Carbon Sequestration: A Local Solution with Global Implications

Appendices

Appendix A: Sequestration and the Global Carbon Cycle

Appendix A provides additional information on carbon sequestration. In addition, to better illustrate how sequestration can play a role in slowing the growth of carbon dioxide (CO_2) emissions, information on the global carbon cycle is included.

Types of Sequestration

Sequestration encompasses all forms of carbon storage. Oceans, plants, and underground geologic formations all function as significant reservoirs for carbon dioxide. They all exchange CO_2 with the atmosphere. These reservoirs will act as carbon sinks if more carbon is flowing into them (or stored in them) than flows out of them.

Three primary categories describe the primary types of sequestration.

Terrestrial: Terrestrial sequestration is a form of indirect sequestration whereby ecosystems (*e.g.*, forests, agricultural lands, and wetlands) are maintained, enhanced, or manipulated to increase their ability to store carbon.

Geologic: There are several types of geologic formations in which CO_2 can be stored, including oil reservoirs, gas reservoirs, unmineable coal seams, saline formations, and shale formations with high organic content. These formations have provided natural storage for crude oil, natural gas, brine, and CO_2 over millions of years. Geologic sequestration techniques would take advantage of these natural storage capacities.

Ocean: Oceans absorb, release, and store large amounts of CO_2 from the atmosphere. There are two approaches for oceanic carbon sequestration which take advantage of the oceans' natural processes. One approach is to enhance the productivity of ocean biological systems (e.g., algae) through fertilization. Another approach is to inject CO_2 into the deep ocean.

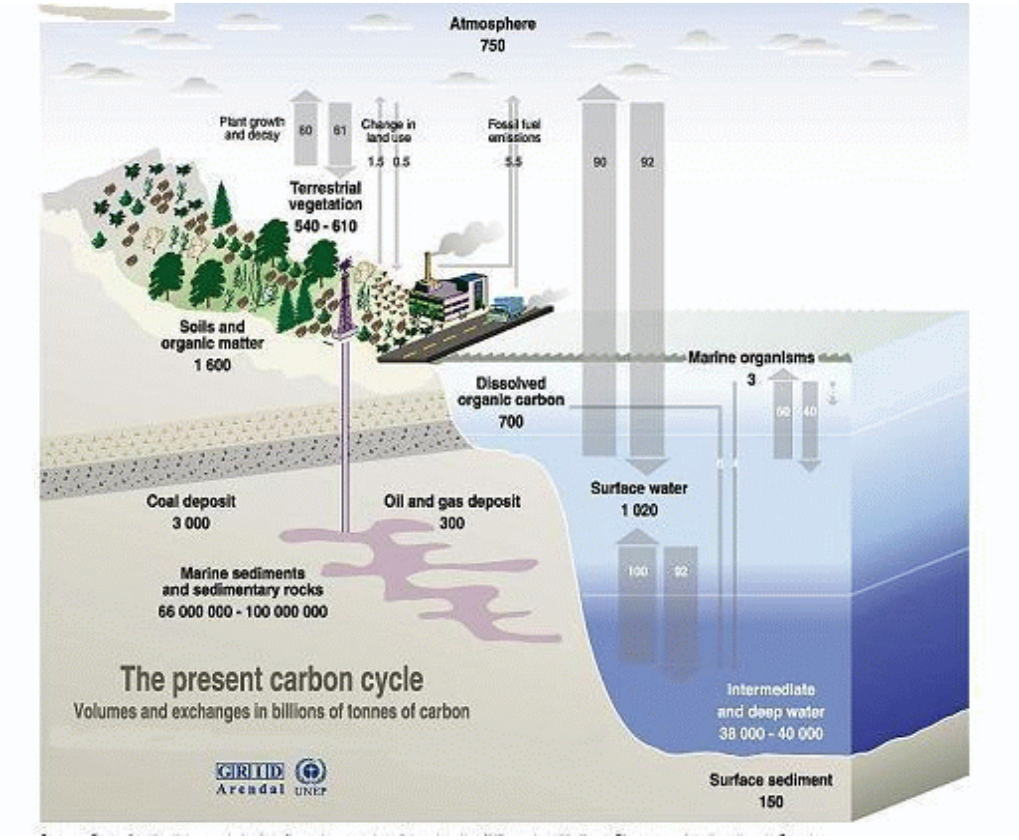
The Global Carbon Cycle

The global carbon cycle describes the Earth's four carbon reservoirs and the exchanges (or flows) of carbon between these reservoirs. These flows are accomplished by various chemical, physical, geological, and biological processes. The four reservoirs are the atmosphere, terrestrial biosphere (including freshwater systems), oceans and sediments (includes fossil fuels). Figure 1 illustrates the global carbon cycle. The large arrows represent natural flows of carbon. The small arrows represent anthropogenic contributions to the carbon cycle. The numbers not in arrows represent carbon sinks.

The flow of carbon is measured in billions of metric tons (gigatons). Annually, plants "give" about 60 billion metric tons of carbon dioxide to the atmosphere through respiration and "take" 61 billion metric tons of carbon dioxide that is turned into new plant biomass through photosynthesis.

These carbon sinks are immense. The atmosphere contains about 750 gigatons of CO_2, the ground contains about 2,190 gigatons of CO_2, and the oceans contain about 40,000 gigatons of CO_2.

Figure 1: Carbon Sinks and Flows



Source: Center for Climatic Research. Institute for Environmental Studies. University of Wisconsin, Madison.

Appendix B: Carbon Trading and Sequestration by Companies and U.S. States

The following tables provide information on carbon trading and banking activities that the private and public in the U.S. have undertaken.

A. Industry Carbon Trading Activities

Company	Carbon Trading and Sequestration Activities
Partnership for Climate Action	The Partnership for Climate Action is a coalition of seven corporations and the nonprofit Environmental Defense. The coalition promotes market-based approaches to reducing greenhouse gas (GHG) emissions. Among other things, corporations have agreed to inventory their emissions and use methods (including sequestration and trading) to attain GHG reduction goals. http://www.pca-online.org/
BP Amoco	BP Amoco set a self-imposed target of reducing internal GHG emissions to 10 percent below 1990 levels by 2010. The company set up an internal credit-trading system that spans all of the company's business operations. Each of BP's 150 business units receives a target. Managers are held as accountable for meeting those targets as they are for meeting financial targets. In addition, costs and revenues from CO_2 transactions will appear on every business unit's financial records and impact on their bottom line financial performance. The average price of CO_2 in the internal trades has been approximately $7.60 per metric ton. http://www.bp.com/
Shell International	Shell International has chosen an approach similar to BP Amoco's. In 2000, it launched a cap-and-trade system called the Shell Tradeable Emissions Permits System. Branches of the company, which participate voluntarily, are allocated tradeable permits. Permits were to be traded between 2000 and 2002 to attain a 2 percent emissions reduction from 1998 baseline levels. http://www.pewclimate.org/what_s_being_done/in_the_business_community/trading.cfm
TXU Energy	TXU Energy, an electricity and natural gas supplier, owns three active coal mines in Texas. Since 1973, the company has been reclaiming its mine lands through reforestation. To date, the company has planted approximately 18 million trees on 25,000 acres. TXU is currently considering reforesting a 70-acre abandoned mine land site to generate carbon sequestration credits. http://www.txucorp.com/envcom/reports/na/reply.asp
Chicago Climate Exchange	CCX is a voluntary pilot trading market and self-regulatory exchange. CCX members have made a voluntary, legally binding commitment to reduce their emissions of greenhouse gases by four percent below the average of their 1998-2001 baseline by 2006. http://www.chicagoclimatex.com/

B. State Carbon Banking Programs and Carbon Inventories

State	Carbon Banking and Inventory Activities
California	The State of California has a Climate Action Registry. This public/private partnership serves as a voluntary greenhouse gas registry to protect, encourage, and promote early actions to reduce GHG emissions. http://www.climateregistry.org
Massachusetts	Massachusetts has developed a multi-pollutant strategy, including CO_2 reductions, for addressing air quality problems associated with older power plants. The state established a multi-pollutant cap that required each of six in-state power plants to reduce emission levels. The target for CO_2 is a 10 percent reduction from 1997-1999 levels. The state gives each plant discretion in choosing the method to achieve the reductions, with the reduction deadline dependent on the method chosen. http://www.mass.gov/envir/Sustainable/initiatives/initiatives_GHG.htm
Nebraska	Dominated by agriculture, Nebraska has explored the possibilities for sequestering carbon on farmland. Nebraska passed legislation establishing a Carbon Sequestration Advisory Committee to develop pilot projects to explore the creation of carbon credits and establishment of carbon trading. http://www.carbon.unl.edu/carbabou.htm
New Jersey	New Jersey was the first state to establish an official GHG reduction goal and to involve all relevant sectors in reaching that goal. In 1998, New Jersey set a target of reducing the state's greenhouse gas emissions to 3.5 percent below 1990 levels by 2005. Meeting that target will require reductions in many sectors including natural resource conservation. The goal was formally incorporated into the state Department of Environmental Protection's Strategic Plan and Performance Partnership Agreement with EPA. http://www.state.nj.us/dep/dsr/gcc/gcc.htm
Oregon	Oregon created North America's first formal standard for CO_2 releases from new power plants. This standard requires any new or expanded power plant in the state to reduce CO_2 releases 17 percent below the most efficient natural gas-fired plant currently in operation in the U.S. The state allows new power-generating plants flexibility in how they meet this standard. They can use new technologies or they can purchase CO_2 offsets through carbon mitigation projects, such as reforestation. http://www.epa.gov/globalwarming/greenhouse/greenhouse2/oregon.html
Wisconsin	Wisconsin began requiring large power plants to report CO_2 releases in May 1993 as part of its emissions inventory reporting regulation. The reporting requirement is mandatory for all facilities releasing more than 100,000 tons of CO_2 annually. This is anticipated to help the development of a registry that will allow any Wisconsin firm to report reductions of CO_2 and other greenhouse gases. These reductions would be registered by the state Department of Natural Resources (DNR) so that facilities receive credit in any future federal or state GHG regulatory program. http://dnr.wi.gov/org/aw/air/registry/index.html

Appendix C: Agencies and Organizations Involved in Abandoned Mine Land Reforestation and Carbon Sequestration Projects

This section provides information on organizations involved in carbon sequestration and reforestation of degraded lands, including former mine lands, in the U.S.

Federal Agency Activities:

Department of Energy (DOE) Office of Fossil Energy
http://www.fe.doe.gov/programs/sequestration/
DOE is funding projects to demonstrate the efficacy of reforestation and terrestrial sequestration. Projects are specifically exploring:

- the sequestration of carbon in terrestrial ecosystems, including how to increase carbon sequestration in forests;
- the degree to which carbon sequestration on reclaimed lands can offset fossil fuel emissions and provide supplemental income to landowners (either through timber or carbon credits); and
- the efficacy of market-based approaches for reclaiming abandoned mine lands. Market-based approaches seek to develop multiple ecological asset values on abandoned mine land sites, including water quality and habitat credits.

Office of Surface Mining (OSM)
http://www.mcrcc.osmre.gov/tree/
OSM has entered into a memorandum of understanding (MOU) with the Department of Energy. This MOU establishes a framework for cooperation between OSM and DOE's Office of Fossil Energy to promote a market-based approach to reclaiming abandoned mine lands through reforestation. OSM's Mid-Continent Regional Coordinating Center has also developed a Reforestation Initiative to examine methods to promote post-mining land use involving reforestation on active and abandoned surface coal mines.

Tennessee Valley Authority (TVA)
http://www.tva.com/environment/air/ontheair/greenhouse_gas.htm
TVA is working with the Electric Power Research Institute on an economic evaluation of carbon sequestration. One research project is an examination of the effects of using by-products from coal-fired plants as a soil amendment for reforested mine lands.

U. S. Department of Agriculture, U.S. Forest Service (USFS)
http://www.fs.fed.us/ne/global/index.html
The USFS is undertaking a Northern Global Change Research Program. The program has produced a U.S. Carbon Budget and has published a book on the potential of U.S. forest soils to sequester carbon and offset the effects of greenhouse gases.

State Reforestation Activities:

Alabama
http://www.mcrcc.osmre.gov/PDF/Forums/MarketBasedReforest/3-2.pdf
Alabama has been reforesting abandoned mine lands for over 25 years. Alabama's program is responsible for planting more trees on abandoned mine lands than any other state's program.

Colorado
http://mining.state.co.us/abanondonedmines/inactivemine.html
Colorado's Division of Minerals and Geology has been working since 1980 to safeguard and reclaim abandoned mines in the state. In particular it has focused recently on reforesting abandoned hard rock mines.

Indiana
http://www.mcrcc.osmre.gov/tree/state_guidelines.htm
http://www.in.gov/dnr/reclamation/
Indiana collaborated with Ohio and the U.S. Forest Service to research the survivability of trees planted in abandoned mine sites. Indiana has also developed guidelines and recommendations for reforestation of former mining sites.

Kentucky
http://www.mcrcc.osmre.gov/tree/state_guidelines.htm
http://www.surfacemining.ky.gov/aml/
Kentucky is using fly-ash from coal-fired power plants as soil amendments on reforested abandoned mine lands. Kentucky's Department of Surface Mining Reclamation and Enforcement has also issued an advisory memorandum on the best reclamation techniques and forestry practices.

Montana
http://ces.iisc.ernet.in/hpg/envis/doc98html/confcar99626.html
Montana established the Montana Carbon Offset Coalition, a quasi-public organization which offers landowners funding for the planting of treas in areas where they do not naturally regenerate. In return, the landowners are required to sign 100-year contracts that transfer control of the carbon offsets to a private entity called Montana Watershed, Inc.

Ohio
http://www.mcrcc.osmre.gov/tree/Success/OH_success.htm
Ohio's Department of Natural Resources has planted over 4.5 million trees on more than 4,000 acres of abandoned mine lands since the early 1980s. As a result of research funded by the Office of Surface Mining, approximately 70 percent of the trees the state has planted have been inoculated with a fungus that enables trees to tolerate acidic soil, drought conditions, and high mine spoil temperatures. This treatment has resulted in a tree survival rate of 80 percent.

Oklahoma
http://www.mines.state.ok.us/
The Oklahoma Department of Mines regulates the placement of coal combustion by-products, including fly ash and cement kiln dust, at Oklahoma mine sites for reclamation purposes.

Pennsylvania
http://www.dep.state.pa.us/dep/deputate/minres/reclaimpa/reclaimpahome.htm
Pennsylvania's Department of Environmental Protection has developed a program to encourage reforestation of mined lands. Since 1980, the coal industry in Pennsylvania has planted an estimated 67 million tree seedlings on abandoned mine lands. During that same period, three million additional trees were planted by other organizations on abandoned mine lands in Pennsylvania under the Surface Mining Control and Reclamation Act.

Virginia
http://www.mme.state.va.us/Dmr/home.dmr.html
Virginia's Division of Mined Land Reclamation (DMLR) has issued guidance for forestry reclamation practices for post-mining land uses. The Virginia Department of Mines, Minerals and Energy, DMLR, The Nature Conservancy, Virginia Tech, and the U. S. Office of Surface Mining have partnered to develop incentives that will promote economically viable and environmentally preferable remining operations as a means to reclaim abandoned mine land sites.

Academic Research and Projects:

Massachusetts Institute of Technology (MIT)
http://sequestration.mit.edu/CSI/index.html
Through its Carbon Capture and Sequestration Technology Program, MIT has launched a Carbon Sequestration Initiative to provide an objective source of information and assessment about carbon sequestration.

Ohio State University
http://www.fe.doe.gov/programs/projectdatabase/stateprofiles/2004/feprojects_ohio.html
Ohio State is conducting research to assess the carbon sequestration potential of reclaimed mine lands and to determine the degree to which the sequestration can offset fossil fuel emissions and provide income to landowners through the trading of carbon credits.

Stephen F. Austin State University (SFASU)
http://www.mcrcc.osmre.gov/PDF/Forums/MarketBasedReforest/1-7.prn.pdf.
SFASU is researching unreclaimed mine lands in the Appalachian region to determine how to increase carbon sequestration in forests while also increasing forest yields and other desirable ecosystem goods and services.

Virginia Polytechnic Institute and State University (Virginia Tech)
http://www.ornl.gov/sci/fossil/Publications/ANNUAL-2003/feaa049.pdf
http://sudan.cses.vt.edu/prp/Programs02-03.html#soils
Faculty members at Virginia Tech have explored the potential for enhancing sequestration and reclamation of degraded lands through use of coal combustion by-products. A Virginia Tech team is also investigating three 75- to 90-acre sites to determine the carbon sequestration potential of sustainable forests planted on mined lands in Appalachia for production of wood, renewable energy, carbon sequestration, and other ecosystem services.

West Virginia University
http://www.cafcs.wvu.edu/plsc/soilscience/Skousen/research.html
Faculty members with the West Virginia Water Research Institute are researching reforestation and carbon sequestration on abandoned mine lands in the state. Recent and ongoing projects include research on tree growth on reclaimed mountaintop removal sites and timber productivity and mine soil development for a white pine plantation.

Non Governmental Organization Activities:

Worldwatch Institute
http://www.worldwatch.org/press/news/1998/10/14/
Worldwatch has published several papers that detail strategies for stabilizing the levels of atmospheric gases and increasing reforestation efforts. For example, the Strategy to Slow Global Warming calls for projects that will lead to net reforestation worldwide.

The Nature Conservancy (TNC)
http://www.mcrcc.osmre.gov/PDF/Forums/MarketBasedReforest/2-2.prn.pdf.prn.pdf
TNC has signed a memorandum of understanding with Virginia's Division of Mined Land Reclamation to promote carbon sequestration by encouraging the planting of trees on mined lands.

World Resources Institute (WRI)
http://pubs.wri.org/pubs_description.cfm?PubID=2991
WRI has a practice area that focuses on emerging markets for storing carbon in forests and trading generated carbon credits.

Private Sector Activities:

Alcoa
http://www.alcoa.com/global/en/environment/overview.asp
In 2003, Alcoa fulfilled a goal of planting one million trees around the world. The company's tree planting programs have resulted in the sequestration of thousands of pounds of CO_2 each year.

Allegheny Energy
http://www.mcrcc.osmre.gov/PDF/Forums/MarketBasedReforest/1-3.pdf
Allegheny Energy has initiated several abandoned mine land reforestation and carbon sequestration projects in Pennsylvania and West Virginia. The company has undertaken these activities both for public relations benefits and to test the feasibility of reclaiming and reforesting abandoned mine lands for carbon credits.

American Electric Power (AEP)
http://www.eere.energy.gov/climatechallenge/progressreport/secx3.htm
AEP has committed to planting up to 15 million trees on company-owned lands. Over the 30-year project period, AEP estimates the trees will sequester about 1.63 million tons of CO_2.

Cooperative Power Association (CPA)
http://www.eere.energy.gov/climatechallenge/progressreport/secx3.htm
CPA began planting trees at its Coal Creek Station generating facility in 1992 with the goals of offsetting carbon dioxide emissions, minimizing dust emissions, and providing wildlife habitat.

Entergy
http://www.entergy.com/corp/she/
Entergy has launched several initiatives to improve the company's carbon sequestration efforts. For instance it partnered with the Conservation Fund and Environmental Synergy, to reforest more than 600 acres of hardwood trees in northwestern Louisiana. The company then transferred the property to the U.S. Fish and Wildlife Service.

Texas Utilities (TXU)
http://www.mcrcc.osmre.gov/tree/Success/TXU_reforestation.htm
TXU has been reclaiming its previously mined lands through reforestation since 1973. The utility is managing its reforested property for timber harvesting and wildlife habitat.

Other Organizations:

Electric Power Research Institute (EPRI)
http://www.epri.com/globalclimate/
EPRI is an energy research consortium that collaborates with companies, universities, and other organizations on a wide range of global climate change projects, including several focused on carbon sequestration through reforestation.

UtiliTree
http://carbonsequestration.us/News&Projects/htm/EEI-utilitree.pdf
UtiliTree is a non-profit company comprising 41 utilities that are sponsoring a range of projects to manage greenhouses gases, especially carbon dioxide. UtiliTree projects include a mix of rural tree planting, forest preservation, forest management, and research at domestic and international sites.

References and Information Sources

In addition to the information included in the Appendices, the documents and resources listed below have been used in developing this paper. This list is not a complete record of all the works and sources that have been consulted in writing this document. Rather, the sources below represent a range of information that have helped inform the shape and content of this paper.

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