



Carbon Sequestration through Reforestation

A LOCAL SOLUTION WITH GLOBAL IMPLICATIONS



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Carbon Sequestration through Reforestation - A Local Solution with Global Implications

This report describes the opportunities available to mine land owners, companies and other interested parties to utilize reforestation to clean up and restore former and abandoned mine lands (AMLs) and generate carbon sequestration credits. It also examines the requirements and limitations for pursuing AML reforestation and carbon sequestration projects and how reforestation projects can fit into emerging markets for carbon trading. Carbon sequestration may be applicable at only a small percentage of AMLs throughout the United States. However, given the large number of AMLs, that small percentage may represent thousands of actual sites.

Introduction

According to the U.S. General Accounting Office, there are between 80,000 and 250,000 abandoned mine lands (AMLs) across the United States. AMLs include abandoned mines and the areas adjacent to or affected by the mines. Because of safety or environmental concerns, the majority of these sites have never been considered for any type of reuse and have remained idle.

What is an AML

Abandoned Mine Lands (AMLs) are those lands, waters and surrounding watersheds where extraction, beneficiation or processing of ores and minerals has occurred. These lands also include areas where mining or processing activity is temporarily inactive.

Federal and state agencies, industry, and other organizations are pursuing proactive approaches to reducing atmospheric carbon, including carbon sequestration projects. Mine reclamation through reforestation can provide major financial and environmental benefits. Financial benefits include revenues from timber and non-timber products, fee-based recreational uses and tax incentives. Environmental benefits include storage of carbon in trees, wildlife habitat enhancement and air and water quality improvement.

Efforts to increase terrestrial carbon sequestration are based on the premise that reforestation adds to the planet's net carbon storage and helps moderate global warming by slowing the growth of carbon emissions in the atmosphere. In a carbon market, each ton of carbon sequestered is called a carbon credit. Using sequestration, companies can buy or generate these credits, which are then sold or traded by companies to offset their own carbon dioxide (CO₂) emissions.

Most recent examples of reforestation and sequestration have come from coal mining sites in the eastern United States and the Pacific Northwest. However, reforestation can also be relevant to former mining sites disturbed by hard-rock mining. For example, in the 2000s, the state of Colorado supported research related to revegetation and reforestation activities on abandoned hard rock mines.

In addition, recent examples of mine land reforestation suggest that such projects will be more successful in areas with sufficient moisture and where forests existed prior to mining activities. Because of low tree survival rates and high costs to plant replacement trees, arid former mining sites may not be suitable candidates for reforestation and sequestration projects.



Reclamation at this site in Washington state (with Mount Rainier in the background) includes reforestation that restores the pre-mining forestry land use. (source: Office of Surface Mining)

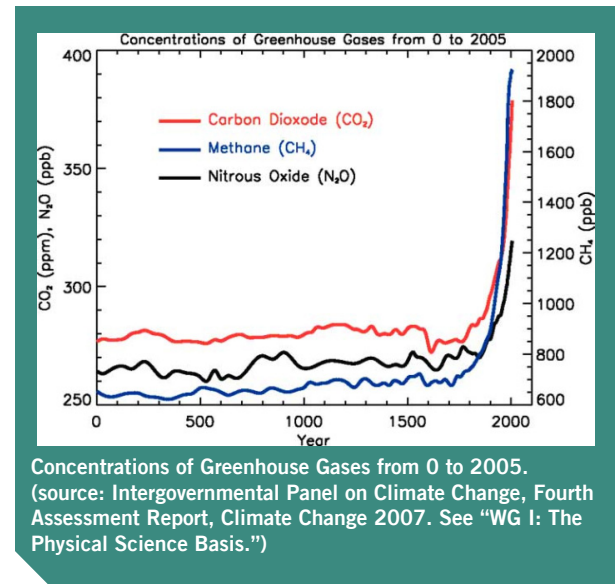
What is Carbon Sequestration?

Carbon sequestration removes carbon, in the form of CO₂, either directly from the atmosphere or at the conclusion of combustion and industrial processes. One type of sequestration is the long-term storage of carbon in trees and plants (the terrestrial biosphere), commonly referred to as terrestrial sequestration. CO₂ removed from the atmosphere is either stored in growing plants in the form of biomass or absorbed by oceans. Sequestering carbon helps to reduce or slow the buildup of CO₂ concentrations in the atmosphere. For organizations interested in generating carbon credits, many former mine lands provide the land necessary to plant trees. Appendix A provides additional information on carbon sequestration and the role that terrestrial sequestration plays in reducing or slowing the growth of CO₂ emissions.

Why is it important

Before the Industrial Revolution, the concentration of greenhouse gases (GHGs) in the atmosphere remained relatively constant. Except for slow changes on a geological time scale, the absorption and release of carbon was kept in balance. During that time, changes in biomass and soil organic carbon¹ were the main sources of fluctuation in atmospheric levels of carbon.

By clearing forests and burning fossil fuels more rapidly than the carbon can be sequestered, industrialization may have altered this equilibrium. Currently, human activity is directly or indirectly responsible for the release of six to seven billion metric tons of carbon annually. Since before the Industrial Revolution, CO₂ concentrations in the atmosphere have increased from 280 parts per million (ppm) to nearly 380 ppm in 2005. CO₂ emissions from energy use are projected to increase between 40 to 110 percent between 2000 and 2030.



Increases in atmospheric CO₂ concentration may be generating increases in average global temperature and other climate change impacts. Although some of the effects of increased CO₂ levels on the global climate are uncertain, most scientists agree that doubling atmospheric CO₂ concentrations may cause serious environmental consequences. Rising global temperatures could raise sea levels, change precipitation patterns and affect both weather and climate conditions.

In light of these potential impacts, strategies to help reverse these emission trends are increasing in importance. Many state, national and international governments are taking steps to more effectively manage and slow the growth of their carbon emissions. For many of these governments, terrestrial sequestration is part of a portfolio of approaches to inventory and reduce GHG emissions. Their experience is demonstrating that establishing new forests can offer cost-effective management options for offsetting carbon emissions, particularly in the near future.²

¹ Soil organic carbon is carbon residue retained by the soil in humus form. It improves soil structure and soil fertility.

Carbon Sequestration through Reforestation: What are the Opportunities for AMLs?

Numerous AMLs are barren or only marginally reclaimed, providing significant opportunities to sequester CO₂ emissions and generate other environmental benefits. The Appalachian coal region alone has nearly one million acres of AMLs which could benefit from reclamation and reforestation efforts. Reforesting former mine lands can help increase the total number of reclaimed mine sites and improve the quality of the site reclamation. If storing carbon in forests is cheaper than paying a carbon tax or complying with government regulations, companies may choose to grow their own “carbon storing” forests or invest in forests grown by others as a means to sequester carbon or offset emissions. Given their large number of underutilized acres, former mine lands offer potentially significant opportunities for mine land owners, companies and other interested parties to invest in reforestation and accrue benefits from those activities.

State Mine Reclamation Guidelines that Encourage Wildlife Habitat

Some states have established mine reclamation guidelines to encourage the enhancement of fish and wildlife habitat. Kentucky's AML reclamation policies discourage excessive grading and shaping of the land and encourage planting of native vegetation, including ground covers, that have high food value for wildlife and are compatible with tree growth.

What are the Benefits of AML Reforestation for Land Owners and Companies?

Environmental Benefits

Air Quality

Improvements in air quality generated by reforestation extend beyond the sequestration of CO₂. Research has shown that reforestation benefits air quality in other ways. For example, the leaf and needle surfaces of trees remove air pollutants such as nitrogen oxides, ammonia and sulfur dioxide. Trees also play a role in intercepting and filtering particulate matter in the air. A study of Chicago's air quality concluded that the city's trees alone produced \$9.2 million (1994 dollars) worth of air quality improvements in just one year.

Wildlife Habitat

Reforestation of land after it has been disturbed by surface mining can create valuable wildlife habitat. In turn, wildlife habitat generates forest litter, which is an important part of the food chain and enriches the soil. A forest's tree canopy moderates the temperatures of rivers and streams, which aids the survival of aquatic species.

Providing habitat for endangered and threatened species is another potential benefit. In some cases, there are government incentives for landowners who restore or create habitat for endangered species. For example, the state of Texas has partnered with the U.S. Fish and Wildlife Service to reimburse landowners for habitat restoration. In this program, landowners can be reimbursed for up to 75 percent of their costs for habitat improvements.³

Recreational Benefits

For local communities, reforested land may provide passive recreational opportunities, such as hunting, hiking and bird watching.

Erosion and Water Quality

Reforestation can help remediate former mine lands by improving water quality. Tree roots stabilize mine land soil, which is susceptible to erosion. By stabilizing the soil, trees prevent sediment and nutrients from washing into nearby streams and rivers.

² According to an expert on the economics of terrestrial carbon sequestration, “Large-scale forest-based carbon sequestration can be a cost-effective tool that should be considered seriously by policy makers.” See Stavins, Robert. 2009. “What Role for U.S. Carbon Sequestration?” Harvard University. John F. Kennedy School of Government. Belfer Center for Science and International Affairs. <http://belfercenter.ksg.harvard.edu/analysis/stavins/?p=225>.

³ See Texas Parks and Wildlife Department. Landowner Incentive Program. <http://www.tpwd.state.tx.us/landwater/land/private/lip/>.

⁴ See Phytoremediation, Jerald L. Schnoor, http://www.clu-in.org/download/toolkit/phyto_e.pdf.

Phytoremediation

Revegetating former mining sites can provide phytoremediation services. Phytoremediation is the “use of vegetation for on-site treatment of contaminated soils, sediments, and water.”⁴ Phytoremediation is less costly than many remediation approaches. However, the process requires considerable time and should be employed at sites where remediation can occur over a long period of time. For mining sites, phytoremediation should generally be viewed as part of a treatment train, and is generally a “polishing” step.

It is important to recognize that planting trees for carbon sequestration does not equate to phytoremediation. Depending on the type of trees selected, reforesting an AML to generate carbon credits may do nothing to extract or remediate any existing contamination at a site. However, some tree types may serve to phytostabilize the soluble metals in the ground water or soil as well as creating a more suitable growth environment on a formerly uninhabitable mine site. In such cases, there may be opportunities to jointly pursue carbon sequestration and phytoremediation.

Financial Benefits - Local Economic Benefits

Recreational Revenue

By creating or enhancing hunting, skiing, fishing, biking and other fee-based outdoor opportunities, reforestation may expand revenue-earning potential for landowners.

Timber Harvest Benefits

Several studies have shown that reclaimed mine lands can generate productive forests, if appropriate forestry practices are used. Researchers from Virginia Tech studied forests on reclaimed mine sites in Appalachia and the Midwest and found that these sites could equal or exceed the productivity of unmined lands. The most productive sites had commercial timber values averaging between \$6,000 and \$8,000 per acre, a figure comparable to timber values on undisturbed sites. The research studied conifers and hardwoods and concluded that the timber value at reclaimed mine sites would be similar to that of non-mined sites for either type of tree.⁵

Secondary economic benefits from reforestation include job creation in forest management and increased property taxes on reforested land.

Non-Timber Harvests

Landowners may generate income by harvesting medicinal, ornamental, or edible plants that grow in forested areas.

Tax Incentives

States and the federal government offer tax deductions or credits for reforesting land. For example, Mississippi allows landowners to recover up to half of their investment in reforestation through the Mississippi Reforestation Tax Credit. (See Appendix C for other state programs.) The federal government also offers a tax credit for reforestation projects; individuals can deduct investments in reforestation projects from their federal income taxes.

Federal Tax Incentives for Reforestation

Taxpayers must generally capitalize direct costs incurred in reforestation. However the federal Reforestation Amortization and Tax Credit allows taxpayers to deduct a limited amount of qualifying reforestation costs for each qualified timber property. To qualify, the property must be for the commercial production of timber and located in the United States. The property must be at least one acre in size and planted with tree seedlings in the manner normally used in forestation or reforestation.

Landowners can deduct up to \$10,000 of qualifying reforestation costs paid or incurred after October 22, 2004, for each qualified timber property. Any remaining costs can be amortized over an 84-month period.

Qualifying costs include: site preparation costs, seeds and seedlings costs, labor, tools expenses, depreciation on equipment used in planting and seeding and costs incurred in planting to replace seedlings.

Qualified timber property does not include property that has been planted with shelter belts or ornamental trees, such as Christmas trees.

Information about the tax credit can be found in the IRS Farmer's Tax Guide: <http://www.irs.gov/pub/irs-pdf/p225.pdf>

⁵ A brief discussion of the uncertain impacts of forest management (thinning and harvesting timber) on carbon sequestration appears on p. 13.

Financial Benefits - Company Benefits

Carbon Credits

Fossil fuels are consumed in large volumes for power generation, industrial processes and transportation. As large emitters of CO₂, companies such as electric utilities understand they may need to reduce GHG emissions. Recognizing this outcome, many utilities are participating in GHG reduction programs. Because market-based emissions trading can offer a low-cost method for managing emissions, companies are beginning to link sequestration projects with the banking and trading of carbon credits.

These carbon credits provide ownership or “rental” rights to the gaseous carbon sequestered in a forest. A company may then buy, sell, or apply the credits to offset its own emissions. Typically, ownership rights pertain to the carbon sequestered in trees rather than the trees themselves. Through this market-based approach, companies can meet their own emission reduction requirements and excess credits can be sold to other companies that find it more cost-effective to purchase credits than reduce their own emissions.



Waste Recycling

For many sites, reclamation and reforestation offer an opportunity for beneficial use of coal-combustion products (CCPs), such as fly ash. Coal-fired power plants generate over 118 million tons of fly ash, flue gas desulfurization solids, and other byproducts each year. Only 31 percent of this ash is put to use. The remainder ends up in landfills.

Other Environmental Credits

Ecological assets are tradable credits that reflect the economic value that has been assigned to an ecosystem “service.” Allegheny Power provides an example of how reforestation and the development of ecological assets can generate tax benefits. Instead of selling 20,000 acres in West Virginia to private developers, Allegheny Power sold the property to the U.S. Fish and Wildlife Service for conservation and habitat purposes. By appraising the ecological asset value of the land before the sale, Allegheny received tax benefits based on the difference between the sale price and the land’s appraised value.

Fly ash produced during the combustion process is high in pH (alkaline) and can be used to buffer AMD in highly acidic soils found at mine sites. The ash neutralizes the soil and provides plant-available nutrients needed for new vegetation and to enhance tree growth. Use of fly ash can provide companies with secondary benefits, including lower disposal costs and less landfill space needed for fly ash disposal. The chemical composition of fly ash varies, depending on the type of coal burned, the size of the ash and the efficiency of smokestack scrubbers. Fly ash is primarily composed of relatively insoluble silicon, aluminum and iron oxides, but it can also contain soluble metals and metal oxides. When exposed to water, the metals in fly ash could leach into the environment, polluting surface or ground water. As a result, some fly ash may not be suitable for all former mining sites.

Other Environmental Credits

In addition to carbon credits, reforestation projects on AMLs can generate complementary ecological assets, including water quality trading credits, wetland banks and endangered species habitat credits. Credits can be sold directly or “banked” for future use. While these credits have ecological and societal values, they also have monetary value for companies.

Case Study #1: Allegheny Energy's Reforestation and Sequestration Pilot

In 2001, Allegheny Energy (Allegheny), in partnership with the U.S. Office of Surface Mining, the U.S. Department of Energy, the Pennsylvania Department of Environmental Protection, and several local conservation groups, undertook a reforestation and sequestration pilot project on previously mined land in western Pennsylvania. Allegheny's objectives for this Limestone Run project were threefold:

- Test the effectiveness of using fly ash from a local coal-fired power station as a soil amendment for new vegetation.
- Test the technical feasibility of reforesting AMLs for carbon credits.
- Improve wildlife habitat and water quality.

In addition, Allegheny believed the project could foster good public relations with the local community and give the company an opportunity to show its commitment to environmental restoration activities. Company representatives also felt that by engaging local community members in the project's outcomes, the company was able to build partnerships with stakeholders who had been less inclined to support the project.

Site Selection

Allegheny focused its attention on sites close to one of the company's coal-fired power stations. This limited transportation costs for shipping fly ash to the selected site. AMLs are prevalent throughout the Appalachian region, so there were many sites from which to choose. However, the company still faced hurdles. Allegheny sought a site with heavy equipment access. Having fallen into disuse, most sites had poor access. In addition, many sites had grass cover in place that needed to be removed prior to planting. To avoid the problem of dealing with additional site owners, Allegheny chose a site already owned by the company.

The selected site, mined in the late 1970s, had been reclaimed and covered with grass pursuant to the requirements of the Surface Mining Control and Reclamation Act. The site's soil was similar to soils found on other mine lands that would be considered for reforestation projects. In addition, although the site had been reclaimed, it remained underutilized and would benefit from reforestation.

Role of Partnerships

Allegheny decided to develop partnerships with local organizations also interested in reforesting AMLs. To improve chances of a successful project, the company encouraged partners to assume some level of responsibility for the project. Allegheny distributed responsibilities for project elements across stakeholders. By the project's conclusion, the company felt that its partners had helped to streamline project development and implementation.

Pilot Implementation

The project replanted 17 acres, with project partners helping with some planting. Fifteen acres were planted with pine and spruce seedlings (over 7,000 trees in total) and two acres were planted with warm season grasses. Fruit and nut trees were planted around the site perimeter for wildlife.

The entire plot was cleared with a brush hog before planting began. Because the land had already been reclaimed, the soil was compacted and needed to be made more suitable for tree growth. Allegheny used heavy-duty farm equipment to prepare the soil for planting. The company had a consultant take soil and fly ash samples to determine the amount of fly ash needed to enhance tree growth. The company used a local contractor experienced in plowing and disking reclaimed sites. Allegheny spent approximately \$10,000 to treat the site's soil and plant the pines.

The site will need to be maintained for weed control for several years until the trees are established. Carbon sequestration rates will be assessed for evergreens starting in the fifth year after planting. The Pennsylvania Department of Environmental Protection calculated that at maturity, the trees at Limestone Run could remove 64 tons of CO₂ per year. Allegheny intends to register the carbon credits with the Department of Energy's voluntary GHG registry.

Lessons learned to date include:

- Cost-effective project implementation will occur at sites with flat terrain and some soil coverage.
- State environmental agency regulations may limit the use of coal combustion products as soil amendments. Due to regulatory limits on arsenic (found in fly ash) in Pennsylvania, Allegheny could apply only 18 tons of fly ash per acre.
- Orders with nurseries for seedlings should be made well in advance of planting.
- Fall may be a more optimal season for planting in some regions. Spring planting can be complicated by waiting for soil to thaw and drain and may not leave enough time before the summer dry season.

For more information, contact Allegheny Energy: <http://www.alleghenyenergy.com/default.asp>.



Students help plant trees at Allegheny's Limestone Run site.
(source: Edison Electric Institute)



An oak seedling takes root on a former mine site.
(source: OSM)

Case Study #2: Carbon Sequestration on Mine Lands in the Appalachian Region

In 2000, researchers at Stephen F. Austin State University (SFASU) began studying the carbon sequestration potential of reforestation of AMLs throughout the Appalachian region. The study, funded by the Department of Energy, had multiple objectives:

- Calculate the profitability of planting and managing forests on former mine lands for both timber production and carbon sequestration.
- Calculate the total amount of carbon that can be stored on these lands.
- Create a carbon credit market between landowners and utility companies.

The study focused on the Appalachian region in part because of its potential to sequester large amounts of carbon. The region has a good climate for tree growth. In addition, the region contains vast mine land acreage, acreage that provides minimal economic, environmental or other benefits.

Study Methodology

The SFASU research team conducted studies on AMLs planted with northern red oaks in Pennsylvania, West Virginia, Tennessee, Maryland and North Carolina. Northern red oak was chosen because of its timber value and because it is commonly used on reclaimed mine sites. The research considered a number of variables such as soil quality, the cost of site preparation, local prices for timber and pulpwood and alternative rates of return on timber investments.

In order to determine the optimal harvest schedule and forestry management regimes for carbon storage, the researchers created computer models to evaluate millions of possible timber harvesting and carbon trading scenarios for their potential financial return. Two scenarios examined the profitability of managing reforested AMLs. The first scenario considered only the value of timber produced on reforested mine lands. The second scenario combined the value of timber production and carbon credits.

The analysis used six alternative rates of return. The model assumed the price of carbon to be \$10, \$50, or \$100 for each additional ton of carbon sequestered by landowners. The first scenario assumed the price of carbon to be \$0 per ton.

Profitability of Forests on Abandoned Mine Lands

The research found that the costs of sequestering carbon on mine lands in West Virginia range from \$7.20 to \$40.50 per metric ton, depending on the cost of site preparation and the initial quality of the soil at a site. The research found that if there are no markets for carbon credits (i.e., the price of carbon = \$0), growing and selling timber is only profitable on sites with good soil at low anticipated return.

The research suggests that if there is no market for carbon credits, it would cost a landowner \$7 per ton to store carbon on a site with average soil, using a return rate of 3.5 percent. However, if a land-owner sells timber and is paid \$10 for every ton of carbon, using the same return rate \$4 for every ton stored could be earned, in net present value terms. With estimates that a carbon credit could be worth \$30 per ton, the \$10 per ton figure is conservative.

Carbon Storage Capacity of Abandoned Mine Lands

The SFASU research found that the amount of carbon that can be stored at reforested sites is affected by site quality and harvesting schedules. Storage capacity ranged from 43 tons per acre of carbon on poor-quality sites to 58 tons on high-quality sites. Research also suggested that the profitability of forest management and carbon storage varies by state. Although Pennsylvania has higher timber prices, it is more profitable to grow trees in Kentucky. Trees grow faster in southern climates, so the value of the timber increases more rapidly in Kentucky than in Pennsylvania.

For more information, contact the Stephen F. Austin College of Forestry: <http://forestry.sfasu.edu/>.

AML Reforestation and Carbon Sequestration Projects and Research: What are Some Examples?

An increasing number of national and state governments, corporations, and non-governmental organizations have begun to pioneer carbon offset markets and undertake or study potential carbon sequestration and banking projects. The previous two case studies examine how organizations have explored the potential for reforestation and sequestration projects on former mine lands.

As seen in the Allegheny case, reclamation and reforestation of mine lands generates a wide range of potential benefits. However, the opportunity to develop and trade carbon credits will often serve as a key incentive for any for AML reforestation project. Due to high costs associated with more traditional environmental controls, interest in market-based approaches to managing environmental issues continues to grow. The goal of such approaches is to encourage the private sector to undertake activities to improve environmental quality and ecosystem services such as climate regulation. Seen in the second case example, carbon markets need not be developed on a large scale. Trading can be simple and involve trades or agreements between two parties.

The two case studies illustrate that forest carbon storage and sequestration may provide interested organizations with options for managing their carbon credits. Some organizations are developing markets to trade carbon credits.

Other organizations are “banking” their carbon credits, including forest-based credits, while waiting for emerging markets to be tested and further developed.⁶

State Programs

In the United States, states have taken the lead in formulating carbon policies. States have developed GHG registries or inventory programs that support carbon banking or the use of trading to reduce GHG emissions within a state’s boundaries.

Minnesota’s Releaf Program promotes the planting, maintenance, and improved health of trees in the state. The program’s goal is to reduce CO₂ levels and promote energy conservation.⁷ California’s Climate Action Registry serves as a voluntary GHG registry to encourage early actions to reduce GHG emissions in the state. Appendix B provides additional information on public and private sector trading and banking programs.

⁶ A carbon bank is a program that enables organizations to keep track of a stock or supply of greenhouse gases in secure fashion for future use in a trading market.

⁷ Funding for Minnesota ReLeaf grants is not currently available. The program remains in effect in case new funding becomes available.

The Chicago Climate Exchange (CCX)

CCX is the first and only voluntary, legally binding integrated trading system in North America to reduce emissions of all six major GHGs.

Building on the U.S. sulfur dioxide trading program, CCX is a cap and trade system. CCX members make a legally binding emission reduction commitment. The commodity traded on CCX is the CFI contract, each of which represents 100 metric tons of CO₂ equivalent. CFI contracts are comprised of “exchange allowances” and “exchange offsets.” Exchange allowances are issued to emitting members in accordance with their emission baseline and the CCX Emission Reduction Schedule. Exchange offsets are generated by qualifying offset projects. Offset projects include forestry carbon sequestration projects.

For more information, contact the Chicago Climate Exchange: <https://www.theice.com/ccx.jhtml>.

Trading Carbon Credits

The success of the U.S. sulfur dioxide trading program in reducing acid rain, as well as other market-based approaches, has illustrated the potential benefits of emissions trading. As a result, support for market-based mechanisms to reduce GHG emissions continues to grow.⁸

Landowners, GHG-emitting firms, states and other organizations have all begun to test and implement carbon offset markets. For example, the World Bank has established a Prototype Carbon Fund.⁹ This Fund invests in projects and programs designed to reduce GHG emissions through offsets and trading systems. Carbon trading markets are also being developed in the United States. The Chicago Climate Exchange is the first operating market in the United States for GHG emissions trading. In 2005, seven states in the northeast United States began

participating in a mandatory, market-based CO₂ emissions reduction program involving regulated power plants, known as the Regional Greenhouse Gas Initiative. As of 2009, ten northeast states were participating in the program.

Department of Energy (DOE) Voluntary Reporting of Greenhouse Gases Program

DOE's program provides organizations, and in particular private sector entities, with an opportunity to create a public record of their sequestration activities. Under Section 1605(b) of the Energy Policy Act, DOE's Voluntary Reporting of Greenhouse Gases Program provides guidelines that permit reporting on GHG reduction activities, including:

- Project-level emissions and reductions: emission reduction consequences of a particular action, such as a reforestation project.
- Entity-level emissions and reductions: emissions and reductions of an entire organization, typically defined as a corporation.
- Commitments to take action to reduce emissions in the future.

Under these guidelines, companies or individuals submit reports to DOE. The reports document the action being taken and the amount of GHGs (reported in equivalent tons of CO₂) being avoided or sequestered. During 2002, 221 U.S. organizations reported that they had undertaken 2,379 projects to reduce or sequester GHGs. A total of 590 carbon sequestration projects were reported for 2005.

Independent verification will be necessary if an organization would like to trade its registered credits.

For more information, contact the DOE Voluntary Reporting of Greenhouse Gases Program: <http://www.eia.doe.gov/oiaf/1605/>.

Banking Carbon Credits

Because emissions trading mechanisms for GHGs are in the early stages of development, some companies that are planting trees on former mine lands are banking sequestration credits. Banking is an alternative to directly trading carbon in a market and recognizes that U.S. markets for trading carbon sequestration credits are emerging and may not develop fully for several years. Through the banking alternative, organizations can verify and "bank" carbon credits with a GHG inventory.

Several states have already implemented state carbon banks in the form of GHG registries. For example, California's Climate Action Registry, a public/private partnership, serves as a voluntary GHG registry to protect, encourage, and promote early actions to reduce GHG emissions. At the federal level, the Department of Energy (DOE) oversees the largest GHG registry in the United States.

Carbon Banking and Mine Land Reforestation

DOE's voluntary GHG registry program, established by the Energy Policy Act of 1992, is designed to record project accomplishments and communicate innovative carbon sequestration

⁸The World Bank estimates that the value of a ton of sequestered carbon could range between \$30 and \$40 per ton in the United States and \$70 and \$100 per ton in European markets.

⁹ See: The World Bank Carbon Finance Unit: The Prototype Carbon Fund. <http://wbcarbonfinance.org/Router.cfm?Page=PCF>.

approaches, including former mine land reforestation.¹⁰

The Piedmont Energy Association case study, adapted from DOE Forestry Sector Guidelines for the Voluntary Reporting of Greenhouse Gases, illustrates how a company might quantify and register carbon sequestration credits generated through AML reforestation.

Additional information about private and public sector organizations involved in reforestation and carbon sequestration can be found in Appendix C.

Case Study #3: Measuring Sequestration Credits Generated on an Abandoned Mine Land

Piedmont Energy Association (PEA), a coal mining cooperative owned by local utilities and independent power producers, wanted to reclaim an abandoned mine land with trees rather than the grasses required by the Surface Mining Control and Reclamation Act. Since the cost of establishing a forest was only slightly higher than the cost of establishing grasslands, planting trees was a logical choice due to additional benefits provided by carbon credits. The company intended to report the change as a sequestration project to the DOE voluntary GHG registry.

The project required PEA to address three issues: (1) identify the appropriate reference case; (2) identify the sequestration levels of both the reference case and the project case; and (3) estimate the net sequestration associated with the project.

For the reference case, PEA asked what would have happened if the reforestation project had not taken place. Absent the project, PEA concluded that the land would have been grassland. One assumption was that the reference case would sequester a relatively small amount of CO₂ due to the growth cycle of the grasslands. A second assumption was that the project case would have higher levels of CO₂ sequestration due to yearly tree growth. The difference between the two would be the sequestration credits that PEA would register in the DOE database.

PEA felt that the data available regarding growth rates of grasslands and forests on reclaimed mines was not applicable to its site. As a result, the company set up a field measurement plan with grassland and forested plots to represent its reference and project cases. The carbon uptake rates on each plot were measured each year for the first three years and were expected to continue to be measured at five-year intervals. The results from these test plots have allowed the company to extrapolate net sequestration levels for the larger reforestation project.

¹⁰ See: U.S. Energy Information Administration. Voluntary Reporting of Greenhouse Gases Program. <http://www.eia.doe.gov/oiaf/1605/index.html>.

When is Reforestation on AMLs Appropriate?

Landowners and companies should consider a number of factors when determining whether reforestation is feasible or suitable for particular AMLs.

Site Demands and Site Preparation

Perhaps the most important factor affecting tree survival, growth and productivity is the quality of soil on a mine site.¹¹ Some mine lands can be productive forestry sites without significant work to prepare the site. However, mine soils may be too harsh for tree survival. These soils may be acidic and rocky and the sites

are often steep, making tree establishment difficult. Compared to native soils, mine soils usually have limited organic matter content, low nutrient levels, poor water holding capacity, low pH and many coarse fragments.



Reclaimed mine lands are home to Christmas tree farms in many areas of the country. (Source: Office of Surface Mining)

Compost has been shown to be a cost-effective tool for use at both large mining sites and smaller urban areas with metal contamination from metal processing (e.g. foundry). Applying compost and biosolids to the surface of mine sites with poor soil has shown the ability to improve soil conditions and enable revegetation in some cases. It can be used in a variety of contexts, including wetlands, and can help the restoration and revegetation of sites. Composted biosolids can be effective because they will be free of pathogens. In addition, the metals that exist in biosolids are minuscule in concentration relative to the levels found at sites.

Selecting Tree Species

There is no universal recipe for successfully selecting and growing tree species on AMLs. The most effective and successful tree selection will account for site-specific conditions. Early consideration of what tree species will be viable at a mine site will increase the potential for tree survival.¹²

Previous Reclamation Activities

The Surface Mining Control and Reclamation Act (SMCRA), passed in 1977, has improved human safety and environmental quality at U.S. mine lands. The law mandates grading and shaping, which have eliminated many safety hazards routinely left behind by pre-SMCRA mining operations. However, mined lands reclaimed under SMCRA typically have heavily compacted surface layers that limit natural forest succession and impede reforestation. In most cases, post-SMCRA reclamation has resulted in the establishment of grasslands rather than forests. While aesthetically pleasing, these grasslands may not fully utilize a site's potential to support diverse and productive forests.

To help address some of these issues in SMCRA, DOE's Office of Fossil Energy and the Department of the Interior's Office of Surface Mining (OSM) signed a Memorandum of Understanding (MOU) in 2000 to promote

¹¹ See U.S. Department of Agriculture Forest Service. Northern Global Change Research Program. <http://www.fs.fed.us/ne/global/index.html>.

¹² A Purdue University study recently found that a new hybrid of the American chestnut tree may be very effective at sequestering large amounts of carbon while remaining disease resistant. See: Purdue University News. 2009. "Reviving American chestnuts may mitigate climate change." <http://news.uns.purdue.edu/x/2009a/090610JacobsChestnuts.html> 13

the reclamation of abandoned coal mine sites through reforestation. By recognizing that there are multiple benefits to reforesting mine lands – restoration of clean water, recreational opportunities, commercial forestry, carbon sequestration – this MOU establishes a framework for cooperation between OSM and DOE. The MOU will help promote market-based approaches to reclaiming AMLs through reforestation.

Regional Variations

In considering reforestation efforts across the country, it is important to recognize that there are no universal approaches for reforesting AMLs or generating carbon sequestration credits on underutilized lands. Different regions of the United States offer unique challenges and opportunities for reclaiming and reforesting mine lands. Understanding limitations due to regional geography or climate will help inform how to best pursue a sequestration project at a former mine site.

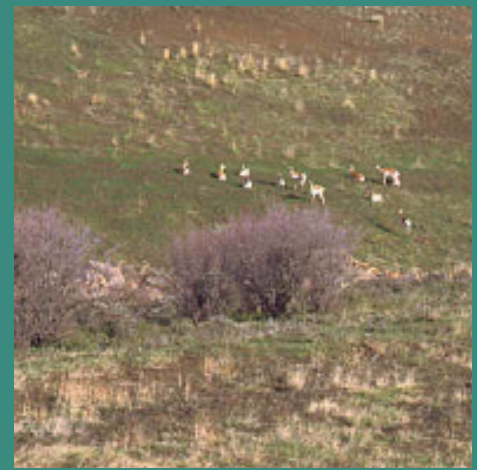
Financial Decisions

Reforesting AMLs to sequester carbon can be expensive. However, economic returns over the long term may equal reforestation costs. For example, the cost to plant or replace trees and shrubs in the arid West can reach \$1,000 per acre. With low survival rates for trees, any revenue from harvesting timber or trading carbon credits is unlikely to cover those costs. In addition, SMCRA requires only grass cover. Therefore, planting trees requires expenditures beyond traditional reclamation requirements. In addition, the more site preparation that is needed, the more financial risk is assumed with the anticipation that carbon credits will be profitable.

Although there is little question that forests accumulate carbon in biomass as they grow, there is considerable uncertainty regarding the effect of forest management (thinning or harvesting timber) on carbon sequestration. When trees are harvested, sequestration is affected for several reasons: carbon in the soil, tree roots and understory will dissipate after harvest and carbon in wood products may be released as those products undergo processing, use and disposal. When a forest is clear-cut, carbon in the soil begins to dissipate, creating a large source of CO₂ emissions. While not completely eliminating these emissions, a sustainable timber harvest can help minimize these releases while keeping carbon sequestered in the harvested wood. Measuring sequestration levels at AMLs where timber is also harvested will be more difficult than at sites reforested only to sequester carbon. Therefore, if an organization combines timber harvesting and carbon credits at an AML, that organization will need to carefully measure and verify any tradable carbon credits.

Ownership of AMLs

Determining site ownership can be a hurdle to reclamation and reforestation. For some AMLs, uncovering legal ownership is straightforward, requiring only minimal title-searching. For other sites, ownership cannot be traced through legal documents and substantial investigation is required to locate and contact landowners or their heirs.



Reestablishment of rangeland after reclamation provides forage for grazing animals, including these antelope on a North Dakota mine site. (Source: Office of Surface Mining)

Plantation Forestry

Sequestration projects developed through intensively managed commercial timberlands can generate unintended consequences. If reforestation and sequestration are focused solely on biomass accumulation, there may be a preference for single-species tree plantations.

Plantations have little in common with bio-diverse forests. Monocultures consisting of thousands of trees of the same species that are bred for rapid growth, and therefore rapid carbon dioxide uptake, create negative environmental impacts. Impacts can include a loss of natural biodiversity, soil compaction and reduced soil fertility.

Once ownership is determined, other issues can complicate reforestation. For example, on sites where mining has ceased and the bonds have been forfeited by the company or owner, title to the land might belong to an original owner no longer in the area. If an organization plants trees on a site owned by someone else, it is important to have a legal agreement in place. As seen in the Allegheny example, having a legal agreement in place can ensure that newly planted vegetation is protected from activities, such as harvesting, that could impact the amount of carbon sequestered at a site. This can be critical if an organization intends to generate carbon credits on a site. Absent a legal agreement, timber could be harvested or the land cleared for other purposes and sequestration benefits or credits would be more difficult to verify and might be lost completely.

Conclusion

With nearly one million acres of abandoned mine land in the Appalachian region alone, the potential benefits that could be generated through reclamation and reforestation of these sites are significant. From supplemental timber revenues to the trading of carbon credits, reforestation of AMLs can accrue financial benefits to local communities, landowners, and companies. Reforestation can also improve environmental quality locally (water quality, habitat restoration) and globally (climate change). In addition, complementary tools such as water quality trading, wetland banking and land conservation could be combined with reforestation and sequestration activities to increase opportunities to return these degraded and underutilized lands to productive use.

While markets for carbon credit transactions exist, U.S. markets are speculative and are still being tested on a pilot project level. Furthermore, the definition of a carbon credit is not always consistent across markets or carbon banks. In spite of this uncertainty, public and private organizations are exploring how terrestrial sequestration on degraded lands can play an important role in dealing with CO₂ emissions and reducing the impacts of climate change.

Uncertainties remain. Not all AMLs will be suitable candidates for reforestation and sequestration projects. Regional variation, financial considerations and site conditions will impact the feasibility of pursuing reforestation and sequestration projects on AMLs. However, for many of these sites, carbon sequestration can provide an array of incentives for encouraging the revitalization of degraded and underutilized landscapes.

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 CO₂ 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 CO₂. They all exchange CO₂ 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 CO₂ can be stored, including oil reservoirs, gas reservoirs, unminable coal seams, saline formations and shale formations with high organic content. These formations have provided natural storage for crude oil, natural gas, brine and CO₂ over millions of years. Geologic sequestration techniques would take advantage of these natural storage capacities.

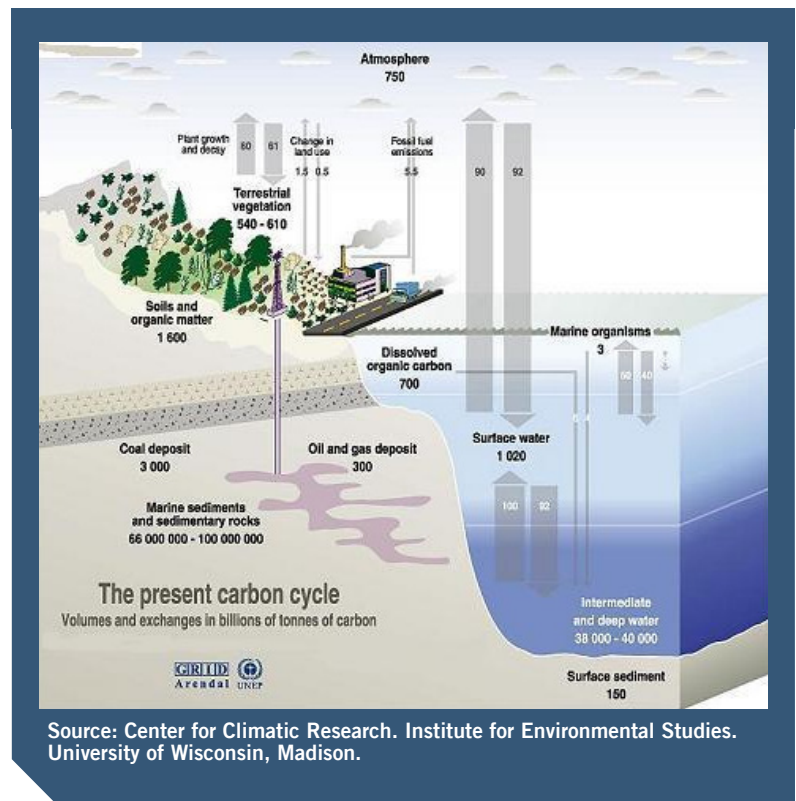
Ocean

Oceans absorb, release and store large amounts of CO₂ 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 CO₂ 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 (including 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 CO₂ to the atmosphere through respiration and "take" 61 billion metric tons of CO₂ that is turned into new plant biomass through photosynthesis. These carbon sinks are immense. The atmosphere contains about 750 gigatons of CO₂, the ground contains about 2,190 gigatons of CO₂ and the oceans contain about 40,000 gigatons of CO₂.



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

Appendix B provides information on carbon trading and banking activities undertaken by public and private sector organizations in the United States.

Industry Carbon Trading and Sequestration Activities

<p>Partnership for Climate Action</p>	<p>The Partnership for Climate Action is a coalition of corporations and the Environmental Defense Fund, a non-profit organization. The coalition promotes market-based approaches to reducing GHG emissions. Among other outcomes, corporations have agreed to inventory their emissions and use methods (including sequestration and trading) to attain GHG reduction goals. http://www.us-cap.org/</p>
<p>Energy Future Holdings Corporation - Luminant</p>	<p>Energy Future Holdings Corporation, formerly TXU Corp., has established a pioneering reforestation program to deal with its mine lands and to help offset its emissions through its subsidiary company Luminant. Since the program began in 1973, the company has planted over 28 million trees as part of its mine land reclamation efforts. http://www.energyfutureholdings.com</p>
<p>Chicago Climate Exchange (CCX)</p>	<p>CCX is the first and only voluntary, legally binding integrated trading system in North America to reduce emissions of all six major GHGs with offset projects. https://www.theice.com/ccx.jhtml</p>

Regional and State Carbon Banking Programs and Carbon Inventories

<p>Regional Greenhouse Gas Initiative (RGGI)</p>	<p>RGGI is the first mandatory, market-based effort in the United States to reduce GHG emissions. Ten northeastern and mid-Atlantic states have capped and will reduce CO2 emissions from the power sector by 10 percent by 2018. States sell nearly all emission allowances through auctions and invest proceeds in consumer benefits: energy efficiency, renewable energy and other clean energy technologies. RGGI will spur innovation in the clean energy economy and create green jobs in each state. The ten states participating in RGGI are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont. http://www.rggi.org/home</p>
<p>California</p>	<p>The State of California has a Climate Action Registry. This public/private partnership serves as a voluntary GHG registry to protect, encourage and promote early actions to reduce GHG emissions. http://www.climateregistry.org</p>

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

Appendix C provides information on organizations involved in carbon sequestration and reforestation of degraded lands, including former mine lands, in the United States. Consult state agency mining regulatory and reclamation programs for state-based carbon sequestration projects: <http://www.epa.gov/aml/states/index.htm>.

Federal Agencies

<p>Partnership for Climate Action</p>	<p>Regional Carbon Sequestration Partnerships - DOE has formed a nationwide network of regional partnerships to help determine the best approaches for capturing and permanently storing gases that can contribute to global climate change. http://www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html</p>
<p>Appalachian Regional Reforestation Initiative (ARRI)</p>	<p>ARRI is a coalition of groups, including citizens, the coal industry, and government dedicated to restoring forests on coal mined lands in the eastern United States. http://arri.osmre.gov/Default.shtm</p>
<p>Office of Surface Mining (OSM)</p>	<p>OSM has entered into a Memorandum of Understanding (MOU) with DOE. This MOU establishes a framework for cooperation between OSM and DOE’s Office of Fossil Energy to promote a market-based approach to reclaiming AMLs through reforestation. http://www.mcrcc.osmre.gov/</p>
<p>Tennessee Valley Authority (TVA)</p>	<p>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 byproducts from coal-fired plants as a soil amendment for reforested mine lands. http://mydocs.epri.com/docs/CorporateDocuments/demo/PC-CCS%20Deliverables%201019586.pdf</p>
<p>U. S. Department of Agriculture, U.S. Forest Service (USFS)</p>	<p>USFS provides a range of tools for carbon inventorying, management and reporting. http://nrs.fs.fed.us/carbon/tools</p>

Research Institutions and Organizations

<p>West Virginia University</p>	<p>Faculty members with the West Virginia Water Research Institute are researching reforestation and carbon sequestration on AMLs 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. http://wwwri.nrcce.wvu.edu/</p>
<p>University of Kentucky</p>	<p>Researchers at the University of Kentucky are undertaking a project that will develop planting sites to demonstrate low-compaction surface mine reclamation techniques for carbon sequestration, through the growth and harvesting of high-value trees. http://www.netl.doe.gov/technologies/carbon_seq/core_rd/terrestrial/41624.html</p>
<p>Electric Power Research Institute (EPRI)</p>	<p>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 projects focused on carbon sequestration through reforestation. http://www.epri.com/globalclimate/</p>

Non-Governmental and Other Organizations

<p>The Nature Conservancy (TNC)</p>	<p>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. http://www.deq.state.va.us/export/sites/default/info/documents/climate.reforestation.minelandsTNCreport.pdf</p>
<p>World Resources Institute (WRI)</p>	<p>WRI has a practice area that focuses on emerging markets for storing carbon in forests and trading generated carbon credits. http://pubs.wri.org/pubs_description.cfm?PubID=2991</p>

Private Sector Activities

<p>Alcoa</p>	<p>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 CO2 each year. http://www.alcoa.com/global/en/eco_alcoa/info_page/eco_overview.asp</p>
<p>Allegheny Energy</p>	<p>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 AMLs for carbon credits. http://www.osmre.gov/topic/reforestation/Reforestation.shtm</p>
<p>Entergy</p>	<p>Entergy has launched several initiatives to improve the company’s carbon sequestration efforts. For example, 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. http://www.entropy.com/our_community/environment/default.aspx</p>
<p>Energy Future Holdings Corp.- Luminant</p>	<p>Energy Future Holdings Corporation, formerly TXU Corp., has established a pioneering reforestation program to address its mine lands and help offset its emissions through its subsidiary company Luminant. Since the program began in 1973, the company has planted over 28 million trees as part of its mine land reclamation efforts. http://www.energyfutureholdings.com</p>

Other

<p>A Landowner’s Guide to Carbon Sequestration Credits (University of Minnesota Department of Forest Resources)</p>	<p>This document helps landowners determine whether or not to enroll their land in a carbon sequestration project. It discusses background information on carbon sequestration and global climate change; current methods of sequestration, including forestry, conservation planting, and methane capture; and landowner responsibilities, including contracts, verification and implementation, once they have made the decision to enroll their property in a sequestration project. http://www.cinram.umn.edu/publications/landowners_guide1.5-1.pdf</p>
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Appendix D: References and Resources

In addition to the information included in the Appendices, the documents and resources listed below have been used in developing this report.

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Carbon Sequestration through Reforestation

A LOCAL SOLUTION WITH GLOBAL IMPLICATIONS



OSRTI
Abandoned Minelands Team

March 2012