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Guidance for Electric Companies on the Use of Forest Carbon Sequestration Projects to Offset Greenhouse Gas Emissions

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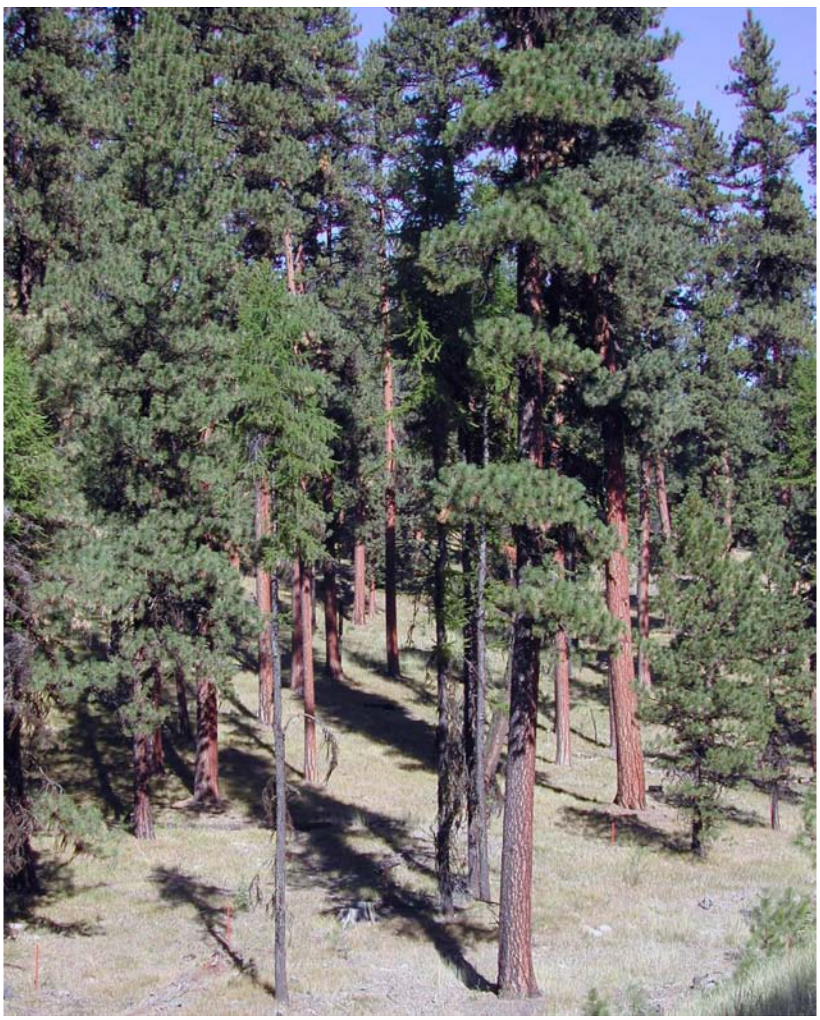

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Technical Update 1, December 2006

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ABSTRACT

The earth's climate is warming and the majority of scientists believe that human-caused emissions of greenhouse gases (GHGs) are contributing significantly to the warming of our atmosphere. Mandatory limits of GHG emissions now exist in most industrialized nations and are being developed in individual states and regions within the United States. It appears increasingly likely that a national mandatory program to limit GHG emissions could be implemented in the U.S. sometime in the next few years.

Forest carbon sequestration can provide electric companies and other entities that emit GHGs with desirable opportunities for GHG emissions mitigation for a variety of reasons. These include:

(i) GHG offsets derived from forest carbon sequestration (FCS) projects can be achieved for a relatively low financial cost per ton of carbon dioxide equivalent(CO_2e) as compared to many other GHG abatement options available to electric companies and other industrial entities;

(ii) FCS projects can generate GHG emission offsets without development of new technology;

(iii) FCS projects offer geographic flexibility in where mitigation can be achieved;

(iv) FCS projects can help to improve a company's public image as the public generally has positive perceptions about forests and forest restoration;

(v) FCS projects can provide a way for companies to diversify their asset portfolio and hedge financial risk; and

(vi) FCS projects, in some cases, may complement other company goals.

Electric companies may use a variety of different organizational approaches to create or acquire GHG emission offsets derived from forest carbon sequestration, including:

- Implementing FCS projects on company-owned lands;
- Joining a consortium of entities that jointly implement FCS projects to create GHG offsets;
- Engaging a third-party contractor to develop an FCS project on behalf of the company; and
- Purchasing FCS-based GHG offsets in the marketplace.

Companies that are considering creating or purchasing FCS-based GHG offsets should try to anticipate how they intend to use the resulting GHG offsets and try to ensure that the GHG offsets are likely to eligible to be used for compliance purposes in whatever mandatory or voluntary GHG emissions mitigation scheme they are involved in. Financial analysis of proposed offset projects should explicitly account for the time value of money and risks. Promising methods for creating GHG emission offsets using forest carbon sequestration include afforestation or reforestation, joint creation of wood products and GHG emissions offsets, and FCS projects that use very fast growing tree species. Preserving forests to avoid future GHG emissions is often a very expensive way to generate FCS-based GHG offsets. Finally, this report provides economic analyses of a variety of FCS projects that could be implemented to create GHG emission offsets.

ACKNOWLEDGEMENTS

EPRI would like to thank Dr. Gordon Smith of EcoFor for preparing this EPRI Technical Update report and for generously sharing with EPRI his expertise and knowledge about implementing forest carbon sequestration projects. Also, we appreciate both the encouragement and enthusiasm of Mr. Boyd Vaughan of Oglethorpe Power Corporation who originally proposed the idea of developing a forest carbon sequestration "User's Manual" for use by electric company staff. Additionally, Boyd's insightful comments and suggestions helped shape this final guide so it will be of more practical use to the staff of electric companies who may be asked to evaluate their company's potential involvement in forest carbon sequestration projects. Christopher Gerlach of EPRI provided copy editing and final production of this report.

CONTENTS

1
INTRODUCTION

This report is targeted primarily towards assisting environmental policy managers and staff in electric companies who may have been requested by more senior management to investigate the potential for their company to:

(1) Invest in forest carbon sequestration to mitigate present and/or future greenhouse gas (GHG) emissions;

(2) Purchase, in the marketplace, GHG emission reduction "credits" generated by forest carbon sequestration projects; or

(3) Develop a comprehensive GHG emission mitigation strategy and assess the role forest carbon sequestration can play within an overall corporate strategy.

The Climate Problem

Increasing amounts of GHGs in the atmosphere and increasing average global temperatures are well documented. There is still uncertainty and scientific debate surrounding exactly how much of the recently observed warming of the globe is human caused, and how much is caused by non-human drivers, but it is clear that some of the warming is human induced.

Today, a large fraction of the world's population already lives under mandatory limits on GHG emissions, implemented by countries that have agreed to undertake GHG emission limits and ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The U.S. and Australia are alone among industrialized countries in not ratifying the Protocol.

Oregon requires new power generation plants to meet a CO_2 emission standard. Several New England and Mid-Atlantic States and California have committed to reducing their GHG emissions with required reductions starting in the next few years. Dozens of other states recently have undertaken studies of GHG emission mitigation options or implemented other preparatory steps toward implementing mandatory reductions in GHG emissions. Due to the substantial amount of GHG emissions associated with electricity generation, electric companies are actively participating in the ongoing dialogue and evolution of programs at the national and regional levels in the United States.

Forest Carbon Sequestration as a Part of the Solution to GHG Emissions

Forest carbon sequestration is one of a variety of tools electric companies may use to mitigate their GHG emissions. The Intergovernmental Panel on Climate Change (IPCC) has estimated that, over the next half century, the average amount of carbon that can be sequestered in forest carbon sequestration projects each year could potentially mitigate GHG emissions equal to 20-30% of 1999 total global GHG emissions.[1]

The U.S. electric sector has been very interested in the potential to offset GHG emissions through investments in FCS projects both in the U.S. and internationally. Since at least the early 1990s, electric companies have taken a pioneering role in using forest carbon sequestration to offset GHG emissions. To date, some of the largest FCS-related investments made worldwide have been made either by individual electric companies operating in the U.S. or by private consortia made up of these companies. Additionally, U.S. electric companies have sponsored substantial research and development efforts to try to improve quantitative methods related to measuring, monitoring, and verifying forest carbon sequestration.

Early tree planting demonstration projects in Oregon were funded by PacifiCorp. In 1995, 41 electric companies from across the U.S. joined together to create UtiliTree Carbon Company. Utilitree developed projects including restoring bottomland hardwood forest in the lower Mississippi River valley, purchasing a forest in Belize that was at risk of being cleared, and implementing reduced impact logging in Malaysia. Subsequently, a consortium of electric companies also formed PowerTree Carbon Company, LLC, a successor to UtiliTree. PowerTree is supported by 25 electric companies and is restoring forests on former agricultural lands in the lower Mississippi River valley.[2]

Aspects of Forest Carbon Sequestration Addressed by this Report

This report builds on the experience of electric companies and others. It presents concepts and gives examples of how forest carbon sequestration can mitigate GHG emissions, alternative mechanisms for how electric companies can acquire or create GHG emission offsets using forest carbon sequestration, and how offsets generated by forest carbon sequestration can be integrated into the corporate GHG emission management strategy of an electric utility. Issues addressed in these guidelines include:

- Costs and the timing of costs associated with creating GHG emission offsets using forest carbon sequestration;
- Amounts and timing of accrual of GHG emission offsets using forest carbon sequestration;
- Reliability of creation of forest carbon sequestration offsets;
- Uses of GHG emission offsets created by forest carbon sequestration;
- Potential compatibilities or conflicts between forest carbon sequestration offsets and other activities of an electric utility company;
- Lead times involved in creating forest carbon sequestration offsets; and
- The potential supply of forest carbon sequestration offsets.

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[1] Percentage calculated from potential sequestration rates given in Intergovernmental Panel on Climate Change, 2000, *Land Use, Land-Use Change, and Forestry,* A Special Report of the IPCC, Cambridge: Cambridge University Press, page 137.

[2] For more information about PowerTree Carbon Company, LLC, visit www.powertree.com.

This report does *not* give step-by-step guidance on how to implement a forest carbon sequestration project or how to quantify the number of tons of GHG offsets achieved by a sequestration project. It does prepare the reader to critically evaluate opportunities to use forest carbon sequestration to mitigate GHG emissions and to choose how to integrate forest carbon sequestration into a corporate strategy to manage GHG emissions and manage GHG emissions related risks.

These guidelines address GHG emissions offsets for use primarily in the United States. Generating offsets outside the U.S. for use within the U.S. also is considered. These guidelines focus on forest carbon sequestration project assessment and accounting, not on the construction of corporate GHG emission inventories.[3] However, some of the accounting methods discussed in these guidelines are applicable to the forestry-related components of comprehensive corporate GHG emission inventories.

Forest Carbon Sequestration is Available to All Electric Companies

Forest carbon sequestration is not just for companies that own large areas of land that can grow trees. When considering forest carbon sequestration, many people think only about the biological issues: What land management activities will be implemented? How fast will trees grow? How much carbon does this tree growth represent, and similar issues. However, these biological issues are only one aspect of creating FCS-based GHG emission offsets.

Legal and organizational issues also are critically important for electric companies and others interested FCS-based GHG offsets to consider. When deciding whether to develop or otherwise acquire FCS-based GHG offsets, the most fundamental legal and organizational issues that need to be considered by electric companies and others is the type of ownership relationship the company would like to have with the underlying FCS projects. Electric companies and other entities interested in using GHG emissions offsets derived from FCS projects can do so in a variety of ways, including:

- Buying “verified” GHG offsets derived from FCS projects;
- Buying a share in a GHG mitigation fund or industry consortium focused on implementing FCS projects, or co-funding a “pool” of GHG mitigation projects;
- Entering into a contract to purchase a specified number of tons of CO_2 or a specified proportion of the GHG offsets to be delivered from an FCS project;
- Taking an equity stake in the ownership of an FCS project; or
- Developing and executing GHG mitigation projects in-house.

This report addresses both the biological issues related to what activities can sequester carbon in forests and the organizational issues that need to be considered by an electric company

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[3] For more information on developing a corporate GHG emission inventory, please refer to *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised Edition.* World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), 2005.

considering becoming directly involved in structuring an FCS project or participating indirectly as the buyer of forestry-related GHG offsets.

Sequestration versus Avoided Emissions

GHG emissions can be mitigated either by:

- Establishing or managing forests to take in atmospheric carbon dioxide (CO_2) and *sequester carbon*, or
- *Avoiding loss of forest biomass* and subsequent conversion of forest biomass to atmospheric CO_2.

Carbon sequestered by forest growth may be retained in stands of trees. When timber harvest occurs, much of the carbon previously stored in live trees is converted back to atmospheric CO_2 as a result of decomposition of logging wastes including stumps, roots, and branches of harvested trees. When harvested wood is used for wood products, some of the carbon in the harvested wood continues to be stored in products for long periods of time. This report includes a discussion of accounting for carbon stored in wood products.

This report does not address GHG emission mitigation achieved by using wood to displace fossil fuel in energy generation. Direct displacement of fossil fuel can create GHG emission offsets and may be very cost effective. However, this fuel switching is outside the scope of this report. EPRI work that addresses the use of biomass fuel to reduce GHG emissions includes *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*, EPRI, Palo Alto, CA: 2004. 1008488.

This report also does not address GHG emission mitigation resulting from sequestration of carbon in soil. Typically, switching vegetation from non-forest to forest or decreasing rates of forest disturbance increases soil carbon. However, some changes in vegetation can result in movement of soil carbon storage from deeper soil to near the soil surface, resulting in increasing carbon in the top few inches of soil without an overall increase of total soil carbon. Also, amounts of soil carbon sequestration are often modest relative to amounts that can be sequestered in woody biomass. For these and other reasons, soil carbon is defined as outside the scope of this report.

Two other GHGs that can be affected by land management are methane (CH_4) and nitrous oxide (N_2O). This report does not address terrestrial methane or nitrous oxide fluxes except to note some particular circumstances that can increase or decrease methane and nitrous oxide fluxes from forests, and to provide some general information on flux rates. Except in extraordinary circumstances, the warming effects of methane and nitrous oxide fluxes from forests will be small relative to the mitigation of warming provided by carbon sequestration in forest biomass.

Organization of this Report

This report is designed to allow the user to go directly to a section of immediate interest. It is not necessary to read all of the chapters of this report in consecutive order, starting from the beginning. Chapters 2 through 4 focus on the benefit to electric companies of using forest carbon sequestration, and how electric companies can access GHG emission offsets generated by forest carbon sequestration. Chapters 5 through 7 address the biological and physical aspects of forest carbon sequestration. Chapters 8 through 11 focus on the organizational, legal, and operational aspects of structuring a project, analyzing proposed projects, and measuring outcomes achieved by projects. Chapter 12 provides illustrative case studies of example types of potential FCS projects. Appendices provide background information including references, a glossary, and sources for additional information. Appendices also provide more detailed technical information on global warming potentials, carbon content of trees, and calculating leakage.

2
KEY BENEFITS OF FOREST CARBON SEQUESTRATION

Given the rapid proliferation of programs and proposals at the federal, state, and regional levels to mandate GHG emission reductions, electric companies increasingly are focused on developing comprehensive corporate strategies to achieve cost-effective GHG emission mitigation. Carefully designed forest carbon sequestration projects can provide GHG emission offsets at relatively low cost and can begin to yield GHG offsets relatively soon after a decision has been made to implement an FCS project. These features—low cost and the potential to achieve near-term GHG emissions offsets—make forest carbon sequestration a worthwhile component for an electric company to consider as part of a comprehensive corporate strategy for mitigating GHG emissions.

Low Cost

Some forest carbon sequestration projects claim to have produced GHG emissions offsets costing $2-4 per metric ton CO_2e (tCO_2e). However, our analysis—including the "time value of money" —suggests that offsets generated in the U.S. are likely to be more expensive than this. Also, land prices are a large component of forest carbon sequestration project costs and U.S. land prices have increased significantly in the past decade. Even so, on many sites, permanent forest carbon sequestration offsets can be generated for a discounted cost of $6-12 per tCO_2e. These costs can be relatively inexpensive when compared to the costs of reducing GHG emissions directly from electricity generation facilities. Also, there may be opportunities to create GHG emission offsets at low costs per tCO_2e by implementing FCS projects in countries other than the United States.

Figure 2-1 summarizes results from a range of case studies, previously reviewed by EPRI, which shows ranges of expected costs for a variety of "on-system" and "off-system" GHG abatement actions that potentially can be implemented by U.S. electric companies. As shown, the costs to implement near-term GHG emissions reductions can be expected to vary widely. Key factors that affect the expected cost of GHG reduction actions include power plant age, generating efficiencies, natural gas and electricity prices, regulatory controls related to mercury, SO_2 and NO_X, and the role that nuclear power may be expected to play in the future. Due to these factors and others, different companies will face different challenges implementing any of these GHG reduction actions. In addition, these GHG reduction actions differ in other important ways that will impact their overall economic viability. Some of these actions may be implemented quickly and inexpensively, while others will require longer lead times and significant up-front capital investment. Some actions utilize existing technologies, while others will require significantly more R&D before they are practical. Some actions can be scaled up more than others, and some offer better opportunities to reduce risks through diversification.[4]

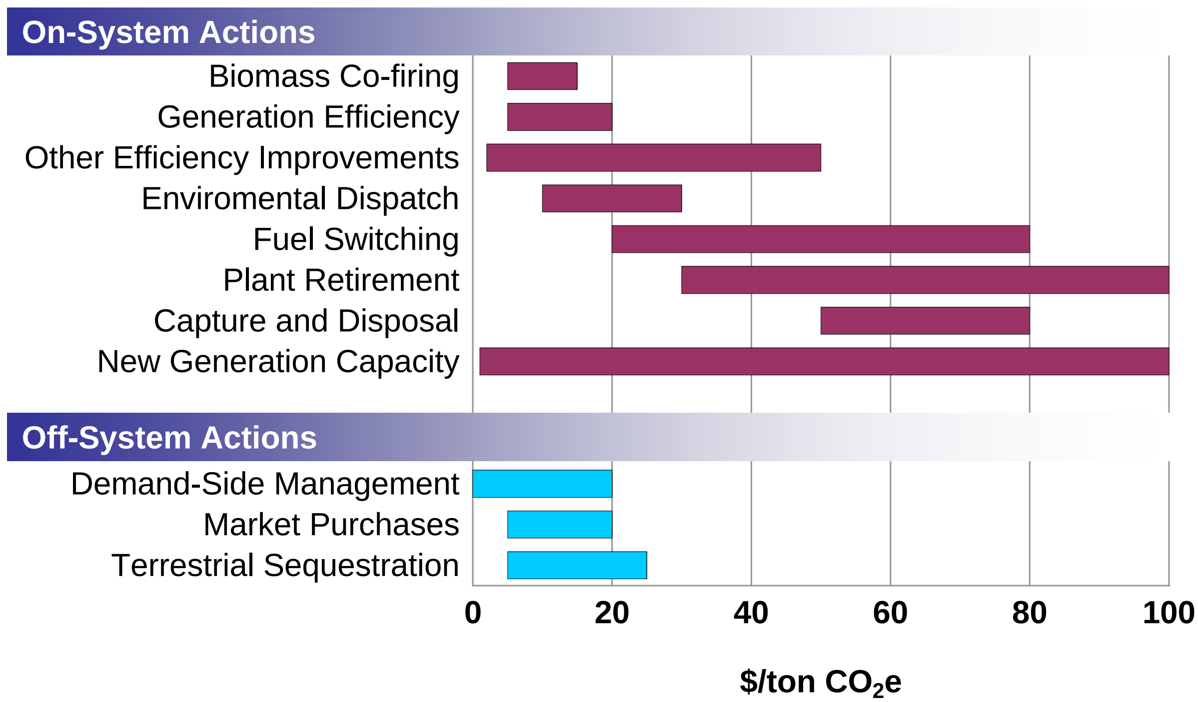

Figure 2-1.
Cost ranges for key electric sector GHG emission reduction options.
Source: EPRI Climate Brief 101113, February 2005.

As shown, terrestrial sequestration appears to offer a comparatively low cost approach to offsetting electric company GHG emissions.

Relatively Fast Offset Creation

Some types of forest carbon sequestration projects can begin generating offsets the year they are implemented, and some types of forest carbon projects can deliver substantial amounts of offsets in the first few years of operations. Other types of forest carbon sequestration projects may take years to begin generating offsets. If a company needs to obtain GHG emissions offsets in the near term—until new, low GHG emission technologies can be implemented cost effectively in its core business functions—forest carbon sequestration may provide a bridge until new technologies can be brought into commercial use. At the same time, forest carbon sequestration projects can easily take more than a year to plan and initiate. If a company, for some reason, needs to obtain GHG offsets for use in the current year, the company is likely to be limited to

[4] See The Costs of Key Electric Sector Greenhouse Gas Reduction Actions, EPRI Climate Brief, 101113, February 2005.

buying GHG offsets on the open market from existing GHG abatement projects including FCS projects.

Forest carbon sequestration offsets are available to companies regardless of whether or not they own lands or have particular kinds of electricity generation facilities. Companies that do not own suitable lands can acquire FCS-based GHG offsets by entering into contracts with landowners, joining a consortium that implements FCS projects, purchasing offsets directly from an FCS project developer, or by purchasing the offsets on one of the many carbon exchanges around the world (e.g., Chicago Climate Exchange (CCX), European Climate Exchange (ECX)).

Geographic Flexibility

Climate change is a global environmental issue. GHG emissions anywhere on the planet exacerbate climate change, while reducing GHG emissions anywhere on the globe help to mitigate human-induced climate change. Due to the global nature of climate change, GHGs can be removed from the atmosphere far from GHG emission sources and still contribute to mitigating climate change. The global nature of climate change makes it possible for electric companies and others to utilize GHG emission offsets that are generated by FCS projects that may be implemented far away from the actual sources of a company’s GHG emissions. This geographic attribution provides companies with flexibility in acquiring or producing offsets from forest carbon sequestration projects.

Positive Public Perception

Forest carbon sequestration—generally perceived to be the restoration or conservation of forests—is viewed, for the most part, as a positive activity by the public. Forest carbon sequestration can also generate substantial ecological co-benefits, including providing wildlife habitat and improving water quality. Publicizing forest enhancement projects and articulation of co-benefits may help improve relationships with corporate stakeholders.

Diversification and Hedging

Forest carbon sequestration can help further diversify a corporate portfolio of GHG emission mitigation activities. For an electric company that may need to substantially reduce its GHG emissions in the future, forest carbon sequestration alone is not likely to provide all of the needed GHG emissions reductions. Most electric companies will need and want to invest in a mix of GHG mitigation activities that may include FCS projects as one component of an overall portfolio of GHG mitigation strategies.

Forest carbon sequestration is not directly correlated with electricity generation. This means the cost of creating FCS-based offsets is largely uncorrelated to changes in fuel costs or electricity prices.

In addition to diversifying a portfolio of GHG emission mitigation activities, forest carbon sequestration projects can be structured so they are likely to have little down-side financial risk. FCS projects can be structured so that if GHG offsets have low economic value in the future, the offsets can be liquidated and the timber and land involved in the project sold. In the U.S., both timber and land prices have appreciated historically on a real-price basis. Therefore, investments in forest carbon sequestration projects may provide a positive investment return on the invested capital even if the value of the GHG offsets were to sink to zero.

Investments in forest carbon sequestration projects also may serve as a hedge against the potential economic costs to an electric company associated with the implementation of mandatory GHG emission constraints. GHG emission limits may reduce the value of a company's fossil-fired power generation assets. At the same time, as the price of GHG emission offsets increases, the value of investments in valid forest carbon sequestration projects likely would increase, with the value of sequestration projects moving in the opposite direction of the value of fossil-fired generation assets. The tighter the future GHG emission cap is set, the greater the demand will be for GHG offsets, assuming that they are allowed to be used for compliance purposes. Increased demand for offsets, in turn, can be expected to result in higher offset prices, which would increase the hedging effect provided by forest carbon sequestration projects.

Complementing Other Company Assets or Goals

Finally, forest carbon sequestration projects may complement other existing company assets. If a company owns land, a modest investment in tree growing and verification might produce revenue from both GHG emission offsets and timber, and might generate a competitive rate of financial return on the cumulative investment of the land plus the forest establishment costs. Alternatively, it may be possible to achieve some forest carbon sequestration with little/no loss of revenue from alternative uses of lands. For example, in remote areas there may be no demand for rental of land beneath transmission lines on "rights-of-ways" owned by a company. If these lands are suitable for tree growing, the company may incur costs of periodically cutting trees before they get tall enough to threaten power lines. If a short tree species can be established beneath the power lines, it is possible that the new species might be able to sequester carbon without threatening the main use of the land as a power line corridor. Site specific analysis is required to estimate returns from proposed carbon sequestration projects. Chapters 8 through 11 of these guidelines describe methods for doing these site-specific analyses.

3

ORGANIZATIONAL APPROACHES FOR USING FOREST CARBON SEQUESTRATION

Electric companies may use a variety of organizational approaches to mitigate GHG emissions using forest carbon sequestration. One key question an electric company will need to consider is what type of ownership role (or roles) the company wants to have in relation to forest carbon sequestration projects and the associated GHG emissions offsets. The main types of organizational approaches for electric companies to consider are:

- Buying verified FCS-based or other kinds of GHG offsets in the market;
- Joining a GHG buying "pool" and purchasing a share of the GHG offsets to be developed by the pool;[5]
- Engaging in bilateral contracts to acquire GHG emissions offsets generated by FCS projects implemented on lands owned by others; and
- Implementing FCS projects on company-owned lands.

Each organizational approach has different strengths and weaknesses. The approach (or approaches) that best meet a particular company's goals will depend on the relative value that the company places on each strength and weakness, and the particular situation of the company.

A key point is that a company can develop and own forest carbon offsets *without* owning forest land. Just as an electric company can own and operate a coal-fired power plant without owning a coal mine, a company can acquire forest carbon sequestration based GHG offsets that are generated on lands that are not owned by the company.

Creating Offsets on Company Lands

One approach an electric company can use to acquire forest carbon sequestration offsets is to develop them on lands owned or controlled by the company. The main advantage to this approach is that the company directly controls land management activities, regardless of whether the activities are implemented by company staff or by contractors.

For many companies, the choice of organizational approach to use with regards to acquiring FCS-based GHG offsets will depend on the company's attitude toward the risk that the GHG offsets might not be developed and maintained adequately if another entity owns the land that is used to generate the GHG offsets. Creating forest carbon sequestration offsets on lands owned by the company can effectively mitigate the risk that a non-company landowner will not diligently develop and protect GHG offsets generated by an FCS project implemented on their land. By

[5] An example of such a GHG buying pool is the Greenhouse Gas Credit Aggregation Pool run by Natsource, LLC.

owning the land on which an FCS project is implemented, an electric company can mitigate this risk (i.e., a counterparty fails to fulfill their obligations and deliver promised GHG emissions offsets).

Another important factor that will influence a company's decision on whether to develop forest carbon sequestration projects on company-owned lands is the existing organizational and staff capabilities of the company. An electric company may or may not have the expertise and focus needed to successfully execute and maintain forest carbon sequestration projects. If a company currently has no in-house forest management expertise, it may not wish to take on implementation of forest management activities using existing company staff. Forest management is not a core business activity for most electric companies, and companies may wish to limit their direct involvement in such non-core activities. Conversely, for companies that already own and manage forestlands, it may make sense to consider developing forest carbon sequestration projects on company-owned lands using in-house land management expertise.

If an electric company implements a sequestration project on lands that it controls but does not actually own (e.g., some rights-of-ways), before implementing a GHG emission offset project on these lands, the electric company should establish an agreement with the landowner that specifies each party's legal rights to GHG emission offsets generated on the property.

A variation on implementing FCS projects on company-owned land is implementing a project on company-owned land, or land purchased specifically for the FCS project, and then selling or otherwise transferring ownership of the land to a conservation-oriented owner. The goal of this kind of approach to an FCS project is to transfer the ongoing responsibility and cost for managing the lands to another entity that is capable of taking on these costs and responsibilities, while maintaining for the company the legal rights to all future carbon sequestration generated by the project. Such a land ownership transfer may be financially advantageous because ongoing management costs can be significant. This approach to implementing FCS projects already has been used by several electric companies to implement FCS projects.

GHG offsets created through the management of forestlands directly owned by a company are easier to report and take credit for under some GHG offset accounting systems than if they were created on another party's land. For example, under the recently revised DOE 1605(b) program for the Voluntary Reporting of Greenhouse Gas Emissions, it is administratively more complex and burdensome to attempt to "report" or "register" a forest carbon sequestration "offset" generated by an entity that does not participate in the 1605(b) program than it is to "report" or "register" a GHG emission reduction associated with changes in carbon stocks on company-owned lands.[6] Chapter 4 provides more information about the DOE's 1605(b) program and how this program can be used to report or register GHG emissions offsets derived from FCS projects.

Also, there are potential tax implications related to creating GHG offsets on lands donated to a conservation entity. This report cannot provide legal and tax accounting advice, so we recommend that companies consult with their legal counsel and tax advisors regarding the conditions that different kinds of GHG offsets may need to be recorded on corporate balance

[6] See Federal Register, Vol. 71, No. 77, Friday, April 21, 2006, P. 20784. The new Final Rule will be codified at 10 CFR Part 300.

sheets and what the tax effects may be of different ownership roles in sequestration projects. In particular, it is worth noting that it is unlikely for companies to receive a tax credit for donating land for conservation purposes if the donor company retains rights to the carbon sequestration that accrues on the donated lands. Donations of land typically do not qualify for tax credits if the ownership of the real property is *split* such that different parties own different attributes of the land.

Buying Land Easements to Generate GHG Offsets

It is possible to generate GHG offsets by purchasing land easements that require landowners to abstain from, or execute, specified activities. For example, an easement could prohibit logging that would leave the forest with less than a specified volume of standing timber.

In theory, a rational landowner would be willing to sell an easement that requires maintaining tree cover for a price that would reflect the present value of some future sale of the land for development purposes plus the present value of any costs or reductions in timber revenue resulting from the easement. Anecdotal evidence suggests that many landowners, however, are very averse to making commitments that would permanently close off future land development opportunities. As a result, in practice, buyers interested in purchasing this kind of conservation easement may be forced to pay a price that approaches the land purchase price.

While purchasing land easements to enhance forest carbon sequestration is not a common practice, we are aware of at least one example of this kind of transaction. In 2004, King County, Washington purchased development rights on 90,000 acres of rural forest land within the county. The $22 million purchase price was equal to about $244 per acre, which reportedly is significantly lower than the price to purchase the land. The relatively low price for this conservation easement reflects the fact that this agreement allows the landowner to continue doing short-rotation clear cutting of timber, and does not require any change in forest management that would allow trees to grow longer to increase the amount of carbon stored on the lands.

Participate in a Forest Carbon Sequestration Consortium

In the U.S. and internationally, there have been several consortia established to develop GHG emission offsets for the benefit of consortium members. A typical structure for these consortia is that members commit a certain level of funding, and consortium staff implement or contract for implementation of GHG emission offset projects. As offsets are generated, consortium members receive the offsets in proportion to their share of funding. An example of a U.S. forest carbon offset consortium is PowerTree Carbon Company, LLC, which was formed and funded by 25 U.S. power companies.

The largest GHG buying “pool” created to date is operated by Natsource, LLC. The Greenhouse Gas Credit Aggregation Pool (GG-CAP) closed in 2006 with total commitments of €455 million

(U.S. $550 million) from 26 participants. Seven of the 26 participants[7] in the program are among the largest consumer product, manufacturing, energy and utility companies in Europe, Japan, and North America, and have a reported combined market capitalization of more than $300 billion. Other large pools have been created by the World Bank, chartered by a variety of national governments, and developed by other private equity managers.

A benefit of participating in a consortium is that the funding can be substantial enough to hire professional management to implement and track GHG offset projects. Also, because buyers receive all GHG offsets generated, it is possible to get offsets at a relatively low price per ton CO_2e.

At the same time, because consortium members are buying a share of future GHG offsets that are yet to be generated, the members bear the risk that projects will not generate as many GHG offsets as initially expected. Because of the time it takes to organize a consortium, find projects, and implement them, it may take five years or more from the date a company commits to join a consortium until the company starts to receive substantial amounts of GHG emission offsets.

Market Purchases of Existing Forest Carbon Offsets

Companies can limit the risk that an FCS project will fail to generate GHG offsets by buying offsets that already exist. Forest carbon sequestration offsets that already exist are based on verified growth of trees, or other verified sequestration. GHG offsets may be purchased directly through a broker such as Natsource, LLC or Evolution Markets, LLC, through an account on a trading platform such as the Chicago Climate Exchange (CCX), or through bilateral deals with individual forest carbon sequestration project developers like Environmental Synergies, LLC.

Purchasing existing GHG offsets on the open market may cost more per ton CO_2e than purchasing a share in a consortium or developing one's own FCS projects, but the GHG offsets can be obtained within a few days and project and counter-party risks can be virtually eliminated. There is still a risk that a future regulatory regime that limits GHG emissions may not accept purchased GHG offsets, but this risk also exists for GHG offsets developed in-house or by a consortium.

A company may limit its up-front cash expenditures and potential financial risks by purchasing forward contracts or options to acquire GHG offsets at a later date, after the offsets have been created and verified. The up-front premium payment to acquire an option often is less than 10% of the final purchase price of the GHG offsets. The buyer of the option or forward contract still has to bear the risk that the project developer may fail to deliver contracted GHG offsets, but the amount of invested capital at risk is modest.

If an electric company is considering the forward purchase of GHG offsets that have not yet been developed, it should carefully examine the capacities of the project developer to execute the

[7] Participants include: The Chugoku Electric Power Co., Inc.; Cosmo Oil Co. Ltd.; Electricity Supply Board (Ireland); Endesa Generacion; E.ON UK; EPCOR; Hokuriku Electric Power Company; Hokkaido Electric Power Co., Inc.; Iberdrola; Norsk Hydro ASA; The Okinawa Electric Power Co., Inc.; Public Power Corporation S.A.; Repsol YPF; Sergey Brin; Suntory, Ltd.; and Tokyo Gas Co., Ltd.

project. Not only should the company consider the project developer's management skills, execution capacity, and financial stability, the company also should consider what other resources and cooperation will be needed to complete the project. Specifically, if the project developer does not already own the land or have options committing the lands that will be used for the project, it will be important to try to determine if the project developer has the financial resources to buy needed land if land prices continue to increase. If the project developer plans to lease land for an FCS project, the company may want to try to ascertain if the planned lease terms are likely to be attractive enough to entice landowners to participate. More than one FCS project has failed to materialize because landowners were not willing to commit their lands in exchange for the payments offered by project developers.

Implementing Projects in Other Countries

In the U.S., land costs often dominate the total cost of forest carbon sequestration projects. Land costs in some other countries, especially developing countries, are much lower than in the U.S. If land can be acquired at a much lower cost per acre, it may be possible to create forest carbon sequestration offsets at a much lower cost per ton CO_2e. However, non-land costs may be higher in developing countries than in the U.S. Travel to the project site may take more time, and thus cost more. Legal transactions and permitting may be subject to delays due to less efficient administrative systems in developing countries. More importantly, land tenure may be weak, potentially opening up a project to risks of poaching, land appropriation, or other loss.

If a U.S. company creates GHG offsets in a developing country, and those offsets are eligible to be sold into the "Kyoto" system, the U.S. Company may forgo a significant amount of revenue if it chooses to use the offsets in the U.S. rather than selling them to other parties that can use them for compliance with the Kyoto Protocol. At this time, prices for GHG offsets generated via the Kyoto Protocol's Clean Development Mechanism (CDM) sell for significantly higher prices than offsets in the voluntary GHG markets that exist in the U.S. However, the transaction costs of accessing the Kyoto market are significantly higher than accessing the U.S. market because the CDM program has imposed stringent requirements for the use of approved quantification methodologies, approved project "validators" and "verifiers," and project registration fees. For small to mid-sized projects, the net return from selling GHG offsets into the U.S. market actually may be greater than the net return to be derived from selling offsets into the Kyoto market because of the relatively high transaction costs associated with accessing the CDM market. In the future, if GHG offset prices rise modestly in the U.S., there may be no difference in the net revenue associated with selling GHG offsets into the U.S. market or the Kyoto market(s), even for large projects.

Renting GHG Offsets

A rented GHG offset is intended to be valid until a specified date, at which time the renter has no further claim to the offset. At that time, the renter must then extend the rental, replace the offset with another offset or allowance, or count the expiring offset as a GHG emission.

Landowners who sequester carbon may be willing to commit to storing carbon for a specified number of years, but may not be willing to commit to storing carbon indefinitely. These landowners would rent offsets, but would not be willing to sell them.

There are two main reasons why a potential purchaser of GHG offsets might be interested in renting GHG offsets rather than purchasing them. First, a company might expect the future cost to acquire GHG offsets to be lower than their current cost. This might be the case, for example, if a new technology breakthrough makes it possible to achieve substantial GHG emissions reductions at a very low cost. Also, a company may believe that it is unlikely that GHG emissions reductions will be mandated in the U.S. in the future. In either case, renting GHG offsets may be more financially advantageous than purchasing them. This is the case because the cost of the initial rental plus the cost to rent or purchase a replacement offset when the initial rental expires is likely to be less than the cost to purchase a permanent offset today. Another reason that some parties may be interested in renting GHG offsets is that this approach is likely to require lower cash outlays than purchasing permanent offsets.

Examples of rentable GHG “credits” that exist today are Temporary Certified Emission Reductions (tCERs) and Long-term Certified Emission Reductions (lCERs) generated by afforestation and reforestation projects issued through the CDM process.

Comparing Organizational Approaches to Acquiring Forest Carbon Sequestration Offsets

Table 3-1 compares different organizational approaches to acquiring forest carbon sequestration GHG offsets. Sequestering forest carbon on lands owned by the company counts as creating offsets in a wide variety of emission mitigation systems. However, it requires land, land management expertise, and can take several years to begin delivering substantial amounts of offsets.

Sequestering carbon on lands owned by other parties where an electric utility company holds an easement requiring the maintenance of trees on the land may reduce land costs. However, the GHG emission mitigation achieved under this organizational approach may not count as an offset within some emission mitigation systems.

Sequestering carbon through the activities of a consortium may count as generating GHG offsets within a wider range of emission mitigation schemes than other potential approaches. Also, a consortium is likely to be large enough to hire professional staff with forest management expertise. Electric companies that do not own substantial amounts of forest land will not have professional forest managers on staff. Finally, by investing in a consortium, a company may be able to reduce project- related risks that it otherwise would be forced to bear if it chose to develop FCS projects on its own.

The main benefit of purchasing GHG offsets in the market is that the offsets can be delivered quickly for an established price and the buyer does not have to bear project and counter-party risks. While the price per ton CO_2e to buy offsets in the market can be known at any given time, this cost may be higher than the cost to the company of implementing its own FCS project to create GHG offsets.

Finally, renting GHG offsets appears to make sense if the renter believes that the price to acquire GHG offsets will not be substantially higher at the end of the rental period than at the beginning of the period. Renting offsets allows a company to obtain offsets with minimal up-front investment.

Table 3-1
Comparison of Alternative Organizational Approaches to Acquiring Forest Carbon Sequestration Offsets

Organizational Approach	Cost per GHG Offset	Expertise Required	Potential Regulatory Acceptance of GHG Offsets	Time to Delivery	Delivery Risk
Own Lands	Low	High	High	Long	Low
Easements	Low	Low	Low	Long	Moderate
Consortia	Low	Low	High	Long	Moderate
Market Purchase	High	Low	Variable	Short	Very Low
Rental	Low	Low	Low	Variable	Variable

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WHERE IS FOREST CARBON SEQUESTRATION RECOGNIZED AS A GHG OFFSET?

A ton of carbon stored in a forest may or may not count as a GHG emission offset, depending on the project baseline, leakage, and the rules of the GHG emission mitigation system in which recognition for the offset may be sought. Today, there is a variety of existing, evolving, and proposed regulatory schemes to mitigate GHG emissions both internationally and within the United States. Generally speaking, four distinct types of schemes have evolved, and the role that FCS projects can play within these schemes varies tremendously. These four generic types of schemes are:

- Existing regulatory systems that mandate GHG emissions constraints;
- Emerging U.S. regulatory systems that are likely to mandate GHG emissions in the future;
- Voluntary emission registration and reporting systems that recognize forest carbon sequestration but that do not directly facilitate trading of GHG offsets; and
- Voluntary market systems and private market transactions that recognize forest carbon sequestration.

When considering an emission mitigation system as a potential venue for using GHG offsets, one must carefully examine and consider what specific types of FCS activities are likely to qualify as generating a recognized GHG offset. A particular emission mitigation system may accept some types of offsets created by changing forest management, but not others. For example, the Clean Development Mechanism (CDM), established by the Kyoto Protocol, only will accept offsets created by afforesting or reforesting selected lands, but will not accept offsets generated by increasing the length of logging rotations. In contrast, the California Climate Action Registry (CCAR) will accept offsets from both afforestation and extending rotations.

Most emission mitigation systems also impose geographic limits on the locations from which acceptable GHG offsets can be created. At this time, the most important limit for U.S. electric companies to be aware of is that GHG offsets generated in the U.S. *are not eligible* for sale into the international market for compliance with the Kyoto Protocol limits on GHG emissions.

Mandatory GHG Emissions Reduction Schemes

Existing GHG Regulatory systems in which some types of forest carbon sequestration is recognized today as a way to create GHG emission offsets include:

- The Clean Development Mechanism (CDM) created by the Kyoto Protocol;[8]

[8] During Phase 1 (2005-07) of the European Emissions Trading Scheme (EU ETS), GHG emissions reductions associated with implementation of forest carbon sequestration projects are not recognized and cannot be counted against GHG emissions.

- The state of Oregon; and
- Australia's New South Wales Greenhouse Gas Abatement Scheme (NSW-GGAS).

The Clean Development Mechanism

Starting with the efforts of the original UNFCCC agreement in 1992, "land use, land use change and forestry" (LULUCF) has been an integral part of the discussions and policy developments associated with climate change on an international level. The Kyoto Protocol (KP) grants all ratifying parties the ability to utilize project-based "flexible mechanisms" (i.e., the Clean Development Mechanism (CDM) and Joint Implementation (JI)) to help achieve their target GHG emissions reductions. Many observers envisioned that these project-based "offset" projects would emphasize increased sequestration of carbon through forestry and agricultural activities. Under the KP, only lands that have not been forested since 1990 are eligible to be used for qualifying FCS-related GHG offset projects. Projects that avoid deforestation or increase the carbon stock in existing forests are not presently eligible to be used to create GHG offsets within the Kyoto system.

In the eight years that have passed since the KP was drafted, the international community has made substantial progress towards implementing the KP and developing the institutional framework to support it. Even though the KP failed to gain the support of the U.S. and Australia, it came into effect internationally in 2005. In that same year, the European Union launched an ambitious EU-wide Emissions Trading Scheme, the EU ETS to help the 25 EU Member States achieve compliance with their KP emission reductions targets. Internationally, the evolution of the CDM continues. In 2005, the CDM formally registered its first projects and issued its first GHG offsets (GHG offsets in the CDM are called Certified Emission Reductions (CERs)). Regardless of all of this activity, the opportunities to pursue GHG offset projects to sequester carbon through forestry, agriculture, and other land management activities have been stymied for the past several years and remain severely limited and fractured.

The role of forest carbon sequestration projects within the CDM has always been contentious. The limitations on what land use activities are recognized as creating GHG emission offsets, as well as the CDM's systemic institutional constraints result in the assessment that relatively few forest carbon sequestration offsets are likely to be generated through the CDM process. To date, 1,403 CDM projects formally have been submitted to the CDM Executive Board for approval, but only 30 of these have been forestry projects. Of these 30 proposed forestry projects, only 4 have been approved as being eligible to create offsets. No CERs have yet been awarded to forestry projects in the CDM.[9]

U.S. offsets are not eligible for sale into the Kyoto system because the U.S. has not ratified the Kyoto Protocol. If the U.S. were to ratify the Kyoto Protocol and commit to the U.S. emission cap contained in that document, then GHG offsets created in the U.S. would be eligible for sale into the Kyoto system, subject to approval by the U.S. government.

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[9] As of November 29, 2006, as tallied by CD4CDM, http://cd4dcm.org/.

If the U.S. were to ratify the Kyoto Protocol or its successor, GHG offsets created in the U.S. could be sold for use in other countries, but still could not be sold as CDM credits. This is because CDM credits are generated by projects within developing countries that do not have emission caps under the Kyoto Protocol. If the U.S. were to implement the Kyoto agreement or a successor agreement, the form that U.S. generated offsets would take would depend on the design of the U.S. domestic emission control program, and possibly also depend on the choice of the offset developer. It is possible that free-standing projects that look like CDM projects could be implemented in the U.S., with the resulting offsets sold by project developers to entities in other countries. Most likely, this would be done under the Kyoto Joint Implementation (JI) program.

The European Union Emission Trading Scheme (EU ETS)

Today, the European Union's Emissions Trading Scheme (EU ETS) is the centerpiece of the international GHG emissions market. The EU ETS began operating on January 1, 2005, and the regulatory scheme is mandatory for all 25 EU member states. Through the national governments, it allocates EU allowances (EUAs) to energy-intensive plants and installations. In turn, these firms must retire a quantity of EUAs equal to their emissions on an annual basis. The first phase of the scheme will last until 2007. From 2008, the scheme will coincide with the Kyoto Protocol's first commitment period.

One of the flexibilities given to the European industry entities covered by the scheme is the ability to use "Kyoto" units from the project-based mechanisms (i.e., CDM and JI) as equivalent compliance units. However, even though the KP provides for use of FCS-based GHG offsets for compliance purposes, forest-based GHG offsets are *not* allowed to be used for compliance purposes in the EU ETS at least through 2007. As a consequence, thousands of installations regulated as part of the EU ETS cannot utilize FCS-related GHG offsets to help achieve their compliance obligation under the program.

State of Oregon

In 1997, the legislature of the State of Oregon enacted the first law in the U.S. that limited GHG emissions. The law requires new power plants built in Oregon to limit their CO_2 emission rate to a rate that is lower than the emission rate of an efficient natural gas fired plant. The Oregon law allows power plants to comply by either limiting their own emissions or by paying a modest fee per ton CO_2 of emission above the threshold rate to a qualifying non-profit organization. The non-profit organization will use the funds to acquire emission offsets. By paying the "in-lieu" fee, power plant owners are absolved of any further obligation to reduce GHG emissions from the new facilities. To date, new power plants affected by the law have chosen to pay the Climate Trust instead of mitigating GHG emissions themselves. The Climate Trust also acquires offsets on behalf of other purchasers.

At this time, the Climate Trust is the only qualifying organization recognized by Oregon. To date, the Climate Trust has established contracts for 10 projects that are scheduled to mitigate 1.9 million metric tons of CO_2 emissions, at a cost of \$4.9 million. The Climate Trust is seeking to finalize contracts for another 3-5 projects. The Climate Trust also acquires offsets on behalf of other buyers including large GHG emitters and operates a retail sales program.

The Climate Trust has purchased offsets from afforestation, avoided forest clearing, and restoration of degraded forest. The Climate Trust has purchased offsets generated by projects in the U.S. and in Central America.

An electric company could purchase limited amounts of offsets from an existing portfolio of Climate Trust projects. If an electric company wishes to purchase more than a few tens of thousands of tons CO_2e of offsets through the Climate Trust, the Climate Trust would issue a request for proposals and negotiate new projects on behalf of the electric company.

Australia's New South Wales Greenhouse Gas Abatement Scheme (NSW-GGAS)

The Australian New South Wales Greenhouse Gas Abatement Scheme currently has mandatory emission limits in force from 2003 through 2012 and recognizes forest based carbon sequestration. This program recognizes GHG offsets created by planting and growing trees on land that was not forested on December 31, 1989. A legal mechanism must be in place to maintain the forest cover for at least 100 years.

As of August 2005, 132 GHG offset projects and 16 million certificates had been registered with the NSW-GGAS program. As of this date, just four FCS projects totaling 160,000 GGAS GHG offset certificates had been issued under this program.

Emerging U.S. GHG Mitigation Programs

A variety of regional efforts are underway now in the U.S. that propose to create GHG emission cap-and-trade programs within portions of the U.S. The most prominent among these efforts is the Regional Greenhouse Gas Initiative (RGGI), involving at least seven Northeastern and Mid-Atlantic States and a GHG mitigation program recently adopted in California.

Northeast Regional Greenhouse Gas Initiative (RGGI)

At this time, RGGI proposes to recognize and allow trading of GHG emission reductions accomplished by regulated emitting entities. The RGGI "model rule" released in August 2006, allows for creation of GHG offsets by afforestation, but does not recognize carbon sequestered by increasing biomass in existing forests. The model rule recognizes offsets created in any state that has enacted the model rule or in any other state that has entered into a memorandum of understanding with a RGGI state, as long as that other state provides for recognition and tracking of offset projects.

California recently executed an MOU with representatives of RGGI to link the evolving CA GHG regulatory process to the implementation of RGGI. The RGGI system also allows UN FCCC allowances and credits (such as CER's from the CDM program) to be used to meet RGGI obligations. However, RGGI has not specified a mechanism by which to formally link its program to KP's CDM program. The RGGI model rule only recognizes forest carbon sequestration accomplished within the first 60 years of a project, including carbon in live and dead wood and soil, but not including carbon in material removed from the project area (such as harvested wood). Also, project lands must be under a permanent conservation easement requiring the land to stay in forest.

California

Two GHG emission mitigation processes now are underway in California and it is important to distinguish between them. First, there is an existing voluntary program call the California Climate Action Registry (CCAR) that provides a way for participating companies to voluntarily register their corporate GHG emissions and GHG offsets. The CCAR is described in more detail below.

Second, in September 2006, Governor Schwarzenegger signed Assembly Bill 32 (AB-32) which requires California to reduce its GHG emissions to a 1990 level by 2020. This new law also sets in motion a regulatory process that could establish a GHG emissions cap-and-trade system in CA by 2012. Pursuant to AB-32, industries covered by the law, including the electric sector, will be required begin reporting their GHG emissions in 2008, and will be required to reduce emissions beginning in 2012. Regulations to implement the scheduled GHG emission reductions are to be written by the California Air Resources Board (CARB).

Regulations to implement AB-32 have not yet been promulgated, so it is not possible to say at this time what types forest carbon sequestration projects (if any) may be used to generate qualifying GHG offsets. However, AB-32 does include language that requires the CARB to consider the protocols established by the CCAR when creating its accounting rules. The CCAR protocols provide methods for quantifying forest carbon sequestration and are discussed below.

Numerous other states (e.g., Arizona, New Mexico, and a variety of Midwestern states) recently have undertaken studies of GHG emissions or taken other emission-related actions that may result in additional state and regional GHG mandates being implemented in the future.

Voluntary GHG Emissions Reporting Programs

In the U.S. today, there exist several important voluntary GHG emissions *reporting* programs. A variety of electric companies currently participate in these voluntary reporting programs. In contrast to the mandatory GHG regulatory schemes previously discussed, these voluntary schemes are designed to provide ways for electric companies and others to voluntarily “report” their corporate GHG emissions. The main voluntary GHG reporting programs described below include:

- The U.S. Department of Energy’s “1605(b)” program for the Voluntary Reporting of Greenhouse Gas Emissions;
- The U.S. Environmental Protection Agency’s Climate Leaders program; and
- The California Climate Action Registry (CCAR).

These programs do not require compliance with mandated GHG emissions limitations and are not institutional platforms designed to facilitate trade of GHG allowances or offsets. However, several of these voluntary reporting programs allow participating organizations to report GHG offsets as part of their voluntary reporting of GHG emissions so long as the reporting entity uses approved methodologies to account for relevant GHG offsets. Additionally, some of these programs explicitly recognize that “approved” GHG offsets can be traded in private transactions, but these programs are not involved in any direct way in the trade of GHG offsets.

The Revised 1605(b) Program

On April 17, 2006, DOE promulgated a new final regulation revising the so-called "1605(b) program" for Voluntary Greenhouse Gas Reporting.[10] These revised guidelines became effective on June 1, 2006. The revised guidelines set forth requirements for all entities reporting under the 1605(b) program, as well as requirements that must be met by the subset of reporters that seek to *register* GHG emissions reductions.[11]

Entities can seek either to *report* or *register* GHG emissions reductions under the revised 1605(b) program. Entities interested only in reporting GHG reductions can do so either on an entity-wide basis or for selected elements of their entities, selected gases or selected sources and projects. *Registered* GHG emission reductions are more highly regarded and potentially more valuable than *reported* GHG emissions reductions. Many parties hope that if a national program to reduce GHG emissions is established in the future, GHG emissions reductions *registered* under the 1605(b) program will be recognized in some way by that future system. DOE supports this view, but may not be able to ensure that registered emissions reductions will be counted in any future federal GHG mitigation program.

Under current rules, a "large" GHG emissions entity[12] (e.g., a typical electric company) would need to demonstrate entity-wide reductions in its GHG emissions over time as compared to a Base Value in order to *register* GHG under the revised 1605(b) program.

Under the revised 1605(b) program, electric companies and other entities may use changes in carbon storage to determine net GHG emission reductions, so long as the entity uses DOE's approved estimation and measurement methods and it includes an assessment of the net changes in all carbon sinks in its entity-wide GHG inventory of GHG emission and carbon storage. An entity seeking to *register* emissions under the 1605(b) program must include an assessment of both carbon emissions and sequestration occurring on lands owned by the entity as part of the entity's inventory of GHG emissions and sequestration.

Most electric companies own and manage some land that is forested, such as rights-of-ways, power plant sites, and lands surrounding office buildings. Some electric companies also own and manage very substantial tracts of forested lands. For the purposes of 1605(b) reporting, an electric company would need to account for the net carbon sequestration or emissions taking place on *all* of its forest lands as part of the company's entity wide inventory of its GHG emissions and sequestration if the company seeks to register GHG emissions reductions.

Under the revised 1605(b) guidelines, electric companies will need to decide how to report their GHG stocks, and GHG emissions and storage associated with forest land they own, including forest land dedicated to forest carbon sequestration projects and rights-of-ways. An electric company can choose to classify its forestlands in one of three ways:

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[10] See Federal Register, Vol. 71, No. 77, Friday, April 21, 2006, P. 20784. The new Final Rule will be codified at 10 CFR Part 300.

[11] See Section300.1 (b) and (c) of the revised 1605(b) rule for a description of the requirements for reporting and registering GHG emissions and reductions.

[12] A "large" GHG emitter is defined as an entity that emits more than 10,000 tons CO_2e per year.

1. Inventorying and tracking carbon stock changes over time;
2. Certifying that the lands are "sustainably" managed; or
3. Declaring the lands to be "incidental" to the core business of the company.

Lands certified by a qualified third-party certification body as being managed on a "sustainable" basis are assumed to have negligible stock changes and the associated GHG emissions can be excluded from an entity's inventory of annual GHG emission and sequestration.

Finally, the 1605(b) General Guidelines also allow companies to exclude "incidental, forested lands" as long as they are not actively managed for wood production or otherwise developed. There are no guidelines as to the acceptable acreage for such "incidental" lands.

The 50@50 Rule and Accelerated Reporting of Forest Carbon Stocks

In revising the 1605(b) program, the DOE adopted a new special provision designed to encourage implementation of forest carbon sequestration projects, which are characterized by up-front financial costs and "back-end" carbon sequestration. This new accounting rule can make forest carbon sequestration projects more attractive to implement under the 1605(b) program because it allows a company to count a substantial amount of anticipated future offsets in the first year of the project.

To encourage terrestrial carbon sequestration activities, DOE now permits entities that have undertaken a forest restoration project and established a permanent easement or deed restriction to protect the land, to report in the next reporting cycle, total carbon stock increases that are equal to 50% of the total carbon stock increases expected on the land over the first 50 years of the forest restoration project. The 50% discounting of the 50-year carbon stock increases closely approximates the present value of a 50-year stream of annual benefits discounted at a rate of 3% per year.

Reporting GHG Offsets Under the 1605(b) Program

In addition to accounting for changes in carbon stocks on their own lands, the revised 1605(b) program provides entities other ways to register or report forest carbon sequestration projects. For example, an entity like PowerTree that creates GHG offsets could register or report FCS-based GHG reductions to the 1605(b) program and then formally transfer the reported or registered GHG reductions to its investor members. While this approach technically would provide ownership of the reported or registered GHG reductions to a member electric company, DOE would continue to identify the original GHG offset creator (e.g., PowerTree) as the entity that registered the emissions reductions in its public reports about the 1605(b) program. DOE would not publicly report the member electric company's ownership of these GHG reductions but would, nonetheless, recognize their actual ownership of the emissions reductions.

Alternatively, an electric company could seek to *report* or *register* FCS-based GHG emissions reductions achieved by third parties as GHG "offsets." In the revised 1605(b) program an "offset" is defined as an "…emissions reduction that is included in a 1605(b) report…but is achieved by an entity other than the reporting entity. Offset reductions must not be reported or registered by any other entity and must appear as a separate and distinct component of an entity's report. Offsets are not integrated into the reporting entity's emissions or net emission reductions."[13]

While it is technically possible for electric companies to *report* or *register* FCS-based GHG offsets achieved by a third-party under the 1605(b) program, in practice doing so is likely to be administratively burdensome and potentially costly.

A "large" GHG emitter under the 1605(b) program (e.g., a typical electric company) that chooses to report emissions reductions on behalf of other entities must meet all of the substantive and procedural requirements applicable to large emitters, including submission of an entity statement, completion of a GHG emissions inventory, and an entity-wide assessment of GHG emission reductions. In addition, the electric company would be required to include in its report all of the information on the third-party entity, including an entity statement, an emissions inventory (when required), and an assessment of emission reductions that would be required if the other entity itself directly reported to the DOE.

DOE has been clear that it does not intend the 1605(b) to be a registry that tracks the trading of GHG reductions among program participants but, rather, it is a program to register and report GHG emission reductions achieved by a reporting entity either directly or via an offset agreement with a third party.

The EPA Climate Leaders Program

The U.S. EPA operates a voluntary GHG emissions reporting program called "Climate Leaders."[14] Companies that want to participate in the Climate Leaders program are required to establish a 5-10 year "aggressive" absolute or intensity-based GHG emissions reduction goal. As part of this program, participating companies provide EPA with annual GHG emissions inventories. EPA allows participating companies to separately report GHG emissions offsets. While this program allows participants to report GHG offsets from FCS projects and other activities, it does not "certify" these GHG offsets and does not support the trading of GHG emission offsets. Currently, 103 companies are participating in the program.

The Climate Leaders GHG Inventory Guidance is based on protocols developed by the World Resources Institute and the World Business Council for Sustainable Development (WRI/WBCSD). In November 2006, the WRI/WBCSD GHG Protocol issued guidance for quantifying forest carbon sequestration and other emissions and sinks from land use. Under the protocols, the method for determining the GHG offsets created by a FCS project is the difference between (a) the change in carbon sequestration over time on project lands, and (b) the change in carbon stock over time on comparable properties used to establish the baseline for the project.

The protocol recognizes carbon sequestration that results from afforestation or changing forest management as a GHG emission offset. The protocol does not explicitly address generation of GHG emission offsets by avoiding forest clearing but, presumably, if a project's baseline

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[13] 10 CFR 300.2 Definitions.

[14] More information is available at http://www.epa.gov/climateleaders/.

included removal of forest from baseline lands, the reduction in the rate of clearing could generate a GHG emission offsets. The protocol states that displacement of emissions caused by reduction in harvest of wood fiber must be accounted for, and such accounting may imply, in practice, that forest conservation projects will generate negligible amounts of GHG emission offsets.

As an alternative to directly reporting GHG emissions using the standard EPA procedure, EPA allows participating companies to obtain third-party verification of their GHG inventories and then to submit a verification report certifying that, at minimum, the requirements of the Climate Leaders GHG inventory review have been met. EPA provides participating companies with limited technical assistance.

The California Climate Action Registry (CCAR)

The California Climate Action Registry is a non-profit organization established by law that provides companies with a way to report their GHG emission inventories and certain types of GHG offset projects, including FCS-based projects. Like the DOE 1605(b) and EPA Climate Leaders programs, the CCAR is a GHG "registry;" it is not a trading platform that facilitates the trading of "qualified" GHG offsets. However, the CCAR has adopted a series of methodologies to be used by participating companies both for reporting their GHG emissions inventory and for reporting certain kinds of GHG offsets, including FCS-based offsets. Companies that may wish to report their GHG emissions inventory and GHG offset projects to the CCAR must use the CCAR's methodologies to do so.

CCAR has protocols for reporting emissions from selected industrial sectors, forest products companies, and forest carbon sequestration projects. CCAR recognizes increases in carbon stocks of existing forests, afforestation, and avoided deforestation as FCS methods that can generate GHG offsets. Methods are prescribed for measuring forest carbon stocks. Deforestation rates are provided for California counties. Developers of avoided deforestation projects can calculate the annual quantity of avoided GHG emissions by multiplying the published annual deforestation rate by the carbon stock on project lands. Avoided deforestation projects must show the existence of, at least, one of several specified indicators of impending development in order to qualify.

Private Markets for GHG Offsets

For the most part, GHG offsets are traded in the U.S. in private market transactions between willing buyers and sellers. In these types of market transactions, both parties agree that the GHG offset being traded meets the private criteria established by the parties involved in the transaction. Even though GHG offsets are traded voluntary in private market transactions, there is no guarantee that these GHG offsets ever will be formally recognized by the existing and evolving GHG regulatory systems.

A number of private parties today are offering GHG offsets for sale in the U.S. on a retail basis. A number of parties also have engaged in large-scale bilateral transactions of GHG emissions offsets. Typically, in these cases, a buyer (e.g., an electric company) will engage a project developer to develop FCS-based, or other types of, GHG offsets on their behalf.

In addition to private retail and bilateral trading of GHG offsets, an organization called the Chicago Climate Exchange has developed a voluntary, private market to facilitate the trading of GHG emissions offsets.

Retail Sales

There is no regulation of retail sales of GHG emission offsets for voluntary use. As a result, any seller can offer any type of GHG emission offset for retail sale. Existing sellers offer GHG offsets that range from undocumented assertions that the seller will invest sales revenues in future GHG emission offset projects to well-documented GHG offsets that have been verified by a reputable third party. The limited data that exists suggests that the U.S. retail market is very small, probably on the order of a few thousand tons CO_2e per year.

Retail sales appear to offer limited opportunities for electric companies. The amounts of offsets available for purchase are limited, and the quality is often not ascertainable. Similarly, if a company wished to sell offsets, it appears that demand is very limited. Retail sellers appear to substantially mark up the prices of the GHG offsets offered for sale.

Bilateral Transactions

By offset volume, much of the U.S. GHG emission offset market has been based on bilateral transactions. For electric companies, bilateral transactions may offer several advantages, including the ability to specify attributes of GHG offsets that will increase the likelihood that the GHG offsets will be accepted by a particular GHG emission mitigation system, and bilateral transactions may provide opportunities to acquire GHG offsets for little more than the cost of producing the offsets.

Prominent disadvantages of bilateral transactions include the chance that counterparty risks may be substantial, significant up-front capital funding may be required, and bilateral transactions can easily take more than a year to negotiate. Also, the costs of negotiating contracts, managing projects, and verifying GHG emission mitigation amounts can be substantial. For large projects, these transaction costs can be low per ton CO_2e of offset created, even if the costs are substantial when considered at the scale of the entire project.

Chicago Climate Exchange (CCX)

The Chicago Climate Exchange (CCX) is a legally binding, multi-sectoral, rule-based, and integrated GHG emission registry, reduction, and trading system.[15] CCX employs independent verification and includes all six GHGs. CCX members include private companies – including electric companies[16], state governments, non-government organizations, cities, and others.

Companies that wish to participate in CCX must become members of the exchange. To do so, companies must provide CCX with comprehensive GHG emission inventories conducted

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[15] More information about CCX can be found at http://www.chicagoclimatex.com.

[16] Electric companies that are CCX members include American Electric Power and Tampa Electric.

according to CCX's proprietary GHG reporting protocol, and members must agree to reduce their absolute GHG emissions ~6% by 2010 over an agreed-upon baseline.

By joining CCX, a company makes a legally-binding contractual commitment to measure, report, and reduce its GHG emissions. The company must establish an emission reduction schedule, implement GHG emissions management systems, and participate in annual GHG emissions audits and "true-up."

CCX Members that cannot reduce their own emissions can purchase "Carbon Financial Instruments (CFIs)" from those members who achieve extra emission reductions beyond their required GHG reductions or from verified GHG offset projects. CCX recognizes GHG offsets only after mitigation has occurred and required documentation has been presented. Since the CCX was established, CFIs have traded for $1-5 per t$CO_2$e.

Forest carbon sequestration projects that are eligible to be used in the CCX fall into three categories:

1. Forestation and forest enrichment;
2. Combined forestation and forest conservation; and
3. Urban tree planting.

Forestation and forest enrichment projects—including urban tree planting—initiated on, or after, January 1, 1990 on unforested or degraded forest land can create eligible GHG offsets at a rate based on the annual increase in the carbon stocks of above-ground, living biomass during the CCX program years (2003-2010).

CCX will recognize FCS-based GHG offsets for combined forestation and forest conservation projects in specified locations provided the two activities occur on contiguous sites. For these kinds of projects, eligible GHG offsets are quantified on the basis of avoided deforestation rates specified for eligible geographic regions.

Project eligibility, project baselines, quantification, and monitoring and verification protocols are specified in the CCX Rulebook. For FCS-based offsets, CCX requires an entity to demonstrate that entity-wide forest holdings are sustainably managed and that the organization has demonstrated a long-term commitment to maintain carbon stocks in forestry. In addition, GHG offsets must be based on CCX-approved methods to quantify carbon stocks and FCS projects are required to be verified by an independent third-party auditor.

Types of FCS Projects Eligible to Create GHG Offsets

Table 4-1 presents an overview of selected existing and evolving GHG emissions mitigation systems and reporting programs and the types of FCS activities that may qualify as GHG offsets. These programs continue to rapidly evolve, and it is likely that the rules that determine which FCS activities qualify to generate GHG offsets are likely to change. The information shown is highly simplified. Each GHG mitigation system or reporting program has its own specific requirements. Each one differs in terms of what FCS activities may qualify, where these activities may be located geographically, what types of entities may engage in FCS activities, and when qualified activities may begin. Please refer to the text of this chapter and the guidance published for each specific program to determine if a proposed FCS project is likely to qualify to generate GHG offsets.

Table 4-1
Types of Forest Carbon Sequestration Projects Recognized by Selected GHG Emission Mitigation Systems

System	Afforestation	Forest Management	Avoided Deforestation	Burying Logs
Kyoto Protocol CDM	Yes	No; possible after 2012	No; possible in the future.	Not yet determined
EU ETS	No; Possibly after 2007	No; Possibly after 2012	No; Possibly in the future	Not yet determined
Climate Trust	Yes	Yes	Yes	Not yet determined
Australia New South Wales	Yes	Yes	Yes	Not yet determined
RGGI	Yes	No	No	Not yet determined
California	Not yet determined	Not yet determined	Not yet determined	Not yet determined
U.S. DOE 1605(b)	Yes	Yes	Yes	Not yet determined
EPA Climate Leaders	Yes	Yes	Yes	Not yet determined
CA Climate Action Registry	Yes	Yes	Yes	Not yet determined
Chicago Climate Exchange	Yes	Yes	Yes	Not yet determined
Retail Sales	Yes	Yes	Yes	Yes
Bilateral Transactions	Yes	Yes	Yes	Yes

5

HOW CARBON SEQUESTRATION OFFSETS GREENHOUSE GAS EMISSIONS

There are two different kinds of greenhouse gas mitigation methods that are referred to by the term "forest carbon sequestration." One kind of mitigation is the removal of GHGs from the atmosphere. A removal is also called a "sink." The other type of mitigation is the reduction of an ongoing stream of emissions. For example, stopping the clearing of an existing forest can reduce future GHG emissions.

Use of biomass as fuel for energy generation may reduce fossil fuel use, and thus may reduce net GHG emissions. However, this displacement of fossil fuel is not sequestration, and is not addressed in these guidelines. See Chapter 2 and Appendix A of this report for references to other EPRI work addressing the use of biomass to reduce GHG emissions.

At the most fundamental level, trees remove CO_2 from the atmosphere. CO_2 is the GHG that is both the largest proportion of anthropogenic GHG emissions, and the gas that results in the largest proportion of anthropogenically-caused climate warming. Trees remove CO_2 from the atmosphere by absorbing it into their leaves. Using photosynthesis, green plants split molecules of CO_2, releasing most of the oxygen back to the atmosphere and using much of the carbon to make carbohydrates. Plants use the carbohydrates that they make for energy and to build plant tissues, including wood. Oven-dry, woody biomass is approximately 50% carbon, by weight[17]. Appendix D provides measurements of the percentage of dry wood weight that is carbon for selected North American tree species. This appendix also provides the proportions of biomass that are carbon for selected tree components of selected species.

Figure 5-1 shows a generalized relationship of the proportions of biomass in parts of a tree. This illustration represents a typical, mature tree from a temperate climate. The proportions are percentages of total biomass. For any single tree, the component proportions must total 100%. As a result, if the proportion of biomass in one component is higher than average, then the proportion of biomass in some other component must be less than average in that tree. For a given size of tree, relative to hardwoods, softwood trees tend to have slightly less of their biomass in branches, and slightly more in foliage and roots. Small trees have a smaller proportion of their biomass in stem wood, and larger proportions in all other components. As stem diameter increases, softwood trees approach mature proportions more quickly than hardwood trees. When trees reach a foot in stem diameter the relative proportions of biomass in different components have largely stabilized. Trees growing on very dry sites may have root biomass that is a much greater proportion of the aboveground biomass.

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[17] When calculating the amount of carbon sequestered by forests, many analysts assume 50% of tree biomass is carbon. This number represents an average of the carbon content of wood of different tree species. In the future, analysts may begin using specific carbon contents for different tree species so as to reduce the total error in the estimates of the amounts of carbon sequestration.

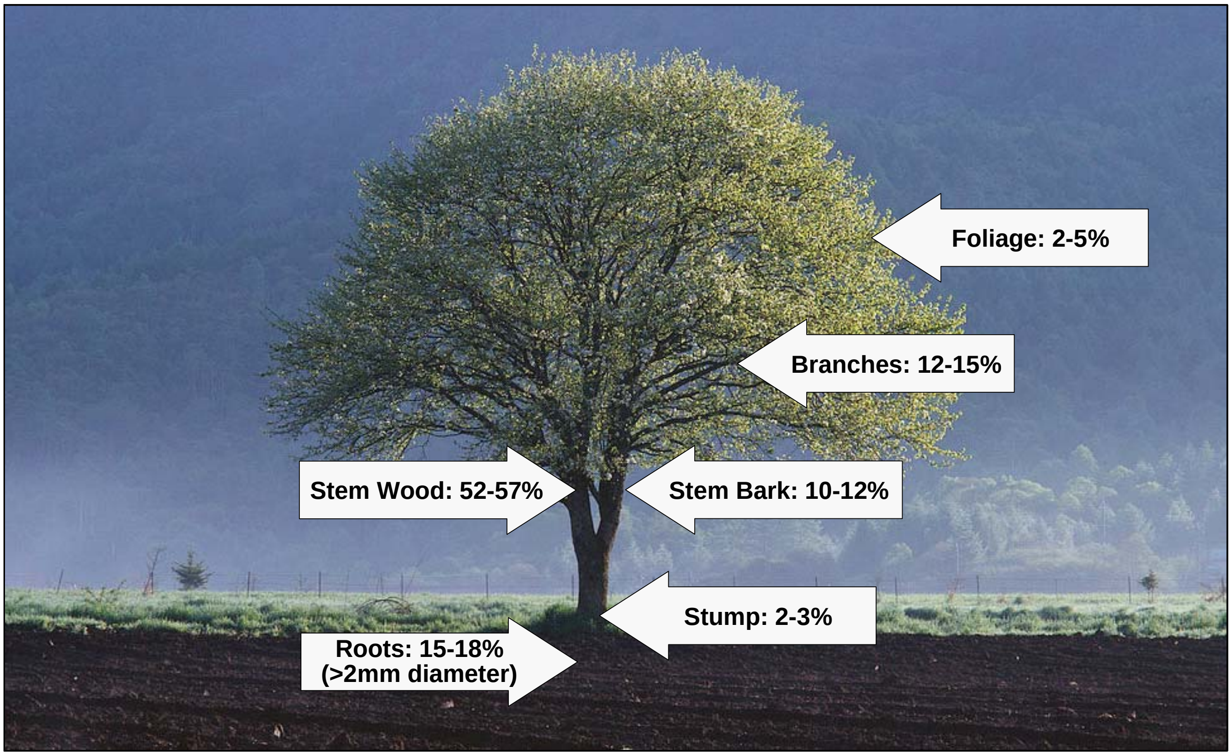

Figure 5-1
Generalized Proportion of Biomass in Components of a Mature Tree

Individual trees can die and decompose while the forest stand in which they grew continues to gain total carbon mass. This net increase can occur because other trees are growing that replace trees that die and decompose.

Carbon *Sequestration* versus Carbon *Storage*

When discussing carbon sequestration, it is important to distinguish the *removal of carbon from the atmosphere* from the *keeping of stored carbon out of the atmosphere*. In this report, the removal of carbon from the atmosphere is called "*sequestration*." Keeping this carbon out of the atmosphere (such as by keeping the trees that make up a forest) is called the "*storage*" of carbon, or maintaining the sequestration. This usage is designed to limit usage of the word "sequestration" to things that might count as GHG emission offsets. Removal of CO_2 from the atmosphere (sequestration) can be a GHG emission offset. Keeping that carbon out of the atmosphere by storing the carbon in wood maintains the offset through time, but *does not create a new offset*.

Some people have used the word "sequestration" to refer to keeping a certain amount of carbon stored in tree biomass. This usage confuses the removal of CO_2 that might count as a GHG emission offset from the continued holding of carbon that maintains the existence of offsets but does not create new offsets.

There are some circumstances, however, in which maintaining a certain amount of carbon storage may create a GHG emission offset. If ongoing loss of forest carbon can be slowed, the decrease in forest loss may reflect a decrease in emissions of forest carbon that may constitute a GHG emission offset. For example, if a native forest is protected from logging (and maintains its stock of carbon) and a new timber plantation is established that provides as much timber as was formerly extracted from the native forest, then loss of carbon stock from the native forest might be avoided and this avoided emission might constitute a GHG emission offset. However, even in this case, it would still be necessary to maintain the storage of carbon in the forest to maintain the offset over time. In this case, there is a net greenhouse benefit because the baseline condition assumed a trend of ongoing loss of forest carbon resulting in CO_2 emissions, and the project either stops or reduces the rate of GHG emission from deforestation.

Figure 5-2 shows an example of a possible baseline and GHG offsets over time for a hypothetical avoided deforestation project. The baseline for the project shows a substantial loss of carbon, dropping from 400 metric tons CO_2e per acre at the start of the project to ~250 metric tons CO_2e in year 20. With the implementation of the avoided deforestation project, the carbon would drop slightly during the first five years of the project. However, this drop is not as great as the drop in the baseline, so the project would generate a net emission benefit that may count as a GHG emission offset. During years 5 through 20 of the project, the carbon stock grows slightly. The baseline carbon stock continues to drop. The difference between the carbon stock with the project and the baseline continues to increase. When the actual carbon stock is greater than the baseline carbon stock, the difference represents the GHG emissions avoided by the project. It is the avoided emission that may qualify as a GHG emission offset. As the amount of avoided GHG emissions increases from one year to the next, new GHG offsets can be created. The amount of offsets that can be created in a particular year is the number of tons CO_2e of increase in avoided GHG emissions, from the prior year to the particular year in question.

While avoided deforestation projects, theoretically, can be used to generate GHG emissions offsets, these kinds of offsets are not widely recognized under most existing and evolving GHG regulatory regimes. At this time, the CCAR, the CCX and WRI's recent guidance for reporting GHG offsets from FCS projects recognize, on a limited basis, GHG emissions offset created by forest conservation projects

A key component of avoided GHG emission projects is assessing how much the project simply displaces emissions to other locations, rather than reducing emissions. This is called "leakage" and is discussed in more detail in Chapter 8.

To calculate GHG offsets, displaced emissions must be subtracted from the gross GHG emission reduction benefit achieved within the project boundary. It is possible to avoid displacement of GHG emissions by taking actions to avoid the displacement. If project activities reduce the amount of a specific good (e.g., timber) that is being provided to a market, one must assume that other suppliers can be expected to make up much of the decrease in supply by increasing their harvest. If the generation of the good results in GHG emissions, the displacement of production needs to be assessed, and the resulting displacement of GHG emissions calculated. To calculate the net GHG emission benefit resulting from an FCS project that reduces timber harvesting, the GHG emissions resulting from any displacement of harvest needs to be calculated and included in the calculation of the net GHG benefit of the project.

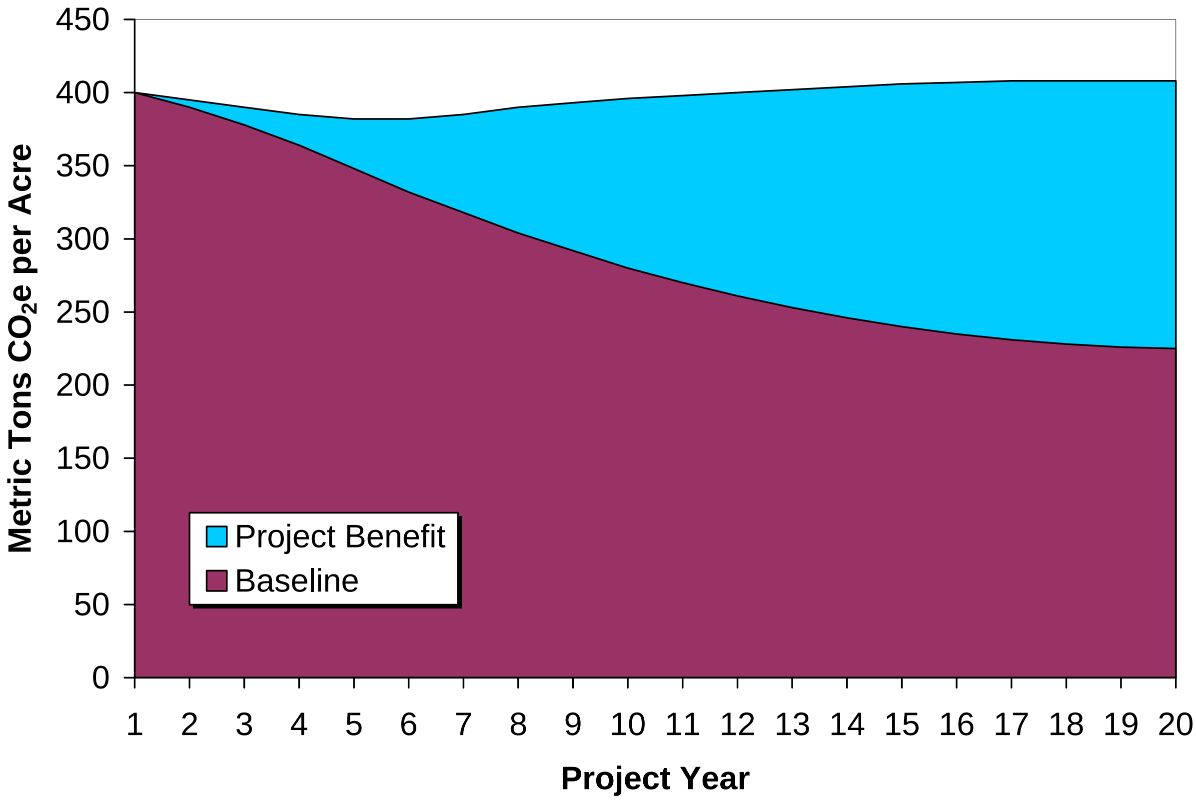

Figure 5-2
Hypothetical Example of GHG Benefit of Avoiding Forest Degradation

Reversal of Forest Carbon Sequestration Offsets (i.e., Permanence)

Forest carbon sequestration can be reversed. This reversibility means that GHG emissions reductions or offsets generated by forest carbon sequestration projects are not *permanent* like GHG emissions achieved by reducing the burning of fossil fuels. The trees can be cut down, burned, die from disease, or left to rot. Burning and decomposition both result in the oxidization of wood, returning the carbon in the wood to the atmosphere.[18] If the carbon in wood is converted back into atmospheric CO_2, any emission offset based on that carbon being sequestered is lost. Due to the possibility that offsets can disappear, forest carbon sequestration must be monitored to make sure that enough carbon remains stored to support all claimed offsets. This requirement for ongoing monitoring exists for any type of reversible offset, not just forest carbon sequestration. Also, because many parties have concerns about the permanence of forest carbon sequestration offsets, most international GHG trading programs in place today only recognize GHG offsets derived from forest carbon sequestration projects as temporary offsets. The Kyoto Protocol's Clean Development Mechanism now provides for the issuance of two

[18] Smoky fires and decomposition under very wet conditions can result in some of the carbon in wood being converted to methane instead of carbon dioxide. Generally, methane emissions are negligible but they should be considered when doing project accounting.

different carbon “credits” for registered CDM afforestation and reforestation projects. These are called tCERs, or Temporary Certified Emissions Reductions, and lCERs, or long-term CERS.

There are several ways of addressing the reversal, or “permanence,” problem of GHG emissions offsets. Reversed offsets can be counted as a corresponding GHG emission, with the amount of the emission added to the GHG emission inventory of the holder of the GHG offset in the year in which the reversal occurs. Reversed offsets can be replaced with a different GHG offset or an emission allowance. Some emission accounting systems have mechanisms for providing partial credit for temporary offsets, recognizing that there is value in holding emissions out of the atmosphere for a number of years.

The renting of GHG offsets is a variation on the reversal theme, in which a landowner commits to maintaining an amount of sequestration for a fixed period of time and has no obligation to continue to keep the carbon sequestered at the end of the contract period. At the end of the contract period, the renter will likely need to count the amount of expiring GHG offsets as a GHG emission, or can replace the expiring offsets with emission allowances or new, valid offsets. Alternatively, the life of the GHG offset can be extended by establishing a new contract that commits the landowner to continue the maintenance of the GHG offset.

6

FOREST MANAGEMENT ACTIVITIES THAT CAN CREATE GHG OFFSETS

A variety of forest carbon sequestration-related activities have been proposed for creating GHG emission offsets. Not all of these activities actually create offsets. Of the set of activities that do create GHG offsets, not all are likely to be able to create GHG offsets for a reasonable cost per ton CO_2e. This chapter discusses specific activities that are commonly proposed to generate GHG emission offsets by changing forest management.

In this section, we describe and evaluate a range of potential forest management activities for their potential to be used to create GHG emissions offsets. These FCS activities include:

- Afforestation / Reforestation (with and without harvest);
- Forest type conversion;
- Lengthening forest harvest rotations;
- Increasing utilization of harvested wood;
- Switching from even-age to uneven-age timber management;
- Avoiding forest clearing / deforestation;
- Burying wood;
- Thinning to decrease fire risk; and
- Using wood as fuel to displace fossil fuel.

Afforestation and Reforestation

Growing trees where trees did not exist before the start of a sequestration project can increase biomass present on project lands, sequestering carbon in the live and dead wood present within project boundaries. Many GHG emission mitigation systems recognize this kind of forest carbon sequestration as generating GHG emission offsets. Forest carbon sequestration projects, such as those being implemented by UtiliTree and PowerTree in the lower Mississippi River basin, provide examples of both afforestation and reforestation projects.

Afforestation is the establishment of trees on lands that were not previously forested. Reforestation establishes trees on lands that are not currently forested, but were forested at some point in the past. Since it is usually not cost effective to grow trees on sites that are not physically suitable for growing trees, most forest carbon sequestration projects are on sites that are physically suitable for growing trees. Most sites that are physically suitable for growing trees have had trees at some point on site sometime in the past several millennia. For the purposes of this report, we use the terms afforestation and reforestation interchangeably. However, many GHG emission existing and evolving GHG mitigation regulatory schemes require lands to have been in non-forest cover or non-forest use at a specified point in time for sequestration on those lands to be recognized as creating offsets. For example, under the Kyoto Protocol, only lands that were not forested in 1990 can qualify to generate forest carbon sequestration offsets. Electric companies and other potential GHG offset buyers should be aware of the requirements of the GHG emission mitigation scheme in which they plan to use the offsets, and create or acquire offsets that are likely to meet the relevant regulatory requirements.

Project developers and electric companies that plan to develop FCS projects on their own lands should pay particular attention to the use of lands prior to the start of a forest carbon sequestration project because this prior use will affect the project's GHG baseline. Project lands could be in forest use, but still have no live trees present at the time of the start of a project. For example, lands immediately after clear cut harvest and before replanting might have no live trees present but still be considered to be in a "forest" use. Prior land use will affect the project baseline used to determine GHG offsets. Lands that were in forest use prior to the start of a project, but that have no live trees present at the start of a project probably will have a without-project baseline that will assume the site will regain some biomass carbon after the start of the project. In contrast, lands previously in non-forest use (such as annual crops like soybeans or corn) may have a baseline that assumes that the lands would stay in crops and, in the absence of the project, would continue to be devoid of carbon in woody biomass.

Projects that establish trees on lands that were not in forest use immediately before the start of the project have several attractive attributes. They can store substantial amounts of carbon, with minimal displacement of emissions. These projects can make robust claims that the project generates a real net GHG emissions reduction benefit. Costs of carrying out afforestation and reforestation projects are relatively discernable. The main costs are land and forest stand establishment. Professional experience and robust existing timber and land markets make it relatively straightforward to estimate these costs accurately. Depending on the trees species and site history, afforestation projects can begin generating substantial amounts of offsets in, as little as, three to five years after project initiation. Over years to decades, FCS projects may generate a few hundred tons CO_2e of offsets per acre. Over time horizons that include a significant portion of tree growth, afforestation projects may generate GHG offsets at a modest cost per ton CO_2e. Also, methods for quantifying the number of tons of CO_2e stored by a forest are well established and reliable.

Afforestation projects also allow the option of generating some revenues from timber harvest. A combination of revenues may provide an attractive total financial return to carbon sequestration projects that combine some sequestration with some timber harvest. Timber harvest has the effect of either delaying generation of some GHG offsets, or reducing the maximum number of tons CO_2e of offsets per acre that can be achieved by afforestation. Trees that are too young to be valuable for timber are storing carbon, and can provide offset sale revenues before they can provide timber revenues. Later, trees may become more valuable for timber than for offsets. It is possible to spread harvesting over time, so that some carbon stock is maintained on the site, allowing some revenue from the sale of GHG offsets to be realized earlier in the project life, and some revenue from timber to be realized later in the project life, but not maximizing the production of either offsets or timber. Due to the time value of money, the present value of this staged approach may be greater than the present value of an approach that only grows timber or only sequesters carbon. This staged sale of offsets and then timber is discussed in more detail in Chapter 9 which addresses the financial analysis of projects.

Forest Type Conversion

Forest type conversion refers to changing the tree species that dominate a forest stand. Changing the composition of an existing forest stand to favor a dominant species that can grow to a larger size, or grow faster than the trees currently stocked on the site, can increase carbon stocks and generate GHG emission offsets.

In particular, sites where previous forest harvest practices have resulted in conversion from commercially valuable tree species to persistent cover by small-stature tree species may offer the opportunity to re-establish large, valuable trees. An example of this opportunity can be found on sites in the coastal forests of northern California that historically supported large conifer trees, but where historic harvest practices have resulted in colonization of the sites by persistent cover of scrubby hardwood species. Creating openings in the hardwood cover can allow re-establishment of conifers, resulting in large increases in biomass carbon stocks as the conifers grow.

Reforestation of reclaimed mine lands could be considered to be a case of vegetation type conversion. Typically, reclamation establishes grass cover on reclaimed lands. After grasses have started to re-create soil on the site, it may be possible to establish and grow trees on the site. In particular, coal-mine lands, potentially, can be restored in Appalachia with newly planted hybrid Chestnut trees that can help to restore mined land; bring back, from the brink of extinction, the American Chestnut; and, potentially, provide large-scale carbon sequestration benefits.[19] However, on some reclaimed mine sites, new trees have grown well for a few years and then stopped growing because of soil quality limitations. Project developers should carefully investigate whether reclaimed mine lands are capable of supporting long-term tree growth before implementing a project on these sites that depends on long-term tree growth.

The main advantage of forest type conversion projects is that lands suitable for these kinds of projects are often of low economic value. Also, conversion to larger trees can create a habitat that is desirable for wildlife.

A disadvantage of forest type conversion projects is that they may result in net GHG emissions during the first years of the project. Emissions result from the creation of openings or clearing of existing cover to make suitable conditions for growth of the new species. The magnitude and duration of the early emissions will depend on the carbon stock present on the site at the start of the project and the degree to which the existing cover must be removed to allow growth of the new trees. Often, forest type conversion projects do not begin to yield net carbon sequestration until one or two decades after the start of the project. Companies may place little value on GHG offsets that they will not receive for decades into the future.

Also, project developers should examine why the existing lands have low carbon stocks before implementing a forest-type conversion project. The reason may be that the lands are unproductive, or that access is very difficult. If the lands are unproductive, they may not ever

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[19] See *Evaluating the Efficiency of Carbon Sequestration in American Chestnut* (Castanea dentata), EPRI, Palo Alto, CA: 2005, 1011518 to learn more about the potential of the American Chestnut to sequester carbon and restore the landscape of the Appalachian region of the United States.

gain a large amount of carbon, or may not gain much carbon for many decades. Financial analysis of the returns that can be expected from these projects should carefully consider the amounts and timing of likely GHG offsets, and how potential buyers or project developers are likely to value GHG offsets that will not accrue until far into the future. Difficult access may, or may not, be a problem for a carbon sequestration project. Difficult access can reduce land value, and land cost is a major component of the cost of creating offsets using forest carbon sequestration. The financial savings associated with using lands that are less expensive because of access challenges are likely to be greater than the modest increases in site preparation and stand establishment costs due to the access difficulties. If an FCS project includes removal of wood products, difficult access may make a project financially unattractive. An FCS project on the same lands that does not include removal of wood products might be financially attractive.

Lengthening Rotations

Lengthening forest harvesting “rotations” means waiting until trees are older and larger before harvesting them for their wood. Averaged over large areas, lengthening rotations increases the average carbon stock per acre. This is because trees continue to grow after commercial rotation ages, and larger trees hold more carbon than smaller trees. A forest managed under longer rotations typically holds more carbon than if it were managed on a shorter rotation. This implies a higher average carbon stock per acre when averaged over the entire rotation.

There are three main difficulties with attempting to generate GHG emission offsets by lengthening rotations. First, minimal net GHG emission benefit can be achieved until the new, longer rotation is in place. This is because the harvest may be displaced during the switching to the longer rotation, since the harvest is deferred on stands that are old enough to harvest under the shorter rotation but not yet old enough to harvest under the new, longer rotation. Considering the time value of money, GHG offsets that accrue later in time are worth less on a present value basis than if the same number of GHG offsets accrued early on in the project. It may be possible to begin generating offsets immediately if it is possible to maintain harvest volume via thinning existing stands.

A second difficulty is that the cost per ton of GHG offset usually is high for FCS projects that are based on lengthening forest rotation. There are, at least, two reasons why the cost of creating GHG offsets in this way may be high. Deferring the harvest means deferring the revenue to be derived from harvest timber. Considering the time value of money, the economic cost of deferring timber harvesting can be high. Methods for calculating the time value of money are given in Chapter 9, which addresses financial analysis of FCS projects. Part of the economic cost associated with deferred harvesting is offset by increased tree growth during the deferral period, which may result in greater total harvest volume per acre annually. However, at commercial discount rates, the economic benefit to be derived from increased tree growth usually is less than the economic cost of extending commercial rotations.

A third difficulty with generating offsets by extending rotations is that most GHG emission mitigation programs do not provide recognition of GHG offsets generated by extending forest rotations. Even if a GHG emission mitigation system counts an increase in forest biomass as generating GHG offsets, if this increase in biomass is achieved by decreasing harvest, there may not be an accepted and tractable method for estimating avoided GHG emissions from the displaced harvest.

Increasing Utilization

Increasing utilization means getting more wood products out of each harvested tree of a given size. If a greater amount of wood products can be obtained from each tree, the same amount of end use can be supplied by harvesting fewer trees. Thus, the harvest can be scaled back with no concurrent displacement of harvesting in other locations. Scaling back the harvest allows more growth of standing trees, sequestering additional carbon.

Since wood products are economically valuable, companies in the U.S. already have invested a lot of resources into increasing their utilization of trees. Competition from low-cost providers of wood from other parts of the world has resulted in U.S. producers becoming very efficient. Today, computers measure logs and calculate how to saw them in a way that yields the maximum amount of lumber. Sizing saws to match smaller logs allows use of thinner saw blades. Lamination allows smaller and lower quality pieces of wood to be fabricated into large and strong structural beams that have predictable strengths. Finger jointing small pieces of wood end-to-end allows manufacturing of long lengths of clear wood. Sawdust and trimmings now are often used either for fuel to power sawmills or manufactured into products like particle board and oriented strand board. Professionals within the timber industry report that available technologies for increasing wood utilization have already been widely adopted across the United States. With current technologies, there appear to be few opportunities for further increasing utilization of harvested wood in the United States.

Utilization may be low in less industrialized countries where access to capital is limited, labor is cheap, and land is cheap. Current use of inefficient practices may provide the opportunity to increase efficiency by applying practices or technologies that are already in near-universal use within the United States.

Switching from Even-age to Uneven-age Management

Even-age management refers to growing trees such that all the trees that dominate a forest stand are about the same age. Among people who are not foresters, even-age management is better known as “clear cutting.” In contrast, uneven-age management means that the trees that form most of the canopy of a forest are of at least three different ages. In uneven-age management, individual trees or small groups of trees are harvested periodically in a selective fashion, making room for new, young trees to establish themselves.

In theory, uneven-age management can grow more wood per acre annually. The logic is that young trees occupy little space, and older trees occupy more space per tree. With even-age management, when trees are small, a large proportion of the land is in spaces between the trees that will eventually be crop trees that fully occupy the site. Uneven-age management allows the trees to more fully occupy the site, through time. As adjacent larger trees are harvested, space is made for smaller trees that have been growing in between the larger trees. Having sites more fully occupied should result in both more wood to harvest and more biomass, providing more sequestration relative to previous even-age management.

In practice, the net increase in carbon stocks resulting from switching from even-age management to uneven-age management is hard to predict, and appears to be small or nonexistent. If the space is available, individual trees can grow broad canopies and thick trunks, storing a lot of carbon per tree. If trees are growing with relatively tight spacing, they tend to grow tall and thin (on sites where water is not the main factor limiting growth). Each tree is narrower, and each tree contains less carbon than a tree of the same age that is open grown, but there are more trees per acre. This plasticity of growth form allows trees to fully occupy land from young ages. Also, young trees that are substantially shaded by larger trees may grow more slowly than if they were located in areas that are open to sunlight. In practice, uneven-age management of tree species that need a substantial amount of direct sunlight to grow vigorously appears to result in little, or no, increase in carbon stock relative to even-age management.

Where clear cutting is now in use, foresters and loggers often resist switching to uneven age management. One reason for resistance is that, with clear cutting, loggers do not have to take care to avoid damaging trees that are left to grow.

Finally, it may be difficult under existing and evolving GHG regulatory schemes to obtain FCS-based GHG offsets for switching from even-age timber management to uneven-age management.

Avoiding Forest Clearing or Deforestation

Globally, forest clearing and the cutting of larger trees in forests has caused a significant portion of anthropogenic GHG emissions. It has been estimated that from 1850 to 1990, carbon associated with human clearing and degradation of forests was approximately equal to one-half the amount of GHG emitted by burning of fossil fuels (Houghton 1999). Avoiding further loss of forest biomass is an opportunity to both reduce emissions and maintain desirable ecological functions of forests. Prominent projects sponsored by electric companies to reduce deforestation include the Noel Kempf project in Bolivia and the Rio Bravo project in Belize.

In the U.S., the majority of forest clearing is done for commercial land development, particularly to build houses and associated roads. Many of the opportunities for reducing land clearing related to development are hard to access for GHG emission offset projects. The best time to implement a GHG offset project based on avoided land clearing would be prior to the planning of large subdivisions. If local planning and zoning authorities accept clustered development, clearing for dwellings and roads can be clustered, leaving a substantial portion of the land that is proposed for development in forest cover. Displacement of clearing can be avoided if the planned number of dwelling units can be arranged in a way that involves fewer acres of clearing, and preservation of the remaining forested area. However, a great deal of land development occurs on existing lots that are laid out in a pattern that does not permit clustered development. Even if clearing can be limited to a portion of an existing parcel, the transaction costs of planning and establishing contracts for a small parcel are likely to be greater than the value of the GHG emission offsets that could be generated on the parcel.

In some developing countries, such as Brazil and Indonesia, deforestation and forest degradation cause substantial GHG emissions. However, methods for reducing forest clearing without displacing emissions to other locations are not well accepted. Also, methods for quantifying GHG emission reductions resulting from avoiding deforestation are not well established.

Avoided deforestation projects are not recognized as generating GHG emissions offsets in GHG emission mitigation systems that only count *increases* in terrestrial carbon stocks as GHG emission mitigation. Also, many accounting systems do not recognize GHG emission mitigation achieved by changing management of existing forests. In the international arena, some proposals have been put forth to create GHG offsets based on avoiding deforestation, but none of the proposed methods are widely accepted. Most recently at COP 12 / MOP2 in Nairobi, Kenya, the delegates adopted a final statement that highlighted a concrete proposal put forward by Brazil for an arrangement to provide positive incentives to reduce deforestation emissions in developing countries. The delegates agreed that this proposal will be discussed at an upcoming UN-sponsored meeting in March 2007.[20]

One approach to assigning a GHG emission reduction benefits for protecting land from clearing is to allow the carbon stock on the protected land to be counted as an offset at the rate at which land clearing is occurring on other nearby lands. The California Climate Action Registry forest project accounting protocols use this method. However, in nearly all localities, annual conversion rates are quite small. For example, the conversion rates published for California counties are almost all below a rate of 0.02% of forest land cleared per year. This means that 0.02% of the total forest area in the locality is converted to non-forest cover each year – for every 10,000 acres of forest, two acres are converted to non-forest cover each year. Converting to a per-acre basis, if an acre of forest land contains 500 metric tons CO_2e and GHG emissions are avoided at a rate of 0.02% per year, the avoided emissions would equal 0.1 metric tons CO_2e per acre annually.

Projects that seek to reduce the loss of forest biomass must address the displacement of forest clearing caused by the GHG emission mitigation project. If a project reduces the amount of wood supplied to a market, other suppliers will make up most of the lost supply (Murray et al. 2004). This displacement of harvesting typically also displaces GHG emissions, meaning that the project has little effect on net GHG emissions. Projects can avoid displacing GHG emissions by maintaining the supply of timber provided by project lands. Timber supply can be maintained by establishing a new forest plantation.

Burying Wood

Considering the continuum of possible approaches to using forest growth to mitigate GHG emissions, burying wood is an extreme but potentially practical example. Burying wood and protecting it from decomposition could allow a parcel of land to continue to remove GHGs from the atmosphere virtually indefinitely.

With afforestation, the gain is realized at one distinct point in time, as previously bare land gains biomass until that biomass approaches an equilibrium amount. When a forest stand approaches biological equilibrium, carbon losses from tree death and decomposition approximately equals carbon gains from the growth of live trees. In reality, there is no single equilibrium, but carbon stocks vary around a theoretical equilibrium, depending on the history of disturbance of the stand in question. Once a forest stand is close to equilibrium, the mass of carbon in the forest remains approximately constant and no further net amount of carbon is removed from the atmosphere.

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[20] "‘“Spirit of Nairobi’” prevails as United Nations Climate Change Conference successfully concludes with decisions to support developing countries," Press Release, UN FCCC, November 17, 2006.

The creation of new emission offsets would cease, and the forest would merely maintain existing offsets.

In contrast, if wood is grown and buried in a way that prevents decomposition, the carbon from previous growth remains sequestered. At the same time, the site can grow more trees, sequestering more carbon. The cycle can be continued indefinitely. The rate of sequestration will vary by the tree species and the productivity of the site. For most forest lands in the U.S., the rate of sequestration in stem wood and stem bark will equal 3-8 metric tons CO_2e per acre annually.

The limiting factor for burying wood to sequester carbon is that it is expensive. Wood is valuable for use in wood products and burying wood forgoes revenue from selling the buried wood. The forgone revenue of wood sales per ton CO_2e will vary by the density of the wood and the value price of timber. Table 6-1 gives the number of cubic feet of logs that represent one metric ton CO_2e, for selected species. The calculations assume that wood is half carbon, by dry weight. Green wood densities are from USDA Forest Service publications.

Table 6-1
Number of Cubic Feet of Wood per Metric Ton CO_2e, for selected North American Tree Species

Tree Species	Cubic Feet per Metric Ton CO_2e	Specific Gravity (green)
Oak, White	32	0.60
Pine, Slash or Longleaf	36	0.54
Pine, Loblolly	41	0.47
Douglas-fir	43	0.45
Cottonwood, Black	62	0.31

The forgone revenue from wood sales will depend on species, log size, and current log prices. Using a very general example for 15" diameter Douglas-fir logs[21] with a stumpage value of $400 per thousand board-feet, the forgone timber revenue per metric ton CO_2e in buried wood will be $100 (assuming no decomposition of the buried wood). Some of the cheapest wood is small material used for chips. Using a moderate chip price of $50 per short "green" ton delivered, and assuming that the green weight of wood is half water and the dry weight of wood is half carbon, the value of carbon in these chips would be $60 per metric ton CO_2e.

Sometimes landowners desire pre-commercial thinning or removal of species that compete with a favored crop species. To achieve stand treatment goals, a landowner may be willing to allow an operator to remove wood from stands to leave those stands in a particular condition, with no charge for the removed wood. An efficient stand treatment operation, removing 10 dry tons per

[21] For 16' long logs, a 15" diameter log will have very close to 6 board feet (Scribner scale) per cubic foot, assuming a form factor of 0.87.

acre, and hauling the material no more than a few miles to a burial site, may be able to deliver wood to a burial site for a cost of $20 per short, dry ton. The cost for harvesting and transport represents a cost of $12 per metric ton CO_2e in the delivered wood.

The cash expenditures required to grow and bury wood would not include the forgone value of the buried timber. The actual financial costs would be equal to the costs of land, afforestation, taxes, cutting and transporting the logs, and burying them. However, a more complete economic analysis of this kind of project also would include the "opportunity cost" associated with burying trees that otherwise could have been sold in the market.

Thinning to Decrease Wildfire

Wildfire can kill trees. The dead trees then decompose, emitting their carbon into the atmosphere as CO_2. If the volume of trees killed by wildfire can be decreased, it may be possible to retain more carbon in forests.

However, thinning also kills trees, and most of the wood in the thinned trees eventually decomposes, converting to atmospheric CO_2. Thinning to decrease wildfire only generates a GHG emission benefit if the GHG emissions from thinning (minus re-growth after thinning) are less than the emissions from fire (minus re-growth after fire).

On a per-acre basis, thinning generally emits less than a stand-replacing wildfire that kills all the trees. This is mainly because thinning focuses on removing the smaller trees, and a single large tree can hold the same amount of carbon as many small trees. The actual carbon emission from thinning will depend on the thinning prescription, the sizes and numbers of trees that happen to be present, and the fate of the wood in trees that are cut.

At the same time, fire does not release as much carbon as the public often thinks. Even so-called "crown" fires that kill all the trees on a site and burn the foliage do not burn most of the wood in the stems and roots of trees, which contain most of the biomass and carbon in trees. In moist climates like the eastern U.S., half of this dead wood mass might decompose in about 10 years. In the dry, fire prone climates of the western U.S., pine and Douglas-fir trees generally take 30-40 years for half of the dead wood to decompose. In the 40 years after a fire, a new forest can grow, replacing most or all of the carbon lost in the fire. If there is a significant amount of carbon in the forest floor, this carbon may be burned in a wildfire, and in some locations these losses may actually be larger than emissions from burning trees.

Across the landscape, it appears that the net emissions from thinning that reduces fire may be larger than the net emissions from fire. This is because only a fraction of one percentage of the forest is killed by fire each year, but a significant portion of the landscape will likely need to be treated to reduce wildfire mortality by a noticeable amount. Analysis of western U.S. forest suggests that a strategic selection of 30% of the landscape might reduce the extent of fire by half (Finney 2001). Furthermore, thinning treatments would have to be repeated, perhaps every 15-20 years, to maintain fire resistant conditions. Across large landscapes, the GHG emissions associated with treating the forest to reduce wildfire risk actually may cause larger GHG emissions than would be avoided by reducing the risk of wildfire on the treated lands.

Another problem with trying to create tradable GHG emission offsets by reducing wildfire is the lack of clear knowledge that a specific benefit has been achieved. A fire may, or may not, have burned through the project area during the project period. Offset buyers would have to accept a probabilistic assessment of how much burning was avoided by thinning. In informal discussions, GHG emitters that are using offsets have expressed an unwillingness to purchase offsets based on the sort of probabilistic estimates that would necessarily underlie the calculations of the amount of GHG emissions avoided by trying to prevent wildfire.

At this time, we are not aware of any GHG emission offset systems that recognize or have a protocol in place for recognizing GHG emission offsets generated by reducing wildfire. It is possible that a large state such as California could have both a large enough area that a change in area burned might be detectable, and resources to model fire spread and measure forest carbon stocks across the state. Even at such a large scale, it may be impossible to measure a reduction in fire mortality resulting from stand treatment. Year-to-year variation in the area of land burned by wildfire can be as much as ten times the expected decrease in the area that might be burned by fire as a consequence of implementing a very extensive thinning program.

Using Biomass to Displace Fossil Fuel

Displacing fossil fuels (such as coal) with biomass fuels (such as wood) is not sequestration, but can reduce GHG emissions from the combustion of fossil fuels. Although the use of woody biomass for fuel can effect forest carbon sequestration, this is not the focus of this report. If the harvest of wood for biomass (or any other use) results in a long-term reduction in forest biomass, this reduction in forest biomass should be counted in calculations of the GHG emissions impact associated with the harvest and use of wood products.

In practice, if enough wood supply can be put under contract it may be feasible for an electric company to build dedicated biomass-fueled electricity generation plants and reduce dispatch from other facilities that have a greater GHG intensity of generation, expressed in tCO_2e/MWh. In this case, the GHG emission reductions would be produced as a consequence of reducing the amount of power generated by higher GHG intensity fossil fuel-fired plants located in the region. Alternatively, an electric company may be able to co-fire biomass in an existing coal-fired facility and thereby directly reduce its GHG emissions.

Almost all of the CO_2 emissions embedded in the biomass component of the fuel are considered to be “net zero” from a GHG accounting standpoint, so the CO_2 emissions associated with the biomass portion of the fuel does not count from a GHG emissions accounting perspective. The cost of the biomass fuel also may be offset partly by the reduced cost of purchasing coal fuel and associated SO_X and NO_X emissions allowances, and partly from revenue derived from GHG emission offsets.

Over many years, the GHG emissions avoided by substituting biomass for fossil fuels can be greater than the GHG emissions associated with reduced forest biomass resulting from the associated harvesting. If harvesting can be done by thinning that promotes the growth of retained trees, the carbon stock in harvested stands may recover in a few years, resulting in effectively no GHG emissions being embodied in the electricity generated from the combustion of biomass fuel. CO_2 goes into the atmosphere from burning wood, but the carbon in this CO_2 originally was removed from the atmosphere a few years earlier. If forest carbon stocks are not reduced by harvesting (averaged over a specified project area and accounting period), then there would be no net GHG emissions associated with using biomass as fuel. This is why biomass fuels are often considered to be “net zero” from a GHG accounting standpoint. However, there are likely to be some GHG emissions associated with operating the equipment to harvest and transport wood, but these emissions are relatively small. Some parties have estimated these residual GHG emissions as being roughly equal to 10% of the total amount of avoided GHG emissions associated with burning biomass-based fuels.

Using wood for biomass fuel may be cost effective if a sufficient supply of biomass is accessible within an economical hauling distance of a power plant (generally thought to be a radius of 50 miles), and if there is little other demand for the wood. In general, wood will have less value if it is from trees that are too small to saw into boards, if the trees are too crooked or have pockets of decay that make them unsuitable for solid wood lumber, or if the species are not suitable for the products made by local wood processors. Paper mills that need wood for paper making usually can pay more for wood than the value of the energy content of the wood.

For further information related to the co-firing of wood with coal to generate electricity, please refer to these other EPRI reports:

- *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*, EPRI, Palo Alto, CA: 2004. 1008488.
- *Biomass Resources, Technologies, and Environmental Benefits*, EPRI, Palo Alto, CA: 2004. 1004602.

Comparing Approaches to Generating GHG Offsets via Forest Carbon Sequestration

Table 6-2 compares the different approaches described above that can be used to generate GHG emission offsets using forest carbon sequestration. Of the options addressed here, afforestation and reforestation are the most widely accepted by existing and evolving GHG emission mitigation systems and GHG emissions reporting protocols. These kinds of FCS projects can be accomplished for relatively moderate costs per ton CO_2e, and can yield substantial amounts of GHG offsets over time.

Using biomass for fuel to generate electric power is not sequestration, but may be economically feasible if companies are forced to bear the cost of emitting CO_2 and CO_2 prices are relatively low. Currently, both dedicated biomass power generation and co-firing of biomass with fossil fuels may be profitable in some specific locations.

At very high GHG emissions / offset prices, burying wood might become economically feasible. However, in most cases, using wood to displace fossil fuel in energy generation would generate GHG emission reductions at lower cost per ton CO_2e than burying the wood.

Avoiding deforestation can reduce GHG emissions but methods for calculating baselines of avoided deforestation projects are not well established. Avoided deforestation may eventually be counted at the national scale but, at the project scale, it is uncertain whether avoided deforestation ever will be recognized as creating GHG offsets.

Increasing utilization of harvested wood may be an approach that can generate GHG offsets in developing countries that now use inefficient harvesting and processing practices, but in the U.S. there are likely to be few opportunities to increase wood utilization.

Forest type conversion can produce GHG emission offsets. However, relatively long lengths of time are generally needed to generate offsets using this mechanism. This long lead time may make offsets relatively expensive, particularly once the time value of money is factored into the analyses.

Lengthening forest rotations, switching from even-age forest management to un-even age management, and thinning to reduce wildfires appear offer little opportunity to generate GHG emissions offsets.

Table 6-2
Comparison of Mechanisms for Forest Carbon Sequestration

Activity	Offsets Recognized	Front-Loaded Costs?	Start of GHG Offset Accrual	Duration of GHG Offset Generation	Reliability of Quantification	Compatibility with other Revenues	Potential Supply	Cost ($/t$CO_2$e)
Afforestation	Widely	Yes	3-30 years	Decades	High	Yes	High	Low to Moderate
Forest Type Conversion	Sometimes	Yes	10-40 years	Decades	High	Yes	Low	Moderate
Lengthen Rotations	Sometimes	Probably	> 5 years	Years	High	Yes (Long-term)	Low	Very High
Increase Utilization	Sometimes	Possibly	< 1 year	Perpetual	Moderate	Yes	NA	Low
Switch to Uneven-age	Sometimes	No	< 1 year	Decades	High	Yes	Low	Unknown
Avoid Clearing	Sometimes	Yes	< 1 year	Decades	Moderate	Yes	Unknown	Very High
Burying Wood	No	Yes	< 1 year	Perpetual	High	No	High	Moderate
Thinning to Reduce Fire	No	Yes	Possibly Never	Unknown	Low	Yes	Possibly Non-Existent	Very High
Biomass for Energy	Widely	Partial	< 2 years	Perpetual	High	Yes	High	Low

Supply scale:	Low	= Less than 100,000 metric tons CO_2e of offset per year in the U.S. by 2015
	Moderate	= 100,000 to 1,000,000 metric tons CO_2e of offset per year in the U.S. by 2015
	High	= More than 1,000,000 metric tons CO_2e of offset per year in the U.S. by 2015
Cost Scale:	Low	= Less than $10 per metric ton CO_2e on a levelized, present value basis.
	Moderate	= 10 to $25 per metric ton CO_2e of offset, discounted
	High	= $25-50 per metric ton CO_2e of offset, discounted
	Very High	= More than $50 per metric ton CO_2e of offset, discounted

7
HOW MUCH AND HOW FAST CAN FORESTS SEQUESTER CARBON?

Factors Affecting Forest Carbon Sequestration Amounts and Rates

Different forest stands can store radically different amounts of carbon. The main factors that drive how much carbon a forest can sequester are *site productivity*, *tree species*, *stand history*, and *forest management practices*. Each of these factors can cause sequestration to range between nothing and hundreds of metric tons CO_2e per acre.

Site productivity is a characterization of how fast trees will grow on a particular site. Site productivity is driven by climate and the physical attributes of the site. The most productive sites can store carbon at a rate several times the rate of storage on the least productive sites that are still classed as forest land or woodland. Land cost is an important factor in the total cost of forest carbon sequestration projects. Low productivity lands are often much less expensive to purchase than high productivity lands because opportunities for revenues from crops or forestry are small. However, unless high productivity lands cost several times as much as low productivity lands, the cost per ton of carbon sequestration on low productivity lands will generally be higher than on high productivity lands. This cost relationship occurs because planting and management costs will be just as high on low productivity lands as on high productivity lands, and these costs will be spread over far fewer tons of GHG emission offsets. Also, lower productivity sites take longer to yield a given number of offsets. Accounting for the time value of money, this delay further increases the cost of offsets generated on low productivity sites.

Different tree species have very different growth rates, maximum sizes, and capacities to sequester carbon. However, each species requires growing conditions within a certain range. Many slower growing species can grow well on sites that are too harsh for faster growing species to survive. Figure 7-1 shows examples of typical carbon stocks of selected tree species growing in the U.S., as a function of the number of years since clear cut harvesting. These amounts are for carbon in all forest biomass except mineral soil. The carbon stock immediately after harvest is mainly in woody debris (much of this is logging debris) and the forest floor. Logging debris decomposes over time, and new trees grow. The carbon stocks depicted in Figure 7-1 are based on data from thousands of sample plots across the U.S. (U.S. Department of Energy 2006). As shown, for most forest types, the gain in carbon stock between the stock present immediately after logging and the stock contained in a mature forest is on the order of 200 metric tons CO_2e per acre. However, for very productive forest sites in the Pacific Northwest, the gain can be more than 900 metric tons CO_2e per acre.

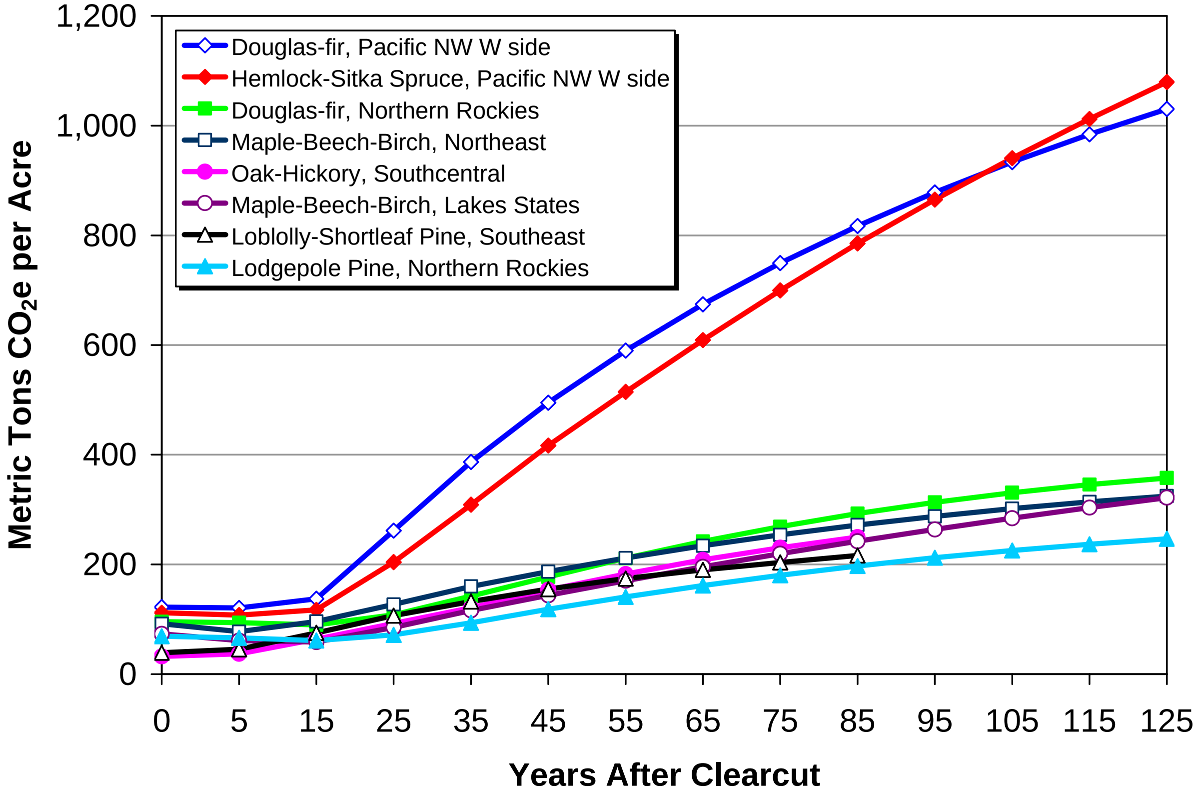

Figure 7-1
Typical Carbon Stock of Selected Tree Species Growing in the U.S., as a Function of the Number of Years Since Clear Cut Harvesting
Source: U.S. DOE 2006b.

One approach to carbon sequestration is to plant extremely fast growing trees, such as Cottonwood or Hybrid Poplar. Often the total number of tons of carbon per acre in a mature Cottonwood stand will be less than the number of tons of carbon per acre that could be stored by a different species on the same site. However, Cottonwood grows very quickly. Through several years of very fast growth, Cottonwood may sequester as much carbon as another species would gain in several decades of growth on the same site. Due to the time value of money, Cottonwood's rapid growth rate may yield offsets at a lower cost per ton than accruing a larger number of tons over a much longer time period.

Figure 7-2 shows predicted sequestration by Cottonwood planted on moderately productive agricultural land. Sequestration begins slowing after only eight years, but for those eight years the average sequestration is nearly 10 metric tons CO_2e per acre annually. The total amount of sequestration is small relative to the carbon storage in mature stands of other species, but other species might take almost half a century to sequester the same amount of carbon per acre.[22]

[22] Cottonwood growth is calculated using the growth model described in Cao and Durand (1991), using a 10-year site index of 90. The growth model predicts stem wood volume. Stem wood volume is converted to total tree biomass and carbon stock using equations published by Jenkins et al. (2003).

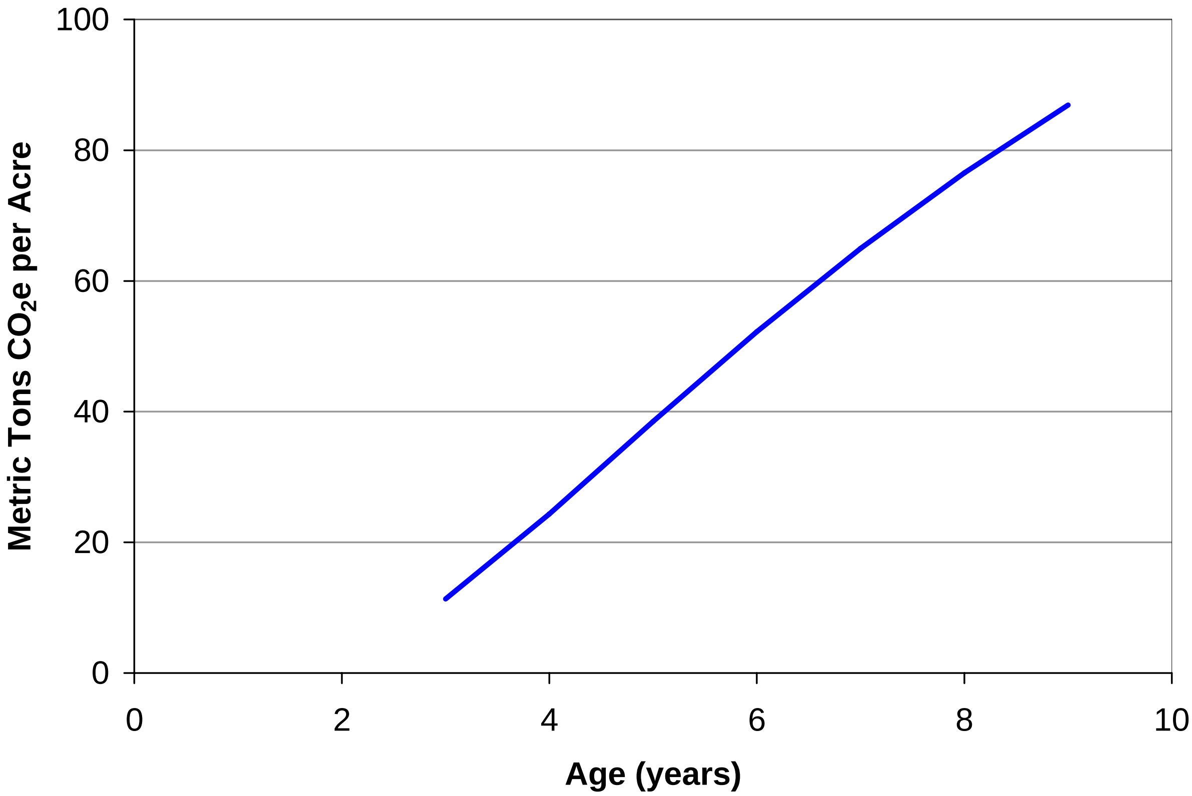

Figure7-2
Predicted Eastern Cottonwood (*Populus deltoides*) Carbon Stock as a Function of Stand Age

Stand history is extremely important to forest carbon sequestration projects because history determines how much carbon is present at the start of the project (i.e., the project's GHG "baseline"). If the stand already is near the high end of its possible carbon stock, there may be little that can be done to increase the carbon stock. In contrast, starting with crop land that has essentially no biomass carbon present offers the possibility of a large gain in carbon stocks.

Forest management also has a substantial effect on carbon stocks. In a private commercial forest, net present value is maximized by growing trees using relatively short rotations. Although harvest revenues will be lower than if trees are grown to maturity, the present value of long rotations is less than the present value of harvesting younger stands. In contrast, National Forests are mandated by law to grow stands at least to the age at which average wood accumulation over time is maximized[23]. Moving from commercial rotations that maximize financial return toward longer rotations that emphasize wood production increases the average carbon stock in forests. However, the cost per ton of CO_2e sequestered can be quite high, when calculated in terms of forgone timber revenues. At the beginning of the rotation, management activities such as control of competing vegetation and fertilization can speed growth, thus speeding carbon sequestration.

[23] Foresters call the age at which average annual tree growth is maximized the "culmination of mean annual increment."

Afforestation projects can include timber harvest. A harvest may be thinning that promotes growth of the retained trees. Thinning reduces or defers some sequestration, but the revenue from the harvest may more than replace the forgone GHG emission offsets. Starting from bare ground, revenue from offsets can provide income during the early years of a project, and revenue from thinning and uneven-age harvests can provide revenue later.

In large afforestation projects, it is possible to include clear cut harvests. In a large project, only a small portion of the project area would be harvested in any given year, and the project area as a whole would maintain a significant carbon stock despite major removals on a small portion of the lands each year.

When debating the GHG effects of intensive forest management, confusion sometimes occurs because stand history is not adequately considered. Some argue that increasing the intensity of forest management and shifting stands into young, fast-growing trees is the way to maximize the rate at which trees take CO_2 out of the atmosphere. This is a true statement about removals of CO_2 from the atmosphere. However, the net GHG emission impact of a project is the sum of the project's GHG removals *from* the atmosphere and GHG emissions *to* the atmosphere. Old forests typically have larger biomass per acre than young forests, and converting from an old forest to a young forest typically causes substantial CO_2emissions from the existing forest. As a result, after summing GHG emissions and sequestration, the net GHG emissions impact of converting an old forest to a young forest usually is negative. Yes, the new trees established by the project take CO_2 out of the air relatively rapidly, but these removals are less than the CO_2 emissions associated with converting the old, high-carbon forest to a young, low-carbon forest.

If bare land is converted to forest and managed intensively, project-related GHG emissions are likely to be small and mainly result from fuel burned in equipment used in project activities. And, as a result, the net GHG sequestration benefit of the project can be large.

Figure 7-3 shows an example of the effect of intensifying management and reducing the harvest rotation length. Figure 7-3 shows the forest carbon stock modeled over time, including carbon in wood products and logging debris. When the rotation length is shortened from 75 years to 50 years, the peak carbon stock in live trees drops from nearly 140 metric tons CO_2e per acre to about 100 metric tons CO_2e per acre, and the average carbon stock drops comparably. At this time, ownership of the GHG benefits of carbon stored in wood products has not been clarified by policy or case law, and few buyers will pay for GHG emission offsets based on carbon stored in wood products. If carbon stored in wood products is not counted, the drop in carbon stocks resulting from decreasing rotation length is even greater. Note that the amount of carbon stored in wood products is rarely more than half of the carbon in harvested trees, and typically less.

The amounts shown in Figure 7-3 are calculated for a typical forest in the northeast. In this study area, the proportion of carbon in wood products is even lower than in locations where production of wood products is predominately for paper or construction wood. In this example, the proportion of harvested carbon going into wood products is small because much of the harvested wood is used for firewood, resulting in most of the carbon in harvested wood being emitted within a year of harvest. Even when logging is done exclusively to produce long-lived wood products such as lumber, a general rule of thumb is that half the carbon from the harvested forest is converted to atmospheric CO_2 within five years. With high-intensity utilization and slash burning, about one fourth of the forest ecosystem carbon enters the wood products carbon pool (Harmon and Marks 2002).

Figure 7-3
Carbon Storage Effect of Switching from a 75-Year Rotation to a 50-Year Rotation in a Northeastern U.S. Hardwood Forest

One method for calculating the amount of GHG emissions avoided by a forest conservation project is to examine the rate of conversion of forest land to non-forest use in the area of the project, and then allow the FCS project to claim avoided GHG emissions at that rate. This method may sound like it will yield substantial amounts of offsets, but in nearly all localities the amounts of offsets will be small. With this approach, for each accounting period, a project will accrue GHG offsets equal to the rate of loss for the period multiplied by the forested area encompassed by the project multiplied by the amount of carbon loss avoided per unit area.

The California Climate Action Registry uses this accounting method, and has published rates of observed forest land conversion for California counties. Of the 41 counties for which rates are published, all but one have rates lower than 0.00016 of the forest land area per year, and 25 of the 41 counties have no forest land conversion (that is, conversion rates of zero). At the conversion rate of 0.00016 per year, and assuming a moderate to large average carbon stock on project lands of 200 metric tons CO_2e per acre that would be lost if the land were converted, a 1,000 acre project would generate 32 metric tons CO_2e of offsets each year from avoided deforestation (i.e., 1,000 acres x 0.00016 x 200 mtCO_2/acre = 32 metric tons CO_2e).

Some people have argued that threats of imminent deforestation should allow much, or all, of the carbon that could be lost from project lands to count as an avoided GHG emission if the lands are protected. There are two problems with this accounting approach. One problem is leakage, discussed above. It is possible for leakage to be addressed but, to date, efforts by forest preservation projects to prevent leakage have been infrequent.

The other key problem is discerning whether or not the lands really would have been deforested in the absence of the GHG emission mitigation project. The California Climate Action Registry attempts to discern imminent threats by requiring a project developer to provide a copy of one or more of the following documents:

- A bid from a developer to purchase the property;
- Plans to subdivide the project area;
- Request for State permission to convert the project lands from forest use to non-forest use;
- A permit from the state allowing conversion; and
- A request for rezoning of the site to allow conversion, filed with the county in which the lands are located.

The California protocol presumes that, in the absence of the project, forest conversion would occur immediately if one of these listed documents exists. Thus, a project would be able to immediately count as GHG offsets all the carbon that would be expected to be lost upon conversion. It appears that someone who plans to protect their land could first obtain one of these development documents and then immediately claim the bulk of the carbon stock on the land as a GHG emission offset.

Relative Amounts of Sequestration in Different Forest Components

Within an individual tree, as the tree size increases, the proportion of that tree's biomass (contained in the trunk) increases. By the time that a typical U.S. hardwood tree has reached 6 inches in diameter, more than half the aboveground biomass is in the stem wood, with the proportion increasing to somewhat more than 65% of the aboveground biomass being in stem wood in large trees. In softwood trees, this concentration of biomass in the stem occurs more quickly, with the proportion of aboveground biomass contained in stem wood rising above half by the time the tree is 2.5 inches in diameter.

Figure 7-4 presents the proportion of biomass in different components of typical U.S. hardwood trees, as a proportion of total aboveground biomass, and as a function of tree diameter. Diameter is shown in inches, and is measured 4.5 feet above the ground (know as "diameter-breast-height" (dbh)).[24] Typically, softwoods have a somewhat smaller proportion of their biomass in branches, and somewhat greater proportions in foliage and roots.

[24] Equations used to calculate these proportions are taken from Jenkins et al. (2003).

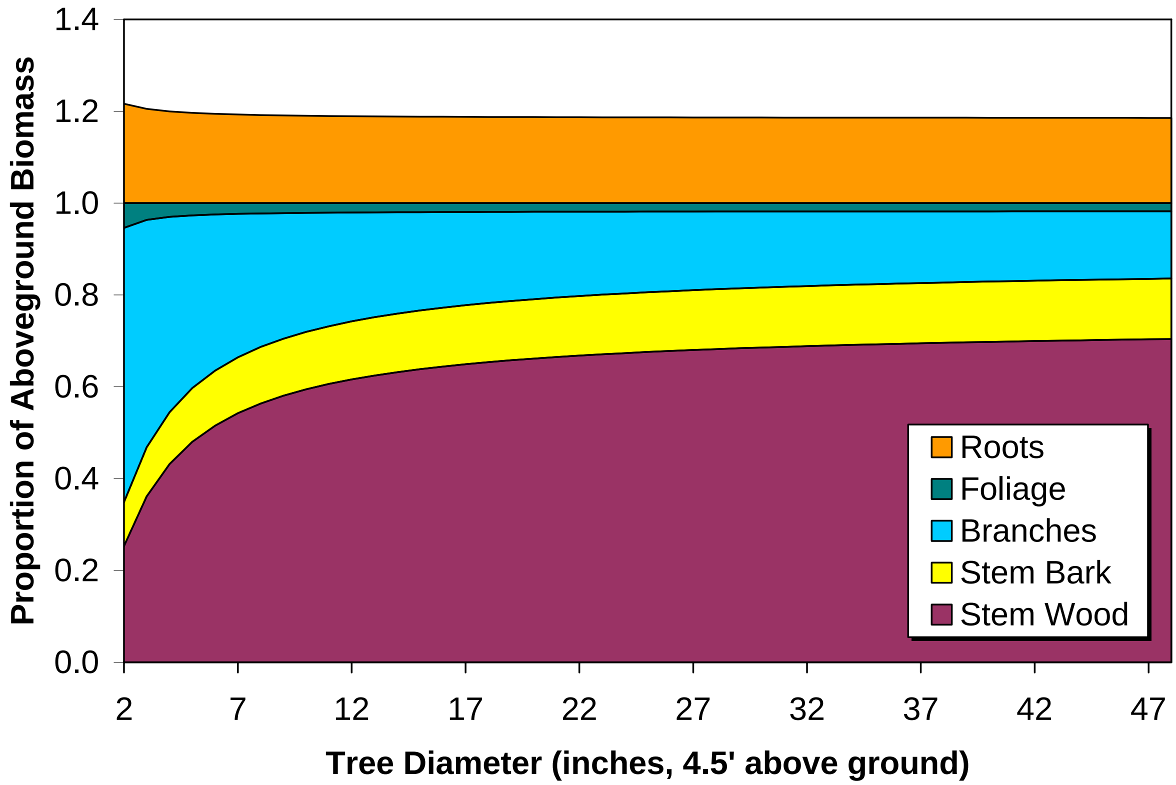

Figure 7-4
Proportion of Total Aboveground Biomass in Different U.S. Hardwood Tree Components, as a Function of Tree Diameter

The proportions of biomass in different components will vary somewhat by species and growing conditions. However, these variations are of limited importance to carbon sequestration projects. The important point is that measurements of tree stem sizes can be used to calculate the biomass of individual trees and the amount of carbon sequestered. Also, for mature trees, removal of tree stem wood (with attached bark) from project lands leaves about a third of the tree carbon (in the roots, the stump, branches, and foliage) left on the site. This logging "slash" takes several years to decompose. During the time that logging slash is decomposing, new trees can grow. If carbon stored in logging slash is counted, it reduces the decrease of on-site carbon stocks resulting from timber harvesting.

When measuring total forest carbon stocks, common divisions are live trees, standing dead trees, understory plants, down dead wood, and the forest floor. Carbon stocks in live trees are a function of the number of trees on the site, the sizes of these trees, and their wood density. Over decades, live tree carbon stocks can increase from nothing to more than two hundred metric tons CO_2e. Clear cut timber harvest reduces live tree biomass to zero.

Carbon stocks in understory plants are almost always small. In most temperate forest types, the understory carbon stock varies from 2 to 7 metric tons CO_2e per acre.

Carbon stocks in standing dead trees, down dead wood, and the forest floor vary widely by stand history and climate. Biomass in standing dead trees and down dead wood will be small if the stand is intensively managed or regularly thinned, if previously non-forest land is afforested, and in climates with rapid decomposition rates. Tree species also matters. Forests composed of species with decay resistant wood can build large carbon stocks in dead wood. Disturbance—including logging disturbance—moves carbon from the live tree pool to dead wood pools. Disturbance also speeds the decomposition of biomass in the forest floor. In cool temperature, old forests, decomposition can be slower than inputs of wood to debris pools, resulting in accumulation of very large carbon stocks in woody debris and the forest floor. In some high elevation old-growth forests in the Pacific Northwest, carbon stocks in dead wood and the forest floor can be huge, and can be even greater than carbon stocks in live trees. However, on lands suitable for commercial forestry and with a history of clear cut logging, most stands—even in cooler climates—will not have variation in the forest floor carbon stocks of more than 30-50 metric tons CO_2e per acre over the course of a logging rotation. In warmer climates, such as the southeastern U.S., forest floor carbon stocks might remain small and might never vary more than 10-15 metric tons CO_2e over the course of a logging rotation.

Sites with organic soils, such as peat bogs, are exceptions. In these areas, decomposition rates are very slow and organic material may build up indefinitely. Draining and logging disturbance can cause rapid decomposition of organic material that took decades to store. If a forested peat bog has been drained and is being tilled, stopping draining and tillage and converting the site back to forest can stop emission of large amounts of CO_2. The avoided loss of soil organic material can be even greater than the GHG benefit derived from sequestering carbon in tree wood.

Carbon Stored in Wood Products and Landfills

When wood is harvested and made into wood products, a portion of the carbon in the cut trees remains stored in wood products and in landfills. Although the owner of the wood product (e.g., the owner of a house, the owner of papers in a file cabinet) owns the physical carbon, it is not practical for most owners of wood products to document and claim ownership of the GHG emission mitigation resulting from their maintaining of the carbon stored in wood products. Instead, it will be a policy decision to establish who has the right to count the GHG sequestration benefits resulting from storing carbon in wood products. At this time, estimated amounts of carbon stored in wood products are included in national emission inventories. Also, estimated amounts of carbon in wood products and wood debris moved to landfills may be reported to the DOE's 1605(b) program and the California Climate Action Registry. However, both programs state that reporting does not imply ownership of *registered* offsets. It is not clear that any buyers are willing to pay for the right to claim GHG offsets based on carbon stored in wood products.

Eventually, wood products go out of use. Mostly, the carbon in products going out of use is either emitted to the atmosphere or transferred to a landfill. Some wood products buried in landfills are essentially permanently sequestered. It is possible that policymakers could assign ownership of GHG emission offsets based on carbon buried in landfills to landfill owners, and assign ownership of emission offsets based on carbon in wood products in use to another entity.

It is tractable for landfill operators to measure the amounts of carbon deposited into their landfills. Many landfills weigh the amount of material deposited because tipping fees are based on weight. Periodic testing can determine the carbon content of material buried in landfills. Methane and CO_2 emitted from the buried material can be measured or estimated using existing equations.

It is *not* tractable to directly measure amounts of carbon persisting in wood products over time. Amounts of carbon entering wood products can be calculated from records of mill production or harvest. Persistence of carbon storage is estimated based on equations developed from studies of the lifespan and fate of wood products. At this time, the most authoritative equations for calculating amounts and persistence of carbon in wood products can be found in the forestry appendix of the revised Technical Guidelines for the 1605(b) program issued in March 2006.[25] These guidelines are based on a small number of studies and the factors and rates could change if further research is done. The DOE Technical Guidelines also contain tables estimating amounts of carbon in various pools over time for selected forest types in the United States.

Figure 7-5 illustrates the amount of carbon that can be sequestered in a loblolly-shortleaf pine forest located in the southeastern U.S., for highly productive lands under intensive management. The values shown in Figure 7-5 are representative of productive pine sites in the southeastern U.S. that are intensively managed. The main two points illustrated in Figure 7-5 are (1) a substantial amount of carbon is emitted during the first five years following harvest, even when sequestration in wood products is counted; and (2) although wood products go out of use over time, with short rotations and high utilization rates, the total amount of carbon stored in wood products can increase from one rotation to the next. Under continuous rotations, some carbon is carried over from previous rotations and added to the new input of carbon in wood products from the most recent rotation. At some point, the amount of carbon going out of use during a rotation will equal the amount of new carbon periodically added by each harvest, and the total amount of carbon in wood products will stop increasing. If forest harvest ceases, the amount of carbon in wood products will decrease over time. If, through time, a landowner manages its lands such that growth equals harvest, the carbon stock on the lands will remain essentially constant. However, this landowner might be increasing the stock of carbon in wood products. The more recently one starts counting inputs of carbon into wood products as sequestration, the faster the amount counted as GHG emissions offsets will grow. If the date for starting to count carbon in wood products is many decades ago, the net amount of carbon counted as stored in wood products may be growing slowly or not at all.

[25] Federal Register, Vol. 71, No. 77, Friday, April 21, 2006, P. 20784. The new Final Rule will be codified at 10 CFR Part 300.

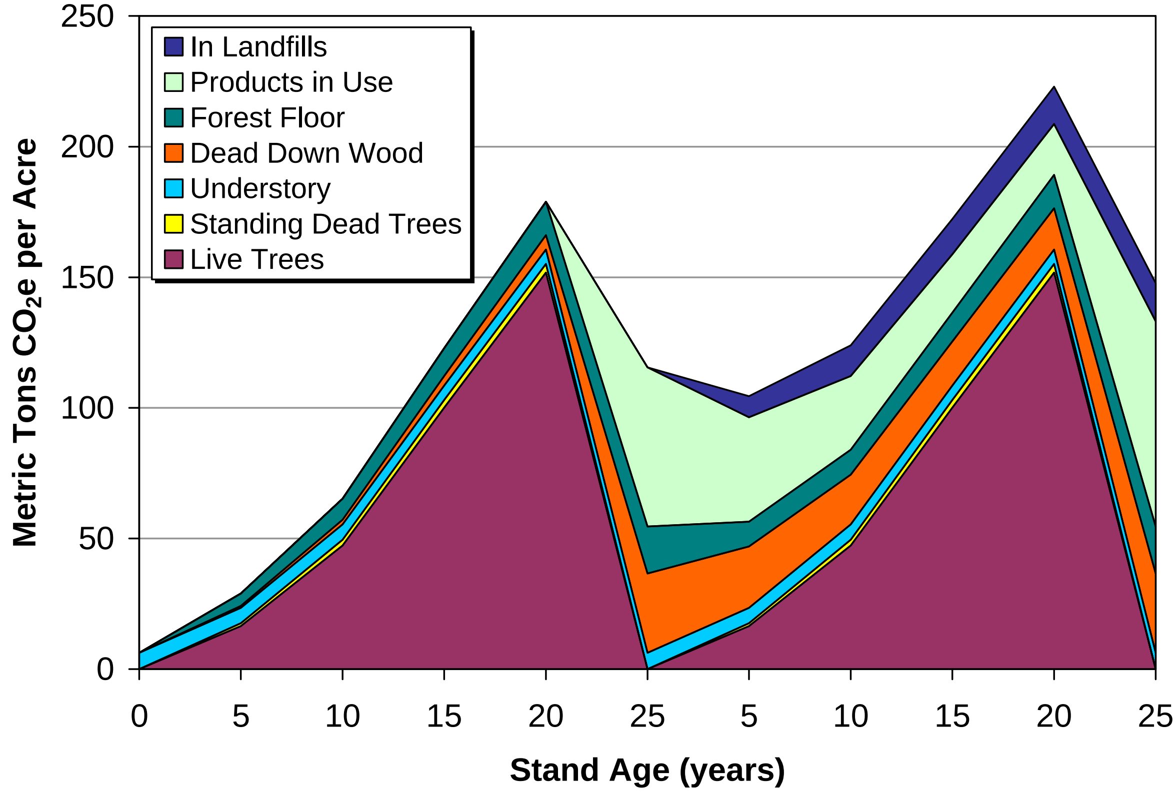

Figure 7-5
Carbon Storage in Forest Components, Wood Products, and Landfilled Wood Products, for Loblolly and Shortleaf Pine in the Southeastern United States
Source: DOE 2006b.

8
DETERMINING WHAT CARBON SEQUESTRATION COUNTS AS GHG EMISSION OFFSETS

Carbon sequestration may, or may not, count as a GHG emission offset. First, as discussed above, a particular GHG emission mitigation regime or reporting program that recognizes GHG offsets may only recognize offsets created using one of a specified set of activities, or may only recognize offsets created within specific geographic boundaries, or both. Even if an FCS project stores a ton of CO_2e through the use of an accepted activity within an accepted geographic area, that ton may not count as an emission offset. The ton of CO_2e sequestered within a project boundary may not count as an offset because it is cancelled by emissions displaced by the project to outside the project boundary, or because it is likely that the carbon would have been sequestered even if the project had not occurred. Displacement of emissions by the project to outside the project boundary is called *leakage*. The baseline developed for an FCS project identifies what emissions and sequestration would likely have occurred in the absence of the project. This section discusses quantification of baselines and leakage.

Before *baselines* and *leakage* can be quantified, the project activity, timing, and location must be determined. Guidance on determining project boundaries can be found in the GHG Protocol for Project Accounting developed by the World Resources Institute and the World Business Council for Sustainable Development.[26] Guidance is also given in the revised DOE 1605(b) program General Guidelines.[27] In general, an entity boundary is defined by what that entity controls, and a project is defined by the extent of the project activity.

Setting a Baseline

Setting a baseline is the most problematic aspect of GHG emission reduction projects that do not have baselines established by policy or regulation. When a regulator assigns an entity a GHG emission cap or emissions allowance, that assignment sets that entity's baseline. When there is no assigned emission or sequestration requirement, and an entity or project developer wishes to claim a GHG emission reduction or sequestration, a baseline must be established. Offsets being brought into a cap-and-trade GHG emission mitigation system are developed in locations that do not have assigned emission caps. As a result, offset projects must define their baselines.

For GHG emissions abatement projects, the simplest baseline is the rate of GHG emission (for emission reduction projects) or the carbon stock on site (for sequestration projects) immediately prior to the start of the project. However, such an unchanging baseline may not be realistic in

[26] The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised Edition, The GHG Protocol for Project Accounting, World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), 2005.

[27] Federal Register, Vol. 71, No. 77, Friday, April 21, 2006.

practice. For example, if cropland had been abandoned at a point in time several years before a project starts, and trees already had begun to establish themselves on the land without any human intervention, the carbon stock present at the time of the start of the project would not be a realistic baseline. Instead, it is most likely that the trees would continue to grow without human intervention and the carbon stock on the property would continue to increase, even if the project did not occur. Baselines may be constant or may rise or fall over time, and their trend may change over time.

Hybrid systems are possible. The Kyoto Protocol is an example of a hybrid system. It specifies emission limits (relative to 1990 emissions) for industrialized countries, thus setting an emissions baseline for those countries. At the same time, it allows GHG emission reduction projects to be implemented in non-industrialized countries through the CDM program, and these projects must establish counter-factual baselines that specify what would likely happen if the project is not implemented.

Another approach is for governments to establish baselines or tools for calculating baselines. An example of such a government-established baseline is the rates of forest land conversion calculated by the California Department of Forestry for use by the California Climate Action Registry. Another example is the "Trends in forest carbon stocks, by ownership type and forest type, at the state level," published in the U.S. Forest Service report *Carbon in U.S. Forests and Wood Products, 1987-1997: State-by-State Estimates* (Birdsey and Lewis 2003). The Forest Service "carbon on line estimator" (COLE, http://ncasi.uml.edu/COLE/) returns an estimated carbon stock, by age class and forest type, for a selected state, based on Forest Service Forest Inventory and Analysis plot data. The tool is suitable for estimating state-level forest carbon stock changes, but the current version appears to be of very limited use for establishing baselines for specific forest carbon sequestration projects.

Another issue that must be dealt with when establishing a GHG baseline is the choice of the baseline *reference period*, which may be prior to the start of the project or concurrent with the project. Either choice may be acceptable. For assessment of growth rates in an afforestation project, a concurrent baseline might be most reliable. For one-time decisions, such as the decision to switch from annual crops to trees, setting the baseline using a reference period prior to the start of the project may best reflect the decision making context and the frequency at which other landowners are choosing the same activity as the project. Project developers prefer to have the baseline established before committing to the project activity because having an established baseline reduces uncertainty about how many tons of sequestration or avoided GHG emissions will count as offsets. As a result, project developers prefer baselines that are established using a reference period prior to the start of a project, instead of a concurrent baseline.

If calculated in advance, project baselines are only valid for a limited period of time. Current GHG offset recognition systems that accept forest carbon sequestration establish lengths of time for which project baselines are valid. In the main GHG emission mitigation systems, these lengths of time for which baselines are valid range from 7 to 20 years. Most GHG emission mitigation systems allow the baseline to be reviewed and renewed or adjusted, to allow the project to continue generating offsets. Most GHG emission mitigation systems limit the total time through which a project may generate offsets to no more than 60 years, with some types of projects in some emission mitigation systems limited to less than 20 years.

If done rigorously, the cost of determining baseline lands and measuring outcomes on baseline lands can be as much as the cost of measuring carbon stock changes within the project boundary. However, to date, virtually all baselines have used less expensive methods such as asserting a trend without relying on actual data, determining the category of land use of comparison lands but not measuring carbon stocks on those lands, or inferring carbon stocks or stock changes by reference to existing benchmark study sites.

Additionality

Many offset accounting systems use the concept of *additionality*. Additionality refers to qualitative and quantitative assessments of the extent to which a project's activities diverge from (or are "additional" to) "business-as-usual" practices. Any GHG emissions trading system that permits imports of GHG reductions from sources not subject to caps or targets such as forest carbon sequestration (e.g., CDM projects implemented in developing countries under the Kyoto Protocol) must grapple with additionality, since crediting "business-as-usual" GHG emissions reductions does not help accomplish GHG emissions reduction objectives, and it undercuts emission targets established for the "capped" countries.

Determining additionality is problematic. Logically, one can never know for certain what might have occurred if history had been different. As a result, most methods for assessing additionality focus on indicators of the intent of the project developer or the options available to the project developer, in an effort to assess the underlying motivation of the project developer. Under these approaches to assessing additionality, the fundamental question is whether the project developer would have done the project if it did not yield GHG emission offsets. Obviously, it is not possible to fully assess the motivation of project developers.

Efforts to avoid having to determine the intentions of project developers have led some parties to suggest the use of a concept known as "proportional additionality".[28] Proportional additionality involves selecting non-project lands that have conditions similar to the starting conditions of the project lands, and observing what happens to these lands over time. For forest carbon projects the entity quantifying the GHG offsets would select comparable lands. The trend over time on the comparison lands can be used as the baseline for the project lands. This method limits opportunities to game the project baseline because project developers do not control what happens on these comparison lands. However, it is a non-trivial job to identify appropriate comparison lands and track their management over time.

A user of GHG offsets may not have the option of using proportional additionality to set project baselines. Many GHG emission mitigation systems prescribe allowable methods for determining additionality and establishing project baselines, and do not include proportional additionality in the suite of acceptable methods. Some emission mitigation systems offer methods for establishing baselines and allow project developers to submit alternative methodologies for

[28] For a presentation of the steps in calculating offsets using the proportional additionality method see Smith, Gordon R., et al., (in press), Harnessing Farms and Forests in the Low Carbon Economy: How to Create, Measure, and Verify Greenhouse Gas Offsets Based on Storing Carbon in Trees and Soil and Reducing Emissions from Land Use, Durham, NC: Duke University Press.

establishing their project baseline. Approaches to establishing baselines include examination of barriers to project implementation, financial return, and being additional to what is required by regulation. A problem with these approaches is that a wide variety of baselines are plausible, and a project developer has a strong incentive to choose a baseline that results in the highest amount of GHG offsets, even if that baseline actually would not have happened in the absence of the project. Ideally, methods for establishing project baselines would avoid attempts to try to assess the underlying intentions of project developers.

Another approach to establishing baselines is to say that practices or technologies are additional and their GHG benefits count as offsets as long as their market penetration is below a stated threshold. Types of thresholds that have been used in additionality rules include market penetration of a project technology (this is most applicable to projects that increase energy efficiency), efficiency standards, regulations limiting allowable practices and technologies, and non-GHG emission requirements such as mandates to control methane emissions from landfills.

Another important consideration is that the definition of additionality can be a “moving target” that can change over time. Countries may pass environmental regulations making a formerly discretionary technology or practice mandatory (e.g., the requirement in the U.S. to flare most methane emanating from municipal landfills), in effect resetting the baseline for project activities and potentially making them “non-additional.” Or, as more projects of a particular type are pursued to create GHG offsets, the barriers that had impeded a technology may be overcome, and it may begin to be considered “business-as-usual.” The first project in a country to capture coalmine methane and utilize it to generate electricity clearly may be “additional,” but would the tenth project also be additional? How about the fiftieth project?

The problem with using a threshold to establish additionality is that a GHG project instantly may go from being classified as completely additional, with all its GHG benefits counting as offsets, to completely not additional, with none of its GHG benefits counting as additional. Proportional additionality avoids this knife edge classification change.

Two commonly used terms in discussions of additionality are *real* (e.g., projects must result in *real* reductions) or *surplus* (e.g., activities generating emissions reductions must exceed regulatory requirements).[29] Baselines are intended to reflect what would have happened in the absence of the project. In theory, they should separate direct effects of management activities from indirect effects and non-anthropogenic occurrences.

Debate about baselines and additionality of forest carbon sequestration projects has been central in discussions of allowing forest carbon sequestration to create offsets that will count toward compliance with Kyoto Protocol emission limits. During the negotiation of the Kyoto Protocol in the 1990s, there were a number of assertions made that increased levels of CO_2 in the atmosphere were acting as fertilization that increases the growth rate of trees. Critics argued that this increase in growth is “anthropogenic” and should be subtracted out when calculating GHG offsets. Recent studies suggest that some CO_2 fertilization has occurred over past decades and is

[29] Additionality is also discussed in Incorporating Offset Projects into Corporate Greenhouse Gas Strategies: Risk Management Under Conditions of Policy and Market Uncertainty, EPRI, Palo Alto, CA: 2003, 1005246, page 3-4.

already built into modeled growth rates. Others studies suggest that CO_2 fertilization does occur but that its effect is limited because other factors (e.g., nutrients, water) quickly become limiting. Recently, there has been little discussion of CO_2 fertilization, and publicly available project monitoring methodologies have ignored the issue. If one were to build CO_2 fertilization into a baseline, the way to do so would be to measure carbon stock changes on comparison lands concurrently with project growth. These “control” sites would include any extra growth resulting from CO_2 fertilization, thus including any CO_2 fertilization effect in the baseline.

Leakage

Leakage refers to the displacement of GHG emissions from inside a project boundary to outside a project boundary that is caused by the project. When calculating the amount of GHG emission offsets created by an FCS project, the amount of displaced emissions should be subtracted from the gross GHG emission benefit achieved within the project boundary.

In general, GHG emissions are likely to be displaced by a project if emissions result from the production of a good (e.g., timber) and the project causes a reduction in the production of such a good. For example, if logging for timber is causing deforestation in a region and a project seeks to avoid deforestation emissions by preventing logging on project lands, then the project will have the effect of reducing the supply of timber from project lands.

Avoided deforestation projects may not reduce emissions, may cause small GHG emission reductions, or cause large reductions in emissions. The net effect on GHG emissions depends on the design of the project, the location of the project, and accounting assumptions. Markets for wood are relatively efficient and econometric analysis shows that if the production of wood is reduced in one location and demand is not changed, the reduction by one supplier is largely replaced by increased production by other suppliers. The situation is similar for land development. If one parcel is taken off the market, in most areas, other parcels are available for development. In GHG emission offset markets, this displacement of emissions by a project is called *leakage*.

The most robust way to avoid leakage is to maintain the supply of goods being delivered to markets before implementation of the GHG emission reduction project. Specifically, if land is being cleared for timber, to avoid displacing emissions by simply conserving land that is being cleared, a conservation project should establish a new timber plantation on land that was not previously in forest use. If this new plantation yields wood in equal volume and similar type to the terminated harvest from preserved lands, then wood supply would be maintained and the project would not displace GHG emissions.

Methods for quantifying leakage from forest projects are given in Murray et al. (2004). An equation for calculating leakage associated with forest carbon sequestration projects is shown in Appendix E.

When projects reduce production of a good such as timber that is widely traded on international markets, leakage tends to be high. Murray et al. (2004) calculated the leakage of timber production resulting from reductions in timber harvest in the Pacific Northwest in the late 1980s and early 1990s. The harvest reductions were imposed to protect the Northern Spotted Owl. Murray et al. calculate that the 88% of the reduced harvest was replaced by increased production of other suppliers, and the proportion would have been higher if the harvest reductions had not been so large. The take-home message is that forest preservation projects that do not replace terminated supply are likely to yield little net GHG reduction benefit.

9
FINANCIAL ANALYSIS OF PROPOSED PROJECTS

Project developers want to implement projects that will yield GHG offsets for low costs per ton of CO_2 sequestered. Standard financial discounting and cost-benefit analysis methods are used to calculate the net cost per ton of GHG offsets from proposed projects. Levelized cost per tCO_2 offset is a metric that can be used to compare alternative GHG abatement projects on the basis of their relative cost-effectiveness, expressed in terms of $/$tCO_2$.

Financial analysis begins with a realistic listing of the amounts and timing of expected costs, and realistic listing of amounts and timing of expected revenues. Then the costs and benefits are discounted to account for the time value of money. *Discounting* is a formal process for quantifying our intuitive preference for receiving payments sooner rather than later and preferring to pay costs later rather than sooner. This is referred to as the "time value of money."

If a project analyst is interested in the expected timing and yield of GHG offsets in order to achieve a GHG emissions compliance target, they may be interested in the timing and absolute quantity of GHG emissions that may be generated by a proposed project than in the cost effectiveness of the project on a $/$tCO_2$ basis.

When doing a financial analysis of a proposed FCS project, all costs should be counted, including transaction costs. Transaction costs include legal costs associated with preparing contracts, costs of staff time spent negotiating agreements, and costs of measuring, verifying and registering forest carbon sequestration offsets. Further adjustments also may be made to project financial analyses to account explicitly for project risk, or alternative scenarios may be calculated.[30, 31]

Project developers or investors also may impose additional requirements on proposed projects, in addition to cost effectiveness. For example, a project developer may need to have access to GHG emissions offsets by a certain date, need a certain number of GHG offsets, or may have a limited amount of funds available to invest in a project. If a company is generating GHG offsets for its own compliance purposes, it may need to know the schedule for the creation of the offsets and undiscounted absolute number of offsets that are likely to be generated. Applying other criteria to the project decision process is not discussed in this report.

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[30] For more information on the important role of discounting in evaluating GHG reduction projects, see *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*, EPRI, Palo Alto, CA: 2004, 1008488.

[31] For more information on using discounting to evaluate GHG abatement projects, please refer to *Using Discounting to Analyze CO_2 Emission Reduction Actions*, EPRI Climate Brief, 1011407, February 2005.

Present Value and Discounting

Discounting is like calculating interest, except when discounting, one moves backwards in time from the future to the present. When contemplating receiving a payment in the future, one can use discounting to determine the value today (called the Present Value) of the payment that will be made in the future. Determining the "levelized" cost of a proposed project is achieved mathematically by dividing the net present value cost of a project by the present discounted value of GHG benefits that will be derived from it. When comparing different GHG abatement options, levelizing makes it possible to compare the projects on the basis of their cost effectiveness expressed in terms of \$/tCO_2e. Equation 1 shows the mathematical formula to use for discounting an expected future financial cost or benefit.

Equation 1

$$\text{Present } Value = \frac{Future\ Cost\ or\ Benefit}{(1 + Discount\ Rate)^n}$$

Where *n* is the number of periods from now until the future cost or benefit accrues. Typically, periods are one year, but they may be a month, day, or other length of time. The discount rate must be the proper rate for the period being used in the analysis. The discount rate is sometimes referred to as the interest rate. Although, technically, a discount rate is not an interest rate, the two are functionally equivalent.

An example of discounting is as follows. Suppose that a project will receive revenue of \$100 ten years after the start of the project. Also suppose that the project developer has a discount rate of 8% per year. Inserting these numbers into Equation 1 and the related calculations are shown in Equation 2.

Equation 2

$$\text{Pr}\,esent\ Value = \frac{Future\ Payment}{(1 + Discount\ Rate)^n} = \frac{\$100}{(1 + 0.08)^{10}} = \frac{\$100}{2.159} = \$46.32$$

When the annual discount rate is 8%, the present value of a \$100 payment that will be received ten years from now is \$46.32.

Projects typically run for several years, and will have costs and revenues that occur at multiple times throughout the life of the project. For each accounting period, the costs occurring in that period are discounted. Then all the discounted costs are summed. Similarly, for each accounting period, the benefits are discounted. Then all the discounted benefits are summed. When calculating the levelized cost per tCO_2 GHG offset, the benefits are in units of tons CO_2, not dollars. The equation for calculating the levelized cost per ton of a GHG offset generated by a proposed GHG abatement project is shown in Equation 3.

Equation 3

$$Levelized\ Cost = \frac{\sum_0^n Cost_n /((1+d)^n)}{\sum_0^n Tons_n /((1+d)^n)}$$

Where *Cost* and *Tons* are the undiscounted amounts occurring in each period, *d* is the periodic discount rate, *n* is the n^{th} period in which a particular cost or offset accrues.

Choosing Discount Rates

Most firms can readily identify the private discount rate that they use internally to analyze potential financial investments. The discount rate may be the interest rate the firm pays to borrow money, or it may be the rate of return that a firm requires before it will make a financial investment. In theory, a firm may have a different discount rate for each cost and each revenue "stream" that is encompassed in a proposed project. The discount rate for each item is the private, risk-free discount rate, plus the risk premium the firm assigns to the particular stream being discounted. Each revenue stream would have its own risk profile, thus its own risk premium, reflecting different financial risks associated with each stream. However, in practice, analysts tend to use a single discount rate for all costs and revenues associated with a particular project.

Unlike discount rates for money, most firms cannot readily identify an appropriate discount rate to use to discount physical units such as tons of CO_2e. In theory, the social discount rate for GHG emission mitigation would reflect the ecological damage function of marginal tons of emissions. However, we do not know the ecological damage function associated with GHG emissions. Boscolo et al. (1998) argue that (unless there are externalities) because the social discount rate should equal the opportunity cost of alternative investments, and the opportunity cost of alternative investments is the risk-free cost of money, the social discount rate should equal the money discount rate. Following this theory, a firm's discount rate for GHG emissions reductions would equal the discount rate the firm applies to financial cash flows, with the same premium above the risk-free rate. As noted above, one could choose a different discount rate to apply to each separate cost or revenue stream associated with a proposed project, so one might choose a different discount rate to apply to expected GHG emissions reductions than the one used to discount the financial cash flows. However, in practice, analysts generally choose a single discount rate for all costs and benefits, although they may apply different risk adjustments to different costs and benefits, and may use price escalation factors for individual inputs that historically have increased in price faster than inflation.

Internal Rate of Return

While users of GHG emissions offsets may be most concerned about the levelized cost of the offsets, the schedule of delivery of the offsets, and the nominal number of tons of offsets to be delivered in each period, financial investors in projects may be more concerned about the internal rate of return of the project. The internal rate of return (IRR) is the discount rate at which the sum of discounted costs and discounted revenues equals zero, which is the same thing as saying the internal rate of return is the discount rate at which the net present value of the costs and benefits is zero. Often, corporations will invest in projects that are expected to yield an IRR that is higher than the private discount rate the firm uses to analyze prospective capital investments. Effectively, the IRR is the interest rate that an investor needs to receive on their investment in order to deploy the necessary capital. When calculating the IRR for a proposed project, revenues should reflect the market value of the project's outputs and not the cost of producing the GHG offsets.

Tax Effects

Taxes and tax credits can substantially change the levelized cost of GHG offsets or the expected IRR for a project. Accelerated depreciation, production tax credits, and other tax credits can double the internal rate of return of some projects. Tax effects are project and time specific. We recommend that interested readers consult with their company's in-house legal counsel or a qualified tax attorney to assess the potential tax effects associated with a proposed project. These effects can then be included in the cash flow analysis of the proposed project.

Project Scale

Forest carbon sequestration projects typically exhibit substantial economies of scale because planning, transaction, and quantification costs are largely fixed. Saying that a cost is "fixed" means that the cost will be roughly equal for a large project as for a small project. In a large project that produces many tons of GHG offsets, these fixed costs can be spread over many tons of offsets, resulting in a small share of the total cost per ton of offset. However, not all project costs are insensitive to project size. Land costs and activity implementation costs typically vary linearly with project size, as do the number of tons of GHG offsets generated and the revenue to be derived from these offsets.

Current costs of acquiring lands and growing trees are often a few dollars per ton CO_2e sequestered (discounted). Currently, forest carbon sequestration transaction costs for a project are usually at least tens of thousands of dollars and can easily be more than one hundred thousand dollars. As a result, to get the transaction cost per ton of GHG offset down to a few cents per ton CO_2e may require that the project generate several hundred thousand tons of offsets.

Possible Non-Offset Revenues

When doing a financial analysis of a proposed project, all revenues should be counted. It may be possible to jointly use the project lands to both sequester carbon and, at the same time, generate revenue from one or more other uses. In some areas, particularly in the southeastern U.S., revenues from leasing lands for hunting can be significant compared to net revenues from logging, cropping, or carbon sequestration. Other forms of recreation may be valuable enough to justify the cost of managing them. Many forested areas can provide mountain biking experiences with little negative effect on carbon sequestration or timber production. Few locations in the U.S. have the attributes necessary to draw significant amounts of revenue from sightseeing, bird watching, rock climbing, or other specialized activities. However, if a site has the unique attributes to support such a non-consumptive use, the use should be compatible with carbon sequestration and may provide a significant addition to total project revenues.

Some revenue-generating land uses conflict with carbon sequestration. Land clearing (for any use, whether cropping or building) removes carbon. Forgoing alternative uses forgoes the revenue that could be obtained from these alternative uses. Thorough financial analysis of a proposed project should consider revenues that would be forgone by implementing the carbon sequestration project. If the cost of acquiring GHG emission offsets elsewhere is less than the revenue that would be forgone by using lands for a carbon sequestration project, total cost of mitigating GHG emissions will be reduced by using the lands for the alternative, non-carbon use and buying offsets elsewhere.

Timber production is an important case that merits attention. Harvesting timber causes most of the carbon in the harvested trees to be emitted within a few years. If the landowner does not own rights to the GHG offsets based on carbon stored in wood products, then from the landowner's perspective, timber harvesting emits all the carbon held in harvested trees (although some of the carbon sequestration remains for several years, in the form of decomposing logging slash). At the same time, at current lumber and GHG offset prices, a tree that is suitable for sawing into lumber is much more valuable for lumber than for GHG emission offsets. Due to the time value of money and because smaller trees have little value for use as wood products, it may be financially optimal to manage lands for a combination of timber and carbon sequestration. During the earlier years of a project, an afforestation project could sell offsets based on sequestration in rapidly growing young trees that are not yet big enough to be valuable for timber. These sales may provide revenues earlier than sales of wood fiber, and thus the present value of the offset revenues may be competitive with the present value of the revenues from the sale of wood products. Then, as trees grow and become more valuable for wood products, the project can stop selling new offsets. The larger trees can be harvested over time, providing timber revenue. Harvesting over time can maintain a moderate carbon stock on the site, and can maintain a carbon stock sufficient to maintain the offsets previously created and sold. This approach does not maximize timber production or maximize carbon sequestration. Instead, it produces some carbon sequestration earlier in the project and some timber later.

A more extreme case of this sequencing would be to sell GHG offsets during the early years of an FCS project, before the trees are valuable for timber, and then purchase replacement offsets on the market when the trees become more valuable for timber than for sequestration. Then the trees can be harvested for timber with no net loss in GHG offsets. If the price of offsets rises dramatically, the trees could remain more valuable as GHG offsets than as lumber. Under these conditions, the project developer would maintain the carbon sequestration rather than harvest the timber.

Another type of joint production of GHG emission offsets and other values would be a situation in which lands are held for some non-GHG use, but where some GHG emission offsets may be generated without interfering with the dominant use. The attractiveness of such a project is that the cost of land can be assigned to the dominant use, avoiding one of the major costs of forest carbon sequestration projects.

Some electric companies may have such an opportunity: transmission line "rights-of-ways" that have historically been cleared and where the ground surface is not presently providing economic returns. If transmission lines are sufficiently high off the ground, access is not impaired by woody vegetation, and woody vegetation can be established that never grows taller than an acceptable height, it may be possible to create GHG emission offsets by sequestering carbon in biomass. Depending on the existing vegetation and site, switching to a sequestration project might reduce vegetation control costs. If the maximum allowable height of vegetation is relatively short, it may not be possible to sequester enough carbon on-site for such a project to be cost effective (although it may be feasible to use the land to grow a crop used to generate electricity from biomass fuel). One challenge for any project that seeks to use land under transmission lines is having access to a large enough area to make the project cost effective.

Even if enough acres can be gathered together to spread fixed project costs, the land may be so widely distributed that the cost of gaining access to it may be prohibitive. Also, some GHG offset mitigation systems set minimum widths for FCS projects that are wider than many transmission line rights-of-ways. Finally, existing regulatory and operational requirements may preclude developing FCS projects on transmission rights-of-ways.

Renewable Energy Certificates (RECs)

Selling GHG emission offsets will be *incompatible* with some other revenues that could be generated by a GHG emission reduction project. One interaction worth noting is the current incompatibility between renewable energy certificates (RECs) and GHG emission offsets. A REC typically represents the environmental attributes associated with the generation of one megawatt hour (MWh) of electricity from a qualifying renewable energy source. Some states and localities require that a specified proportion of electricity be generated from renewable sources. In some states, RECs can be used to satisfy these kinds of renewable portfolio standards (RPS).

RECs are related to GHG emission offsets because the renewable energy underlying a REC may displace electric generation from more GHG-intensive electric generation sources the supply power in a regional electricity "grid," thus avoiding GHG emissions. Assuming all other things remain constant, if the generator of a REC displaces its *own* fossil-fired generation, then the GHG emission reductions automatically will accrue to the generator. Direct emission reductions are owned by the entity making the reduction. Strictly speaking, the fact that a megawatt hour of electricity is generated from a renewable source is a separate attribute of the entity's activities than the fact that the entity reduced its GHG emissions. However, some parties have strongly advocated for an interpretation of RECs that implies that RECs must include *all* environmental attributes related to the MWh of electricity generated by the renewable resource underlying the REC. Based on this interpretation, an electric company would *not* be able to take credit for both its renewable generation *and* the associated reduced GHG emissions.

The interplay between RECs and GHG offsets becomes even more complex in a situation in which a merchant renewable power generator seeks to sell RECs to one party and GHG offsets based on avoided GHG emissions in the electric grid to a separate party. Analytically, it is very difficult to determine exactly which specific power generation facilities operating in a regional grid are displaced by the introduction of a new renewable resource like a wind power plant. To determine the avoided emissions associated with this potential displacement, some parties have advocated for the use of simplified average avoided GHG emissions factors to calculate avoided GHG emissions. From an analytic perspective, it is more appropriate to use an emissions factor based on the *marginal rate* of avoided GHG emissions rather than an average rate, although it can be costly and very challenging to determine marginal avoided GHG emission rates. A second problem related to using GHG offsets for avoided grid emissions is that there is no way to determine which party actually owns the avoided GHG emissions. Some parties advocate that the renewable power generator should own these avoided emissions, while other parties have argued that the electric company that actually reduced emissions from its displaced generation should own the avoided GHG emissions. Resolution of these issues will require further direction from policy makers and regulatory agencies.

The relationship of RECs and GHG offsets may remain different in voluntary GHG reporting systems than in fully developed GHG regulatory schemes. In situations where the use of RECs and mitigation of GHG emissions are both voluntary, the buyer and seller may agree to any definitions they wish without interference from other parties.

In a situation where there is a mandatory RPS in place, but no regulatory limits on GHG emissions, the GHG emission reductions resulting from meeting an RPS may be considered to be baseline emissions reductions, and any GHG emission reductions that result from meeting the RPS would be assumed to take place in the absence of a GHG emission mitigation project, and so would not qualify as project-related GHG offsets. However, the GHG emission reductions associated with the use of renewable power to displace more GHG intensive generation that is owned by the same company will help to reduce the company's direct GHG emissions.

If mandatory limits on GHG emissions are imposed in the future in a location where no RPS exists, then the GHG regulations would specify accounting rules and entity emission baselines. Presumably, the attributes of RECs generated within such a system would be clarified to conform to the system regulating GHG emissions.

If mandatory limits on GHG emissions *and* a mandatory RPS both apply to an entity that generates renewable power to avoid GHG emissions, then the parties involved in both the REC and GHG offset markets would have to face the reality that the other regulatory system and market exists, and may have to limit their claims to the attributes addressed in their own regulatory system.

Uncertainty and No-Regrets Strategies

Where there is large uncertainty in future prices or abilities to operate, financial analyses are most robust if they consider the range of probable outcomes. In the GHG world, there is huge uncertainty about future prices of GHG emission offsets and what actions will count as offsets. One way to evaluate proposed projects is to consider what net return they will have if, in the future, GHG emission offsets have *no* value. In this case, purchased GHG offsets would lose their value and the offset buyer would probably not share in any other benefits created by the project. In contrast, if the user of the offsets has an ownership stake in the project that creates GHG offsets, the user can share in any other benefits accruing to the project. Some forest sequestration projects offer the possibility of providing positive financial returns even if the value of GHG offsets falls to zero in the future. Specifically, the trees that are holding carbon may be sold for timber. Also, lands in the U.S. historically have increased in value over time in a fairly consistent manner, making the land underlying a project a potentially profitable financial investment. Alternatively, a GHG offset user may need land in the future for other uses, such as new power plants, and a forest carbon sequestration project may provide an option for obtaining revenue from land held in case it is needed for another use.

In several existing EPRI quantitative modeling efforts related to global climate change, EPRI has used "Monte-Carlo" simulation approaches to simulate the values for uncertain variables like the expected future price of CO_2 emissions based on a statistical representation of the range of potential CO_2 abatement costs. A Monte Carlo simulation calculates numerous scenarios of a model by repeatedly choosing values from the probability distribution used to define the uncertain variables, and then uses those values for whatever additional calculations are dependent upon that value in the model.[32] For Monte Carlo simulations to be valid from a project validation standpoint, the probability distributions used in the scenarios would need to be based on observations of reality, not expert guesses about the shape and width of relevant statistical distributions.

Valuing Offset Rentals

Some landowners are not willing to permanently commit to maintaining carbon storage, but may be willing to maintain sequestration for a fixed period of time. Offsets maintained for a fixed term are considered to be temporary. At the end of the fixed term, the expiring offset must be renewed, replaced, or counted as a GHG emission. If the price of GHG offsets is expected to remain constant over time, temporary offsets can be valued using the standard methods to value any rental. Most people are familiar with loans of money, which is a case of one party renting money to another party. Using the analogy of interest on a loan, if an entity rents an offset worth $1 at an annual 5% interest rate, that entity would expect to pay $0.05 per year for the rental.

Rentals can be a way to get offsets with minimal up-front expenditure. But the low values of rentals mean that many landowners do not want to bother with them, or that transactions costs of establishing the rental agreement are greater than the value of the rental.

Renters of GHG offset should also consider the situation they expect to be in at the end of the rental period. If the renter expects offsets prices to drop over time, the sum of the cost of the initial GHG offset rental plus the cost of replacing the expiring offset will be less than the cost of buying a permanent offset today, so the rental is likely to be a good value. If the renter will have to replace the offset with a different offset that is more expensive than GHG offsets today, this additional cost should be included in the calculation, and will decrease the value of the rental. If the cost of offsets is expected to rise at the interest rate, the value of a rental is zero because the present value of the cost of replacing the expiring rental offset at the end of the rental period is likely to be equal to the cost of acquiring a permanent offset today. If the cost of GHG offsets rises faster than the interest rate, the cost of buying a permanent offset now would be less than the present value of the offset that the entity would need to acquire at the end of the rental period to replace the expiring rented offset.

While the term “rental” is not typically applied to GHG offsets, several markets accept forest carbon sequestration offsets that are structured as rentals. Temporary offsets granted to forest carbon sequestration projects by the CDM process are, in effect, rentals. Other GHG emission mitigation systems require that forests be protected for a fixed length of time (often the minimum required length of time of protection is between 50 and 100 years). If, after the expiration of this period, the landowner is not required to continue storing sequestered carbon, then the storage is effectively a rental.

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[32] For more information about using Monte Carlo simulation related to financial analysis of GHG emission reduction projects, see *Greenhouse Gas Emissions Reduction Cost Analysis Model Version 2.02 Software User’s Manual*, EPRI, Palo Alto, CA: 2005, 1013004.

10
RISKS

Key to any business deal is recognizing the sources and degrees of risk, and limiting risk to an acceptable level. Forest carbon sequestration projects are no different, although the types and magnitudes of risks vary from activity to activity. Each FCS project will have its own unique risk profile. However, there are some general types of risks that should be considered when considering whether or not to implement or invest in forest carbon sequestration-based offsets. This chapter discusses some prominent types of risks faced in forest carbon sequestration projects.

An electric company faces different risks when undertaking a forest carbon sequestration project than the company would face doing a GHG emission reduction project that involves changing its ongoing operations. Projects that change an electric company's ongoing operations include activities like fuel switching from coal to natural gas and boiler efficiency upgrades.

Variation in observed market prices for different kinds of GHG offsets and emissions allowances reflect the variation in risk profiles buyers believe are embodied in different kinds of GHG offsets and emission allowances. For example, in the EU ETS, there is a wide discrepancy between the prices paid for EUAs (EU GHG emissions allowances) and the prices paid for GHG offsets generated by CDM projects, called Certified Emission Reductions (CERs). CERs often trade for 50% of the price of EUAs of similar "vintage." The reason for this substantial discount is often attributed to the risk of buying CERs in the international CDM marketplace where the discounted price reflects all of the risks associated with the CER transactions and the eventual delivery of the CERs to the buyer. Risk profiles also result in the lack of CER standard pricing. CERs expected for delivery at the same time for similar types of projects may command very different prices in the marketplace reflecting differences in the risk profiles of the specific projects and the contracting mechanisms used to distribute risks among parties to the transaction.

Reversibility

One of the most important characteristics of forest carbon sequestration is that the sequestration can be reversed – the trees can be killed, and the wood burned or left to decompose, with the effect of converting biomass carbon into atmospheric CO_2. Historic rates of forest loss in the U.S. are very small (a small fraction of one percent per year, averaged over large areas), suggesting that this risk is low. However, the fact that forest carbon offsets are reversible means that they must be monitored over time, and monitoring is an ongoing project cost. If significant climatic changes occur, drought and storm intensity may increase, and may reduce growth or increase loss of trees to fire or wind.

Management Focus

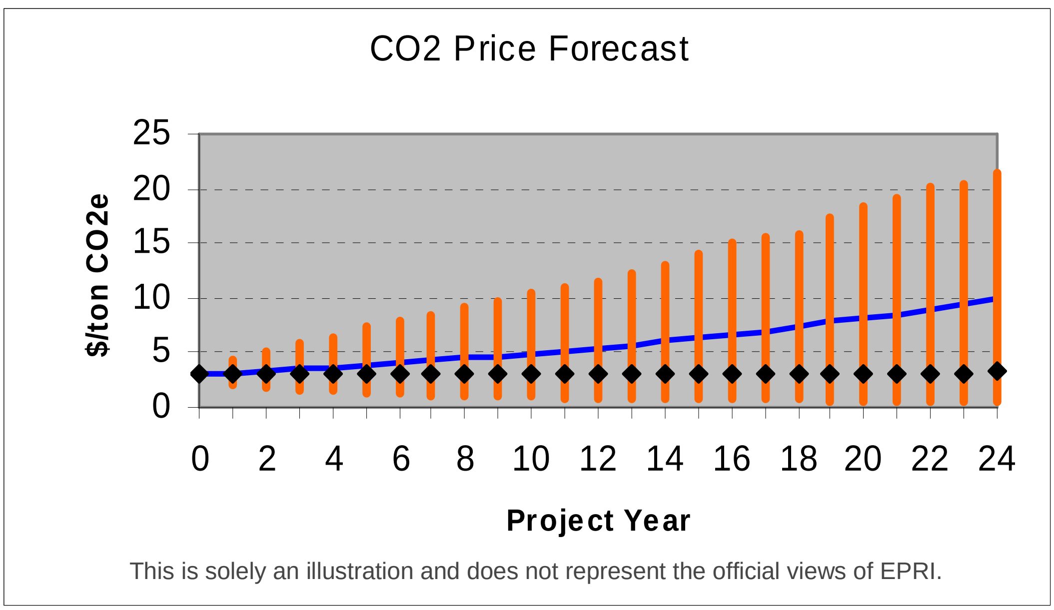
Forestry is not a core business for most electric companies. This may increase the risk that a project will not be implemented properly nor tracked adequately over time. However, if an electric company has land management staff with forest management expertise (as is the case in a number of companies), then this risk is reduced significantly.

Price Volatility

If an electric company is creating GHG offsets for its own use, the volatility of GHG offset prices may be of minimal importance to the company. In fact, the company may choose to execute projects itself to insulate itself from this price volatility.

Price volatility is critically important to a project developer who initiates a project without a contract for the sale of all of the offsets expected to be generated by the project. Most forest carbon sequestration projects generate the bulk of their offsets years to decades after the start of the project. The undeveloped state of the U.S. GHG market suggests that GHG offset prices will be volatile, and makes it difficult to estimate likely future prices. Observation of the volatility of offset prices in the developing EU ETS market reinforces the prediction that U.S. offset prices will be very volatile if the U.S. adopts a GHG emission cap and the costs of achieving emission reductions are determined by market forces.

Electric companies are also concerned about the forward price trajectory for CO_2 emissions as this curve effectively defines what it may cost to purchase GHG emission allowance or offsets in the market in the future. In mature cap-and-trade programs for emissions reductions, the forward price curve of a pollutant will approximate the cost of abatement for that pollutant (e.g., CO_2). An example of this type of forward price trajectory is shown in Figure 10-1.



Notes: **Blue Line** = Mean Price
Black Diamonds = Median Price
Orange Bars = 10-90 confidence interval

Figure 10-1
Illustrative CO_2 Forward Price Trajectory

Developing a reasonable and analytically-defensible forward price trajectory for CO_2 emissions is not a trivial task and is beyond the scope of this report. Companies and research organizations use a variety of methods to forecast future commodity prices, including CO_2 emissions reductions, and as a result there are a variety of CO_2 price projections in use by different parties for different purposes. In Figure 10-1, the blue-colored line represents the *mean* CO_2 price forecast; the black-colored diamonds represents the *median* forecast, and the orange bars represent the *10-90% confidence interval*. The figure illustrates that uncertainty about future prices increases as the forecast time horizon expands into the future.

Another approach that can be used is to make a "conservative" assumption that future offset prices will not be any higher than the current prices occurring in the absence of a U.S. emissions cap. This is "conservative" from the perspective of a forest carbon sequestration project because it implies very low prices for CO_2 emissions offsets. If a proposed project is still acceptable at current CO_2 offset prices, it will likely be very robust from a financial perspective at higher GHG offset prices. This "conservative" approach doesn't seem particularly reasonable in light of the recent experience in the EU ETS and other emerging CO_2 markets, and in light of the recent proliferation of state and regional actions to establish limits on GHG emissions in the U.S. However, if corporate decision makers are extremely risk averse, it may be a good idea to evaluate a proposed project using this kind of "conservative" analytic approach.

If the project developer is risk neutral, the best way to evaluate the financial return from a proposed project is to calculate the expected economic value of the project. Expected value is the average of all foreseeable outcomes. Expected value is calculated by first identifying the financial return of each foreseeable outcome. Second, a probability is assigned to each outcome. Third, for each outcome, the financial return is multiplied by the likelihood, to obtain the weighted value of each outcome. Finally, the weighted values of all outcomes are summed. Monte Carlo simulations done by EPRI in other climate policy analyses are examples of expected value analysis.

However, most project developers are not strictly risk neutral. For example, projects might be developed by an electric company to generate offsets for its own use. Such a company may be very averse to failing to get the number of GHG offsets it may need for compliance purposes. In this case, the electric company may risk paying more for GHG offsets in order to avoid not getting sufficient offsets in time to meet its compliance obligations. If there are outcomes that a project developer strongly wishes to avoid, the project developer should identify those outcomes, and then run scenarios and see which of the highly undesirable outcomes occur. If so, it may be worth revising the project design until a highly undesirable outcome is eliminated, and then determine if this project design is acceptable.

Future Market Rules

To a significant degree, GHG offset prices will depend on market rules and the degree to which emissions must be reduced. If offset markets are well designed, offset prices will depend on the marginal cost of abatement. The greater the amount of GHG emission reductions that are required, the higher the expected price of GHG emission offsets. A weaker cap on GHG emissions implies less demand for GHG offsets, which in turn would imply lower GHG offset prices. If market rules are poorly designed, it may be difficult to obtain recognition for GHG offsets, and offset developers might receive low payments for their offsets. At the same time, users of offsets would pay higher prices for offsets because of the administrative restriction or scarcity imposed on the supply of offsets. There is no guarantee that a market for GHG emission offsets will be designed efficiently.

An important aspect of market design is whether the inter-temporal "banking" of GHG offsets or allowances is permitted. Banking refers to a regulatory approach that allows a regulated party to save an emissions allowance or credit created in one accounting period and use that allowance or credit in a later accounting period for compliance purposes. If banking is not allowed, the price of GHG offsets created during one accounting period would be expected to drop to zero after that accounting period (and any true-up period). Banking is widely recognized as an important way to (1) reward "early action" to reduce pollutant emissions, and (2) dampen unexpected price spikes. Banking is a featured component of the successful U.S. SO_2 emissions trading market and is allowed, to a limited extent, in the EU ETS. In the EU ETS, companies are allowed to bank emissions allowances *within* each of the two administrative phases of the existing program, but companies cannot bank *between* the "Pilot" phase (2005-07) and the "Kyoto" phase (2008-12).

A different kind of risk faced by forest carbon sequestration projects is the risk that sequestration achieved by the project will not be recognized as a GHG emissions offset by a relevant regulatory authority. Since there is no mandatory GHG emission reduction program in place in the U.S., it is not possible to know what activities may count as generating qualifying GHG emissions offsets in a potential GHG regulatory scheme. Looking at existing U.S. voluntary markets and the mandatory international Kyoto GHG markets suggests that afforestation projects will be accepted in any future U.S. GHG emissions cap-and-trade program as qualifying for GHG offsets. These issues are described further in Chapters 4 and 6.

A serious concern about the design of any future GHG emission mitigation regulatory system in the U.S. is whether GHG abatement projects started now will be recognized as creating GHG offsets (i.e., it is not clear whether "early actions" will be credited). GHG offset accounting systems generally establish a baseline date, and activities initiated before the "start" date typically do not count as generating qualified GHG offsets. It is possible that a future U.S. GHG emission limitation system would not count the carbon stored by a project that is started today as an offset. However, in recent years this issue has been debated and, as a result, the U.S. DOE 1605(b) program recently adopted a two-tiered approach to recognizing voluntary GHG emissions reductions, so-called *registered* and *reported* GHG emission reductions. The differences between these two kinds of recognition are described in more detail in Chapter 4.

It may be possible to limit the risks by insuring a project. By purchasing insurance, one takes on a smaller—but certain—cost to avoid the chance of suffering an uncertain—but possibly much larger—cost. Some projects "self insure" by retaining a portion of the GHG offsets created by the project, in case an unanticipated future shortfall or loss occurs. In some cases, with self insurance it may be possible to later sell or use some of the GHG offsets held as insurance, reducing the amount of revenue forgone by holding them. Some project developers have offered GHG offset buyers the guarantee that the project developer will make good on any shortfall of offsets. This guarantee exposes the guarantor to the risk that offset prices will rise, and the guarantor will be forced to buy offsets on the open market at a high cost. Commercial insurance for GHG offset projects is only starting to develop. In June 2006, the large re-insurance company Swiss Re started offering CDM project insurance to cover the risk that a proposed CDM project will not be approved and issued credits by the CDM Executive Board.

Currency Risk

For international projects there is another price risk, the relative prices of the currencies of the country in which a forest carbon sequestration project is implemented and the currency of the country in which the GHG offsets are to be used. This report focuses on offsets that are recognized and used in the U.S. and funded using U.S. capital. If the U.S. dollar weakens relative to the host country currency before implementation costs have been paid, then the implementation costs will increase in terms of U.S. dollars. Currency risk is less of an issue for a company that is creating GHG offsets for its own use than for a company that is creating offsets for speculative future sale.

Land Tenure Security

In some countries, privately-owned lands are not necessarily secure from timber theft or may even be appropriated by the state. The tenure risks should be considered when evaluating proposed international FCS projects, even if they are addressed only in a qualitative manner.

Counterparty Risk

Another important type of risk to consider when developing a contract for a forest carbon sequestration (or any other kind of GHG offset) project is called *counterparty risk*. Do partners in the project have the management skills, staff capacity, and financial stability to fulfill their obligations? Most land management practices that would be used in forest carbon sequestration projects are well-established practices. However, if a project partner does not have the skills, size, or financial capacity necessary to complete the project, the project may fail; leaving the project investors with financial losses and few or no GHG offsets. Financial exchanges (e.g., New York Stock Exchange, European Carbon Exchange (ECX)) exist largely because these institutions provide a way for investors and others to remove a great deal of the inherent counter-party risk from a stock purchase or sale transaction since all exchange members are required to have the same high-quality credit rating and available liquidity to trade on the exchange.

Weather and Climate Risks

Forest carbon sequestration projects also face unique biological-related risks that technology-based GHG abatement projects do not face. For example, drought can slow tree growth or kill young trees. Storms can knock over trees. Although global climate models do not yet have the analytic resolution to provide detailed predictions about how the climate of specific locations may change, they do suggest that the interior of the U.S. may have more frequent drought, and that weather is likely to be more variable from year to year. Climate models also suggest that intense storms might be occurring more frequently. Forest carbon project developers may wish to limit their exposure to coastal areas that have a history of large, intense storms, and interior areas where historic average precipitation rates are only slightly above the minimum amounts needed to grow trees.

Wildfire

Lay people are sometimes concerned about the risk of wildfire releasing the carbon stored by forest sequestration projects. However, this risk is small. National wildfire statistics sum the total area burned by wildfires each year, but these statistics do not identify the type of vegetative cover of the burned areas. Presumably, much of the area burned by wildfires is not forest, as forest is about one-third of the total U.S. land area, and grasslands and shrub lands are more prone to fire than forest. From 1960 through 2005, the average area burned by wildfire in the U.S. was 4.3 million acres per year (National Interagency Fire Center 2006). Even if all wildfire acres were forested, the total forest area in the U.S. is 737 million acres, and the total area burned by all U.S. wildfires each year would equal 0.58% of the total forest area. Looking at National Forest System lands gives an idea of the proportion of forest land that burns each year. The National Forest System encompasses 191 million acres (most of it covered by forest) and the average annual acreage burned on National Forest lands from 1998 though 2005 was 101,000 acres per year, or 0.05% annually. California state fire statistics provide another benchmark for comparison. California estimates the area burned by cover type, showing that in this state with large areas of forest that evolved with frequent fires, about 0.4% of the conifer forest burns each year.

Two other aspects of forest fire should be noted. One, fire can burn a forest without killing the dominant trees that form most of the tree canopy. These areas of forest burning include ground fires that do not kill overstory trees as well as "crown" fires that kill dominant, overstory trees. Understory fires do emit carbon, but generally only a fraction of the total amount that is stored in the forest. Understory fires can allow large trees to continue growing and sequestering carbon. And, even when a crown fire does kill all the trees in a forest stand, much of the carbon in the forest remains in the trunks and roots of the killed trees (see Figure 5-1 for the proportion of tree biomass in different tree components). Most crown fires also leave the majority of branch and bark biomass on the site. This dead wood typically takes years to decompose, continuing to hold carbon until new trees can begin growing vigorously.

Some people note that wildfires may produce methane (CH_4), a potent greenhouse gas. Smoky fires, where combustion is incomplete, are believed to produce measurable amounts of methane. However, forest carbon sequestration projects should not noticeably change the amount of methane calculated to be released by fires. Even factoring in the high global warming potential of methane, methane emissions from wildfires are estimated to be small when compared to the GHG mitigation benefit associated with sequestering carbon sequestration in trees, and probably smaller than the uncertainty in the measurement of the sequestration benefit.

11

QUANTIFYING OFFSETS

Methods for quantifying offsets must be very reliable and relatively transparent because offset buyers typically take possession of a serial number, not a physical ton of CO_2 or its equivalent mass in carbon. Without reliable quantification, GHG buyers don't know if they are getting what they pay for, and regulators and the public don't know if GHG emitters are meeting their emission reduction commitments. Transparency allows others to check the accuracy of GHG offset claims.

Project-based carbon accounting should include:

- Carbon pools expected to have large amounts of sequestration;
- All types of GHG emissions; and
- Carbon pools with small amounts of sequestration, if quantification is cost effective.

Not all GHG emission fluxes must be measured directly. Instead of measuring a particular flux or stock, it is reasonable to assign a number to the flux or stock such that there is a very high probability that actual carbon sequestration will not be less than the estimated amount, or that GHG emissions will not be greater than the estimated amount. A "very high probability" often is operationalized as meaning that in 90 or 95 cases out of 100 the actual GHG benefits will be at least as great as the claimed amount of benefits. For example, measurements of many forests of a particular type may show that, on average, a mature forest may have 50 metric tons CO_2e of woody debris per acre and that 95 out of 100 forests have at least 10 metric tons CO_2e of woody debris per acre. A project that establishes a forest on formerly tilled land (which has no woody debris) might assume that, at maturity, the forest will have 10 metric tons CO_2e of woody debris per acre. Without measuring the woody debris on project lands, one can say that there is a 95% probability that the amount of debris within the project forest will be equal to, or greater than, the claimed amount of 10 metric tCO_2e per acre.

If the cost of measuring a carbon pool is greater than the likely value of sequestration in that pool, it is cost effective to estimate sequestration in this way. Continuing the example above, the project developer is, on average, forgoing 40 metric tons CO_2e per acre of sequestration by not measuring the woody debris, but is avoiding the cost of measuring the stocks of carbon in woody debris over the life of the project. If the average incremental cost per acre of adding measurement and monitoring of woody debris sequestration to project measurement and monitoring activities is less than the value of 40 metric tons CO_2e of offsets, then it may be worth spending the extra money to measure the amount of sequestration in woody debris and generate 40 more metric tons CO_2e of offsets per acre. Alternatively, if a carbon pool gains only a small amount of carbon over time, one can simply assume that the pool sequesters no carbon. For example, in any productive forest, understory vegetation in forests typically does not sequester much carbon, relative to the amount sequestered by trees. If a project afforests formerly tilled land, the project accounting can assume that no carbon is gained by understory vegetation within the project lands. Similarly, if measuring a specific GHG emission is expensive, it is usually acceptable to assume that the emission is high, and calculate net fluxes using a representative "high" emission value.

For any given GHG flux, there are usually multiple methods for quantifying the flux. Often there is a choice between more expensive methods that give more precise and accurate results, and less expensive methods that give less precise and accurate results. Regardless of the quantification methods used, there should be a very high degree of confidence that at least the claimed amount of GHG emission mitigation is achieved. A GHG emission mitigation system may specify a required level of certainty. If a specified level of certainty is not required, it is recommended that claimed amounts of GHG offsets be calculated using statistical sampling designs that have at least a 90% statistical confidence level. This level of statistical confidence is required for an "A" rating for registration of forest carbon sequestration in the recently revised DOE 1605(b) program, and this level of statistical confidence is required by the forest project protocols of the California Climate Action Registry. This level of statistical confidence is also recommended in forthcoming scientific guidelines being published by Duke University Press,[33] that present methods for quantifying GHG emission offsets generated by changing land management.

For smaller pools of sequestration, it may be cost effective to use an inexpensive quantification methodology, even if this methodology requires forgoing counting as offsets a substantial proportion of the sequestration that may have been achieved by the project. Forgoing counting offsets is cost effective if the avoided cost of measurement is greater than the market value of the forgone offsets. For carbon pools with large amounts of sequestration, it is often worth spending large amounts of money to detect a high proportion of the achieved sequestration, thus increasing the number of tons CO_2e of offsets produced by a project.

Fluxes that are reversed within a single accounting cycle are generally not counted. For example, if accounting cycles are based on calendar years, and an annual crop is grown for use as a fuel for electricity generation, and the biomass material is burned in the same year that it is grown, then the sequestration and release of carbon in the biomass material is not counted.

A key aspect of any approach to quantifying GHG offsets is the setting of the project baseline and quantifying leakage. Baselines and leakage are discussed in Chapter 8.

Measuring Biomass Carbon Stocks

The main focus of forest carbon sequestration projects is to increase or avoid the decrease of biomass carbon stocks. With this focus, it is essential to reliably quantify change in biomass carbon stocks.

An inexpensive method for estimating changes in biomass carbon stocks is to find the expected change in carbon stock for the appropriate type and age of the forest using general forest carbon yield tables, such as the tables included in the Forestry appendix to the recently revised DOE 1605(b) GHG program and accounting guidelines.[34] This change in carbon stock per acre is

[33]Smith, Gordon R., et al., (in press).

[34] Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program, Chapter 1, Emission Inventories, Part I Appendix: Forestry. March 2006.

multiplied by the number of acres in the project to estimate the total project change in carbon stock. However, these regional average numbers may be off by 50% or more, due to variation in site productivity, tree species mix, stand history, and other factors.

Forest carbon sequestration emissions reductions calculated on the basis of carbon estimates taken from so-called “look-up” tables do not meet the new data quality requirements for *registering* GHG emissions reductions under the revised 1605(b) program. However, for electric companies who may seek to r*egister* GHG reductions under the revised 1605(b) program, this lack of data quality may not necessarily preclude registration of forest carbon-related GHG reductions. The reason for this is that the 1605(b) program requires reporting entities to use quantification methods that result in the entity achieving a relatively high data quality score of 3 or better (using a point system that ranges from 1-4,[35] with 4 being the highest quality measurement) on an *entity-wide* basis when conducting their entity-wide GHG emissions inventory. If the forestry component of a company’s GHG inventory is relatively small compared to its fossil-fuel based GHG emissions, then the relatively poor quality of the data used to estimate the GHG offsets associated with a given forest carbon sequestration project may be easily offset by the relatively high quality of the data used to estimate the electric company’s direct GHG emissions from fossil-fuel combustion (i.e., based on fuel-usage data or derived from company-operated Continuous Emissions Monitors (CEMS)).

An alternative to quantifying forest carbon sequestration by using look-up tables is to make direct measurements using a statistical sampling design. Properly done, direct measurements are more accurate than estimating carbon stocks using general tables or comparison to other sites that already have been measured. When measuring forest carbon, measurements should be made before project activities are implemented, and then re-measurements should be made at periodic intervals. The difference between the stock observed at the most recent measurement and the stock observed before implementation of project activities is the change in carbon stock within the project boundary.

Forest carbon pools that typically are measured separately are:

- Live trees (may be divided into multiple size classes);
- Standing dead trees;
- Understory shrubs and seedlings;
- Woody debris (may be divided into multiple size categories); and
- Leaf litter and other organic material on the forest floor.

The categories to be measured should be defined such that any particular piece of material is in only one carbon pool, and is not counted in any other carbon pool. Except when specific types of material are explicitly excluded from measurement, all pieces of woody material that may occur

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[35] The 1605(b) Technical Guidelines provide an alphabetical rating system with a numerical point score assigned to each particular rating. Quality level “A” measurement or estimation methods are given 4 points, quality “B” methods are given 3 points, quality “C” methods are given 2 points, and quality “D” methods are given 1 point. A reporting entity must achieve a weighted average score of 3 points to register GHG emission reductions.

in a forest should be encompassed by one category of material, with no gaps between the category definitions.

The overall approach to measuring biomass carbon is statistical sampling. A proper selection of several hundred to a few thousand trees (which would be the number of trees on a few acres of forest) can give a reliable estimate of the number and sizes of trees over thousands of acres. Statistical sampling designs use methods to select which trees to measure that make it likely that the measured trees are representative of all the trees in the area. Depending on the variability of the trees and their growth, and the way data analysis is done, it may improve the precision of the estimate to stratify the project area into sub-areas that are relatively homogeneous. If stratification is used, each stratum is measured separately.

There are two general approaches to measuring live trees: *variable radius plots* and *fixed area plots*. Either approach is acceptable. The choice of method will depend on the capacities of the organization doing the measurement and whether new measurements will be compared to past measurements.

To select which trees will be measured as part of a particular variable radius plot, a forestry technician stands at plot center and views trees using a prism that gives a very precise, narrow, fixed angle of view. If a tree has a diameter greater than the fixed angle of view, it is counted. Otherwise, it is ignored. Smaller trees near plot center will be counted. If a tree is far from plot center, it must be large to be counted. A technician then measures and records the species and diameter of each counted tree. The technician may also measure and record other attributes of the counted trees. Generally, the height of every fourth counted tree is measured. Variable plots are easy to measure using inexpensive equipment. Variable radius plots are commonly used in one-time timber inventories. Variable radius plots are also called point plots.

The other general approach to measuring trees is to use fixed area plots. Fixed area plots are just that – a plot size and shape is specified in the sampling design, plot boundaries are located, and technicians measure each qualifying tree growing within the plot boundary. Because small trees are often frequent and large trees are more widely spaced, fixed area plot designs often use nested subplots, with smaller subplots for measuring smaller trees and larger subplots for measuring larger trees. Tree subplot sizes generally range from about 1/400 acre for small, frequently occurring trees that do not store much carbon, to ¼ acre for the largest trees. On average, large trees are widely spaced, and a ¼ acre plot typically might contain 2-10 large trees. If a plot is larger than about ¼ acre, it can be very time-consuming to determine the exact locations of plot boundaries (i.e., to determine whether a tree that is near the plot boundary is inside or outside of the plot).

A permanent plot is a plot where the location is recorded, and the same plot boundaries (for fixed area plots) or plot center (for variable radius plots) are used for measurements made at different times. A few dozen permanent plots can give a precise measurement of modest changes in biomass carbon stock. Achieving the same level of precision using temporary plots could require many hundred plots or might not be possible.

In most forest types, shrubs and litter will not store much carbon. As a result, it is not efficient to spend a lot of effort getting a precise measurement of their carbon stocks. For example, if trees gain 100 tons CO_2e per acre, getting a measurement that is accurate to ±5% means having an error of 5 tons CO_2e per acre. If the shrub layer gains only 2 tons CO_2e per acre, having a measurement that is only accurate to ±50% means an error of 1 ton CO_2e per acre.

Standing dead trees can be measured with live trees. To account for decomposition, the biomass of dead trees often is calculated separately from the biomass of live trees.

Down dead wood can be quickly measured with a line transect. For line transect measurements, a line of a pre-determined length is marked in a position that is specified relative to the plot reference point (the plot reference point is often called "plot center" even if it is not at the center of all the subplots). As the field technician travels from one end of the transect line to the other, they measure any piece of dead wood that crosses the line and that is of the specified size to be measured. Line transects are fast and have been shown to yield measurements that are accurate to within about 10%. Most forest carbon sequestration projects have very low to moderate carbon stocks in woody debris, and this accuracy level is adequate to get an accuracy of the total biomass to within ±2-5%.

In many forests, the stock of carbon in leaf litter and the forest floor never becomes large. For these forests, it is adequate to carefully gather and weigh the forest floor collected from a few small plots. These plots can be used to generate a project-specific ratio of mass per unit of depth. On all other plots, a few quick measurements of the thickness of the forest floor can be used to calculate the mass in the forest floor.

Since the purpose of measurements in forest carbon sequestration projects is to get an accurate measurement of the change in carbon stock, and because other kinds of biomass are measured in addition to live trees, many forest carbon sequestration projects use fixed area plots instead of variable radius plots.

Field measurements typically are used to record the sizes and numbers of pieces, not their weight.[36] These sizes must be converted to weight of carbon. For pieces of dead wood, standard shapes are used to calculate the volume of pieces, and the volume converted to mass by using a species-specific density. For decomposing wood, densities should be used that reflect the degree of decomposition. For live trees, the calculations are a bit more complex. Equations are developed that predict the dry weight of a tree as a function of the species, diameter, and the tree height. These biomass equations are developed by measuring several dozen trees, cutting down each tree, and weighing each tree. Sub-samples are taken to find the ratio of "dry" weight to the field wet, or "green," weight. For large trees, numerous measurements may be made to accurately determine the volume of the trunk and main branches, and sub-samples can be cut, measured, dried, and then weighed to get a density for converting the volume measurements to weight. Then the weight of the measured trees is regressed on the height and diameter to develop a biomass equation. Equations have been published for many U.S. tree species, up to moderately large sizes. As a result, it is usually not necessary for developers of carbon sequestration projects in the U.S. to develop their own live tree biomass equations. Root biomass is typically estimated as a function of tree species group, aboveground biomass, and diameter. Biomass is converted to

[36] There are exceptions to this approach where field measurements are used to record weight. Field measurements of the forest floor often record the weight of material collected from a small sub-plot of a specified area and shape.

carbon mass using the ratio of weight of carbon to total biomass weight. Many projects use the default ratio that half the dry weight of a tree is carbon. More detailed measurements of the proportion of carbon in trees of different species and different parts of trees are given in Appendix D. Carbon mass is converted to CO_2 equivalent mass by multiplying by 3.67.

After the mass of each piece of wood is calculated, the plot size is used to determine how many pieces per hectare (or per acre, if one is using English units instead of metric units) each piece represents. The mass is multiplied by this ratio, and then the masses of all pieces are summed to get the tons per hectare (or per acre). If permanent plots are used, and one is finding the change in carbon stock over time, the most statistical power is gained by next finding the change in carbon stock on each plot, in terms of tons per hectare (or acre). Then the confidence interval of the estimate of the mean change in carbon stock per plot is calculated using the calculated change in carbon stock on each plot. The mean change is multiplied by the number of hectares (or acres) in the project to get the total mean estimated change in carbon stock.

As discussed above, it is recommended that the claimed gain in carbon stock be the mean estimated change minus a statistical confidence interval to achieve a 90% statistical confidence level. Some emission mitigation systems recommend or require 95% statistical confidence. The confidence interval to be used should be specified in the project's monitoring plan. For example, suppose that the mean estimate for a given project is that it has gained 100 tons CO_2e per acre, with a 95% confidence interval[37] of 4 tons CO_2e per acre. Subtracting the confidence interval, this project would claim that it has sequestered 96 tons CO_2e per acre, with 95% confidence.

When harvested wood is made into wood products, some of the carbon in the harvested trees remains stored in the wood products. Storage of carbon in wood products is discussed in Chapter 7. As noted in Chapter 7, it has not yet been made clear in the U.S. context exactly who might get to claim the GHG emission mitigation benefits of carbon stored in wood products in use and in landfills. At this time, the most authoritative methods for estimating quantities of carbon stored in wood products and landfills are in the Technical Guidelines, Forestry Appendix, of the revised DOE 1605(b) program. Methods for estimating the amounts of carbon stored in wood products and landfills are also given in the forestry protocols of the California Clean Air Registry.

Some GHG emission mitigation systems specify that forest biomass measurements shall be made at least once every five years. Some monitoring plans specify more frequent measurement of young stands that are expected to be growing quickly, and much less frequent measurement of older stands that are expected to grow more slowly. Measuring less frequently reduces total measurement cost. When biomass is measured every five years, GHG emission mitigation systems typically allow straight line extrapolation of a sequestration trend, or modeling of sequestration, and allow project developers to sell most of the anticipated credits. The Chicago Climate Exchange (CCX), for example, allows the sale of 80% of these anticipated forest carbon

[37] The confidence interval should be determined using a "one-tailed" statistical test. This is because we only care that the actual amount of sequestration is at least the claimed amount, with the specified level of confidence. We are not concerned about the possibility that the actual amount of sequestration may be more than the mean estimated amount.

related "credits". It is recommended that inexpensive annual checks be made to assure that trees are still present and growing on the project site.. If a significant portion of the trees have been killed or are not growing as expected, the project developer should either conduct a reliable measurement of biomass stock, or not sell any new GHG offsets beyond the amount observed in the most recent reliable measurement.

Possible Non-Biomass GHG Fluxes

Some people have expressed concerns about GHG emissions from burning fossil fuel to conduct land management activities and monitoring. Although analysis shows that these emissions are almost always very small relative to the GHG benefits of forest carbon sequestration, some observers argue that these *de minimus* GHG emissions should be accounted for simply for the sake of doing comprehensive project GHG emissions accounting. Including these small GHG emissions is not difficult, as they can be calculated easily using data activity records, estimates or records of miles traveled or fuel consumed, and published GHG emissions factors for gasoline and diesel fuel.

For non-intensive forest management, fuel emissions are likely to represent a small fraction of a ton CO_2e per acre, over the course of a project. Under intensive management, emissions may be a few tons CO_2e per acre over the life of the project, mostly resulting from site preparation and thinning. A project may also opt to count indirect emissions from the manufacturing of fertilizer, if fertilizer is used by the project. Indirect emissions from manufacturing fertilizer may range up to a few tons CO_2e per acre over the life of a project.

Some observes have also argued that methane and nitrous oxide[38] emissions should be included in project accounting. Soils that are not saturated with water are typically methane sinks (i.e., they take methane out of the atmosphere). A project could emit methane from fires if burning occurs. If fire occurs, a complete accounting should include an estimate of methane emissions, even though these emissions almost always will be very small relative to the GHG benefit of forest carbon sequestration. Nitrous oxide emissions from forest carbon sequestration projects should be negligible as well, except for emissions from nitrogen fertilizer, if fertilizer is applied to the site. The CO_2e of nitrous oxide emissions from forestry projects should not be more than a few tons CO_2e per acre, over the life of the project.

Most FCS projects do not measure changes in soil carbon. Many projects do not measure soil carbon because they assume that soil carbon stocks will remain constant or increase during the project period. In general, if a project reduces soil disturbance and does not significantly reduce carbon inputs into soil, soil carbon stocks should increase. However, projects that reduce fertilization (such as switching from annual crops to trees) may reduce carbon inputs to soil. Also, switching from deep rooted pasture grasses to trees may reduce soil carbon stocks in

[38] The three GHGs that are affected by land management and addressed under the UNFCCC are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). There are other climate effects from land management, including emissions of particulates, black carbon, aerosols, water vapor, and changing albedo, but their effects are very short term, small, and/or poorly understood, and these other factors are not typically addressed in forest carbon sequestration project accounting.

depths ranging from greater than 8 inches up to 6 feet below the soil surface. The greatest likely increases in soil carbon would occur if switching from annual plowing to fast-growing trees. Soil carbon sequestration will be higher in finer textured soils and in cooler climates. In general, it would be rare that a FCS project would sequester more than 35 metric tons CO_2e per acre in soil, over a few decades. Some types of projects, such as lengthening rotations and increasing utilization, have no discernable effect on soil carbon stocks. Projects that increase soil disturbance may cause a loss of soil carbon. Forest type conversion might cause a modest initial reduction in soil carbon, but a modest increase over several decades. Types of projects that may, or may not, decrease soil carbon are switching from even-age to uneven-age management, and thinning to decrease fire risk.

Direct measurements of changes in soil carbon stocks within the project area are affordable for large projects. Soil carbon measurements require technical expertise to ensure that they will be able to detect changes in soil carbon stocks that might occur. Soil erosion can transport soil carbon to outside of the project boundary. Part of eroded soil carbon is converted in atmospheric CO_2. Some eroded carbon may be buried or deposited in a lake or ocean, and sequestered permanently. Methods for estimating soil carbon sequestration that may result from erosion are not well established, and soil carbon sequestration projects have assumed that soil carbon removed from the site is emitted into the atmosphere.

Documentation, Transparency, and Verification

Project developers should document the methods used to quantify carbon stocks in detail. Written monitoring plans and monitoring reports should include field protocols for data collection, protocols for any needed laboratory analysis, detailed descriptions of data analysis procedures, and all equations and factors used in calculations and conversions. A copy of field data and monitoring reports should be archived by project developer, project "verifier," and any registry in which the associated GHG emissions offsets are registered.

Some project developers have argued that their quantification methods are proprietary. However, buyers, regulators, and the public will have no way to assess whether claimed GHG offsets are valid unless quantification methods are described publicly. A project developer or quantifier does not need to release proprietary software they may have developed, but quantifiers should make available upon request detailed descriptions of data collection procedures, factors, and equations used in their calculations. Alternatively, quantifiers can use published methodologies (e.g., 1605(b) methods, an approved CDM methodology). With published methodologies, some project-specific data will also need to be made public. This disclosure can be done without revealing trade secrets.

Most GHG emission offset trading systems either strongly recommend or require so-called "third-party" verification of GHG offset claims. The UNFCCC CDM process requires that, for larger projects, one approved project "verifier" must review and validate the monitoring design, and a second approved verifier must review and verify claims of achieved amounts of GHG emissions reductions or carbon sequestration. This model assumes that the project developer will collect the data and the project developer, or its agent, will calculate the offsets. Conceivably, where measurement and data analysis requires significant technical expertise, this data collection and data analysis work will be contracted out to an entity that specializes in GHG offset quantification. Under some emerging GHG mitigation systems, it is acceptable for a third-party verifier to collect its own data and do its own calculations. Under the UNFCCC system, a second independent entity would have to verify the quantification, even if the quantification is done by an entity that is independent of the project developer.

The DOE's recently revised 1605(b) program encourages both entities that seek to *report* and *register* GHG emission reductions to obtain independent third-party certification of their GHG emissions inventories and other documentation, but this is *not* required. One benefit of subjecting a GHG inventory to third-party verification is that DOE will allow entities who do so to simply report their total GHG emissions by type of gas and not provide DOE with a specific breakdown of what specific company operations generate the reported GHG emissions.

Before embarking on a carbon sequestration project, it is advisable for companies to identify the GHG emission mitigation system in which the company expects to use the GHG offsets. Then the project should be developed using that GHG regulatory system's definitions of what activities generate acceptable GHG emission offsets. The project should also follow the system's rules addressing how the offsets should be quantified.

In the GHG emission offset world, *registration* is a term of art with a specific meaning. Registration means that a particular GHG emission offset has met some standard of quality and has been accepted into a *registry*. A registry will assign each offset unit (such as each ton CO_2e) a unique tracking number. If a registry does not maintain copies of all verification reports, the registry should maintain a record of where each report can be accessed. Some registries also track changes in ownership and disposition of each registered GHG offset. When an entity uses an offset to mitigate an emission, that GHG offset is cancelled or retired from its registry. After cancellation or retirement, an offset can no longer be traded, and can not be used for any other purpose. Tracking the ownership of each offset avoids double counting or multiple uses of a single offset. In regulatory programs, the regulator operates the registry or contracts with an entity to operate the official registry for the program.

In the U.S., creators of GHG emissions offsets and users may seek to *register* their reductions under the revised DOE 1605(b) program or other GHG registries operated by non-profit organizations and others. One reason organizations seek to register GHG reductions is in the hope of having them recognized under any mandatory U.S. GHG emission mitigation policy that may be implemented in the future.

12

CASE STUDY EXAMPLES

The case studies described below provide examples of the type of financial analysis that might be done by an electric company considering either investing in a forest carbon sequestration project being developed by a third-party or developing an FCS project on its own.

For the purposes of illustration, we have developed a number of case study examples that illustrate the different costs of sequestering carbon in forests. The case studies are based on using different species, different contractual approaches, and different project designs to create potential forest carbon sequestration projects. Electric companies interested in doing this kind of analysis can use these examples as models for their own analyses of proposed FCS projects they may be considering.

The range of costs for different forest carbon sequestration projects described here are higher than many of the $/t$CO_2$e prices that forest carbon project proponents and others often cite for achieving GHG offsets based on forest carbon sequestration projects. There are several reasons for this difference.

First, most financial analyses completed on forest carbon sequestration projects estimate the cost effectiveness of the proposed projects ($/t$CO_2$e) in a simplified manner that does not take into account the need to discount the flows of carbon sequestration as well as the cash flows that are included in the proposed project. The examples given here use *levelized cost* (i.e., present value cash flow divided by present value tCO_2e) as the metric for assessing each project's cost effectiveness.

Second, many analyses of proposed projects fail to accurately account for either the purchase cost of the land used for the project, the opportunity cost of the land, and/or the final disposition of the land at the end of the proposed project. Land costs are often the single largest component of the overall cost of a forest carbon sequestration project.

Third, many analyses of specific projects make use of project-specific data. On productive sites with reasonably diligent management, the carbon sequestration rates may be significantly higher than the general rates used in these examples. The expected rates of carbon sequestration used in the example analyses shown here assume rates of carbon sequestration that are averaged across a wide range of site productivities and forest management intensities.

Our analysis is focused on calculating the *levelized cost-effectiveness* ($/t$CO_2$e) sequestered, or the present value of the financial flows derived for a proposed project divided by the present value of the carbon dioxide emission reductions expected to be generated by the proposed project. These examples focus on cost, and costs are stated as positive numbers. Revenues are stated as negative numbers. Revenues decrease net costs.

Additionally, EPRI's program on Greenhouse Gas Reduction Options has developed the Greenhouse Gas Emissions Reduction Cost Analysis Model v2.02.[39] This model is an interactive, "real-options"-enabled Microsoft® Excel spreadsheet model that can help electric companies to estimate the levelized cost effectiveness (\$/ton CO_2e) and the net economic benefits (or costs) of potential greenhouse gas (GHG) abatement projects. The model can analyze 8 types of GHG abatement projects,[40] including the planting of trees and the management of forested land to biologically sequester and store carbon in growing timber stock.

As discussed in Chapter 9, an investor seeking a financial return on a potential investment in a GHG emission reduction project that would develop GHG offsets for sale also may be interested in the internal rate of return (IRR) of the project. Electric companies analyzing proposed FCS projects may wish to calculate project costs and benefits multiple times, using different forward price trajectories for GHG emissions offsets or different schedules for the creation of offsets.

Lower Mississippi Afforestation, Buying Agricultural Land

This scenario assumes an electric company or other project developer purchases crop lands and then establishes and manages the growth of a new forest on project lands. At the end of the 30-year project time horizon, the land is assumed to be sold, bound by a conservation easement that requires the existing carbon stock to be maintained in the future, but that allows the buyer to harvest additional growth above the amount present in year 30. Input assumptions are shown in Table 12-1 and an overview of the project finances is shown in Table 12-2.

This scenario assumes that land generally appreciates in value, in real terms, but that the conservation easement reduces the selling price of the land in year 30 to the same nominal amount as the purchase price in year 1. The present value of this \$8 million future land sale is about \$2.5 million, resulting in a net land cost of about \$5.5 million, in present value. This scenario's baseline is that the land would have continued to remain in use as cropland (with a constant biomass carbon stock of effectively zero) and there is no leakage.

In this scenario, the levelized cost of GHG emission offsets would be \$17 per metric ton CO_2e. The largest single component of the cost is the purchase price of the land. The second largest component of the total cost is the cost of establishing trees on the property. This scenario assumes that offsets accrue and are valued every five years, as they are verified. Offset accrual could be estimated annually, and "trued up" every five years, upon verification. Annual accrual would make some offsets accrue one to four years earlier than in this scenario, and would reduce the levelized cost of offsets by about one dollar per ton CO_2e. For simplicity, annual accrual is not shown.

[39] GHG-CAM v2.02 was developed by Adam Diamant, Tom Wilson, and Christopher Gerlach of EPRI, and EPRI-contractor Charles Clark.

[40] The seven other GHG abatement projects that can be analyzed using GHG-CAM include biomass cofiring with coal, heat rate improvement, new wind generation, new solar generation, energy conservation, dedicated biomass power production, and methane destruction.

Table 12-1
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
	Metric tons CO_2e calculated from U.S. DOE 2006b, table B50

Table 12-2
Project Financial Overview: Buying and Agricultural Land[41]

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	8,000,000	3,500,000	20,000	20,000	0	11,540,000	0
2			20,000			19,231	0
3			20,000			18,491	0
4			20,000			17,780	0
5			20,000	20,000	191,000	34,192	156,988
6			20,000			16,439	0
7			20,000			15,806	0
8			20,000			15,198	0
9			20,000			14,614	0
10			20,000	20,000	194,000	28,103	131,059
11			20,000			13,511	0
12			20,000			12,992	0
13			20,000			12,492	0
14			20,000			12,011	0
15			20,000	20,000	158,000	23,099	87,731
16			20,000			11,105	0
17			20,000			10,678	0
18			20,000			10,267	0
19			20,000			9,873	0
20			20,000	20,000	161,000	18,986	73,478
21			20,000			9,128	0
22			20,000			8,777	0
23			20,000			8,439	0
24			20,000			8,115	0
25			20,000	20,000	147,000	15,605	55,142
26			20,000			7,502	0
27			20,000			7,214	0
28			20,000			6,936	0
29			20,000			6,670	0
30	-8,000,000		20,000	20,000	139,000	-2,552,385	42,856
Total	**0**	**3,500,000**	**600,000**	**140,000**	**990,000**	**9,380,869**	**547,254**
			Levelized \$/ton CO_2e			**17**	

[41] In these financial overviews, costs are given as positive numbers and revenues are given as negative numbers.

Lower Mississippi Afforestation, Buying and Donating Land

This scenario assumes an electric company or other project developer purchases crop lands, establishes and grows trees on those lands, and then donates the lands to a conservation organization. The donation is assumed to include a conservation easement that requires the lands to be maintained in forest cover. As part of the conservation easement, the project developer would retain the rights to all carbon sequestered in the forest. Input assumptions are shown in Table 12-3 and an overview of the project finances is shown in Table 12-4.

This scenario shows no revenue from the sale of land because the land is expected to be donated. Since the donor would retain an easement that requires the recipient to maintain the forest and give the donor rights to all the GHG emission offsets generated by the trees on the land, it is assumed that the donor does not get to claim any tax credit or other value from the donation. Importantly, by adopting this approach, the project developer / donor avoids annual management and tax costs. This case example is similar to the contractual approach that has been used by several electric companies to implement forest carbon sequestration projects in the United States.

This scenario's baseline is that the land would have continued to remain in use as cropland (with a constant biomass carbon stock of effectively zero) and there is no leakage.

In this scenario, the levelized cost of GHG offsets is estimated at $21 per metric ton CO_2e. The largest single component of this cost is the purchase price of the land. The second largest component of the total cost is the cost of establishing trees on the property. Relative to the scenario of selling the land with a conservation easement, forgoing the revenue from sale of the land is greater than the avoided management and tax costs, resulting in this scenario having a higher cost per ton CO_2e of offset.

Table 12-3
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
	Metric tons CO_2e calculated from U.S. DOE 2006b, table B50

Table 12-4
Project Financial Overview: Buying and Donating Land

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	8,000,000	3,500,000	20,000	20,000	0	11,540,000	-
2						0	-
3						0	-
4						0	-
5				20,000	191,000	17,096	156,988
6						0	-
7						0	-
8						0	-
9						0	-
10				20,000	194,000	14,052	131,059
11						0	-
12						0	-
13						0	-
14						0	-
15				20,000	158,000	11,550	87,732
16						0	-
17						0	-
18						0	-
19						0	-
20				20,000	161,000	9,493	73,478
21						0	-
22						0	-
23						0	-
24						0	-
25				20,000	147,000	7,802	55,142
26						0	-
27						0	-
28						0	-
29						0	-
30				20,000	139,000	6,413	42,856
Total	**8,000,000**	**3,500,000**	**20,000**	**140,000**	**990,000**	**11,606,406**	**547,256**

Levelized \$/ton CO_2e **21**

International Afforestation

This scenario assumes that an electric company or other project developer purchases crop lands in a foreign country where land costs are low and then establishes and grows trees on those lands. Other than the land cost, to make this scenario comparable to others, all costs and growth rates are assumed to be the same as in the first scenario, buying and afforesting agricultural land. At the end of the 30-year project, the land is assumed to be sold with a conservation easement that requires the existing carbon stock to be maintained, but that allows the buyer to harvest additional growth above the amount present in year 30. Input assumptions are shown in Table 12-5 and an overview of the project finances is shown in Table 12-6.

This scenario assumes that land generally appreciates in value, in real terms, but that the conservation easement reduces the selling price of the land in year 30 to the same nominal amount as the purchase price in year 1. This scenario's baseline is that the land would have continued to remain in use as cropland (with a constant biomass carbon stock of effectively zero) and there is no leakage.

In this scenario, the levelized cost of offsets is \$8 per metric ton CO_2e. This is significantly less than the cost of GHG offsets created where land costs are higher, but still not in the same low-cost dollar-per-ton CO_2e range (i.e., \$1-2 / tCO_2e) claimed by some international projects. In part, this is because the largest single component of the cost is the cost of establishing trees, and this example assumes that tree establishment costs will be the same as in the U.S. In practice, establishment costs might be significantly lower than in the United States.

Table 12-5
Project Assumptions

10,000	Number of acres
100	Land purchase price (\$/acre)
350	Planting and site prep cost (\$/acre)
2	Tax & management (\$/acre)
0.04	Annual discount rate
	Metric tons CO_2e calculated from U.S. DOE 2006b, table B50

Table 12-6
Project Financial Overview: International Afforestation

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	1,000,000	3,500,000	20,000	20,000	0	4,540,000	0
2			20,000			19,231	0
3			20,000			18,491	0
4			20,000			17,780	0
5			20,000	20,000	191,000	34,192	156,988
6			20,000			16,439	0
7			20,000			15,806	0
8			20,000			15,198	0
9			20,000			14,614	0
10			20,000	20,000	194,000	28,103	131,059
11			20,000			13,511	0
12			20,000			12,992	0
13			20,000			12,492	0
14			20,000			12,011	0
15			20,000	20,000	158,000	23,099	87,732
16			20,000			11,105	0
17			20,000			10,678	0
18			20,000			10,267	0
19			20,000			9,873	0
20			20,000	20,000	161,000	18,986	73,478
21			20,000			9,128	0
22			20,000			8,777	0
23			20,000			8,439	0
24			20,000			8,115	0
25			20,000	20,000	147,000	15,605	55,142
26			20,000			7,502	0
27			20,000			7,214	0
28			20,000			6,936	0
29			20,000			6,670	0
30	(1,000,000)		20,000	20,000	139,000	-307,825	42,856
Total	**-**	**3,500,000**	**600,000**	**140,000**	**990,000**	**4,625,429**	**547,255**
			Levelized \$/ton CO_2e			**8**	

Lower Mississippi Afforestation Using Company Land

This scenario assumes that a project is implemented on crop land a company already owns, and rents for agricultural use. By switching from renting the land to growing trees on it, the company would forgo annual land rental payments. Input assumptions are shown in Table 12-7 and an overview of the finances of the project is shown in Table 12-8.

This scenario's baseline is that the land would have continued to remain in use as cropland (with a constant biomass carbon stock of effectively zero). The calculations assume that there is no displacement of GHG emissions caused by the project.

The largest single cost in this scenario is the forgone rental income, from ceasing to rent the land to farmers. The present value of this forgone stream of rental payments is approximately the same as the cost of buying the land. Other costs and the schedule of accrual of tons of CO_2e is the same as in the scenario where land is purchased. As a result, the levelized cost of $19 per ton of CO_2e in this scenario is close to the cost of GHG offsets in the scenario where land is purchased and afforested.

Table 12-7
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
35	Forgone annual land rental payment ($/acre)
	Metric tons CO_2e calculated from U.S. DOE 2006b, table B50

Table 12-8
Project Financial Overview: Afforesting Company Land

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	350,000	3,500,000	20,000	20,000	0	3,890,000	0
2	350,000		20,000			355,769	0
3	350,000		20,000			342,086	0
4	350,000		20,000			328,929	0
5	350,000		20,000	20,000	191,000	333,374	156,988
6	350,000		20,000			304,113	0
7	350,000		20,000			292,416	0
8	350,000		20,000			281,170	0
9	350,000		20,000			270,355	0
10	350,000		20,000	20,000	194,000	274,009	131,059
11	350,000		20,000			249,959	0
12	350,000		20,000			240,345	0
13	350,000		20,000			231,101	0
14	350,000		20,000			222,212	0
15	350,000		20,000	20,000	158,000	225,215	87,732
16	350,000		20,000			205,448	0
17	350,000		20,000			197,546	0
18	350,000		20,000			189,948	0
19	350,000		20,000			182,642	0
20	350,000		20,000	20,000	161,000	185,111	73,478
21	350,000		20,000			168,863	0
22	350,000		20,000			162,368	0
23	350,000		20,000			156,123	0
24	350,000		20,000			150,119	0
25	350,000		20,000	20,000	147,000	152,147	55,142
26	350,000		20,000			138,793	0
27	350,000		20,000			133,455	0
28	350,000		20,000			128,322	0
29	350,000		20,000			123,387	0
30	350,000		20,000	20,000	139,000	125,054	42,856
Total	**10,500,000**	**3,500,000**	**600,000**	**140,000**	**990,000**	**10,240,379**	**547,255**

Levelized \$/ton CO_2e 19

Afforestation of Mined Lands

This scenario assumes that mined lands for coal that otherwise would have been restored to grass are restored to forest instead. To make this scenario easier to compare to the other afforestation examples described here, the schedule of carbon sequestration is the same as for afforestation of hardwoods in the lower Mississippi River valley. If one were doing an actual project, the analysis would be done using a schedule of carbon sequestration for the specific geographic area in which the project would be implemented.

On some mine reclamation projects, tree growth has stalled after an initial period of robust tree growth. To reflect this possible incomplete restoration, this scenario assumes that trees stop growing at age 15, and gain no more carbon after that age.

This scenario assumes that there is no cost for land. The scenario assumes that the mining company is fulfilling its regulatory obligation to restore the land, and that there is no commercial value to unrestored land.

The baseline for this project is that the lands would have been restored to grass. It is assumed that soil carbon gains under restoration with grass are the same as soil carbon gains under restoration with trees, so there is no adjustment for a different amount of soil carbon sequestration under trees versus grass. The carbon in grass biomass is assumed to be negligible. Finally, we assume that there is no displacement of GHG emissions caused by the project.

In this scenario, the largest cost is the cost of establishing trees on the lands. Since this scenario avoids the large land costs that are present in other examples, the net cost per ton CO_2e of offset is lower for this scenario, even though the project generates only a modest number of tons CO_2e offset per acre. In this scenario, the levelized net cost of offsets is $11 per metric ton CO_2e. Also, the GHG offsets accrue in the first years of the projects, which causes the discounted number of tons of sequestration to be closer to the undiscounted number of tons, which also helps to reduce the levelized cost per ton.

Table 12-9
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
	Metric tons CO_2e calculated from U.S. DOE 2006b, table B50

Table 12-10
Project Financial Overview: Afforesting Strip-Mined Lands

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	0	3,500,000	20,000	20,000	0	3,540,000	-
2			20,000			19,231	-
3			20,000			18,491	-
4			20,000			17,780	-
5			20,000	20,000	191,000	34,192	156,988
6			20,000			16,439	-
7			20,000			15,806	-
8			20,000			15,198	-
9			20,000			14,614	-
10			20,000	20,000	194,000	28,103	131,059
11			20,000			13,511	-
12			20,000			12,992	-
13			20,000			12,492	-
14			20,000			12,011	-
15			20,000	20,000	158,000	23,099	87,732
16			20,000			11,105	-
17			20,000			10,678	-
18			20,000			10,267	-
19			20,000			9,873	-
20			20,000	20,000		18,986	-
21			20,000			9,128	-
22			20,000			8,777	-
23			20,000			8,439	-
24			20,000			8,115	-
25			20,000	20,000		15,605	-
26			20,000			7,502	-
27			20,000			7,214	-
28			20,000			6,936	-
29			20,000			6,670	-
30			20,000	20,000		12,826	-
Total	**0**	**3,500,000**	**600,000**	**140,000**	**543,000**	**3,946,080**	**375,779**
			Levelized \$/ton CO_2e			**11**	

Afforestation Combining Offsets and Pulp Wood Production

This scenario assumes an electric company or other project developer purchases crop land and converts it to pulpwood production in order to generate GHG offsets equal to the average carbon stock under pulpwood forest rotations. At the end of this example project, we assume the land will be sold with a conservation easement requiring trees to be maintained on the property, with a requirement that the new owner maintain at least the average carbon stock present over the course of a pulpwood rotation. Such an easement would allow commercial forestry, but would not allow further land development on the site. Due to the prohibition on development, the value of the land is assumed not to appreciate.

This scenario's baseline is that the land would have continued to remain in use as cropland (with a constant biomass carbon stock of effectively zero) and there is no leakage.

The largest cost element in this scenario is the cost of establishing trees on the site. The revenue from wood harvest more than offsets the tree establishment cost, yielding a positive return on the planting investment. The second largest cost is the loss in the present value of the land. The carrying cost of the capital invested in land over the 8 years of the project is equal to about 27% of the initial land investment. This forgone revenue on a possible alternative use of money invested in the project must be counted as a project cost.

Due to the significant revenues from wood and limited cost of capital for land, this project yields GHG offsets at a relatively low levelized cost of $8 per metric ton CO_2e.

Table 12-11
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
	Metric tons CO_2e from Cao model (Cao and Durand 1991), site 85
12	Initial pulp stumpage price, $ per green, short ton
0.01	Pulp price annual escalation rate

Table 12-12
Project Financial Overview: Afforestation with Pulp Wood Production

Project year	Land cost	Implementation Cost	Management, tax & monitoring costs	Wood Revenue	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	8,000,000	3,500,000	40,000	0	0	11,540,000	-
2			20,000	0	26,503	19,231	24,503
3			20,000	0	45,643	18,491	40,577
4			20,000	0	58,568	17,780	50,064
5			40,000	0	40,800	34,192	33,534
6			20,000	0	0	16,439	-
7			20,000	0	0	15,806	-
8	-8,000,000		20,000	-5,789,531	0	-10,463,712	-
Total	**0**	**3,500,000**	**200,000**	**-5,789,531**	**171,514**	**1,198,227**	**148,678**

Levelized \$/ton CO_2e **8**

Burying Logs

This scenario assumes that an electric company or other project developer buys crop land, afforests the land with fast growing Cottonwood trees, then harvests the trees and buries the stem wood and stem bark. Carbon in stumps, roots and logging slash is not counted. Counting carbon in this debris would slightly increase the amount of GHG emission offsets, thus slightly decreasing the expected levelized cost per ton CO_2e.

The land used to grow the trees is assumed to be sold at the end of the project. Since the carbon is not stored on the land used to grow the trees (instead it is stored elsewhere, at a burial site), the land can be sold with no encumbrances. As a result, the value of the land is assumed to increase at the discount rate.

This scenario includes the stumpage revenue that is forgone when the trees are buried instead of being sold for wood. The scenario does *not* include the cost of harvesting the trees and placing them in the ground. If these costs are moderate or large, they will have a significant effect on the levelized cost per ton of GHG offset generated by the project.

The largest component of costs in this scenario is the forgone revenue that is lost when the trees are not sold for wood. Nearly as large as the forgone stumpage revenue is the cost of establishing trees on the site. Since the land price is assumed to appreciate at the discount rate, the present value of the revenue from the sale of the land is equal to the capital invested in the land. Although tree establishment costs are high, this scenario yields a large number of tons CO_2e, resulting in a levelized cost per ton that is comparable to the costs of offsets generated by domestic afforestation projects.

Instead of burying logs, a project could store carbon in wood products. A much smaller proportion of the wood in trees would be stored in wood products than would be stored by burying logs. However, the economics of the project could be favorable because revenues from the sale of wood products should be substantial. At this time, ownership has not been clarified for GHG emission offsets based on storing carbon in wood products.

As shown in Table 12-14, the levelized cost of GHG offsets generated by burying wood in this example would be $25 per metric ton CO_2e.

Table 12-13
Project Assumptions

10,000	Number of acres
800	Land purchase price ($/acre)
350	Planting and site prep cost ($/acre)
2	Tax & management ($/acre)
0.04	Annual discount rate
	Metric tons CO_2e from Cao model (Cao and Durand 1991), site 85
0	Burial cost, per ton
$10	Forgone stumpage value[42] ($/green short ton of wood)

[42] The "stumpage value" is the fee paid to a landowner for the right to harvest trees. This value is not the same as the price paid for trees that have been harvested and delivered to a wood processing facility.

Table 12-14
Project Financial Overview: Burying Logs

Project year	Land cost	Implementation Cost	Management and tax costs	Monitoring cost	Forgone Stumpage	Offsets (tons CO_2e)	Present value of costs	Discounted tons CO_2e
1	8,000,000	3,500,000	20,000	20,000	0	0	11,540,000	0
2			20,000		0	0	19,231	0
3			20,000		0	0	18,491	0
4			20,000		0	0	17,780	0
5			20,000		0	0	17,096	0
6			20,000		0	0	16,439	0
7			20,000		0	0	15,806	0
8			20,000	10,000	4,500,000	374,850	3,442,428	273,899
9		3,500,000	20,000		0	0	2,572,030	0
10			20,000		0	0	14,052	0
11			20,000		0	0	13,511	0
12			20,000		0	0	12,992	0
13			20,000		0	0	12,492	0
14			20,000		0	0	12,011	0
15			20,000		0	0	11,550	0
16			20,000	10,000	4,500,000	374,850	2,515,348	200,135
17		3,500,000	20,000		0	0	1,879,357	0
18			20,000		0	0	10,267	0
19			20,000		0	0	9,873	0
20			20,000		0	0	9,493	0
21			20,000		0	0	9,128	0
22			20,000		0	0	8,777	0
23			20,000		0	0	8,439	0
24			20,000	10,000	4,500,000	374,850	1,837,940	146,237
25		3,500,000	20,000		0	0	1,373,228	0
26			20,000		0	0	7,502	0
27			20,000		0	0	7,214	0
28			20,000		0	0	6,936	0
29			20,000		0	0	6,670	0
30			20,000		0	0	6,413	0
31			20,000		0	0	6,166	0
32	-28,064,470		20,000	10,000	4,500,000	374,850	-6,977,035	106,854
Total	**-20,064,470**	**14,000,000**	**640,000**	**60,000**	**18,000,000**	**1,499,400**	**18,461,625**	**727,125**

Levelized \$/ton CO_2e 25

Preservation of Existing Forest

Globally, GHG emissions from forest clearing and forest degradation are significant. However, at the project scale, it is difficult to assess the actual benefit of forest conservation efforts, and estimated costs per ton of avoided GHG emission often are quite high.

This scenario assumes an electric company or other project developer purchases a conservation easement on existing commercial forest land that binds the land to remain in forest cover. The cost of the easement can be considered to be the value of the option to develop the land in the future. We assume that the land has been managed as commercial forest for many decades and that the easement allows the continuation of commercial logging. With this management assumption, the history of commercial forestry means that the carbon stock on the land is not changing over time, and allowing the continuation of commercial forestry means that the landowner does not lose revenue from logging and does not need to be compensated for the timber value of trees.

For this scenario, the price of the easement was taken to be the price paid by King County, Washington, for the development rights to 90,000 acres of the Snoqualmie Tree Farm. The Snoqualmie Tree Farm is commercial forest land located within the county. The price paid for the development rights was about $244 per acre. This price is less than the per-acre price paid for recent sales of forest land in the area.

Commercial forests tend to have modest carbon stocks because trees are cut relatively soon after they become merchantable for timber. As a result, most of the area of commercial forest is in young stands of small trees. The average carbon stock of the commercial forest is an approximate number taken from a study of the Snoqualmie Tree Farm.

A major challenge of a project that seeks to create GHG emissions offsets based on avoided deforestation is assigning a rate at which clearing would be avoided. This scenario takes the rate of avoided clearing to be 0.02% per year. This means that 0.02% of the total forest area in the region is converted to non-forest cover each year. This rate means that for every 10,000 acres of forest, two acres are converted to non-forest cover each year. This rate is faster than all but one of the counties in California for which the State of California has determined annual rates of forest conversion, as published in the forest project accounting protocols of the California Climate Action Registry. Choosing a faster development rate results in the carbon within the project area counting as offsets more quickly, reducing the cost per ton of GHG offset.

The discount rate used in this scenario is the same as the discount rate used in the other analysis scenarios described in this report.

The GHG emission benefit is calculated by multiplying the rate of avoided clearing by the number of tons of CO_2e within the project area. This is the annual number of tons of avoided GHG emission that may be credited to this land conservation project. The benefit of the project is assumed to be the discounted number of tons CO_2e over the first 30 years of the project. The choice of a 30-year accounting period is arbitrary, but is comparable to the analysis periods used in the previous examples considering different types of afforestation projects.

Since the rate of avoided emissions is very low, the cost per ton CO_2e of offset is high as shown in Table 12-16. In this example, the cost is $1,400 per metric ton CO_2e of avoided emissions, roughly two orders of magnitude higher than other approaches. This example does not consider leakage. If leakage is considered, and no actions are taken to mitigate leakage, the rate of avoided clearing will be less than the average rate of avoiding clearing in the vicinity. All other factors remaining constant, the cost of offsets will increase as the rate of clearing decreases.

Table 12-15
Project Assumptions and Financial Overview

10,000	Number of acres
$244	Easement cost ($/acre)
50	Average forest carbon stock (tCO_2e)
0.0002	Annual avoided emission rate
0.04	Discount rate
0.1729203	Total discounted tons/acre avoided emissions, 30 years
$1,411	Levelized $/ton CO_2e of offset

Table 12-16
Project Financial Overview: Preserving Existing Forest

Project year	Avoided Emission (Tons CO_2e)	Present Value of Costs	Discounted Avoided Emission (Tons CO_2e)
1	100	2,440,000	96.2
2	100	0	92.5
3	100	0	88.9
4	100	0	85.5
5	100	0	82.2
6	100	0	79.0
7	100	0	76.0
8	100	0	73.1
9	100	0	70.3
10	100	0	67.6
11	100	0	65.0
12	100	0	62.5
13	100	0	60.1
14	100	0	57.7
15	100	0	55.5
16	100	0	53.4
17	100	0	51.3
18	100	0	49.4
19	100	0	47.5
20	100	0	45.6
21	100	0	43.9
22	100	0	42.2
23	100	0	40.6
24	100	0	39.0
25	100	0	37.5
26	100	0	36.1
27	100	0	34.7
28	100	0	33.3
29	100	0	32.1
30	100	0	30.8
Total	**3,000**	**2,440,000**	**1,729.5**
	Levelized \$/ton CO_2e	**1,411**	

Comparing the Costs of Alternative Forest Carbon Sequestration Strategies

The case study examples described here should not be interpreted as showing the specific costs of developing GHG emissions offsets using a specific methodology. Actual costs and benefits will be different for different projects in different geographic locations. The case studies illustrate *how* to assess the levelized cost of GHG emission offsets that may be produced by different kinds of proposed forest carbon sequestration projects.

The case studies give an approximate idea of the relative costs of creating offsets using various approaches to implementing forest carbon sequestration projects. Some main points are worth noting. Large costs that occur early in projects will dominate the total cost of FCS projects. Similarly, if an FCS project can quickly produce large amounts of carbon sequestration, the cost per ton CO_2e of offsets may be modest, even if the land purchase cost per acre is expected to be high. Over several decades, the cost of creating GHG offsets is likely to be similar for projects that involve land purchase and projects that forgo land rental payments from lands a company already owns. Projects that can avoid large land costs often can produce offsets at lower cost. Ways to avoid large land costs include selling lands after a modest period of time, and implementing projects on lands in geographic locations where land prices are low. Projects that can earn significant revenues from outputs other than GHG offsets may be able to produce GHG offsets at lower cost. In particular, project developers may wish to look closely at project designs that are expected to yield some revenue from wood products and some revenue from offsets. Projects that create GHG offsets by avoiding deforestation are likely to yield very expensive GHG emission offsets on a levelized cost basis, unless the rate of avoided deforestation is extraordinarily high.

These examples are highly simplified. Actual economic assessments of a specific proposed project usually will include a wider range of costs. Actual assessments should address the tax implications of projects. Also, the examples shown here do not seek to account directly for different kinds of risks that might be inherent in a specific project. One way that actual assessments of specific projects can account for risk is by using relatively conservative input assumptions. Another strategy for addressing risk is to calculate financial cost and offset generation for alternative outcomes for a proposed project and weighting each different outcome by the expected probability that the outcome might occur. Yet another way to account for risk is to add a risk premium into project-specific discount rates.[43]

When evaluating a proposed project, a project analyst should be careful to obtain and use realistic input numbers appropriate to the specific conditions associated with the proposed project.

[43] For more information about different ways to incorporate risk into the economic analysis of forest carbon sequestration projects, please refer to *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*, EPRI, Palo Alto, CA: 2004, 1008488.

Case Study Summary

Table 12-17 shows the results for all of the case study examples described above. Each of these projects is assumed to be 10,000 acres in size to make them comparable to one another.

Table 12-17
Summary Comparison of Case Study Results

Strategy	Total Discounted 30-Year Costs ($)	Total GHG Emission Reductions (Undiscounted tCO_2e)	Discounted GHG Emission Reductions (tCO_2e)	Levelized Cost ($\$/tCO_2$)
1. Lower MS Afforestation; Buy Agricultural Land	$9,380,869	990,000	547,256	17
2. Lower MS Afforestation; Buy and Donate Land	$11,606,406	990,000	547,256	21
3. International Afforestation	$4,625,429	990,000	547,256	8
4. Lower MS Afforestation Using Company-Owned Lands	$10,240,380	990,000	547,256	19
5. Afforestation of Restored Strip-mined Land	$3,946,080	543,000	375,779	11
6. Afforestation Combined Offsets and Pulp Wood Production	$1,198,227	171,514	148,678	8
7. Burying Logs	$18,461,623	1,499,400	727,126	25
8. Preservation of Existing Forest	$2,440,000	3,000	1,729	1,411

The numbers shown in Table 12-16 should be interpreted as approximate relative rankings, not as the specific absolute cost to implement the specific projects described.

The costs of afforestation on purchased land, existing company property, and land donated with a conservation easement are substantially similar because the cost of land is similar across the examples. In contrast, doing a forest carbon sequestration project internationally yields a lower cost per ton CO_2e of GHG offset because the land cost is expected to be substantially lower. Projects with substantial land costs typically show high estimated overall costs, even in discounted terms.

Restoring mined lands is expected to sequester only a modest amount of carbon per acre because tree growth is expected to be stunted by poor growing conditions. However, the land is expected to be very cheap, resulting in a relatively low cost per ton CO_2e of GHG offset.

Burying logs to generate GHG emissions offsets is a relatively expensive approach as compared to most of the other FCS approaches described here. The primary reason for this relatively high cost is that an entity that chooses to bury logs must forgo revenues from the sale of wood products. The reason burying logs is not even more expensive in the example described above is that a very fast growing tree species is assumed to be used and, as a result, multiple harvests (and thus multiple rounds of sequestration) can be achieved on each acre of land, rather than the one-time gain of converting crop land to forest. Also, the capital investment in the land is recovered because the land can be sold at the end of the project without any limitations on its use. Burying logs also has a high overall requirement for cash investment, because of the substantial cost of replanting after every 9-year rotation.

Combining afforestation with pulp wood production yields low-cost GHG offsets because fast-growing pulp wood trees quickly provide GHG offsets.

Offsets generated by preserving existing forests are extraordinarily expensive because slow deforestation rates in the U.S. mean that very few tons of GHG offsets can be generated per acre, per year. However, in the international context, it may be much more cost effective to preserve existing forests in places that experience very high rates of deforestation such as Brazil and Indonesia.

In the project that combines growing pulp wood with creating GHG offsets using sequestration, the total cost is kept low because expenditures for forest management activities are largely recouped from revenues from sales of wood. As a result, even though this kind of project generates a modest number of GHG offsets, the cost per ton of GHG offset is also modest.

When considering investment in a carbon sequestration project, an electric utility company should consider the specifics of the project, the emission mitigation system in which the company desires to use the GHG offsets, the timing and total amounts of expected GHG offsets, the cash flow schedule, the levelized cost per ton of each GHG offset, and the magnitude of risks that costs will be higher or offset generation lower than planned. The company should also consider to what extent a proposed FCS project is consistent with company strategy, organizational capacities, and any hedging or diversification benefits the project may provide. Considering all of these factors, forest carbon sequestration projects can potentially be a valuable component of an electric company’s future GHG emission mitigation portfolio**.**

A
REFERENCES

Birdsey, R.A. and G.M. Lewis. 2003. *Carbon in U.S. Forests and Wood Products, 1987-1997: State-by-State Estimates.* General Technical Report NE-310. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 42 p.

Boscolo, Marco, Jeffrey R. Vincent, and Theodore Panayotou. 1998. *Discounting Costs and Benefits in Carbon Sequestration Projects.* Harvard Institute for International Development Discussion Paper 638. Cambridge, MA: Harvard Institute for International Development, Harvard University.

Cao, Quang V. and Kenneth M. Durand. 1991. A growth and yield model for improved Eastern Cottonwood plantations in the lower Mississippi delta. *Southern Journal of Applied Forestry*. 15: 213-216.

EPRI. 2001. *What's Wrong with Global Warming Potentials*? Climate Brief. EPRI, Palo Alto, CA. 1001320.

EPRI. 2003. *Incorporating Offset Projects into Corporate Greenhouse Gas Strategies: Risk Management Under Conditions of Policy and Market Uncertainty*. EPRI, Palo Alto, CA. 1005246.

EPRI. 2004a. *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*. EPRI, Palo Alto, CA. 1008488.

EPRI. 2004b. *Biomass Resources, Technologies, and Environmental Benefits*, EPRI, Palo Alto, CA: 2004. 1004602

EPRI. 2005a. *Measuring Logging Impacts on Forest Stocks Using Ground and Aerial-based Methods.* EPRI, Palo Alto, CA. 1010170.

EPRI. 2005b. *Expanding the Role of "Land Use, Land Use Change and Forestry" Projects and the Carbon Market in Addressing Global Climate Change.* EPRI, Palo Alto, CA. 1010172.

EPRI. 2005c. *Using Discounting to Analyze CO_2 Emission Reduction Actions*, Climate Brief, EPRI, Palo Alto, CA. 1011407.

EPRI. 2005d. *Evaluating the Efficiency of Carbon Sequestration in American Chestnut* (Castanea dentata). EPRI, Palo Alto, CA. 1011518.

EPRI. 2005e. *Moving Beyond Concentrations: The Challenge of Limiting Temperature Change.* Climate Brief. EPRI, Palo Alto, CA. 1013014.

EPRI. 2006. *Greenhouse Gas Emissions Reduction Cost Analysis Model Version 2.02 Software User's Manual*. EPRI, Palo Alto, CA. 1013004.

Federal Register, Vol. 71, No. 77, Friday, April 21, 2006, P. 20784.

Finney, M.A. 2001. Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. *Forest Science.* 47: 219-228.

Harmon, Mark E. and Barbara Marks. 2002. Effects of silvicultural practices on carbon stores in Douglas-fir – western hemlock forests in the Pacific Northwest, U.S.A.: results from a simulation model. *Canadian Journal of Forest Research.* 32: 863-877.

Houghton, R. A. 1999. The annual net flux of carbon to the atmosphere from changes in land use 1850-1990. *Tellus.* 51B: 298-313.

Intergovernmental Panel on Climate Change. 1996. *Greenhouse Gas Inventory Reporting Instructions: IPCC Guidelines for National Greenhouse Gas Inventories, Revised. Volume 3: Reference Manual.* IPCC National Greenhouse Gas Inventories Programme Technical Support Unit, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/index.html.

Intergovernmental Panel on Climate Change. 2000. *Land Use, Land-Use Change, and Forestry.* A Special Report of the IPCC. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis.* Cambridge: Cambridge University Press.

Jenkins, Jennifer C., David C. Chojnacky, Linda S. Heath, and Richard A. Birdsey. 2003. National-scale biomass estimators for United States tree species. *Forest Science.* 49(1): 12-35.

Koch, Peter. 1989. Estimates by species group and region in the USA of: I. Below-ground root weight as a percentage of ovendry complete-tree weight; and II. Carbon content of tree portions. Corvallis, MT: Wood Science Laboratory, Inc. Manuscript report on file with USDA, Forest Service, Northeastern Research Station, Newtown Square, PA.

Lamlom, S.H. and R.A. Savidge. A reassessment of carbon content in wood: variation within and between 41 North American species. *Biomass & Bioenergy.* 25: 381-388.

Murray, Brian C., Bruce A. McCarl, and Heng-Chi Lee. 2004. Estimating leakage from forest carbon sequestration programs. *Land Economics.* 80(1): 109-124.

National Interagency Fire Center. Wildland Fire Statistics. http://www.nifc.gov.

Smith, Gordon R., Bruce A. McCarl, Changsheng S. Li, Joel H. Reynolds, Roel Hammerschlag, Ron L. Sass, William J. Parton, Steven M. Ogle, Keith Paustian, James Holtkamp, and Wiley Barbour (In press). Harnessing Farms and Forests in the Low Carbon Economy: How to Create, Measure, and Verify Greenhouse Gas Offsets Based on Storing Carbon in Trees and Soil and Reducing Emissions from Land Use. Durham, NC: Duke University Press.

U.S. Department of Energy. 2006a. Voluntary Reporting of Greenhouse Gases (1605(b)) Program. Final Technical Guidelines. http://www.pi.energy.gov/enhancingGHGregistry/

U.S. Department of Energy. 2006b. Voluntary Reporting of Greenhouse Gases (1605(b)) Program. Final Technical Guidelines. Chapter 1, Emission Inventories, Part I Appendix: Forestry. http://www.pi.energy.gov/enhancingGHGregistry/

World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI). 2005a. *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised Edition.* World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI).

World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI). 2005b. *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised Edition, The GHG Protocol for Project Accounting*. World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI).

B
GLOSSARY

1605(b)	The U.S. Department of Energy's program for *Voluntary Greenhouse Gas Reporting*. This program was created pursuant to Section 1605(b) of the Energy Policy Act of 1992 (42 U.S.C. 13385(b)).
Additionality	The degree to which GHG benefits achieved by an emission mitigation project would not have occurred in the absence of the added incentive of creating GHG emission mitigation.
Afforestation	An activity included under Article 3.3 of the Kyoto Protocol; more generally, establishing new forests on land that has not ever, or in recent times, been forested.
Annex I countries, non-Annex I countries	Countries listed, or not listed, in Annex I of the UNFCCC; Annex I is a list of industrialized countries, non-Annex I countries are developing countries.
Annex B countries	Annex B of the Kyoto Protocol is a list of industrialized countries; they must also then ratify the Kyoto Protocol.
A,R & D	Afforestation, Reforestation and Deforestation.
Assigned amount	The number of emission units that an Annex B country holds; the initial amount for the first compliance period of 2008-2102 equals the emissions target for the country times five.
Assigned Amount Unit (AAU)	An emissions unit under the Kyoto Protocol; AAUs are issued by Annex B countries equal to their "initial assigned amount."
A&R Activities	Afforestation and Reforestation activities.
Baseline	The schedule of GHG emissions related to a project that would be expected to occur in the absence of a project.
BAU	Business As Usual.
Clean Development Mechanism (CDM)	A provision described in Article 12 of the Kyoto Protocol that allows tradable credits, called CERs, to be generated through projects in developing countries that can be used by industrialized countries for compliance with their Kyoto commitments.
CDM Executive Board (EB)	The executive body that is charged by the UNFCCC COP to oversee the operation of the CDM.

Certified Emission Reduction (CER)	An emissions unit under the Kyoto Protocol that is issued under the procedures of the CDM.
Conference of the Parties (COP)	The main operational body of the UNFCCC, representing all countries that have ratified the Convention. It meets annually.
Deforestation	An activity included under Article 3.3 of the Kyoto Protocol; more generally, the conversion of forested land to some other land use following forest clearance (e.g., by harvesting or forest fire).
Emission Reduction Unit (ERU)	An emissions unit under the Kyoto Protocol from projects under the Joint Implementation (Article 6) mechanism.
FCS	Forest carbon sequestration, including removals of CO_2 from the atmosphere by the growth of woody plants that break the CO_2 molecules into carbon and oxygen and retain carbon in plant tissues, and avoided conversion of carbon in plant tissues into atmospheric CO_2.
Forest management	An activity included under Article 3.4 of the Kyoto Protocol; more generally, the management of forests to reduce emissions of carbon and/or increase the sequestration of carbon.
GHG	Greenhouse gas. This term usually is used to refer to the collection of all six types of GHGs regulated by the Kyoto Protocol (CO_2, CH_4, N_2O, SF_6, PFCs and HFCs)
Joint Implementation (JI)	A provision described in Article 6 of the Kyoto Protocol that allows tradable credits called ERUs to be generated through projects in Annex B (industrialized) countries that can be used by Annex B countries for compliance with their Kyoto commitments.
Kyoto Protocol (KP)	A protocol under the UNFCCC where, *inter-alia*, industrialized countries took on binding commitments to reduce their greenhouse gas emissions in a first commitment period (cp1), 2008-2012.
lCER	Long-term CER; a particular form of CER issued under the CDM for LULUCF A&R projects.
Leakage	A GHG effect occurring outside the boundary of what is being reported or accounted for a project or activity that, however, is caused by the project or activity and reduces its environmental benefit.
LULUCF	Land use, land use change and forestry, a sector covered under Articles 3.3 and 3.4 of the Kyoto Protocol; becoming used more generally than just related to the Kyoto Protocol.
NGO	Non-governmental organization. For example, environmental (ENGO), business and industry (BINGO), or research institute (RINGO).

Offset	A GHG emission reduction or sequestration that typically is achieved outside of an organization's internal operations. In this report, the term "offsets" refers generally to a GHG emissions offset and frequently refers specifically to CO_2 removed from the atmosphere through implementation of forest carbon sequestration projects.
Permanence, non-permanence, reversal	Generally, the issue that removals of carbon from the atmosphere by biological processes, such as the growing of forests, are not permanent and can be reversed (i.e., sinks can become sources) as a consequence of fire, disease, die-off, timber harvesting, and other activities.
Reforestation	An activity included under Article 3.3 of the Kyoto Protocol; more generally, establishing forests on land that has in recent past times been forested but in more recent times has been under some other land use.
Removals	The sequestration of carbon from the atmosphere (the opposite of emissions); a process that does this is a "sink."
Removal Unit (RMU)	An emissions unit under the Kyoto Protocol that is issued by Annex B countries for LULUCF activities under Articles 3.3 and 3.4.
Sequestration	The absorption of carbon from the atmosphere by some process; normally of CO_2 but can be for other greenhouse gases (e.g., methane).
Sink	A process that removes carbon from the atmosphere (e.g., a growing forest).
Storage	Keeping sequestered carbon out of the atmosphere.
tCERs	Temporary CER; a particular form of CER issued under the CDM for LULUCF A&R projects.
The Carbon Market	An emissions trading market for greenhouse gas (GHG) emission units, sometimes limited to just CO_2. Several distinct carbon "markets" operate around the world today, such as the EU's Emissions Trading Scheme (EU ETS).
UNFCCC	United Nations Framework Convention on Climate Change, the multilateral environmental agreement to address the risk of global climate change.
US DOE	U.S. Department of Energy.
USDA	U.S. Department of Agriculture.

C

GLOBAL WARMING POTENTIALS AND CARBON DIOXIDE EQUIVALENTS

A number of gases contribute to the warming of the planet's atmosphere. Assigning each gas a Global Warming Potential (GWP) allows the emissions of different greenhouse gases to be compared using a single, common scale.[44] Different GHGs cause different amounts of "radiative forcing," or warming, per unit of gas in the atmosphere. Also, each GHG persists in the atmosphere for a different length of time. The net warming effect of the emission of an amount of a GHG is an interaction between the radiative forcing of that gas and the length of time the gas persists in the atmosphere. GWPs are relative to each other. By convention, the warming effect of one ton of CO_2 emitted into the atmosphere is the standard unit, and by definition the GWP of CO_2 is one. GWPs of other gases are given relative to the GWP of CO_2.

The GHGs emitted by land management activities and addressed by the Kyoto Protocol of the United Nations Framework Convention on Climate Change are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

GWP ratios vary by the length of time considered. For example, the effects of emitting one ton of methane into the atmosphere persist for less time than the effects of emitting one ton of CO_2.[45] However, while it is in the atmosphere one ton of methane causes much more warming than a ton of CO_2. As a result, over a shorter time period methane has a higher GWP (relative to CO_2) than it has for longer time periods. By convention, unless otherwise stated, GWPs refer to a 100-year time period. The 100-year GWPs for CO_2, methane, and nitrous oxide are shown in Table C-1. As of this publication, the 2001 GWPs have not been adopted by the Kyoto Protocol Conference of Parties, and projects with GHG emissions offsets generated within the Kyoto system currently use the 1996 values. In the U.S., it is more typical to use the 2001 values shown in Table C-1.

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[44] For more information about Global Warming Potentials and their limitations, please refer to *What's Wrong with Global Warming Potentials*?, EPRI Climate Brief, 1001320, July 2001 and *Moving Beyond Concentrations: The Challenge of Limiting Temperature Change*, EPRI Climate Brief, 1013014, December 2005."

[45] Technically, a molecule of CO_2 emitted to the atmosphere, on average, leaves the atmosphere more quickly than a molecule of emitted methane, but most CO_2 leaving the atmosphere is absorbed by oceans, that in turn re-emit more CO_2 as the CO_2 concentration in their waters rises. As a result, emitting a ton of CO_2 to the atmosphere results in a chain of absorptions and emissions of CO_2 that, on average, last a century.

Table C-1
100 Year Global Warming Potentials
Source: Intergovernmental Panel on Climate Change (1996, 2001).

Gas	1996 GWP	2001 GWP
Carbon Dioxide	1	1
Methane	21	23
Nitrous Oxide	310	296

Emissions may be referred to in amounts of the gas emitted, but are often referred to in amounts of CO_2 equivalent (CO_2e). For example, using the 2001 GWP, one ton of methane emission would have the same global warming potential as 23 tons of CO_2, and thus the emission of one ton of methane would be "equal" to the emission of 23 tons CO_2e from a 100-year GWP perspective. GHG emissions and offsets generally are denominated in metric tons, or mega grams (Mg). One metric ton is 1000 kg, and equals approximately 2205 pounds, or approximately 1.1 short tons.

Carbon is converted to CO_2 equivalent using the molar weights of the elements in these compounds. The molecular weight of carbon is 12 and the molecular weight of oxygen is 16. One carbon atom, when converted to CO_2, makes one CO_2 molecule. Adding the molar weights of the carbon and oxygen atoms in CO_2 shows that, when carbon is converted to CO_2, the weight of the CO_2 will be 44/12 times the weight of the carbon. Thus, one ton of carbon would make $3^2/_3$ (about 3.67) tons CO_2. Doing the transformation in the other direction, if atmospheric CO_2 is converted to forest carbon, each ton of CO_2 converted into biomass carbon makes 1/3.67 tons of biomass carbon, or about 0.2727 tons of carbon.

D

CARBON CONTENT OF TREES

Trees remove carbon dioxide (CO_2) from the atmosphere by absorbing it into their leaves. Using photosynthesis, green plants split molecules of carbon dioxide, releasing most of the oxygen back to the atmosphere and use much of the carbon to make carbohydrates. Plants use the carbohydrates that they make for energy and to build plant tissues, including wood. Oven-dry, woody biomass is approximately half carbon, by weight. Table D-1 provides recent measurements of the percentage of dry wood weight that is carbon for selected North American tree species. Achieving net tree growth increases the amount of biomass in trees, thus increasing the amount of carbon stored in trees, and removing carbon dioxide from the atmosphere.

The proportion of dry biomass that is carbon varies by tree species and, within a tree, varies between different parts of the tree. Table D-1 provides selected measurements of the percentage of dry weight that is carbon for wood, bark, and foliage of several common species found in North America. These older measurements were made using less precise laboratory methods than the newer wood carbon measurements shown in Table D-2, and it is possible that these older numbers are less reliable than the newer numbers. However, the older numbers do show that, on average, the proportion of biomass that is carbon is not substantially different in wood and bark but may be, on average, slightly higher in bark than in wood. Tree foliage may, on average, have a few percent higher carbon content than wood and bark.

When calculating the amount of carbon sequestered by forests, many analysts assume that the proportion of tree biomass that is carbon is 50%. This number is approximately the average of the carbon content of wood of different tree species. Analysts may begin using specific carbon contents for different tree species, to reduce total error in estimates of amounts of carbon sequestration. It would be desirable to have more knowledge of how the carbon content varies by position in the tree (for example, how branch bark carbon content differs from stem bark carbon content) to support improvement in the accuracy of calculations of the amount of total tree biomass that is carbon. If further research is not done on carbon contents, it may be possible to calculate the proportion carbon in different tree components from existing research on the chemical make-up of different tree parts.

In the absence of a more detailed understanding of how the carbon content of tree biomass varies with species, tree size, and tree growing conditions; existing data and tree geometry indicate that errors introduced by using a general carbon content of wood will be small. As trees get larger, a greater proportion of the total biomass is in wood, and bark and foliage become a small proportion of total biomass. Generally, once trees are 2-4 inches in diameter, stem bark is less than 20% of stem wood biomass. It appears that, on average, the carbon content of stem bark is within 2% of the carbon content of stem wood. Multiplying the average difference times the proportion indicates that the average error in the estimated total amount of carbon by using a bark carbon proportion that is wrong by 2% would be an average error of less than 0.4%. If the differences between branch wood and bark and root wood and bark are the same as the difference between stem wood and bark, the error introduced by using the wood carbon content for bark would the same proportion, less than 0.4%.

Table D-16
Carbon Content of Selected North American Tree Species, ± Standard Deviation
Source: Lamlom and Savidge (2003).

Hardwood species$^{(type)}$	Carbon%	Softwood species$^{(type)}$	Carbon%
Acer macrophyllum^{jc}	49.64 ± 0.27	Abies amabilis^{jc}	48.55 ± 0.99
Acer negundo^{mn}	49.34 ± 0.53	Abies balsamea^{jc}	50.08 ± 0.45
Acer rubrum^{jc}	48.64 ± 0.52	Chamaecyparis nootkatensis^{mn}	52.84 ± 0.55
Acer saccharum^{cw}	49.32 ± 0.19	Juniperus virginiana^{cw}	52.14 ± 0.88
Alnus rubra^{cw}	47.70 ± 0.12	Larix laricina^{jc}	47.21 ± 09.35
Betula alleghaniensis^{cw}	46.27 ± 0.33	Laris occidentalis^{jc}	47.60 ± 0.21
Betual papyrifera^{jc}	48.37 ± 0.21	Picea glauca^{jc}	50.39 ± 0.45
Carya^{cw}	48.47 ± 0.41	Picea sitchensis^{cw}	49.95 ± 0.02
Fagus grandifolia^{jc}	46.60 ± 0.39	Pinus banksiana^{cw}	50.40 ± 0.43
Fraxinus americana^{jc}	48.28 ± 0.36	Pinus contorta^{jc}	50.32 ± 0.43
Fraxinus nigra^{mw}	47.80 ± 0.48	Pinus ponderosa^{jc}	52.47 ± 0.38
Juglans cinerea^{cw}	48.53 ± 0.36	Pinus resinosa^{cw}	53.28 ± 0.33
Juglans nigra^{cw}	49.17 ± 0.12	Pinus strobus^{jc}	49.74 ± 0.16
Platanus occidentalis^{jc}	49.97 ± 0.82	Psuedotsuga menziesii^{cw}	50.50 ± 0.36
Populus tremuloides^{jc}	47.09 ± 0.75	Thuja occidentalis^{jc}	51.72 ± 0.17
Populus trichocarpa^{jc}	49.25 ± 0.25	Thuja plicata^{mn}	51.54 ± 0.38
Prunus serotina^{jc}	49.53 ± 0.18	Tsuga canadensis^{jc}	50.53 ± 0.32
Quercus alba^{mw}	49.57 ± 0.22	Tsuga heterophylla^{mw}	50.60 ± 0.45
Quercus rubra^{jc}	49.63 ± 0.32	Sequoiadendron giganteum$^{hw, mn}$	55.16 ± 0.52
Salix^{cw}	49.05 ± 0.58	Sequoiadendron giganteum$^{sw, mn}$	54.66 ± 0.27
Tilia americana^{cw}	46.43 ± 0.17	Sequoiadendron giganteum$^{tz, mn}$	52.52 ± 0.27
Ulmus^{jc}	46.32 ± 0.27		

Wood type codes:
^{cw} core wood, 2-4 mm ring width
^{hw} heart wood
^{jc} juvenile core wood, rings > 5 mm radial width
^{mn} mature wood, rings < 2 mm radial width
^{mw} mature wood, rings > 2 mm radial width
^{sw} sapwood
^{tz} transitional between heartwood and sapwood

Table D-2
Percent Carbon, of Dry Weight, of Selected Tree Components of Selected Tree Species (differing values from different studies separated by commas)
Source: Koch (1089).

Species	Wood %C	Bark %C	Foliage %C
Alder, Red	49.6		
Alder, Speckled			51.87
Ash, White	49.7		
Beech	51.6	47.5	57.17
Birch, White	49.8	57.4	
Cottonwood, Eastern	49.9-50.5		
Hickory	49.7		
Maple, hard			50.4
Maple, soft			50.1
Oak, Black	48.8		
Oak, Red	49.5	39.3*	
Oak species			57.39
Oak, White	50.4		
Cedar, White	48.8		
Douglas-fir	52.3	51.2, 56.2	
Fir, Grand			62.77
Hemlock, Eastern		53.6	
Hemlock, Western	50.4	53.0	
Pine, species	51.8	52.3	
Pine, Pitch	59.0		
Pine, White	52.6		
Pine, Yellow	52.6		
Redwood	53.5	51.9	

* This value is questioned by the author and should be confirmed by testing.

E
DEMAND AND SUPPLY ELASTICITIES

Leakage is the displacement of GHG emissions from inside a project's boundary to outside the project boundary, caused by the project. When calculating the GHG emission offsets created by a GHG mitigation project, amounts of displaced GHG emissions should be subtracted from the emission benefit achieved within the project boundary.

Displacement is quantified by the amount of supply of a good that is reduced by the project, and the changes in supply and demand for the product that result from a small increment of change in the price of the product. The rate of change in the amount of the good supplied as a function of a change in price is called the price elasticity of supply. The rate of change of the amount of a good demanded by consumers as a function of change in the price of the good is called the price elasticity of demand.

Economists classify supply and demand as *elastic* or *inelastic*. Supply is inelastic if the quantity of product supplied to the market changes by less than 1% when a 1% change in price occurs. Supply elasticities with values between zero and one are inelastic. A supply elasticity of one is unitary, which means that for a one percent increase in price there is a one percent increase in supply. Supply elasticities with values greater than one are elastic, meaning the quantity of product supplied to the market changes by more than 1% when a 1% change in price occurs. If there is no change in supply when a price change occurs, the supply is perfectly inelastic. If there is only one price for all amounts of supply, the supply is perfectly elastic.

Similarly, demand elasticity is classified as elastic or inelastic. Generally, demand decreases as price increases, so demand elasticities are displayed as negative numbers. As with supply, elasticity of demand is classified as inelastic when a 1% change in price causes less than a 1% change in the amount of the product demanded by buyers. Elasticities with values between zero and negative one are said to be inelastic. Demand elasticity of negative one is unitary, which means that for a one percent increase in price there is a one percent decrease in demand. Demand is elastic when a 1% change in price causes more than a 1% change in the quantity of the good demanded by buyers. Demand elasticities with values between negative one and negative infinity are elastic.

For projects that decrease production of some product, such as harvested timber, Murray et al. (2004) calculate leakage as:

$$L = \frac{e * C_{out}}{\left(e - \left(E * (1 + \phi)\right)\right) C_{proj}}$$

where:

L	=	the proportion of the project emission mitigation benefit that is lost to leakage.
e	=	the price elasticity of supply for off-project producers.
E	=	the price elasticity of demand for the consumption of the final commodity produced.
C_{out}	=	the amount of GHG emissions produced per unit of increased commodity production outside the project area.
C_{proj}	=	the amount of GHG emission reduction (or sink) per unit of reduced commodity production within the project area.
ϕ	=	the proportion of market supply produced by the project defined as the change in the quantity of the commodity produced from project lands divided by the amount produced outside the project.

In practice, because projects generally involve tiny proportions of market share, it is generally acceptable to drop the market proportion term from the equation. For market proportions of 0.1 and typical elasticities, dropping the term changes the leakage estimate by less than 2%, which is probably less than the errors in elasticity estimates.

In general, for non-luxury goods, both supply and demand tend to be more elastic over longer periods of time than over shorter periods of time. Also, in general, for modest changes in price, supply tends to more elastic than demand.

F
SOURCES OF ADDITIONAL INFORMATION

A wide variety of information is available that can provide the reader with more detail about creating GHG emission offsets by changing forest and agricultural land management, quantifying these offsets, transferring offsets, and using offsets in GHG emission mitigation programs. Selected sources of information are given below.

For broadly applicable guidance on conducting GHG emission inventories and quantifying emission reductions, see the WBCSD / WRI Greenhouse Gas Protocol Initiative (GHG Protocol) at http://www.ghgprotocol.org.

For guidance on calculating entity emissions or forest carbon sequestration for reporting or registering amounts of forest carbon sequestration in the U.S. 1605(b) Voluntary Reporting of Greenhouse Gases Program, see http://www.eia.doe.gov/oiaf/1605/guidelns.html. These guidelines provide tables that predict forest carbon sequestration by forest type and region of the country. These tables are useful for initial scoping of the feasibility of a project, but are not adequate for seeking to register GHG offsets from forest carbon sequestration in the 1605(b) program. The Forestry appendix to the guidelines provides guidance for measuring forest carbon stocks and calculating sequestration with sufficient rigor so that the calculated amounts of sequestration may be registered in the 1605(b) program, provided an entity meets the myriad other substantive and procedural requirements imposed by the 1605(b) program.

The Intergovernmental Panel on Climate Change (IPCC) has published authoritative studies of forest carbon stocks, land use change, and accounting practices. Many IPCC publications can be downloaded from the IPCC website at http://www.ipcc.ch/. The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories remain an authoritative source for GHG emission factors and methods for conducting GHG emission inventories. Even though these guidelines are written for national inventories, they contain a lot of material that is frequently applied to project-level accounting. Another prominent IPCC publication is Good Practice Guidance for Land Use, Land-Use Change, and Forestry (2003).

A source for project-scale accounting methodologies is the Clean Development Mechanism (CDM) website, http://cdm.unfccc.int/. In particular, project design documents submitted by project developers, and approved methodologies accepted by the CDM Executive Board provide standards for acceptable quantification of forest carbon sequestration within the CDM program. Search for “afforestation” and “reforestation” project activities, which are sometimes referred to as “AR” methodologies or projects.

The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort by states in the Northeastern and Mid-Atlantic regions of the U.S. to reduce greenhouse gas emissions. RGGI has promulgated a model rule that provides guidance for quantifying greenhouse gas emission reductions and forest carbon sequestration. Relevant material can be found at http://www.rggi.org/. RGGI is important because the process has advanced to the point that participating states are adopting a common model rule that mandates GHG emission reductions and establishes a cap-and-trade program for achieving these emission reductions.

With the recent passage of Assembly Bill 32 (AB-32), California has now mandated GHG emissions in the state to be reduced to the 1990 level by 2020. This new legislation provides the California Air Resources Board (http://www.arb.ca.gov/homepage.htm) with regulatory authority and responsibility for promulgating regulations to implement the GHG emissions requirements mandated by the new law.

The California Climate Action Registry (CCAR) is a program for voluntary reporting of GHG emissions and reductions. The program was developed prior to the recent adoption by California of mandatory carbon emissions constraints. CCAR registration is voluntary, but CCAR has published detailed and prescriptive guidance for quantifying forest carbon sequestration. Protocols are available at http://www.climateregistry.org/. Also, AB-32 requires the state to utilize the GHG accounting protocols and methods developed by the CCAR as the state develops new regulations to implement AB-32.

Oregon has had a regulatory limit on GHG emissions in place since 1997. New power plants must meet a CO_2 emission standard. Regulated facilities can comply with regulations by paying a modest *in-lieu* fee per ton CO_2 emitted above the allowed emission rate. The fee is paid to the Climate Trust, which uses the money to acquire GHG emission offsets. The Climate Trust website is at http://www.climatetrust.org/ and includes useful emissions ratios. Also, very extensive lists of GHG emission ratios can be accessed through the U.S. Energy Information Administration at http://www.eia.doe.gov/environment.html.

The most comprehensive data set for vegetation cover in the U.S. is the National Resources Inventory conducted by the USDA Natural Resources Conservation Service (NRCS). The NRI includes data back to 1997, and this data can be used to establish baselines for projects. The NRI website can be found at http://www.nrcs.usda.gov/TECHNICAL/NRI/.

Despite its breadth and depth, the NRI dataset provides only modest information about the carbon stocks in particular forests. Local forest growth and yield tables may provide more accurate information. Yield tables are sometimes published by the USDA Forest Service research stations. Many reports of growth and yield can be accessed through the main Forest Service website, at http://www.fs.fed.us/, by searching for research publications. Leading local consulting forestry firms can model tree and forest growth. A growth model should only be used if it has been calibrated and validated on the species of interest, in conditions similar to the project conditions under consideration. Growth estimates can be converted to carbon stocks using biomass (also called allometric) equations. Searching Forest Service publications for the term “allometric” or “biomass” and the scientific name of a species of interest often reveals appropriate equations for calculating carbon stocks from tree data. For verification, calculations should be made using individual tree equations. For initial scoping, calculations made using average stand diameter may be adequate.

Factors and equations for calculating conversion of trees to wood products, persistence of wood products, and the fate of products going out of use are given in the Forestry guidelines for the revised DOE 1605(b) program. Equations and factors for wood products and landfills are also given in the CCAR forestry protocols.

Sample contracts for trading emission credits can be downloaded from the International Emissions Trading Association website, http://www.ieta.org/ieta/www/pages/index.php.

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