The concept of controlling the level of CO_2 in the atmosphere is generally referred to as "carbon management." Carbon management includes the following strategies to reduce carbon emissions: carbon capture and sequestration, enhanced efficiency of power use and generation, the use of low-carbon fuels, and the use of renewable energy sources.

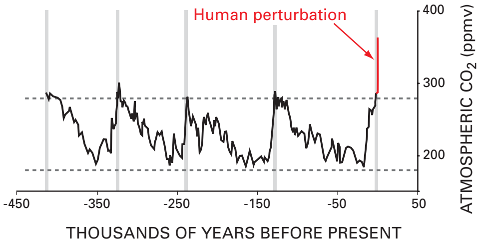

Figure 1. Ice cores indicate that in the past 420,000 years, the concentration of CO_2 in the atmosphere has ranged from 180 to 280 parts per million by volume (ppmv). The current CO_2 atmospheric concentration is ~360 ppmv; this dramatic increase is primarily the result of human combustion of fossil fuels. Graph is excerpted with permission from Falkowski and others (2000); copyright 2000, American Association for the Advancement of Science.

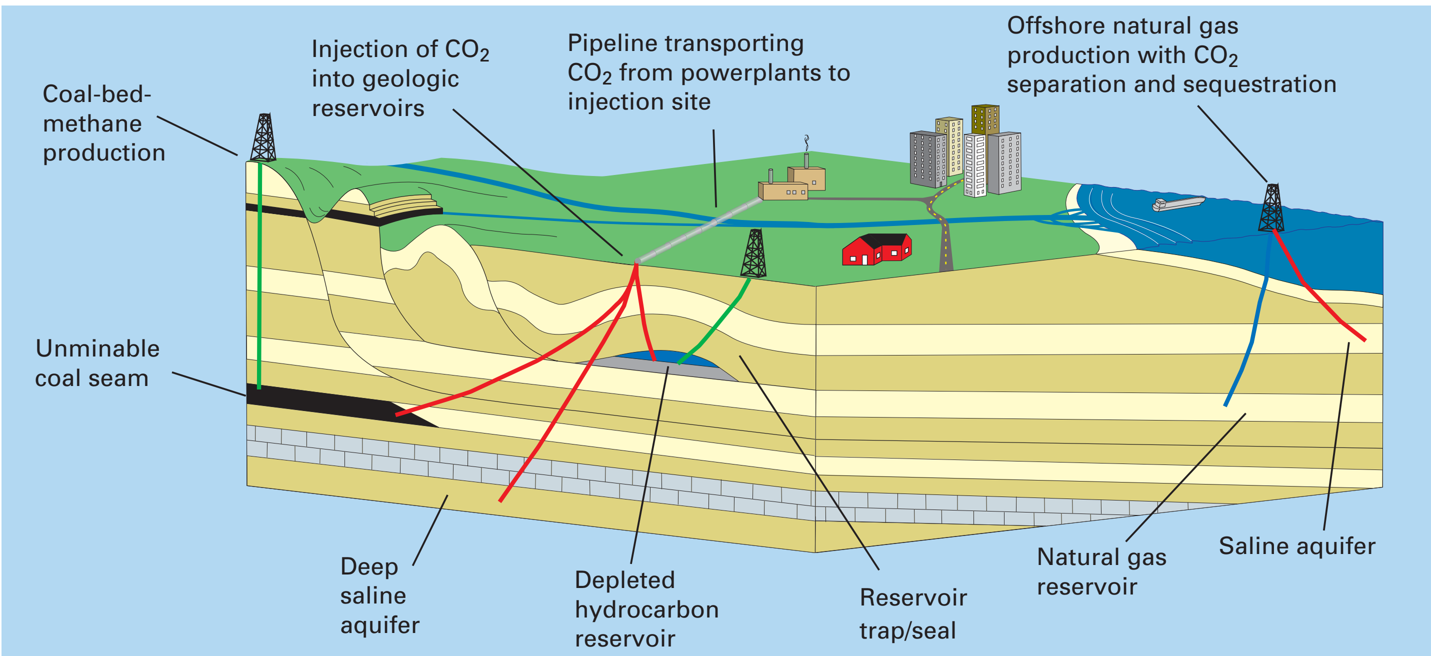

Figure 2. Potential CO_2 sequestration reservoirs and products. Red lines indicate CO_2 being pumped into the reservoirs for sequestration, green lines indicate enhanced recovery of fossil fuels caused by CO_2 sequestration, and the blue line indicates conventional recovery of fossil fuels. The offshore natural gas production (blue line) and CO_2 sequestration scenario is currently occurring off the coast of Norway at the Sleipner complex (fig. 3), operated by Statoil. There, the gas produced is a mixture of CO_2 and methane. The CO_2 is removed and injected into a nearby saline aquifer.

Carbon sequestration, broadly defined, is a term that includes the removal of CO_2 from the atmosphere by agricultural modifications and reforestation as well as the reduction of CO_2 emissions by capture and storage. Storage of anthropogenic CO_2 within geologic reservoirs is a method of carbon sequestration. The U.S. Geological Survey (USGS) is currently studying geologic options for storing CO_2 in depleted oil and gas reservoirs, unminable coal seams, or saline aquifers (fig. 2).

USGS Project Activities

USGS project activities focus on two broad themes. First, research is being conducted by the USGS on the geologic and geochemical factors that control the capacity to store CO_2 in geologic formations. The tasks of this part of the project include the following: (i) characterizing possible interactions between the injected CO_2 and any of the components of the reservoirs and (ii) comparing benefits and risks of various storage reservoirs. The second topic of research involves identifying potential geologic reservoirs and assessing how much CO_2 could be sequestered within them. One product planned to come from this assessment is a geographic information system (GIS) map that will compare the location of major CO_2 sources with the size, location, and type of potential storage reservoirs. Understanding the spatial relations between the CO_2 sources and potential geologic sinks will help to determine the extent of infrastructure needed to complete the sequestration project. These two broad areas of research will help to assess the scientific and economic feasibility of using CO_2 sequestration in geologic formations as a method to slow the increase of atmospheric CO_2 levels.

In addition to these tasks, the USGS is collaborating with the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy and with the NETL-supported consortia GEO-SEQ and MIDCARB. Collaborative USGS activities are focused on new measurements of the solubility of CO_2 in brines and on methods of assessing the CO_2 sequestration capacity of geologic formations.

Figure 3. The Sleipner complex off the coast of Norway. Natural gas produced in the Sleipner field is high in CO_2; this CO_2 is removed from the natural gas stream and is then pumped into the Utsira Formation, which is a highly permeable sandstone. The operator of the Sleipner field, Statoil, geologically sequesters the CO_2 because the sequestration cost is less than the Norwegian carbon emission tax. Photograph is courtesy of Øyvind Hagen, Statoil.

What We Need to Know

Initial strategies for geologic sequestration of CO_2 should focus on the most cost-effective options. Therefore, these options need to be identified. Storage sites that are close to CO_2 sources (powerplants) lead to relatively lower transportation costs. Furthermore, CO_2 sequestration in some oil, gas, and coal-bed-methane reservoirs has the potential to increase the amount of fossil fuel that can be removed from those reservoirs. These enhanced recovery methods—for example, enhanced oil recovery (EOR), enhanced coal-bed-methane recovery, or enhanced gas recovery (EGR)—have an economic payback that will help to subsidize the net cost of CO_2 storage. Additionally, one of the important goals of this project is to determine storage capacity of both enhanced recovery reservoirs and non-economic reservoirs.

Reference Cited

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