Cooling Climate Change with Carbon Capture and Sequestration

One of the proposed strategies for limiting the magnitude of future climate change is carbon sequestration—the removal of carbon dioxide or other forms of carbon from exhaust gases or the atmosphere and long-term storage of this carbon in a biological or geological reservoir. Five general types of carbon sequestration are described in the 2010 National Research Council report, *Limiting the Magnitude of Future Climate Change*: (1) carbon capture and storage—i.e., removing carbon from the waste stream of large point sources of emissions and sequestering it underground; (2) sequestration in forests and other agricultural systems—i.e., enhancing the storage of carbon in forests and croplands; (3) ocean sequestration—i.e., enhancing the natural biological carbon uptake of the oceans; (4) geochemical sequestration—i.e., using geochemical reactions such as mineral carbonization, altering ocean alkalinity; or in situ geochemical processes to enhance the transformation of carbon dioxide gas into dissolved or solid-phase carbon; and (5) direct air capture—i.e., extracting carbon dioxide directly from the ambient air. Following are brief descriptions of the current state of technical understanding of each type of carbon sequestration based on the *Limiting the Magnitude of Climate Change* report:

Carbon capture and storage technologies have been demonstrated at the commercial scale in several large industrial processes, but no large power plant today captures and stores its carbon dioxide. More reliable cost and performance data are needed both for capture and storage, and these data can be obtained only by construction and operation of full-scale demonstration facilities. Several recent NRC committees concluded that this information could be acquired by 2020 if deployments of demonstration projects proceed rapidly—however, the July 2011 decision by American Electric Power to drop its plans to build a full-scale carbon-capture plant in Mountaineer, West Virginia raises questions about the future prospects of such large-scale demonstration projects.

Sequestration in forests and agricultural systems is potentially important because forests and agricultural systems are a significant source of global greenhouse gas emissions and because the cost (per ton of carbon dioxide emissions) tends to be much less than emissions reductions from the energy sector. A variety of practices can be used to enhance carbon sequestration in forests and croplands, including planting new forests (afforestation), protecting existing forests against loss and degradation, reducing cropland tillage, and enhancing conversion to grasslands. Different types of land-use practices have different mitigation potentials, with forestry practices generally demonstrating much larger sequestration capacity than agricultural soil management.

One of the **oceanic sequestration strategies** that have been discussed to enhance natural biological carbon uptake is iron fertilization of the oceans. This involves the intentional introduction of iron to upper ocean waters to stimulate a phytoplankton bloom, with the goal of enhancing biological productivity (the growth of plant biomass) and enhanced removal of carbon dioxide from the atmosphere. Preliminary research has demonstrated that phytoplankton blooms can be stimulated by iron addition, but much controversy remains over its effectiveness and possible effects on ocean ecology and biology, as well as the likely political and institutional hurdles of carrying out large-scale tests in international waters.

A variety of **geochemical sequestration strategies** have been proposed to enhance the transformation of carbon dioxide gas into dissolved or solid-phase carbon, including methods to: accelerate the naturally slow reactions that convert carbon dioxide in the atmosphere to carbonate minerals via weathering; increase ocean alkalinity to enhance the ocean's capacity to store dissolved inorganic carbon; and enhance carbonate-forming reactions in locations where minerals exist naturally.

Direct air capture of carbon dioxide from ambient air offers a number of potential advantages relative to other carbon sequestration approaches. For example, direct air capture facilities could be co-located with suitable geological disposal sites, thereby eliminating the need to transport captured carbon dioxide long distances. Although several prototypes of such systems are in development, major challenges remain in making such systems viable in terms of cost and energy efficiency. If the technology were to someday become technically and economically feasible, however, the amount or carbon dioxide that could be captured would face no physical limit (other than global storage capacity) and, thus, could fundamentally alter the picture for efforts to reduce atmospheric greenhouse gas concentrations.

The National Research Council's Division on Earth and Life Studies will consider recent developments and future potential of these carbon sequestration strategies during its October 28, 2011 meeting in Irvine, California. The session will include presentations by leading scientists, engineers, and policy experts who will share their insights on these topics, participate in informal discussions with members of the DELS Committee and other invited attendees, and explore ideas for how the NRC could help move the nation's thinking forward on this important issue.