IN FOCUS

Reducing Global Warming by Storing Carbon Dioxide beneath the Earth's Surface—Exploring the Prospects for Carbon Sequestration

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Carbon dioxide emissions and global warming

Hydrocarbons (oil, natural gas, and coal) are expected to be the primary source of energy in the United States for at least the next 50 years. There is mounting scientific evidence that increasing concentrations of carbon dioxide (CO_2) are contributing to global warming. Carbon dioxide is released to the atmsophere when carbon-containing fuels such as oil, natural gas, and coal are burned. This problem is compounded by carbon emissions from forest fires and forests burned to clear land.

Carbon dioxide increases the capacity of the atmosphere to trap heat (the "greenhouse effect") and this contributes to global warming. Daily activities by all of us add to the problem—CO_2 is released in emissions from vehicles, large industrial complexes, and power plants.

In 1988, the World Meterological Organization and the United Nations Environmental Programme established the Intergovernmental Panel on Climate Change (www.ipcc.ch) to assess scientific, technical, and socioeconomic factors relevant for understanding climate change. In its 2001 report, the IPCC concluded that the atmospheric concentration of CO_2 increased 31 percent from 280 parts per million in 1750 to 367 ppm in 1999. It also concluded that the global average surface temperature (the average of near-surface air temperature over land and sea surface temperature) increased over the 20th century by about 0.6 degrees Celsius. The IPCC reported, "Globally, it is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record, since 1861." (www.grida.no/climate/ipcc_tar/wg1/016.htm)

In a December 2003 policy statement, "Human Impacts on Climate," the Council of the American Geophysical Union said that "it is virtually certain that increasing atmospheric concentrations of carbon dioxide and other greenhouse gases will cause global surface climate to be warmer." (www.agu.org/sci_soc/policy/climate_change_position.html). The environmental impact of global warming is not well understood but diverse and widespread; it includes glaciers melting more rapidly than in the past, increased loss of forests damaged by pests (e.g., budworm and pine beetle), and earlier spring weather and hotter summer weather in places around the globe. Although roughly half of the CO_2 released in the atmosphere is absorbed by plants and trees in forests as part of photosynthesis or absorbed by oceans, a significant amount of CO_2 remains in the atmosphere.

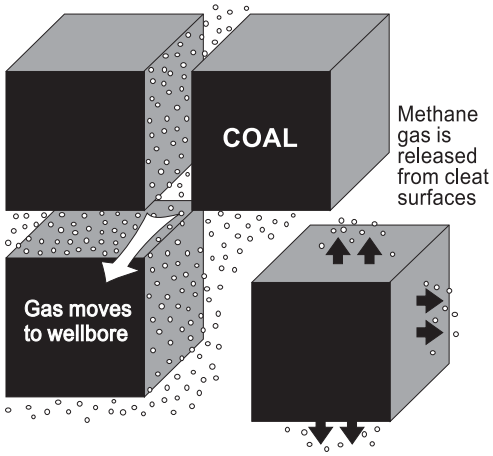
Carbon sequestration technology

Carbon sequestration research is focused on finding ways to capture and safely store CO_2 from emission stacks of coal-fired power plants and other industrial plants. Carbon dioxide can be captured from a power plant's flue-gas stream (i.e., the gas produced as a byproduct of burning coal). The flue gas can be "scrubbed" or "cleaned" to remove the CO_2. The CO_2 can be converted into a concentrated stream, pressurized until it becomes a liquid, and then transported by pipeline to a site for injection into underground reservoirs for long-term storage.

In projects across the nation, geologists are evaluating the potential for sequestering CO_2 in traditional and unconventional oil and gas reservoirs, uneconomic coal seams, and saline aquifers. They are also evaluating potential economic benefits of enhanced production of oil and coalbed methane that might result from carbon sequestration operations.

During the past 20 years, CO_2 has been injected into mature oil fields, particularly in Texas, Colorado, Wyoming, and New Mexico, to produce oil remaining in reservoir pores after primary production is complete. The injected CO_2 affects chemical interactions among the reservoir rock and oil. When CO_2 mixes with the remaining oil, it can expand its volume and reduce its viscosity (thickness), making it easier to pump to the surface. This process is referred to as "enhanced oil recovery" or "EOR."

The success of EOR operations has spurred scientists to investigate coal seams to determine if they may also absorb CO_2 and displace methane as a recoverable product to enhance natural gas production.



Research at KGS

Geologists at KGS are providing regional leadership in carbon sequestration research. With current funding of more than $680,000 from the U.S. Department of Energy and industry partners, KGS geologists are active in numerous carbon sequestration research projects.

MIDCARB. The Survey's involvement in carbon sequestration research began in 2000 with the Midcontinent Interactive Digital Atlas and Relational Database (MIDCARB) project (www.midcarb.org). For the past 3

years, KGS has cooperated with the geological surveys of Illinois, Indiana, Kansas, and Ohio to evaluate the potential for carbon sequestration in the Midwest. The Ohio River Valley has the largest concentration of power plants in the nation.

The MIDCARB team built an integrated database of information and maps that could be used by decision-makers in the public and private sectors to evaluate options for the future management of CO_2 emissions. This research has been timely—a question being debated publicly is whether Congress should begin to regulate CO_2emissions from coal-fired power plants.

The five-state MIDCARB team identified the locations of large sources of CO_2 emissions, such as coal-fired power plants, petroleum refineries, cement plants, and other large industrial complexes in the Midwest. They also identified potential sites for storage of CO_2, including oil and gas reservoirs, coal beds, organic-rich shales, and saline aquifers. An Internet mapping site was then constructed to link geologic data and maps from the five states and allow decision-makers to evaluate alternative carbon sequestration options.

In 2004, the MIDCARB project is being expanded to include geologic data and maps for 33 states. The data and maps are being compiled by seven regional sequestration partnerships. KGS is participating in two of the seven partnerships (the Midwest and Appalachia partnerships discussed below). KGS is also helping West Virginia and Pennsylvania to add information about CO_2 sources and potential geologic sites for carbon sequestration in their states. KGS received $100,000 from DOE for the 1-year extension of the MIDCARB project.

Carbon sequestration in the Midwest and Appalachia. Building on the expertise and data we acquired in the MIDCARB project, KGS is researching in greater detail the prospects for carbon sequestration in the Midwest and Appalachia. KGS geologists are studying the geologic framework of the regions in order to get a better understanding of CO_2 storage options. They are also including geographic information system (GIS) data to identify pipelines and other infrastructure that could be used to transport CO_2 from emission sources to storage sites. The goal is to eventually drill wells to demonstrate the feasibility of sequestering CO_2 in various geologic storage sites.

The MIDCARB Internet mapping site was the first system developed in the nation for the U.S. Department of Energy that successfully linked and integrated geologic maps and data from multiple states.

In the study of the Midwest region, KGS is collaborating with the Illinois and Indiana geological surveys. KGS received a grant of $200,842 from DOE for this research.

In the study of the Appalachian region, KGS is collaborating with Battelle National Energy Technology Laboratory; the geological surveys of Indiana, Ohio, Pennsylvania, and West Virginia; Ohio State University; Pennsylvania State University; Purdue University; West Virginia University; and seven energy companies. DOE provided KGS with a grant of $50,066 for this 2-year project.

Devonian black shale. Researchers at KGS are also investigating the potential to dispose of CO_2 by sequestering it in black shales in Kentucky. In this 3-year project (July 1, 2002–June 30, 2005), funded with a DOE grant of $532,966, KGS is collaborating with scientists at the University of British Columbia and DOE's National Energy Technology Laboratory.

Devonian black shales are organic-rich rocks that serve as a source and trap for natural gas. Most of the natural gas is adsorbed on clay and kerogen (fossilized insoluable organic material) surfaces; this is similar to the way in which methane gas is stored in coal beds. It has been demonstrated that in high-rank coal, on average, CO_2 is preferentially adsorbed, displacing methane at a ratio of two for one. In other words, approximately two CO_2 molecules will adsorb to every one methane molecule released. In a similar way, black shales may desorb methane in the presence of adsorbing CO_2. If this is the case, and preliminary research is indicating that it is, black shales may be an excellent trap for storing CO_2 and it could have the added economic incentive of enhancing natural gas production.

Benefits of carbon sequestration

The potential benefits of carbon sequestration are numerous. It could provide revenue for the petroleum industry from enhanced production of oil and natural gas. It could allow our nation to continue to use its abundant and inexpensive coal resources to generate electricity; this would benefit coal producers, as well as electricity consumers. It could also provide a bridge to ease the transition away from dependence on fossil fuels toward increased reliance on renewable fuels, energy efficiency, and energy conservation in this century.

For information about carbon sequestration research at KGS, contact **Jim Drahovzal,** head of the Energy and Minerals Section, at 859.257.5500 (ext. 175) or send an e-mail to drahovzal@uky.edu. Additional information about carbon sequestration research projects is found on the KGS Web site at www.uky.edu/kgs.

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