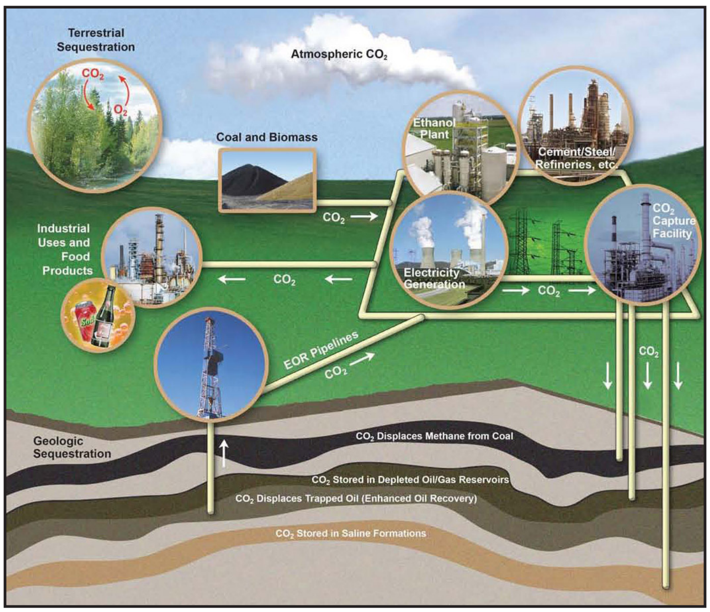
Carbon Capture and Storage

Carbon capture and storage (CCS) technologies capture carbon dioxide (CO_2) at industrial point sources, such as fossil-fuel combustion, natural gas refining, ethanol production and cement manufacturing plants. Once captured, the CO_2 gas is compressed and transported to a suitable location for injection and storage in deep geologic formations, such as saline reservoirs, mature oil and gas fields, and potentially unmineable coal seams, basalts or other formations. Once stored, the CO_2 is isolated from drinking water supplies and prevented from release into the atmosphere by a confining zone that includes a dense layer of rock, which acts as a seal, and through additional trapping mechanisms. Monitoring devices are also installed to ensure process integrity. CCS applied to a modern conventional coal-based power plant could reduce CO_2 emissions to the atmosphere by approximately 80-90 percent compared to a plant without CCS.



CO2 storage and uses schematic from the National Energy Technology Laboratory (NETL)

Globally, CCS technologies have the potential to reduce overall climate change mitigation costs and increase flexibility in reducing greenhouse gas emissions. According to the 2005 report, Carbon Dioxide Capture and Storage by the Intergovernmental Panel on Climate Change, application of carbon sequestration technologies could reduce the costs of stabilizing CO_2 concentrations in the atmosphere by 30 percent or more compared to scenarios where such technologies are not deployed.

Economic growth is closely tied to energy availability and consumption, particularly lower-cost fuels such as coal. While the use of coal and other fossil fuels results in the release of carbon dioxide, CCS technologies balance economic value and environmental concern – retaining coal as an affordable source of electricity in a carbon constrained world.

There are three large-scale projects demonstrating CO_2 storage in operation today (large-scale is defined as storing one million tons per year of CO_2). CCS has not yet been applied to large-scale electricity generation due to a number of technological, infrastructure, cost and legal challenges. Public policy measures and sustained funding to support continued CCS research, development and demonstration will be necessary to accelerate large-scale commercial deployment of this critical technology.

Status of CCS Development

In addition to the three large-scale demonstration projects, several pilot projects are in operation in six countries (none are in the U.S.). Of these, only one project captures CO_2 at a coal-based plant. The other current projects demonstrate carbon storage or reuse at enhanced coal bed methane. Additionally, more than 20 capture and storage projects are proposed in the U.S. and five other countries between now and 2020. (See below for a list of current and proposed CCS projects.)

CCS Deployment Timeline and Cost

A substantial amount of continued research, development and demonstration of CCS technologies will be required before CCS can be applied to large-scale commercial power plants. Analysis from the Massachusetts Institute of Technology Future of Coal report estimates that a 10-year RD&D funding commitment of $8-8.5 billion will be required to advance the technology to a stage where it is ready for commercial deployment. Similarly, the Electric Power Research Institute (EPRI) estimates that approximately $10 billion will be required through 2017. EPRI also notes that over the next 20 years, it is expected that a total RD&D investment of roughly $19 billion will be required to develop and deploy advanced coal power and CCS technologies needed to achieve major, affordable CO_2 emissions reductions. In sum, both organizations find that CCS technologies will not be available for commercial deployment until approximately 2020 or 2025.

Barriers to CCS

At present, uncertainty over siting requirements and long-term liability issues associated with the underground storage of CO_2 have deterred project developers, financiers and insurers from moving forward with CCS. However, CCS as a tool for mitigating CO_2 emissions and ensuring a secure and affordable energy supply for America represents a vital public interest that merits a federal-level program to clarify and resolve these long-term liability issues and to clear the way for the rapid and widespread commercialization of the technology. Some of the key issues that must be resolved in order to foster widespread commercialization of CCS include:

- Determining responsibility for post-closure monitoring;
- Avoiding application of the federal Superfund program to injections of CO_2;
- Avoiding characterization of CO_2 as a waste and CCS activi-

ties as waste disposal to avoid triggering expensive "cradle to grave" regulations of the Resource Conservation and Recovery Act (RCRA); and

- Resolving property rights issues, including pore space ownership, trespass and interstate issues relating to CO_2 transportation and placement.

Current Worldwide CCS Projects

Demonstration Projects

- Sleipner West (Norway). Statoil and IEA began injecting CO_2 from the natural gas field into a saline formation under the North Sea in 1996. Currently, they store one million tons of CO_2 per year with no leakage. The projected cost is more than €350 million. (Storage)
- Weyburn CO_2 Flood Project (Canada). EnCana and the International Energy Agency (IEA) began storing CO_2 from enhanced oil recovery (EOR) in 2000. During Phase I (2000-2004), more than seven million tons of CO_2 were stored, and the geology has been found suitable for long-term storage. The site will be maintained in order to study long-term sequestration. The second phase will include site characterization, leakage risks, monitoring and verification and a performance assessment. (Storage)

Weyburn CO2 project. (photo: NETL)

- In Salah (Algeria). Sonatrach, BP and Statoil began capturing CO_2 from natural gas production in 2004 and storing it in depleted gas reservoirs. They store about one million tons of CO_2 per year, and the projected cost for the project is $1.7 billion. This is the world's first full-scale CO_2 capture and storage project at a gas field. (Storage)
- K12B (Netherlands). Gaz de France is investigating the feasibility of CO_2 storage in depleted natural gas reservoirs on the Dutch continental shelf. The CO_2 is injected in the same place from which it came. Injection started in 2004. (Storage)
- Snøhvit (Norway). Statoil began storing CO_2 from gas production beneath the seabed in April 2008. At full capacity, they plan to store 700,000 tons of CO_2 a year. The projected cost is $110 million. (Storage)

Pilot Projects

- Fenn Big Valley (Canada). The Alberta Research Council began injecting CO_2 into deep coal beds for enhanced coal bed methane in 1999, with a project cost of C$3.4 million. Thus far, all testing has been successful, and they are assessing the economics of the project. (Enhanced coal bed methane)
- Ketzin (Germany). GFZ Potsdam, as part of the European research project, CO2SINK, began storing CO_2 in aquifers at a depth of 600 meters on June 30, 2008. They plan to store up to 60,000 tons of CO_2 over two years, at a cost of €15 million. (Storage)
- Schwarze Pumpe (Germany). Vattenfall opened their pilot 30Mw coal oxyfuel combustion plant with CO_2 capture on Sept. 9, 2008. (Coal plant with capture)
- Otway (Australia). CO2CRC has begun injecting CO_2 from natural gas wells in hydrocarbon reserves; eventually, 100,000 tons will be stored. The object is to provide technical information on CO_2 storage and monitoring and verification. The project's budget is A$40 million. (Storage)

Proposed Projects

Domestic

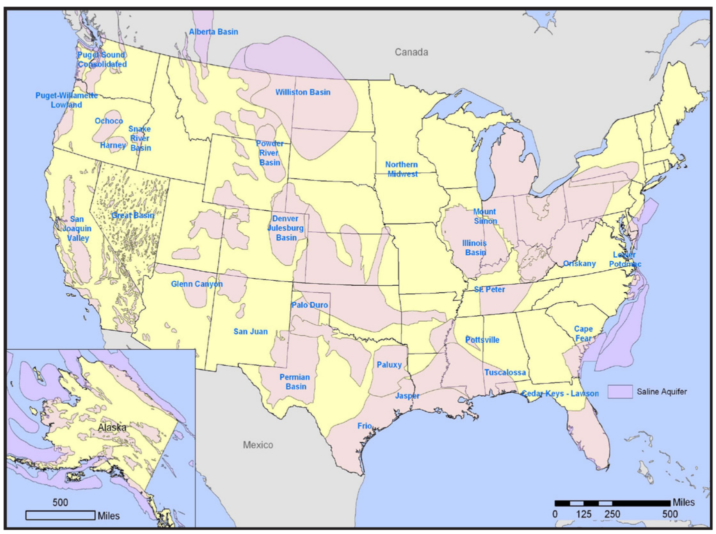
- Mountaineer Power Plant (West Virginia). Beginning in 2009, American Electric Power (AEP) will capture about 100,000 tons of CO_2 per year from a portion of the coal-based plant's emissions using chilled ammonia and store it in a deep saline aquifer injection well. In 2012, the project would be increased to capture and store 1.5 million tons of CO_2 per year. (Coal CCS)
- Antelope Valley Station (North Dakota). About one million tons of CO_2 per year will be captured and stored from this 120MW slipstream project at a coal-based plant. Announced by Basin Electric Power Cooperative and Powerspan Corporation, this project is expected to begin in 2009 and be operational in 2012. (Coal CCS)
- Northeastern Plant (Oklahoma). At a 450MW coal-fired unit, AEP plans to capture up to 1.5 million tons of CO_2 per year beginning in 2011. This CO_2 will be used in EOR. (Coal capture, EOR)
- Carson Project (California). A 500MW power plant will be powered by hydrogen, and CO_2 will be stored beginning in 2011. (CCS)

U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships

- The West Coast Regional Carbon Sequestration Partnership will conduct a large-scale test in which they will inject one million tons of CO_2 over four years into deep geologic formations in the San Joaquin Valley of California. This project will cost $90.6 million (the DOE share, subject to annual appropriations, is $65.6 million). (Storage)
- The Southwest Regional Partnership on Carbon Sequestration will inject two million tons of CO_2 over four years from a natural CO_2 deposit into Jurassic-age sandstone. This project will cost $88.8 million (the DOE share, subject to annual appropriations, is $65.4 million). (Storage)

Carbon Capture and Storage

- The Plains CO_2 Reduction Partnership will inject one million tons of CO_2 (from coal-based plants and gas processing plants) per year into a deep carbonate saline formation in the Williston Basin in North Dakota. It will also inject 1.8 million tons of CO_2 into a deep saline sandstone formation in the Alberta Basin in British Columbia. Together, these projects will cost $135.6 million (the DOE share, subject to annual appropriations, is $67.0 million). (Storage)
- The Midwest Geological Sequestration Consortium will inject one million tons of CO_2 from an ethanol plant over three years into the Mount Simon sandstone formation in central Illinois. This project will cost $84.3 million (the DOE share, subject to annual appropriations, is $66.7 million). (Storage)
- The Midwest Regional Carbon Sequestration Partnership will inject one million tons of CO^2 from an ethanol plant into the Mount Simon sandstone formation in Ohio. This project will cost $92.8 million (the DOE share, subject to annual appropriation, is $61.1 million). (Storage)
- The Southeast Regional Carbon Sequestration Partnership will inject one million tons of CO_2 from natural deposits per year into the Tuscaloosa Massive Sandstone in Mississippi and Louisiana. Phase Two of this test will involve constructing a post-combustion CO_2 capture plant, below which CO_2 will be inject for up to six years. This project will cost $93.7 million (the DOE share, subject to annual appropriations, is $64.9 million). (Storage and eventually coal CCS)



Saline aquifers in the U.S. being studied by the DOE Regional Carbon Sequestration Partnerships for potential CO_2 storage.

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International

- Tjeldbergodden (Norway). Shell and Statoil will store 2.5 million tons of CO_2 per year, beginning 2010-2011, captured from a 700MW gas-fired power plant. (CCS)
- ZeroGen (Australia). An IGCC power plant (120MW) at which CO_2 will be captured and stored in a saline formation beginning in 2012. (Coal CCS)
- Gorgon (Australia). CO_2 captured from gas production will be injected into deep formations off the coast beginning in 2011. (CCS)
- Progressive Energy (UK). An IGCC plant (800MW) at which CO_2 will be captured for EOR beginning in 2011. (Capture from coal for EOR)
- Powerfuel (UK). An IGCC plant (900MW) that will use CCS technology after 2012.
- E.On (UK). An IGCC plant (450MW) that will add CCS after 2012. (Coal CCS)
- RWE (Germany). IGCC technology (400-450MW) at which CO_2 will be captured and stored in a saline formation or gas reservoir beginning in 2014. (Coal CCS)
- Hydrogen Energy-BP and Rio Tinto (Australia). A hydrogen-fueled power plant (500MW) at which CO_2 would be captured and stored under the seabed, likely beginning around 2014. (CCS)
- E.On (UK). Two supercritical units (800MW each) at a power station at which CCS will begin in 2015. (Coal CCS)
- RWE nPower (UK). Supercritical technology and post-combustion CCS (1000MW) will be used beginning in 2016). (Coal CCS)
- GreenGen (China). An IGCC plant (650MW) will have CCS in 2018. (Peabody is a partner in this project.) (Coal CCS)
- Vattenfall (Germany). A large-scale commercial plant (1000MW) will have CCS in 2020. (Coal CCS)