Forestry Sector

Part 5 of 6 Supporting Documents

Sector-Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases under Section 1605(b) of the Energy Policy Act of 1992

Forestry Sector

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5.0 Forestry Sector

This document supports and supplements the General Guidelines for reporting greenhouse gas information under Section 1605(b) of the Energy Policy Act (EPAct) of 1992. The General Guidelines provide the rationale for the voluntary reporting program and overall concepts and methods to be used in reporting. Before proceeding to the more specific discussion contained in this supporting document, you should read the General Guidelines. Then read this document, which relates the general guidance to the issues, methods, and data specific to the forestry sector. Other supporting documents address the electricity supply sector, the residential and commercial buildings sector, the industrial sector, the transportation sector, and the agricultural sector.

The General Guidelines and supporting documents describe the rationale and processes for estimating emissions and analyzing emissions-reducing and carbon sequestration projects. When you understand the approaches taken by the voluntary reporting program, you will have the background needed to complete the reporting forms.

The General Guidelines and supporting documents address four major greenhouse gases: carbon dioxide, methane, nitrous oxide, and halogenated substances. Although other radiatively enhancing gases are not generally discussed, you will be able to report nitrogen oxides (NO_x), nonmethane volatile organic compounds (NMVOCs), and carbon monoxide (CO) after the second reporting cycle (that is, after 1996).

The Department of Energy (DOE) has designed this voluntary reporting program to be flexible and easy to use. For example, you are encouraged to use the same fuel consumption or energy savings data that you may already have compiled for existing programs or for your own internal tracking. In addition, you may use the default emissions factors and stipulated factors that this document provides for some types of projects to convert your existing data directly into estimated emissions reductions. The intent of the default emissions and stipulated factors is to simplify the reporting process, not to discourage you from developing your own emissions estimates.

Whether you report for your whole organization, only for one project, or at some level in between, you will find guidance and overall approaches that will help you in analyzing your projects and developing your reports. If you need reporting forms, contact the Energy Information Administration (EIA) of DOE, 1000 Independence Avenue, SW, Washington, DC 20585.

5.1 Forestry: Overview

The forestry sector affects a broad range of potential greenhouse gas emissions sources, emissions reductions activities and carbon sequestration activities. Examples include, but are not limited to, the following:

- Afforestation of agricultural land can lead to large increases in carbon capture and storage by the treated area.

- Reforestation of harvested forestland can accelerate the natural regeneration process and encourage establishment of fast-growing species.

- Agroforestry can decrease requirements for fossil energy and energy-intensive chemicals in the production of food and fuel.

- Short-rotation woody biomass energy plantations can provide fuel that displaces fossil fuels in the electricity production process.

- Low-impact harvesting methods can decrease the emissions from soil disturbance and biomass decay that often follow timber harvest.

The emissions reductions and carbon sequestration projects in the forestry sector range from those that are relatively easy to evaluate (such as construction of wooden bridges) to those with more difficult-to-estimate effects (such as agroforestry projects). Some of the most cost-effective forestry projects may also be the most difficult to evaluate.

5.1.1 Reporting Entities

You can report forestry activities to the EPAct 1605(b) database if you own, control, financially support, or participate in operations that affect forestry-related greenhouse gas emissions, emissions reductions, or carbon sequestration. Reportable activities could include tree planting, forest preservation, biomass energy plantation establishment, use of natural or plantation forests to displace fossil fuels, agroforestry, marketing of new wood products, and introduction of improved forest management practices.

You may choose to report your organization's net emissions on an entity-wide basis and derive your emissions reductions/carbon sequestration accomplishments directly from that report. You may choose to report your net emissions separately from your project accomplishments, or you may opt to not report entity-wide emissions at all, concentrating instead on the accomplishments of your individual projects.

If your company has multiple subsidiaries, you might choose to aggregate some or all of your projects in a single report or to have the subsidiaries report separately. The decision to report on an entity-wide basis or separately should be based on the types of emissions reduction activities, keeping in mind that your report should identify all significant effects of a project. (See the General Guidelines, "What Are the Minimum Reporting Requirements?")

5.1.2 Sector-Specific Issues

The supporting documents for the electricity supply, residential and commercial buildings, and the industrial and transportation sectors, address only emissions and emissions reductions activities. The forestry sector must also deal with emissions and emissions reductions. However, unlike activities in the other sectors, forestry (and agricultural) sector activities can also remove carbon from the atmosphere and store it, a process known as carbon sequestration.

Carbon sequestration is a two-step process: carbon dioxide is first withdrawn from the atmosphere through the photosynthetic process, and then carbon is stored in organic materials over a period of time. The sequestration process ends when the carbon is released back to the atmosphere principally as carbon dioxide, through either combustion or decay processes. In this sense, carbon sequestration is completely defined by net flows of carbon between forests and the atmosphere. Carbon sequestration in forests is increasing when the amount of carbon withdrawal from the atmosphere exceeds the release of carbon to the atmosphere.

Carbon can also be removed from the forest as trees are harvested. However, some of the carbon might not be returned directly to the atmosphere. If the trees are used to make wood products, a portion of the carbon sequestered over the growth period will remain in solid form up to several decades. If the harvested trees are used to produce energy, carbon will be released through combustion. This could offset carbon that would have been released through the burning of fossil fuels. Both cases demonstrate the variety of effects that forestry activities may have on carbon flows.

This supporting document focuses on measuring these net flows of carbon as accurately as is practical. Accuracy clearly depends on accounting for all positive flows (emissions) of carbon from forests and negative flows (capture) of carbon to forests. By focusing on flows of carbon (rather than simple inventories of carbon stocks), this forestry guidance is consistent and directly comparable with estimates of emissions described in supporting documents for other sectors.

Reporting the effects of forestry activities may prove especially challenging. Nearly every action undertaken in the management of forests causes changes in stocks of biomass—and therefore in flows of carbon. Tree planting establishes a new carbon sink; thinning forests shifts biomass to fewer, faster growing trees; harvesting removes stored carbon from the forest (but does not necessarily release all stored carbon back into the atmosphere). Even the elimination of an activity, such as stopping the clearing of forests to develop agricultural land, can influence carbon flows by allowing forest growth and other natural processes to proceed uninterrupted.

Two important issues relate to measuring the effects of forestry activities on carbon flows. The first is that forestry activities typically trigger a sequence of effects that change through time. For example, a newly established forest will take up carbon in trees at a low rate initially, then pass into a period of relatively rapid carbon capture. The uptake of carbon will then typically decline as growth is balanced against mortality in the older forest. From this point in time, tree biomass may cease to capture carbon, but evidence suggests that carbon may continue to flow into soils until the forest is removed by harvest or a natural disturbance event. Measures of carbon flows must account for these dynamic effects.

A second and related issue for measuring carbon flows in forests is the need to define the net rather than the gross effects of the activity. Forestry activities may be very effective at increasing the accumulation of biomass in commercially valuable forms—that is, in the trunks of commercial tree species. This type of accumulation is typically the focus of forest measurements. This "increased" growth may simply result from reducing competition from other types of trees, effecting a transfer of carbon uptake from one group of trees to another. In this case, the net carbon flow effects of the activity may in fact be zero when all relevant parts of the forest are measured. Defining net effects also requires an accounting for the release of carbon to the atmosphere through forest harvesting.

5.1.3 Organization of This Supporting Document

Section 5.2 provides guidance on reporting historical patterns of carbon flow related to forests and forestry activities. Section 5.3 builds on the discussion of project analysis in the General Guidelines and explains the two basic categories of projects: standard projects and reporter-designed projects. That section then explains the reporting procedure for either pathway. Section 5.4 provides guidance for reporting various categories of forestry activities. While the categories are neither exhaustive nor mutually exclusive, they do provide insight into the kinds of issues that must be addressed in evaluating various types of projects. Section 5.5 provides references cited in the discussion of activities in Sections 5.3 and 5.4. Appendix 5.A provides stipulated factors for certain types of projects involving tree planting in the United States. While this document focuses almost exclusively on carbon flows, you should be aware that forestry activities can also lead to emissions, and reductions of emissions, of methane and nitrous oxide.

5.2 Estimating Annual Carbon Flows

The General Guidelines ("What is Involved in Reporting Emissions?") explain that reporting information on greenhouse gas emissions for the baseline period of 1987 through 1990 and for subsequent calendar years on an annual basis is considered an important element of this program. If you are able to report carbon flows for your entire organization, you should consider providing a comprehensive accounting so that your audience can gain a clear understanding of your overall activities.

While this is not a prerequisite to reporting the effects of your forestry projects, a comprehensive report of net annual greenhouse gas emissions or carbon flows may increase the usefulness of your carbon flow reduction report. Because of the complexity of project analysis and the potential for unanticipated effects, users of the database may have more confidence in reports that include comprehensive accounts of the reporter's greenhouse gas emissions and carbon flows.

As with the discussion of forestry projects, this discussion of greenhouse gas flows will be limited to a discussion of carbon. All final measures of carbon flow should be expressed in the form of carbon dioxide equivalent.

Your annual flow of carbon expresses the net release of carbon to the atmosphere from the forests you control and the fossil fuels that you use. Your reports of carbon flows should include negative flows from the capture of carbon from the atmosphere and positive flows from the combustion and decay of organic matter and the use of fossil fuels. Consequently, if your forest areas and operations are capturing more carbon then they are releasing, you would report a negative flow.

Typically, carbon flows from forests and forest operations are estimated using changes in carbon inventory or stocks. The annual flow in carbon is the difference in carbon stocks in consecutive years. The general formula for calculating annual carbon flows is

$$\text{Annual carbon flow in year } t = (I_{t-1} - I_t) + E_t$$

where I_t = carbon inventory (for example, tons) in the forest area in year t

I_{t-1} = carbon inventory (for example, tons) in the forest area in the year immediately preceding t

E_t = carbon emissions from forestry-related fossil fuel use in year t.

Few reporters will be able to measure or develop meaningful estimates of their carbon inventories every year, so it is acceptable to report average annual carbon flows. Suppose you want to report your average carbon flows for several years, say from year s to year t. The average flow can be derived as follows:

$$\text{Average annual carbon flow for years s to t} = \left[(I_s - I_t) + \sum_{n=(s+1)}^{t} E_n \right] / (t-s)$$

where I_s = carbon inventory in the forest area in year s
I_t = carbon inventory in the forest area in year t
E_n = carbon emissions from fossil fuel use for the year n.

Note that in both cases a negative flow implies the carbon captured by the forest is greater than the sum of the fossil fuel carbon emitted and the carbon released from the forest (that is, a negative flow indicates that carbon has been sequestered).

This approach measures the net carbon flow from the forest area. However, some carbon removed from the forest area may not flow to the atmosphere immediately. For example, carbon stored in wood products may not be released to the atmosphere for years or even decades. If you wish to account for these effects, you may want to modify this accounting process to reflect delayed releases of carbon.

There is an alternative to this inventory approach for estimating annual flows of carbon. Rather than using changes in carbon inventory to approximate carbon flows, you may directly estimate carbon flow using models of the impacts of certain forestry practices on carbon flows into and out of forest carbon sinks. These models start from an estimate of a carbon stock for a specific site, and data about the forest type and its physical characteristics. Then, based on information about forest practices, the models develop estimates of annual carbon flows.

Some models are already available for simple conditions and standard treatments, such as tree planting on agricultural land. More complex models are being developed and appear to be progressing rapidly. As they become available for different regions of the country and for a broader array of forest types and forest practices, they may be useful tools for analyzing both entity-wide carbon flows, as described in this section, and project-level accomplishments as described in Sections 5.3 and 5.4.

Example 5.1 illustrates one method for estimating and reporting carbon flows at the entity level. In this example, the reporter used models to estimate flows for five years, then corrected those reports with measured data.

Example 5.1 - Reporting Entity-Wide Carbon Flows

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Pacific House, Inc. (PHI) conducted inventories of its timber stands every five years. Because PHI had been expanding its holdings of timberland, primarily by planting on understocked forestland and converting marginal agricultural land, PHI's average stand age was only 10 years. This meant that the carbon inventory was expanding.

Based on extrapolations and models that used data from 1991 and 1996 inventories and knowledge about their fuel use patterns in forestry operations, PHI reported to the EPAct 1605(b) program estimated average annual carbon dioxide flows in the years 1996 to 2000 of -348,000 tons per year; that is, forests and forest operations were estimated to capture more carbon than they released.

In the year 2001 PHI undertook its regular 5-year inventory. Based on the field samples and fuel use records PHI staff found the following:

carbon inventory (2001): 15.0 million tons
carbon inventory (1996): 14.3 million tons
carbon from fuel use and forestry operations (1996-2000): 130,000 tons.

From this information they calculated:

$$\text{annual average carbon flow} = [(14.3\text{x}10^6 - 15.0\text{x}10^6) + 130{,}000]/5$$

$$= -114{,}000 \text{ tons carbon.}$$

Multiplying this by the factor for converting from carbon to carbon dioxide as described in Appendix D (3.67 tons of carbon dioxide per ton of carbon), PHI calculated a -418,000 ton flow of carbon dioxide per year.

PHI analysts attributed the higher-than-predicted carbon capture to the success of their innovations in forest practices that emphasized increases in carbon stock. On the basis of the measurements and calculations, they amended their reports of modeled estimates of accomplishments for the years 1996 to 2000 to reflect the actual measurements.

5.3 Performing Project Analysis

The analysis of carbon flow reductions in the forestry sector follows the process described in the General Guidelines, "How Should I Analyze Projects I Wish to Report?"

- Establish the reference case to use as a basis for comparison with the project.
- Identify the project effects.
- Estimate carbon flows for the reference case and the project.

These three steps are illustrated in Example 5.2 at the end of Section 5.3.3.

As described in the General Guidelines, this voluntary program is designed to both record project accomplishments and communicate innovative approaches to reducing greenhouse gas emissions and increasing carbon sequestration. Reflecting these dual objectives, the voluntary reporting program allows two different pathways for reporting activities and their effects. Standard projects focus on activities having effects that can be estimated with data provided by this supporting document. Reporter-designed projects allow for reporting innovative activities with estimates you develop and reporting standard projects using other sources of data.

In the forestry sector, standard projects involve activities for which DOE has assembled data that can be used to estimate carbon flow effects. At this time, the only forestry activities classified as standard are tree planting projects. These standard projects are discussed later in this section and again in Section 5.4.

Any project that does not fit the requirements of a standard project is a reporter-designed project, for which you need to develop estimates of effects. However, you are required to report several physical parameters for each activity so that estimates of effects can be accurately compared across entities. Reporting this information may also allow database users to reevaluate estimated effects in the future, as better data become available.

You may also report standard projects as reporter-designed projects. This could be the case, for example, if you wish to report the effects of your activity using a method different from the standard approach. This may encourage innovation in estimating the effects of standard projects. If you choose to report a standard project in this way, you should provide estimates of its effects using both standard and reporter-designed pathways. This will allow users of the database to evaluate differences between the two approaches.

5.3.1 Define the Reference Case

For both categories of projects the basic structure of reporting is the same. Defining the effects of the forestry activity starts with defining a reference case. This reference case describes the physical parameters of the activity and the carbon flows without the activity. Once the reference case is established, it serves as the basis for evaluating the effects of the reported activity (the project). In simple terms, the carbon flow reduction is defined by the carbon flows for the reference case minus the carbon flows for the project case.

Development of the reference case can be relatively simple in some cases. Where you do not expect the flows of carbon from the land area involved in the project to change from historic levels in the absence of the project, then you can evaluate the project accomplishments by comparing carbon flows in the reporting year to the historic level of carbon flows from the same area for some specified year or years. As defined in the General Guidelines, this is called the basic reference case.

In other instances you might expect that, even in the absence of the project, the carbon flows from the project area will change because of the natural processes (for example, tree growth) or external influences (for example, harvest or other forms of clearing). When the reference case is based on an assumption that carbon flows, in the absence of the project, would have been different than in the past, it is called a modified reference case. You should be particularly careful in constructing modified reference cases. Clearly state both the methods and assumptions that you used to arrive at the reference case. The credibility of your project analysis depends a great deal on your definition of a convincing reference case to which the carbon flows for your project are compared.

5.3.2 Identify Effects of the Project

Your report should address as many of the effects of your project as you can identify. The General Guidelines ("What Effects Did the Project Have?") describe many types of potential effects of emissions reductions projects. You should quantify as many of the effects as possible, using best professional judgement as to which are important. You should identify all potential effects, even if you are not able to quantify them.

Projects in the forestry sector run the gamut from discrete, well-defined projects to projects that can have both reinforcing and antagonistic effects within and outside of a reporting entity. When projects begin to interact such that the effects of each project cannot clearly be separated, you should consider reporting your total net carbon flows rather than the reductions in flows associated with individual projects. For example, you may wish to compute the carbon flows associated with your total forestry operations before and after the projects. After accounting for effects outside your organization (for example, associated with outsourcing or market effects), you can report the reduction in total carbon flows. If you choose to report in this way, you must identify the specific projects or, at a minimum, categories of projects that you undertook to reduce carbon flows, even if you are not able to determine the fraction of your total reductions associated with each project.

Forestry activities can have a wide range of effects. For example, forest management may reduce the likelihood of natural forest fires. In addition, and perhaps of more relevance here, foresters use fire as a management tool to control competing vegetation and to prepare a site for regeneration. These activities lead to important effects on greenhouse gas emissions (including effects on nitrous oxide and methane emissions), beyond the obvious effect of increasing carbon capture in a growing forest. Other effects arise from fertilizer use, which can increase nitrous oxide emissions, and fossil fuel use in harvesting and transporting timber.

Forestry activities may also have impacts on greenhouse gas emissions from sectors other than the forestry sector. This is particularly true for urban forestry, where the principal objective is to improve the living environment of cities, especially by decreasing the extent and severity of urban heat islands. Urban forestry potentially reduces the consumption of electricity used to cool buildings, thereby reducing the emissions of greenhouse gases. The emissions reductions resulting from the additional shade created by urban tree planting is an example where the indirect effects on emissions probably outweigh the direct carbon capture effects.

Other indirect effects occur through market forces. For example, preservation of a mature forest in the United States could lead to increased harvest of timber elsewhere in the United States or overseas in order to meet market demand. Alternatively, reduction of harvesting could increase the recycling rates for paper and wood products and increase the efficiency of manufacturing and use of wood products. Similarly, the afforestation of one area could displace afforestation or deforestation in another, as competition among timber suppliers affects tree planting decisions.

The guidance for analyzing specific activities in Sections 5.4 provides some description of likely effects of each type of project. However, actual effects will be site-specific. You should carefully attempt to identify all effects and, where possible, quantify those effects.

5.3.3 Estimate Emissions for the Reference Case and the Project

Your report must include estimation of carbon flow effects associated with your project. For standard projects, effects can be estimated using tables of stipulated factors provided by this and other supporting documents. For all other projects you must provide your own estimation process, taking several factors into account.

Carbon elements

Carbon is stored in the trunks of trees, but it is also stored in other components of the forest. You may (if you have data) consider the effects of reported activities on the following four components (Birdsey 1992, page 23):

1. Trees = All above- and below-ground portions of all live and dead trees, including the merchantable stem; limbs, tops, and cull sections; stump; foliage; bark and root bark; and coarse tree roots (greater than 2 mm in diameter)

2. Soil = All organic carbon in mineral horizons to a depth of 1m, excluding coarse tree roots

3. Forest Floor = All dead organic matter above the mineral soil horizons, including litter, humus, and other woody debris

4. Understory vegetation = All live vegetation except that defined as live trees.

Emissions effects

Carbon sequestration in forests is only one component of the total greenhouse gas regime associated with forestry. Forestry activities may also have indirect and direct effects on the emission of greenhouse gases. For example, the use of fire in site preparation results in greenhouse gas emissions. In addition, changes in the use of fossil fuels in forest management activities have implications for emissions. Where possible, your report should include these types of effects in carbon budgets at the time they occur for both the reference case and the project case to accurately account for total net change in carbon flows.

Time frame

Forest growth is variable through time, so that the time frame used to report effects will have an important bearing on the evaluation of activities. You must report estimates of activity effects for the year the project begins. In addition, you may report anticipated effects for any future years throughout the life of the activity. If you choose to forecast carbon flow estimates for the life of the activity, you must document how the duration of the project was defined. Although you do not need to redocument each activity every year, the program does require that you certify annually that the project appears to be performing as expected, or that you provide a revised estimate. If your revised estimates, or results from actual measurements, in later years are different from your reported anticipated effects, you should revise your past and current reports and update your estimate of future carbon flows to reflect the new information.

If you choose to stop reporting, but wish to preserve information in the EPAct Section 1605(b) database regarding the final disposition of your forestry project, you will have the option of submitting a closing report that indicates your reason for cessation of annual reporting and the expected fate of the sequestered carbon. This may help users of the database to better assess the contributions of your project.

Field measurements

While the effects of activities can often be estimated using standard tables and computer models, field measurements may also be applied and are generally preferred. When appropriately designed and executed, site-specific field studies will provide higher quality data and thus higher credibility with users of the database. If you use field measurements, your report should briefly describe the sampling scheme under the reporter-designed project pathway. Also, if you use field measurements for standard projects, estimate your accomplishments for the standard project pathway using tables and report the results of the field measurements using the reporter-designed pathway.

The following example illustrates the overall process of forestry project analysis and reporting under the EPAct 1605(b) program. The example discusses establishing a reference case, determining project effects, estimating carbon flows, and reporting over time.

Example 5.2 - Project Analysis and Reporting

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

This example illustrates how one company worked through several of the decisions related to project analysis and reporting. It builds on Case Study 4 from the General Guidelines.

Project Description and Emissions Reporting

Black Forest Cake, Inc. (BFCI) was a family-owned business that was experiencing extremely rapid growth in demand for its products, which included bakery products produced at 13 sites in five states, catering services at 10 shops in seven states, and equipment rentals in 15 stores in three states. It operated from a total of 23 sites spread across nine states.

The family members and many of their staff were environmentally conscious. While they were delighted with the increased demand for their products, they were concerned to see their energy consumption rising, particularly their natural gas consumption for baking ovens and space heating, and their gasoline use in delivery vehicles. They knew that increased energy use signaled increased greenhouse gas emissions.

At its annual business meeting, the board of directors decided to voluntarily offset some of the increase in emissions by undertaking a tree-planting (carbon sequestration) project on farmland they owned. They were not interested in receiving official recognition for their effort. They were motivated purely by their interest in environmental protection and a desire to project an image of BFCI as a "good global citizen." They did, however, want to be sure that their project actually reduced net carbon dioxide emissions, not just have appeared to do so. Therefore, BFCI decided that its project should at least meet the minimum reporting standards used by DOE in the EPAct 1605(b) voluntary reporting program.

The first decision BFCI had to make was whether to report its entire operation's emissions of greenhouse gases. The company chose not to report emissions for two reasons. First, since BFCI had operations at 23 sites and record-handling was decentralized, and, since the company emitted at least three gases covered by the program (carbon dioxide, methane, and chlorofluorocarbons), the burden of reporting emissions was considered too great for a small company. Second, since the directors were not undertaking the project out of concern for meeting agreements with the government or in anticipation of possible future legislative action, they were not concerned with the size of the carbon sequestration project relative to their total emissions.

Reference Case

The BFCI project involved conversion of agricultural land to forestland. This land had been used for a combination of crops and grazing for more than three decades and, in the absence of this project, is unlikely to have been used for any other new purpose. Therefore, BFCI used a basic reference case, using the year 1990 as its designated year.

Project Effects

BFCI quickly identified that the major effect its tree-planting project would have was to sequester, over a long period of time, carbon that would not have been captured in the absence of this project. However, BFCI wanted to be sure that its analysis was going to capture all important effects. Review by an extension forester suggested that the project might have at least two effects in addition to the obvious carbon sequestration. First, the forester said that if this agricultural land were taken out of production, other farm operations could be expanded to supply the BFCI farm's former customers. If they did this by clearing forest areas, that action would offset some of BFCI's accomplishments. Second, even though BFCI did not plan to harvest this area, other land-owners who had been considering establishing new woodlots might decide not to do so because of the perceived competition from BFCI's newly established forest stand.

BFCI then went to an agricultural economist at the local college to ask him to evaluate these possibilities. After careful consideration, he reported to BFCI that, given the nature of local agricultural practices, other farms would likely meet the needs of the BFCI farm's former customers through increased productivity rates and not through expanded land area. While this might lead to some increase in emissions, for example, through increased fertilizer use, the effect would be small, and measurement of it would be speculative at best. Further, the agricultural economist observed that local decisions to convert land to forests or to replant after harvest were largely driven by factors other than financial returns to investment. Therefore, BFCI's relatively small entry would not likely discourage other tree-planting activities.

Example 5.2 - (cont'd)

Based on this evaluation, BFCI felt that it could credibly limit its quantitative analysis to the project's intended effects. BFCI developed a worksheet that summarized the effects of its project.

Project Effects	Contribution to Reduction	Significance
Carbon sequestered on BFCI farm	+	Large
Some forest area may be converted to agricultural land to meet demand for farm produce	-	Negligible
People would have planted trees but did not	-	Negligible

Estimation Methods

The state forester who was advising BFCI on the project pointed out that its project coincided with one of the tree-planting projects for which this supporting document provides stipulated factors. Since using the default estimates of carbon sequestration involved so little expense and effort, when compared to carrying out field measurements, BFCI decided to take advantage of the default data and report its project as a standard project.

Long-Term Project Reporting

In its first report following the establishment of the tree stand, BFCI reported that it had planted the trees and reported information consistent with the guidance provided in the forestry sector supporting document. It also reported that it expected the forest to capture carbon at a rate consistent with the stipulated factors provided in Appendix 5.A of this supporting document. Each year thereafter BFCI confirmed in its report to EIA that the project appeared to continue to perform as expected.

After eight years of relying on the default stipulated factors, BFCI became engaged in a dialogue with a local environmental group. One consequence of the discussions was that BFCI agreed to measure the standing carbon on its project site to determine whether the project had met the expectations established by the stipulated factors. The field measurements, including random sampling of both soils and biomass, revealed that the project had actually exceeded expectations by 20 percent. This was attributed to the fact that the original soils were particularly rich in phosphorous and nitrogen.

BFCI amended its previous reports to reflect this new information by increasing the reported carbon dioxide flows to the forestland by 20 percent in each of the first ten years. BFCI also amended the projected annual carbon capture rates for the second decade to reflect the higher-than-expected performance. BFCI thus transformed its project from a standard project to a reporter-defined project.

5.3.4 Reporting Procedures

Regardless of the reporting pathway (standard or reporter-designed) you use, you must provide certain information to identify the reporting entity and to describe the activity. This information is listed and discussed in this section. A discussion of procedures for reporting the effects of activities using the two pathways then follows.

Activity location and physical parameters

You must provide the following information regarding the type, location, and extent of the activity:

1. County/State. If the activity extends across state or county boundaries, you must indicate the portion of the activity in place in each of these areas.

2. Zip code for each area in which an activity takes place.

3. Date activity was undertaken.

4. Latitude and longitude measured as close to the center of the activity as possible.

5. Activity type(s). Valid activity types are shown in the table below:

Activity Type	Data Code
Tree planting	1
Establishing a woody-biomass plantation/forest biomass energy project	2
Modified forest management	3
Forest preservation	4
Urban forestry	5
Agroforestry	6
Wood product modification	7
Other	8

If you select the "other" activity type, you should describe it. If you are reporting an urban forestry or wood product modification activity, the balance of this section does not apply to you. For all other types of activities, however, provide the following information:

6. Site index or site productivity. Site index is defined by site class. Site index is equal to the height of the dominant trees at 50 years of age. Specify the species of tree used to establish site index.

7. Average slope of the site.

8. Dominant aspect of the site. Aspect is simply the direction that the site faces. If the area is flat, then it has no aspect and "none" should be entered. Otherwise, the dominant aspect (north, northwest, west, southwest, south, southeast, east, northeast) should be entered.

9. Elevation of the site.

10. Area of the activity (for example; acres, hectares).

These data provide key information on the physical attributes of the activity. If the site is highly variable—for example, a portion is very steep, while the remainder is flat—then you should split the activity into two or more activities to report on relatively homogenous land units. This will more accurately reflect the effects of the activity.

To help establish reference case parameters provide, to the best of your knowledge, the following:

11. Land use one year ago.

12. Land use five years ago.

13. Land use ten years ago.

If the previous land use does not provide an accurate description of the reference case, then provide additional information. For an example of a modified reference case, see Example 5.8.

Effects of activities: standard projects

Effects of activities are reported using either standard or reporter-designed project pathways. Currently, standard projects are limited to the planting of certain species of trees in the United States. Appendix 5.A provides tables of stipulated factors that estimate the carbon flows associated with these activities. To access these tables, include the following information:

1. Broad region. See the map in Figure 5.1 for a definition of broad regions. Their respective codes are:

Regions of the United States	Data Code
Southeast	1
South Central	2
Northeast	3
Mid-Atlantic	4
Lake States	5
Central States	6
Northern Rockies	7
Southern Rockies	8
Pacific Coast	9

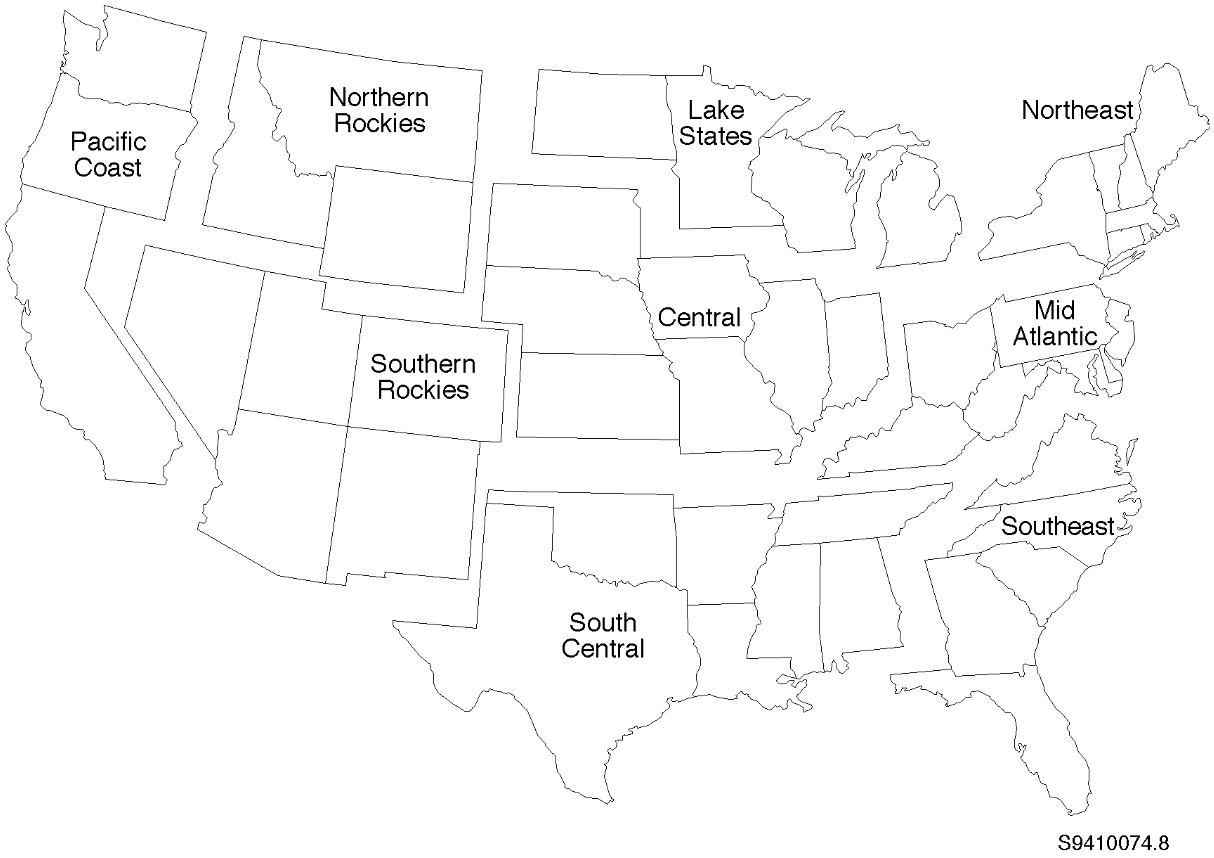

Figure 5.1 Geographic Regions Used to Estimate Carbon Storage

2. Species or forest type. Species and forest types differ among broad regions. Codes according to forest type are provided in the following table:

Standard Project Forest Types by Region	
Southeast: Southern Pine-1	**Central States**: White/Red Pine-1 Oak/Hickory-2
South Central: Southern Pine-1	**Northern Rockies**: Ponderosa Pine-1
Northeast: White/Red Pine-1 Spruce/Fir-2	**Southern Rockies**: Ponderosa Pine-1
Mid Atlantic: None available	**Pacific Coast**: Douglas Fir-1 Ponderosa Pine-2
Lake States: White/Red Pine-1 Spruce/Fir-2	

If you are planting species other than those listed here or are planting outside the United States, this document does not provide data for the activity. This means that your project is not a standard project; you should develop your own analysis for a reporter-defined project.

3. Site class. Site class data should be provided for tree planting for all forest types in Southeastern and South Central regions and for the Douglas fir type in the Pacific Coast region. Codes according to site class are provided in the following table:

Site Class	Definition	Data Code
High	Site index of 79 feet or more[a]	1
Medium	Site index between 60 and 78 feet	2
Not applicable		0
(a) Site index is equal to the height of the dominant trees at 50 years of age.		

4. Land status codes are provided in the following table:

Land Status	Data Code
Clearcut Forest	1
Cropland	2
Pasture	3

Codes entered for categories 1-4 in this section define a four-digit access code. For example, a site in the Southeast (1) with southern pine (2), medium site class (2), and with a reference case that reflects a land status of pastureland (3), has the access code: 1123. The access code points to Table 5.A.4 in Appendix 5.A, which can be used for estimating the effects of the activity on carbon sequestration. The application of this estimation technique is illustrated by Example 5.5 in Section 5.4.

5. Management objectives. To provide users of the database with a complete picture of your project, you should also include information on the intended use of the forest. Appropriate codes are the following:

Management Objective	**Data Code**
Commercial timber production	1
Forest preserve	2
Do not know	3

6. Anticipated harvest age. If the management objective is commercial timber production, then estimate the anticipated harvest age. Age should be entered in units of years. If you cannot estimate a harvest age, then enter 0.

7. Stocking. The tables provided in Appendix 5.A are based on a set of average yields observed for stands within a region. They are built on the assumption that the planting site will be fully stocked with trees. To allow users of the database to confirm full stocking, please enter the number of trees planted per acre and the approximate number of trees surviving to date.

Effects of activities: reporter-designed projects

Activities not listed as standard projects should be reported as reporter-designed projects. You have considerable freedom in selecting activities to report and deciding how to estimate their effects. At a minimum, however, you must meet the reporting requirements described in the General Guidelines, "What Are the Minimum Reporting Requirements?" You need to provide information on a reference case (carbon flows and greenhouse gas emissions had the activity not been undertaken) and the project case (the carbon flows and greenhouse gas emissions with the activity in place). You must identify the significant effects of the project. Finally, you must estimate the carbon flows associated with the reference case and the project, and calculate the difference between them as an estimate of your project accomplishment.

Remember that use of accepted analytical practices is important to the credibility of your report. You may want to review the guidance provided in Section 5.4 that discusses some accepted procedures for estimating the carbon flow effects for several types of forestry projects.

The forms for reporting these effects will ask for information specifically on the carbon flow effects and reductions in greenhouse gas emissions associated with your project. You should maintain documentation of how these effects were derived.

5.4 Estimating Carbon Flow Effects for Forestry Activities

This section addresses the eight general categories of forestry activities that contribute to changes in carbon flow—afforestation on agricultural land, short rotation woody biomass plantations, agroforestry, reforestation forest management, forest preservation, wood products, and urban forestry. An overview of anticipated effects is provided. Also, several published studies that may be useful for framing your estimates are identified. However, reference to a particular study should not be construed as an endorsement of its contents by DOE.

In many situations, project evaluation will rely on a basic reference case. However, for a variety of reasons, even in the absence of an emissions reduction project, the past carbon capture and release from a given forest area might not be an adequate predictor of future carbon flows. The most dramatic example of this is when a forest area is about to be cleared to provide land for other uses. While the forest may have actually had negative flows (captured more carbon than it released) in the recent past, its positive flows in the near future are expected to be very high, at least in the short term. Therefore, a forest preservation project using a basic reference case would understate the expected flows associated with the reference case.

An impending forest harvest is an example of a change due to external influences. In addition, natural, relatively predictable changes in carbon flows such as natural regeneration and forest growth should be reflected in the reference case. Similarly, prevailing trends in forest management and wood product use should be reflected in the reference case. The credibility of your project report will be significantly enhanced if you account for these changes when you develop your reference case.

5.4.1 Afforestation

Forests may be established either to replace another land use such as cropland or pastureland (afforestation), or to replace trees removed by a timber harvest (reforestation, see Section 5.4.4). Afforestation of agricultural land may greatly alter the carbon storage accomplished on a site. Planting trees on nonforested land has been widely promoted as an effective tool for increasing carbon sinks globally. Accordingly, tree planting has received the most attention in the analysis of forestry's effects on global carbon cycles. There are several sources of information on the carbon sequestered and stored by forests as they develop. Published studies by Birdsey (1992a; 1992b) define carbon storage on forest sites in different ecological regions of the United States. These studies are highly detailed and distinguish among species types, the productivity class of the forest site, and the intensity of efforts.

Tree planting activities have the benefit of producing large carbon storage gains (at least in the initial decades of tree growth) because they replace relatively low carbon storage land uses. Because of annual production cycles, agricultural land uses store comparatively little carbon.

Analyzing tree planting activities on agricultural land is relatively simple, compared to the other forestry projects discussed in the guidelines.

Reference case

In the absence of special management practices such as conservation tillage, agricultural lands, particularly those that are candidates for conversion to forests, generally do not accumulate significant amounts of carbon from one season to the next. Therefore, you can use a reference case from the year(s) immediately prior to the tree planting. That is, in the absence of information to the contrary, you can assume that the area would have remained as agricultural land, with a constant carbon stock, and no net carbon flows.

Effects of the Project

The major effect of conversion of agricultural land to forestland is to decrease net flow of carbon to the atmosphere, relative to the reference case, through capture and storage of carbon by the growing trees and the forest ecosystem. Counterproductive effects could arise if the conversion of the agricultural land had market effects that encouraged other parties to (1) convert their forestland to agricultural land, (2) avoid tree planting they might otherwise have done, or (3) harvest their existing forest stands earlier then they might otherwise have done. Other effects include biological and energy-related emissions during the planting process, and emissions resulting from the use of fertilizers. (The effects of harvesting are treated separately in Section 5.4.)

Generally, other carbon flow effects, such as market leakage and energy related emissions, are not expected to rise to a significant level compared to the effect of capturing carbon. However, if the circumstances of your project suggest otherwise, you should note all significant effects in your report and, if possible, quantify them.

Estimating carbon flows for the reference case and project

As noted above, most analyses of conversion of agricultural land to forestland assume that in the reference case, the agricultural use would capture little or no additional carbon over time. Therefore, net flows of carbon in the reference case, for all years, would be zero. However, if the converted land were under a management regime that resulted in changes in carbon stocks on the land, and hence non-zero carbon flows, you should reflect that situation in the reference case estimation–that is, you should use a modified reference case.

Net flows with the project are expected to be negative, but the level depends upon several factors, including tree species, geographic area, soil type, precipitation, slope, and aspect. You must determine the annual carbon exchange between your treated forest area and the atmosphere for each year you report. As described in Section 5.3, this can be done on the basis of periodic field measurements, scientific literature, computer models, or stipulated factors provided by this supporting document.

If your calculations of annual carbon flow are based on estimates of carbon inventories, then the calculation you would use for deriving annual changes in flows for the year is

$$\text{Annual carbon flow reduction for year t} = (I^R_{t-1} - I^R_t) - (I^P_{t-1} - I^P_t)$$

where I^R_t = the reference case carbon inventory (for example, tons) at the end of year t

I^R_{t-1} = the reference case carbon inventory (for example, tons) at the end of the previous year, t-1

I^P_t = the project inventory (for example, tons) at the end of year t

I^P_{t-1} = the project inventory (for example, tons) at the end of the previous year, t-1.

If you have assumed that there is no net flow of carbon in the agricultural land use in the reference case, this becomes

$$\text{Annual reduction in carbon flows in year t} = (I^P_t - I^P_{t-1})$$

If your analysis is based directly on flows of carbon rather than inventories, the expression for calculating flow reduction is

$$\text{Annual carbon flow reduction} = (F^R - F^P)$$

where F^R = the carbon flow (for example, tons) in the reference case

F^P = the carbon flow (for example, tons) with the project.

For example, if F^R is assumed to be zero for the afforestation project and F^P is negative (that is, the project removes carbon from the atmosphere), annual flow reduction is positive.

If you are reporting an entity-level analysis of your accomplishments across many interrelated projects, then the inventory approach is probably more suited to your needs. Example 5.3 illustrates this approach. If, instead, you are analyzing a single activity with well-defined and documented effects, the carbon flow approach may be simpler. Example 5.4 illustrates project analysis on a carbon flow basis. At the same time, some simple projects will be readily analyzed in a carbon inventory context. Note, for example, that the stipulated data for tree planting activities in the United States (Appendix 5.A) are all expressed in terms of carbon inventories. Analysis of a standard project is illustrated in Example 5.5.

Example 5.3 - Afforestation: Analyzing a Project on an Inventory Basis

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

John Fama had been practicing conservation tillage on his 40 acres of cropland for the past 10 years. He decided to convert his cropland to forestland. His reference case for the project was the land under conservation tillage. He anticipated no significant effects from the project other than carbon capture. Based on soil samples taken during his decade of farming, and just before the tree planting, he knew that the inventory of carbon was 100 tons of carbon per acre, which could have been expected to accumulate at a rate of 1 ton per acre per year.

Forest yield models for the fast growing trees that he planted indicate that the inventory of carbon was expected to grow at a rate of 3 tons per acre per year. Mr. Fama confirmed these growth rates with a field measurement of carbon stocks (including carbon in trees, litter, and soils) at the end of the fifth year of forest growth.

He used the equation described above to calculate his annual reduction in carbon flow.

$$\text{Annual carbon flow reduction for year } t = (I^R_{t-1} - I^R_t) - (I^P_{t-1} - I^P_t)$$

For example, in the fifth year he calculated:

Reference case inventory in the 5th year: $I^R_5 = 105$ tons/acre

Reference case inventory in the 4th year: $I^R_4 = 104$ tones/acre

Project case inventory in the 5th year: $I^P_5 = 115$ tons/acre

Project case inventory in the 4th year: $I^P_4 = 112$ tons/acre

$$\begin{aligned}\text{Annual reduction in carbon flow in year 5} &= (104 - 105) - (112 - 115) \\ &= (-1) - (-3) \\ &= 2 \text{ tons/acre}\end{aligned}$$

That is, in the fifth year of the project there has been a 2 ton/acre reduction in carbon flow to the atmosphere, in this case achieved by removing carbon from the atmosphere.

Since Mr. Fama has 40 acres, his total reduction in carbon flow was 80 tons in the fifth year.

As described in Appendix D, the factor for converting carbon to carbon dioxide is 3.67.

$$\begin{aligned}\text{Reduction in } CO_2 \text{ flow} &= 80 \text{ tons C} \bullet 3.67 \text{ tons } CO_2\text{/ton C} \\ &= 293 \text{ tons } CO_2\end{aligned}$$

Example 5.4 - Afforestation: Analyzing a Project on a Flow Basis

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Taking the same facts as Example 5.3, John Fama could have used the information he had to analyze his project based directly on flows of carbon. He knew that in his reference case the land was capturing one ton of carbon per acre per year, and with the project it was capturing three tons per acre per year.

$$\text{Annual reduction in carbon flows in year } t = (I^{P}_{t} - I^{P}_{t-1})$$

Since he had 40 acres he could have used the above equation to calculate:

$$\begin{aligned}\text{Annual carbon flow reduction} &= (-1 \bullet 40) - (-3 \bullet 40)\\ &= (-40) - (-120)\\ &= 80 \text{ tons}\end{aligned}$$

That is, he reduced annual flows to the atmosphere by capturing 80 tons of carbon. Using the conversion factor for translating carbon to carbon dioxide, this was equivalent to 293 tons of carbon dioxide.

Example 5.5 - Afforestation: Analyzing a Standard Project

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Betty Silvan decided to plant trees on a field she had planted in soybeans for the previous 25 years. This 40-acre tract was part of her farm outside of Durham, North Carolina. It was a relatively level and highly productive site. She planned to plant loblolly pine and intended to report the effects of her tree planting on carbon flows to the Department of Energy.

Within the EPAct Section 1605(b) reporting program, tree planting is considered a standard project, so Betty used the standard data tables to estimate the effects of her activity. To access the tables, she provided the following information:

1. Broad Region in the Southeast (code 1)
2. Forest Type is Southern Pine (code 1)
3. Site Class is High (code 1)
4. Reference Case Land Use is Cropland (code 2).

These four codes, 1112, point to Table 5.A.2 in Appendix 5.A of this document. Accessing the table, Betty reported the following net carbon storage over time, based upon planting pine trees instead of maintaining the land in crops:

Year 0	0 lbs/acre
Year 5	10,000 lbs/acre
Year 10	22,000 lbs/acre
Year 20	74,000 lbs/acre

These numbers measure the net effect of the project on stocks of stored carbon. To estimate the average annual flow of carbon attributable to the project, she compared stock measures across time. For example, the annual flow of carbon for the first five years of the project was estimated as

$$\text{Average Annual Flow of Carbon} = (I_o - I_5) / 5$$
$$= (0\text{-}10{,}000 \text{ lbs/acre})/(5 \text{ years}) = -2000 \text{ lbs/acre/year}.$$

On the 40 acres then, a flow of 40 x 2000 = 80,000 lbs of carbon was stored each year. By applying this method to other periods, Betty derived the following schedule of carbon flows for her project:

Period	Average Carbon Flow	Total Carbon Flow	Total CO_2 Flow
1-5	-2,000 lbs/acre/year	-80,000 lbs/year	-293,600 lbs/year
6-10	-2,400 lbs/acre/year	-96,000 lbs/year	-352,320 lbs/year
11-20	-5,200 lbs/acre/year	-208,000 lbs/year	-763,360 lbs/year

Note that Betty should (1) annually confirm that her project appears to be forming as expected (that is, the trees are still standing and appear healthy), and (2) report the positive flow (release) of carbon that occurs when she harvests the timber she has grown.

5.4.2 Short-Rotation Woody Biomass Energy Plantations

The preceding discussion of afforestation anticipates a conventional view of a managed forest. That is, initial forest establishment is followed by a relatively extensive period of growth (and carbon accumulation). In contrast, biomass energy plantations occupy an intermediate position between forestry and annual agriculture. With woody biomass crops, harvesting occurs approximately every 5-12 years, and regeneration is accomplished by coppice methods that rely on regrowth of new stands from the root stock of the harvested stand.

Biomass energy plantations also occupy an intermediate position between forestry and the electricity supply sector. Analysis of these projects, and particularly their reference cases, will depend upon information regarding how energy would have been supplied in the absence of the project. For purposes of reporting, you should account for emissions related to the biomass fuels and the displaced fossil fuels in the electricity supply sector, and the capture of carbon in the forestry sector.

For a discussion of the production of liquid fuels from biomass crops see Section 6.4.7 of the supporting document for the agriculture sector.

Reference case

The reference case you adopt will be specific to your particular circumstances. In general, the reference case should account for both the carbon flows associated with the land in the absence of the project, and the emissions from the fossil fuels displaced by the biomass fuel. If the land used for the woody biomass crop was forested immediately prior to establishment of the plantation, then the reference case should reflect carbon flows appropriate for that specific forest type and age. If the plantation is established on agricultural land that has had a constant carbon stock over several years, then the reference case would reflect zero carbon flows to the land.

Effects of the Project

The principal effect of a biomass energy project is to displace fossil energy with biomass energy, thereby reducing fossil fuel carbon emissions to the atmosphere. Hence, the reference case should include an annual accounting for the positive carbon flow that would have occurred if the fossil fuel had not been displaced, and the negative carbon flow (carbon capture), if any, that would have occurred had the land area of the new plantation not been converted to a woody biomass stand. The project case should include a year-by-year accounting of negative carbon flows (carbon capture) by the new plantation, and positive carbon flows (release) from harvesting, transportation, and combustion of the biomass fuel.

You should consider other effects of this type of project. Positive effects include, for example, elimination of emissions associated with the transport of the displaced fossil fuel. Negative effects include energy-related emissions associated with the planting, management, harvest, and transport of the biomass crop; and emissions from the biological process, such as decay of litter and carbon emissions from soils due to disturbance from harvesting. These positive and negative effects may rise to a significant level and should be quantified whenever possible.

Estimation of emissions

Biomass energy defines an important cross-sectoral linkage between forestry and the electricity supply sector. Analysis of the project carbon flows should account for both increased carbon flows from the burning of biomass fuels and decreased carbon flows from displaced fossil fuels. The carbon capture resulting from woody biomass plantations can be analyzed in conventional forestry sector terms. At the same time, the release of carbon from the combustion of biomass fuel and the displacement of emissions from fossil fuels relates more closely to activities in the electricity supply sector. You should familiarize yourself with the guidance provided in the supporting document for the electricity supply sector before analyzing this type of biomass energy project. Note, however, that it is not necessarily correct to simply assume that a ton of carbon emissions from biomass offsets a ton of fossil fuel emissions. The on-site (generation site) carbon emissions associated with the generation of a kilowatt hour of electricity may be somewhat higher for biomass fuel than for fossil fuels. The actual ratio will vary, depending upon the characteristics of the biomass fuel, the fossil fuel, and their relative combustion efficiencies.

When compared with agriculture, short rotation woody biomass plantations can increase the carbon stored upon a site. Wright et al. (1992), citing an analysis conducted by Ranney et al. (1991), report that in equilibrium the carbon increment between agriculture and short rotation woody biomass plantations can be as much as 13 to 18 tons of carbon per acre. The greatest share of this increase is stored in the soil and root components of the site. For purposes of reporting a project's effects, you need to convert this to a year-by-year estimate for the difference between the plantation and the reference case.

Example 5.6 - Short Rotation Woody Biomass Crops

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Biomass and Forestry Development, Inc. (BFDI) was a subsidiary of Illinois Plains Power (IPP), an independent power producer in the midwest. Most of IPP's power requirements were met with coal-fired electricity generation plants. BFDI's purpose was to find opportunities to reduce IPP's reliance on coal by establishing and operating biomass-fired electricity generation plants.

BFDI's manager decided that the most recently initiated biomass project should be treated as a pilot study on carbon dioxide emissions reductions, the results of which would be reported to the EPAct 1605(b) database. The project involved a group of small generation plants located in a rural area of the Great Lakes region. As a primary source of fuel supply, BFDI purchased a 2,000-acre farm—500 acres in mature forests and 1,500 acres that had for several decades been in cropland. The latter had recently been poorly tended and, consequently, underproductive for several years.

The management plan called for establishing one generation plant immediately, to be fueled for five years by the biomass harvested (after selective harvesting for saw timber) from the 500 acres of existing forest. The harvested forestland would be immediately replanted to short rotation woody biomass crops. The retired cropland would be planted at a rate of 300 acres per year over the same five-year period. Both the former cropland and the replanted forestland would be managed on 5-year rotations. Three new modular plants would be added to the initial plant by the end of the fifth year. Starting in the sixth year, the biomass plantations would be harvested at a rate of 400 acres (one-fifth of the total land purchased) per year to supply the four electricity generation plants.

If the cropland and forestland produced woody crops at the expected rate, BFDI's 2,000 acres of land would supply 75 percent of the biomass fuel needs of the four modular plants. The company planned to meet the balance of the fuel demand with purchases from area forestland owners and farmers. In particular, the company had one contract with farmer Jon Sven to harvest 25 acres of Sven's forestland per year for the first five years and another contract with farmer Eric Toleruth to purchase wood biomass from a 700-acre short rotation woody biomass plantation starting in the sixth year. Toleruth had expressed an interest in both participating in the voluntary reporting program and experimenting with alternative woody biomass cropping methods.

BFDI's analysis of the project involved considerable engineering work, bookkeeping, and negotiation with the participants. The project manager identified the reference case as one under which the electricity would be supplied by a new coal-fired plant, and the farmland and mature forestland continued to be managed as they had been in the recent past. The only significant carbon flows under the reference case were those from the combustion and transportation of the coal. Many more activities affected carbon flows in the project case, including the following:

Example 5.6 - (cont'd)

	Years[a]	Effect on Carbon Flow
BFDI's Existing Forestland		
Harvest and transportation of biomass	1-5	+
Soil disturbance and combustion of biomass	1-5	+
Use of fossil fuels in site preparation for replanting	1-5	+
Growth of new biomass crop	1-EOP	-
BFDI's Cropland		
Use of fossil fuels in site preparation for planting biomass crop	1-EOP	+
Growth of new biomass crop	1-EOP	-
Harvest and transportation of biomass	6-EOP	+
Soil disturbance and combustion of biomass	6-EOP	+
Sven's Land		
Harvest and transportation of biomass	1-5	+
Soil disturbance and combustion of biomass	1-5	+
Toleruth's Land		
Use of fossil fuel in site preparation for planting biomass crop	1-EOP	+
Growth of new biomass crop	1-5	-
Harvest and transportation of biomass	6-EOP	+
Soil disturbance and combustion of biomass	6-EOP	+

(a) (EOP = end of project)

For the biomass plantations, BFDI considered the possibility of simply balancing the release of carbon from soil disturbance and combustion against the carbon capture from the growth of the biomass. Ultimately, these two quantities are essentially equal. However, to drop these two factors from the analysis would obscure the difference in timing of the carbon uptake and release. Since one of the purposes of the pilot analysis was to share detailed information about the performance of the project, BFDI opted for a more detailed approach.

BFDI projected the quantities associated with each of the 14 carbon flows identified above (see Table 5.1). These projections, based on expected crop yields, energy generation, and combustion efficiencies, were included in the initial report. They were updated annually to reflect actual performance for the reporting year. The project carbon flow figures were subtracted from the carbon flows for the coal-burning reference case to yield a net carbon flow reduction associated with the project. As illustrated by the last line of Table 5.1, the carbon flow reduction was translated to a carbon dioxide emission reduction for purposes of reporting to the EPAct 1605(b) database.

For purposes of accounting and reporting, BFDI wanted to be clear with both Sven and Toleruth that the BFDI report would incorporate the biomass growth and harvest activities on their lands as well. This raised a problem with Toleruth, who had hoped to file a separate report. BFDI and Toleruth discussed several possible reporting arrangements, including (1) joint reporting where both parties would submit the same report, (2) dual reporting, where parties would submit separate overlapping reports, (3) dual reporting where Toleruth would report the capture of carbon only, and BFDI would report the release of biomass carbon and displacement of fossil carbon, and (4) dual reporting where Toleruth would report the capture and release of biomass carbon and BFDI would report the displacement of fossil carbon only. Both parties recognized that accurate and complete reporting was the most important issue, and that whatever reporting configuration was adopted must ensure that all carbon flows are reported. Ultimately, Toleruth agreed to cede all reporting rights to BFDI in return for a small increase in the price of the purchased fuel.

Table 5.1. Carbon Flows for BFDI's Biomass Energy Project

	Annual Carbon Flow (tons), by Year					
	1	2	3	4	5	6-EOP(a)
BFDI's Existing Forestland						
Harvest and transportation of biomass	50	50	50	50	50	30
Soil disturbance and combustion of biomass	4,000	4,000	4,000	4,000	4,000	3,500
Use of fossil fuel/site preparation for replanting	10	10	10	10	10	5
Growth of new biomass crop	-700	-1,400	-2,100	-2,800	-3,500	-3,500
Subtotal	3,360	2,660	1,960	1,260	560	35
BFDI's Cropland						
Use of fossil fuels/site preparation for planting biomass crop	21	21	21	21	21	15
Growth of new biomass crop	-2,100	-4,200	-6,300	-8,400	-10,500	-10,500
Harvest and transportation of biomass	0	0	0	0	0	90
Soil disturbance and combustion of biomass	0	0	0	0	0	-10,500
Subtotal	-2,079	-4,179	-6,279	-8,379	-10,479	105
Sven's Land						
Harvest and transportation of biomass	15	15	15	15	15	0
Soil disturbance and combustion of biomass	1,000	1,000	1,000	1,000	1,000	0
Subtotal	1,015	1,015	1,015	1,015	1,015	0
Toleruth's Land						
Use of fossil fuel/site preparation for planting	10	10	10	10	10	7
Growth of new biomass crop	-900	-1,800	-2,700	-3,600	-4,500	-4,500
Harvest and transportation of biomass	0	0	0	0	0	60
Soil disturbance and combustion of biomass	0	0	0	0	0	4,500
Subtotal	-890	-1,790	-2,690	-3,590	-4,490	67
Total project flows	1,406	-2,294	-5,994	-9,694	-13,394	207
Reference case flows	3,000	3,000	3,000	3,000	3,000	12,000
Carbon flow reduction	1,594	5,294	8,994	12,694	16,394	11,793
Carbon dioxide flow reduction	5,845	19,411	32,978	46,545	60,111	43,241

(a) EOP = End of project.

5.4.3 Agroforestry

Agroforestry combines agriculture and silviculture on the same tract of land. Because it emphasizes the use of woody and perennial crops and biological fertilizers, it may provide agricultural products with less intensive energy uses and sequester more carbon than traditional agriculture. These agroforestry systems can be quite complex, addressing not only production of grains and fruits for human consumption, but the production of feed and forage for livestock, the production of wood fuel and building materials, and the restoration of degraded land.

Where agroforestry projects replace existing patterns of agricultural and fuel wood harvesting, it may be appropriate to use a basic reference case.

Identifying the wide range of potential effects of agroforestry projects is a difficult task. Arguably, the major effect of an agroforestry project is to remove carbon from the atmosphere through the photosynthesis process. However, this type of project can also affect energy-related emissions from farm and irrigation equipment, biological emissions from soil disturbance and livestock, emissions related to the production and use of fertilizer, and emissions related to fuel wood use.

While identifying these effects is difficult, quantifying them is still more difficult. Agroforestry projects are made up of a wide range of interdependent actions. While substantial research has been conducted to evaluate various agroforestry activities, it is not clear how much the results of the research can be generalized to provide evaluation of other projects. In the face of the difficulties with estimating project effects, you may develop a more credible report if you limit your analysis to the most certain of the effects, such as carbon capture and release by trees.

5.4.4 Reforestation

In contrast to afforestation, reforestation activities are used to regenerate a recently harvested or otherwise cleared forest site. In this case, the reference case would likely be natural regeneration of the forest, which leads to slower growth than managed reforestation. At the same time, the increase in carbon capture that can be attributed to the activity is likely to be considerably smaller than in afforestation, where the reference case reflects no growth of forest at all. In fact, for reforestation, the difference between the reference and activity cases may not be substantial.

It is even possible that intensifying management for the production of wood products may not result in more carbon stored upon a site when all the carbon-storing elements are considered. Birdsey (1992b) examines cases where conversion of natural stands to pine plantations would result in a net loss in carbon storage. The results depend on a number of factors, including the length of the rotation period. Examples 5.7 and 5.8 illustrate some of the considerations in analyzing reforestation projects.

Example 5.7 - Reforestation: Analyzing a Standard Project

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Ned Skidder, a tree farmer in South Carolina, intended, as part of his overall forest management program, to plant pine on a recently acquired 25-acre cut-over site that had been an Oak-Hickory forest. He wanted to report the effects that this reforestation activity would have on greenhouse gases.

Tree planting for reforestation is considered a standard project. The difference between reforestation and afforestation is simply the reference case—for reforestation. The reference case is defined by natural regeneration to the original forest cover. In Ned's case, if he had not replanted the site in pine it would have regenerated to Oak-Hickory. The tables in Appendix 5.A for standard projects incorporate the effects of the reference case directly into the carbon stock figures. To access the table of stipulated factors for this forestry project, Ned provided the following information:

1. Broad Region was the Southeast (code 1)
2. Forest Type was Southern pine (code 1)
3. Site Class was High (code 1)
4. Reference Land Use was clearcut forest (code 1)

This led Ned to Table 5.A.1 in Appendix 5.A of this document. Comparing tree planting with the reference case of Oak-Hickory in that table defined the following carbon storage effects:

Year 0	0 lbs/acre
Year 5	3,000 lbs/acre
Year 10	10,000 lbs/acre
Year 20	45,000 lbs/acre

These numbers measure stocks of stored carbon. To estimate the average annual flow of carbon, he compared stock measures across time. For example, the annual flow of carbon for the first five years of the project was estimated as

$$\text{Average Annual Flow of Carbon} = (I_o - I_5) / 5$$
$$= (0\text{-}3{,}000 \text{ lbs/acre})/(5 \text{ years}) = -600 \text{ lbs/acre/year.}$$

On the 25 acres, a total of 25 • 600 = 15,000 lbs of carbon was captured each year for the first five years. By applying this method to other periods, the following schedule of carbon flows was derived for the project:

Period	Average Carbon Flow	Total Carbon Flow	Total CO_2 Flow
1-5	-600 lbs/acre/year	-15,000 lbs/year	-55,050 lbs/year
6-10	-1,400 lbs/acre/year	-35,000 lbs/year	-128,450 lbs/year
11-20	-3,500 lbs/acre/year	-87,500 lbs/year	-321,125 lbs/year

To this point, the project has been analyzed as a standard project. Suppose, however, that Ned planned to use fire to prepare the harvested site for regeneration. His report would need to reflect the additional carbon flow from the burning in the first year of the project. Suppose Ned's research revealed that burning under his specific conditions released 50 lbs of carbon per acre, or 1,250 lbs for his 25 acres. Then his first year report of carbon flow reductions would have to be revised from 55,050 lbs down to 53,800 lbs to reflect the effects of burning. Using the conversion factor from Appendix D, the 53,800 lbs of carbon is equivalent to 197.4×10^3 lbs of carbon dioxide or 98.7 short tons of carbon dioxide.

Example 5.8 - Reforestation: Reclamation of Mined Lands

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

The Piedmont Energy Association (PEA) was a coal surface mining cooperative owned by several local utilities and independent power producers. Under its past practices, PEA had met local, state, and Federal environmental regulations to reclaim mined areas as grasslands. At a board of directors meeting, one of the member companies suggested that, if recently mined areas were planted in trees rather than grasses, the cooperative could report the change as a sequestration project to the EPAct 1605(b) database. Preliminary cost studies indicated that, given the types of resources available to the cooperative and its member companies, the costs of establishing forests would be only slightly higher than the costs of establishing grasslands.

Evaluation of the project required PEA to address three critical issues: (1) identifying the appropriate reference case, (2) identifying the significant carbon flow effects of both the reference case and the project case, and (3) estimating the carbon flows associated with both cases.

PEA's first decision was whether to use a basic or modified reference case. The EPAct 1605(b) guidelines required PEA to identify the dominant land use on the reforestation area for 1, 5, and 10 years prior to initiation of the project. Since the area had been forested before mining began (10 and 5 years prior to the project), some participants in the project expected that the reference case would be a forested one. However, as the project manager pointed out, the correct question to ask was, "What would have happened had the project—reforestation—not taken place?" The answer to this question, that the land area would have been in grassland in the absence of the project, indicated that a modified reference case would be most appropriate for this project.

Identifying the carbon flow effects of the reference and project cases was relatively straightforward. The reference case was assumed to have moderate negative carbon flows (that is, carbon capture) resulting from the growth of newly seeded grasslands. The project case was expected to have somewhat higher negative flows from the forest stands. Both cases would include initial emissions of greenhouse gases associated with the seeding and site preparation. Because PEA kept reclaimed areas out of other uses for 40-60 years, the project manager decided that any market effects associated with the new forestry project could be ignored.

Estimating the carbon flows associated with the reference and project cases required considerably more work. The project manager believed that the available data regarding growth rates of grasslands and timberstands on reclaimed mine sites could not credibly be applied to PEA's particular sites. Further, PEA could not translate available data for above-ground biomass to estimates of whole ecosystem carbon uptake rates. Consequently, PEA set up a carefully designed field measurement plan with both untreated (grassland) and treated (forested) plots to represent the reference and project cases. The carbon stocks on each plot were measured each year for the first 3 years and at 5-year intervals thereafter. The estimates for years in which measurement took place were derived by linear extrapolation from previous years, and then corrected as soon as the next measurement took place.

5.4.5 Forest Management

The previous discussion in this supporting document has described activities that relate to the establishment or replacement of forests or trees. It may also be possible to modify the management regimes of existing forests to increase their carbon capture rates. Activities may be applied either during the period of forest growth (intermediate forest treatments) or at the time of harvest and regeneration. Intermediate treatments include the following:

- Hardwood control
- Precommercial thin
- Commercial thin

- Firewood harvests
- Fertilization
- Prescribed fire.

These activities may increase (or decrease) carbon capture rates. While several studies have estimated the total carbon content of forests, less information exists on the effects of various forestry management regimes on carbon flows. Carbon flow effects of various treatments tend to be highly site-specific. As a consequence, fewer options exist for estimating the effects of these activities on a generalized basis, and estimation requires significant effort. However, new modeling tools are being developed to assist in this type of analysis.

Reducing the carbon flows to the atmosphere may also be possible by altering the processes used to harvest and regenerate the forest site. Logging techniques influence the amount of residual material left in the forest to decompose and the survivability of residual trees. In addition, techniques used to prepare and encourage forest regeneration can release greenhouse gases—especially through burning. Site preparation techniques include the following:

- Mechanical site preparation
- Site preparation burning
- Chemical site preparation.

As with intermediate treatments, carbon storage effects of alternative logging and site preparation methods can be difficult and costly to estimate. Defining reference cases for management regimes presents additional difficulties. Forestry research in this area is progressing rapidly. Relevant data and analytical methods may become much more accessible in the near future. Example 5.9 illustrates the use of various estimation and measurement tools in analyzing a forest management project.

Example 5.9 - Modified Forest Management

***Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors*.**

Lower Thiebault Bay, Limited (LTBL), a Pacific Coast power company, decided that it wanted to offset the carbon dioxide emissions from its coal-fired generating plant with a carbon sequestration project. LTBL identified that the typical management of commercial forestlands in its region was one of short-term, even-age, 40-year rotations of Douglas fir. This presented an opportunity to LTBL to increase carbon capture, since the mean annual carbon increment for Douglas fir continues to increase through the sixth to eighth decade. From a carbon sequestration standpoint, some of the most productive years are lost when harvest occurs at the end of the fourth decade.

LTBL decided to harvest a number of products from the forests under a modified forest management plan, while increasing carbon sequestration relative to the 40-year rotation regime. To confirm that the effects of its project would not be dissipated through market leakage, LTBL consulted a forest economist and the regional representative of a forest products trade association to identify what effects a change in the harvest schedule might have on wood product markets. Given the influence of the global market, recognizing the range and rapid shift of market demands for different products, and the fact that timberland owners largely make their harvest decisions based on a wide variety of issues, such as their own financial needs, it was determined that LTBL's harvest change would not make a significant difference in product availability or others' harvest patterns.

LTBL learned that commercial thinnings, which comprised part of a potential modified timber management plan, could be used for oriented strand board products. Later-harvest trees, those of 80-100 years, would provide particularly valuable larger dimension saw-timber. The company found that this kind of timber is increasingly rare; therefore, builders are substituting materials, such as steel, that have strength comparable to older timber. Steel requires considerable energy for fabrication, however, so using mature wood products could reduce the carbon dioxide emissions associated with producing alternative building materials. LTBL decided that it would not attempt to quantify the emission reductions associated with this substitution, but felt that any market leakage was more than compensated for by the displacement of steel.

LTBL contracted with a forest ecologist and a silviculturalist at the state university to design the modified forest management regime, to model the reference case and the project case, and to carry out a field measurement and monitoring program to confirm that the project performed as expected. They knew that if they did not intervene (that is, in the reference case), a clear-cut harvest was scheduled for every 40 years, to be quickly followed by replanting. Under the modified management regime that the consultants developed, commercial thins of standing inventory would occur at ages 40, 60, 80 and 100 years. A harvest of 90 percent of merchantable timber would occur at age 120. The remaining 10 percent would be left to grow without harvest.

In the modeling stage the ecologist and silviculturalist drew on extensive forestry yield data, soil samples, and past field trials to assemble the data they needed to forecast expected carbon flows. The pre-project inventory for the 39-year-old stand was based on field samples from the project site. Both the reference case and project case models included as comprehensive an accounting of carbon as was feasible including components for soils; understory; coarse and fine roots; snags and stumps; and tree boles, branches and foliage. Where they relied on yield tables for model data, they used tables developed for second-growth forests, since tables developed for old growth forests do not accurately reflect second- and third-growth conditions, and therefore, carbon stores. Based on their sequestration modeling, they derived the site-specific forecast of carbon inventories for the stand ages 40 to 120, listed in the table below.

Example 5.9 - (cont'd)

Carbon Stocks as Estimated for LTBL's Project

Forest stand age	Reference case carbon stock (Mtc/ha)	Project case carbon stock (Mtc/ha)
39	333	333
40	138 (CC)	295 (T)
50	138	394
59	153	473
60	155	369 (T)
70	234	440
79	333	493
80	138 (CC)	407 (T)
90	138	456
99	153	495
100	155	419 (T)
110	234	458
119	333	492
120	138 (CC)	229 (PC)
CC=clear cut; T=thin; PC=partial cut.		

The carbon inventories were then converted into annual carbon flows for the reference case and the project case, and carbon flow reductions. The annual carbon flow reductions, expressed in metric tons of carbon per hectare (Mtc/ha/yr), were multiplied by both the project size (21,000 hectares) and the factor for converting carbon to carbon dioxide, 3.67 (Appendix D to this volume). This yielded the whole-project carbon dioxide flow reductions that would be reported to the EPAct 1605(b) program. The results of these calculations are shown in the table below. (Recall that negative flows refer to carbon capture.)

LTBL noted that the project involved some years for which there was a net increase of carbon dioxide flows in the project case relative to the reference case (years 60-79 and 100-120). However, those increases were more than outweighed by the years in which there were even greater reductions in flows. In year 120 there would be an additional 91 metric tons of carbon per hectare in storage than under the reference case, a net increase of slightly more than 7 million metric tons of carbon dioxide that would not be in the atmosphere. Equally importantly, LTBL believed, was that the large flow reductions occurred earlier than the flow increases. Because LTBL valued earlier reductions more than later reductions, this increased the value of the project from the company's perspective.

LTBL was very careful to report flows for all years, and conducted annual visual inspections and 5-year field measurements to confirm that the project was performing as predicted. The company believed that providing as comprehensive and transparent a report as possible would increase the database users' confidence in its analysis.

Example 5.9 - (cont'd)

Carbon Flows as Estimated for LTBL's Project

Annual flow for years	Reference case carbon flow (Mtc/ha/yr)	Project case carbon flow (Mtc/ha/yr)	Flow reduction (Mtc/ha/yr)	Reportable reduction in CO_2 flows (10^3 $MtCO_2$/yr)
40	195.0	38.0	157.0	12,089
41-50	0.0	-9.9	9.9	762
51-59	-1.7	-8.7	7.0	539
60	-2.0	104.0	-106.0	-8,162
61-70	-7.9	-7.1	-0.8	-62
71-79	-11.0	-5.3	-5.7	-439
80	195.0	86.0	109.0	8,393
81-90	0.0	-4.9	4.9	377
91-99	-1.7	-4.3	2.6	200
100	-2.0	76.0	-78.0	-6,006
101-110	-7.9	-3.9	-4.0	-308
111-119	-11.0	-3.8	-7.2	-554
120	195.0	263.0	-68.0	-5,236

5.4.6 Forest Preservation

Protecting existing forests from harvest and, in some cases, conversion to another land use has been proposed as a means of mitigating increases in atmospheric carbon. Carbon dioxide released in the harvesting or clearing of primary forests has contributed significantly to global increases in atmospheric carbon. Alternatively, it could be argued that conversion of existing mature forests (with high levels of stored carbon, but little net uptake of additional carbon) to intensively managed forests (with high annual uptakes of carbon) could reduce atmospheric carbon. The actual result may depend on a number of factors, including the productivity of the site, the quality and age of the existing forest, and the growth patterns of the replacement forests (Marland and Marland 1992).

The effect of forest preservation on carbon flows depends critically on how the reference case is defined. For the case where the forest would otherwise be converted to some form of managed forest, the carbon flow effects of forest preservation are questionable. If however, the credible reference case is not continued forest production but rather conversion to another land use, then the reduction in carbon flow may be substantial.

Another important issue is whether forest preservation actually leads to a reduction in global carbon flows–preserving one forest may simply mean that another forest will be harvested. In the case of individual projects, you might assume there are no market-level impacts on total timber harvesting. However, forest preservation may be more effective in reducing deforestation associated with land-use conversions (for example, from forests to agriculture). To be credible to users of the database, your report should clearly demonstrate that preserving a particular forest leads to a net increase in forest carbon relative to the reference case.

5.4.7 Wood Products

Several of the projects discussed in this supporting document could also involve the harvest of timber or pulpwood for use in wood products. Studies have indicated that the carbon contained in forest stands follows several different paths after harvest. A significant amount of carbon is released from the forest site because of soil disturbance and decay of debris. More is released during the industrial processing of the raw materials. Of the carbon that reaches wood products, some remains only for a short time (1-5 years), but a significant amount remains stored in the wood products for long periods (on the order of decades) before returning to the atmosphere.

The evaluation of projects involving timber harvest may account for this long-term storage in wood products by showing incremental releases of carbon following harvest rather than sudden release at the time of harvest. However, defining a reference case for this type of activity can be quite difficult. Presumably, had the harvesting and wood products activities not taken place in the context of the reported project, the market demand for the products would have been met by harvesting from another site. This suggests that the project may have caused forests to be preserved elsewhere. Alternatively, the fact that the forest in the project had been planted in the first place may have discouraged planting or reforestation elsewhere.

These effects can only be understood in the context of a full market model. It is difficult to argue that any individual activity will have enough price effect to shift the aggregate consumption of wood products within the market. This suggests that the most credible, and certainly the most conservative, approach is to treat carbon destined for wood products as if it is released immediately after harvest.

The one clear exception to the ambiguous effects of carbon stored in wood products is in the case of projects that develop new wood products, particularly those that substitute for non-wood products, such as steel, aluminum and cement used in construction. To be credible, the reference case would have to convincingly explain why, in the absence of the reported project, the demand would have been met using other materials. If this were accomplished, however, the project could then credibly report additional emissions reductions from foregone production of the displaced construction materials. Example 5.10 illustrates such a project.

Example 5.10 - New Wood-Products

***Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors*.**

Bagley Timber Company (BTC) acquired several thousand acres of secondary mixed species forestland in the Northern Rocky Mountain Region. These timber stands were relatively mature, ranging in age from 70-90 years. The land was acquired for the purpose of complementing an aggressive marketing plan to promote the revitalization of an old technology—wooden bridges. BTC established contracts with the State Department of Transportation (DOT) to construct 15 new bridges, in lieu of the steel, concrete, and aluminum structures the state had initially planned.

The first step in BTC's project analysis was to identify the reference case associated with the project. Since this was an introduction of a completely new activity, it was clear BTC would have to use a modified reference case. Analysis suggested that in the reference case the mature, newly purchased forests would have remained undisturbed, capturing carbon slowly and storing it primarily in soils. At the same time, the state would have constructed the bridges using energy-intensive materials such as steel, aluminum, and concrete.

In the project case, the effects of the project included the positive carbon flows in the first years associated with the initial harvesting and processing of the timber, and the negative flows in the later years resulting from the reforestation of the harvested area.

The other effects of the project were expected to be small. The decrease in purchases of the other building materials–steel, aluminum, and concrete–by the State DOT was not expected to have significant effects on the prices of these goods; hence, there would be no market leakage of the emissions reductions associated with their displacement. The construction site energy use associated with building the wooden bridge was assumed to be equal to the on-site energy use for constructing a conventional bridge. BTC identified several other minor effects, but chose not to quantify them.

To estimate the change in carbon flows associated with the construction of the wooden bridges, BTC analysts had to gather several sets of data. First, for the reference case, they had to consider the annual carbon capture (negative flow) that would have occurred on the forest sites that supplied the timber for the 15 bridges. An average of 15 acres was required for each bridge. Since the sites supported relatively mature stands, the carbon capture rates were low. BTC foresters estimated that, during the next 50 years, the harvested area would have captured 0.5 tons of carbon per acre per year. For the reference case, they estimated that, for at least 50 years, the area would have had a carbon flow rate of

$$15 \text{ acres/bridge} \bullet 15 \text{ bridges} \bullet -0.5 \text{ tons carbon/acre/yr} = -112.5 \text{ tons carbon/yr}$$

The second piece of data required in the reference case was the emissions that would have occurred in the manufacture of the steel, aluminum, and concrete used in conventional bridges. BTC located factors for the life-cycle emissions of each of these materials. Although those emissions might have actually occurred over two to three years, BTC considered it a reasonable approximation to treat these emissions as if they would have occurred in the first year. Engineers found that the materials required for the average conventional bridge would have led to emissions of 1,500 tons of carbon.

Example 5.10 - (cont'd)

Thus, the reference case carbon flow was

Year 1: (1,500 tons/bridge) • (15 bridges) - 112.5 tons = 22,387.5 tons
Years 2-50: - 112.5 tons/yr

The project case involved an initial release of carbon associated with the harvesting and processing of timber. Based on an extensive review of the technical literature and a survey of the affected land, BTC foresters estimated that for each acre harvested an average of 40 tons of carbon flowed to the atmosphere in the first three years of the project. This carbon flow was the result of soil disturbance and litter decay, energy used in the harvesting, transportation and timber production process, and decay of wood wastes. They approximated this effect by assuming the entire flow occurred in the first year of the project.

On this basis, they calculated a project carbon flow for this component:

40 tons/acre • 15 acres/bridge • 15 bridges = 9,000 tons

Finally, BTC considered the carbon capture (negative flow) due to reforesting the harvested area with larch, a fast-growing tree species. To estimate this effect, the foresters took advantage of the estimates provided in Table 5.A.27. Although their project was not a standard project, this information was useful for this purpose. Table 5.A.27 indicates that a larch forest planted on harvested forestland can expect to have carbon stocks of

Year	Carbon stored (10^3 lbs/acre)
0	103
5	110
10	115
20	131
30	157
40	190
50	225

The average annual flow during the first five years was calculated using the relation

$$\frac{I_0 - I_5}{5} = \frac{103-110}{5} = -1.4$$

For subsequent years, the average annual flow rates would be

Years	Carbon flow rate (10^3lbs/acre/yr)	Project carbon flow (short tons/yr)
1-5	-1.4	-157.5
6-10	-1.0	-112.5
11-20	-1.6	-180.0
21-30	-2.6	-292.5
31-40	-3.3	-371.3
41-50	-3.5	-393.8

Example 5.10 - (cont'd)

Finally, the bridges themselves would eventually decay, releasing the carbon back to the atmosphere. Since the expected life of these bridges was 50 years, the release of the carbon from the structures, 400 tons per bridge, was treated as if it would all occur in that year.

Hence, the project case carbon flows were calculated as

Year 1: 9000 tons - 157.5 tons = 8,842.5 tons
Years 2-5: -157.5 tons/yr
Years 6-10: -112.5 tons/yr
Years 11-20: -180.0 tons/yr
Years 21-30: -292.5 tons/yr
Years 31-40: -371.3 tons/yr
Years 41-49: -393.8 tons/yr
Year 50: 6,000-393.8 = 5,606.2 tons

BTC then calculated its reduction in carbon and carbon dioxide flows (in short tons) as follows:

$$\text{Reduction in Carbon Flow} = \text{Carbon Flow}_{ref} - \text{Carbon Flow}_{proj}$$

Years	Carbon Flow$_{ref}$	Carbon Flow$_{proj}$	Annual Reduction in Carbon Flow	Annual Reduction in Carbon Dioxide Flow
1	22,387.5	8,842.5	13,545.0	49,665.0
2-5	-112.5	-157.5	45.0	165.0
6-10	-112.5	-112.5	0.0	0.0
11-20	-112.5	-180.0	67.5	247.5
21-30	-112.5	-292.5	180.0	660.0
31-40	-112.5	-371.3	258.8	948.9
41-49	-112.5	-393.8	281.3	1,031.4
50	-112.5	5,606.2	-5,718.7	-20,968.6

After they had completed the construction of the wooden bridges and replanted the harvested area, BTC submitted this projected stream of carbon dioxide flow reductions with its first report to the EPAct 1605(b) program. However, the company only reported the first year carbon dioxide flow reduction of 49,665 tons as an accomplishment. In each subsequent year, BTC confirmed that the project continued to perform as expected. To do this, the company simply checked that all 15 bridges continued in service (that is, they continued to store carbon, as projected) and that the reforested area continued to grow satisfactorily.

5.4.8 Urban Forestry

Forest management, practiced in large contiguous blocks generally to produce wood products, is a rural activity. When forestry is practiced in an urban setting, it provides an entirely different set of benefits. The primary focus of urban forestry is on modifying the landscape and environment dominated by manmade structures. (See Sampson, Moll, and Kielbaso 1992.)

Urban forestry can influence greenhouse gas emissions by modifying the urban environment in two ways. Trees can directly reduce summer temperatures in their immediate surroundings. They can also reduce the electricity consumed for heating and air conditioning when placed at strategic locations around buildings. In addition, tree growth can capture carbon dioxide from the air in the form of woody biomass.

Two types of urban forestry activities are relevant to EPAct Section 1605(b). Both involve tree planting, but on two different scales. On a site-specific scale, trees may be planted to influence individual buildings. The second type of activity involves tree planting on a larger, perhaps community, scale. In this case, the effects of tree planting extend beyond the effects on individual buildings to address changes in the temperature regime of large urban areas (Akbari et al. 1990).

Urban forestry activities can have two principal effects on greenhouse gas emissions and carbon capture. One is carbon capture through tree growth. As with all forestation activities, urban trees also capture and store carbon in above- and below-ground components. They may also contribute to carbon uptake in soils. However, urban trees may require maintenance efforts—such as trimming and leaf collection—that need to be factored into the carbon flow accounts.

The other principal effect is the avoidance of greenhouse gas emissions through energy conservation. Simulation models have indicated that strategically located trees may provide two kinds of effects in this regard. One is through increased shading during peak cooling periods. Deciduous trees conveniently cast a great deal of shade during the growing season and much less during the winter. The other effect results from providing a windbreak during winter heating months. This effect can often be provided by conifers. Again, the location of the trees relative to the targeted building is a critical factor. (See Huang et al. 1989.)

Efforts are underway to develop a model that applies recent research on the energy conservation effects of urban tree cover to develop a spatial model, using geographic information system technology, for assessing energy and cost savings of various tree planting strategies at the neighborhood scale. The model is currently being tested in several locations through the Cool Communities program sponsored by the Federal government. When that model is fully developed, it may facilitate the analysis of the energy effects of urban forestry projects.

The measurement of carbon storage is directly analogous to that described for forest management activities. That is, carbon stored by trees is measured as the net increase above the previous land use (for example, lawn). This should account for both above- and below-ground components and all relevant tree maintenance activities.

Estimating reductions in greenhouse gas emissions through energy conservation involves estimating energy consumed with and without the project. This can be a complicated endeavor because many factors are variable over the life of the project. One source of variation is climate; the temperature regime differs from year to year. Another source of variation is additional modifications in the building that may influence energy consumption (and the energy saving contribution of trees). These factors are key in developing a modified reference case as discussed in the supporting document for the residential and commercial buildings sector.

Example 5.11 - Urban Tree Planting

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

The Leafy Need Tree Cooperative initiated a tree-planting program in Greenway, a small town in Georgia. The program aimed to increase the shading of homes in this area, and trees have been planted in strategic locations around 500 homes at a rate of two trees per home.

While Leafy Need intended to monitor the energy consumed to heat and cool these homes, it would report its activities to DOE in its initial report. Accordingly, Leafy Need needed to estimate the project's net effects. Because this was not a standard project—that is, DOE does not provide standard data tables—Leafy Need had to develop its own forecast of energy savings and resulting reductions in greenhouse gas emissions.

After searching the literature, Leafy Need selected a study by McPherson, Sacamanoo, and Wensman (1993) for the project's estimates. This study examined similar tree-planting programs in several U.S. cities, including Atlanta, which is relatively close to Greenway.

In the initial year of the project there was obviously no effect on energy use. However, the McPherson report shows that after ten years two well-placed trees could reduce electricity used to cool a 1,761 square foot house by about 222 kWh per year. However, heating needs increase about 609 kBtu per year because of the trees. According to the Leafy Need's survey of heating equipment in Greenway, this translates into an increase in electricity use of 35 kWh per year.

The net effect of the tree planting program in year 10 was therefore calculated as

$$\text{Energy Saved} = 500 \text{ houses} \bullet (222 - 35) \text{ kWh/house/year} = 93{,}500 \text{ kWh/year}$$

However, this was the annual effect in year 10. Noting that there was no effect in year 1 of the activity; Leafy Need assumed that energy savings associated with this activity would increase in a straight line manner from zero in the initial year to 93,500 kWh/year in the 10th year. So, for example, energy savings in the seventh year would be

$$\begin{aligned}\text{Energy Savings in year 7} &= 7/10\ (93{,}500) \text{ kWh/year}\\ &= 65{,}450 \text{ kWh}\end{aligned}$$

Energy savings for each year can be converted to effects on carbon dioxide emissions using the standard conversion factors provided in Appendix C and discussed in Section 1.7 of the supporting document for the electricity supply sector.

The carbon dioxide factor for deriving carbon dioxide emissions reductions from electricity savings in Georgia from a combined utility/nonutility source is 1,220 lb/MWh.

$$\begin{aligned}CO_2 \text{ Emissions Reductions} &= (\text{Electricity Savings}) \bullet (\text{Emission Factor})\\ &= 65.45 \text{ MWh} \bullet 1{,}220 \text{ lb/MWh} \bullet \text{short tons/2,000 lb}\\ &= 39.9 \text{ short tons of } CO_2 \text{ per year}\end{aligned}$$

To finish the calculation of net greenhouse emission effects of its program, Leafy Need next factored in the direct carbon dioxide emissions that resulted from its tree planting efforts—equal to about 25 tons of carbon dioxide. This was reported as an emission in the initial year. These resulted mainly from the truck used to haul trees and labor to planting sites. In addition, the trees required maintenance including leaf disposal and trimming. Leafy Need documented its maintenance plan and estimated the maintenance program to result in 5 tons of carbon dioxide emissions per year. Accordingly, Leafy Need estimated the effects in the seventh year of the program as a 34.9 short ton reduction in net flows of carbon dioxide. Each year, Leafy Need verified that its program continued to operate as expected, calculated its annual emissions reductions, and submitted an annual report to the EPAct 1605(b) program.

All of these factors need to be accounted for in estimating the effects of tree planting on energy consumption. Once this estimate has been made, the concomitant reduction in greenhouse gas emissions can be calculated as a multiple of the energy saved. The factors applied will depend on the type of fuel displaced.

Estimating the effects of large scale programs aimed at reducing the ambient temperatures of urban areas would follow the same types of methods. However, an additional layer of analysis will be required. That is, the effect of the tree planting program on average temperature levels would be estimated and then applied to all buildings in the relevant neighborhood of the project. For detailed information on how to estimate the effects of urban forestry activities, see McPherson et al. (1993).

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Appendix 5.A

Tables for Standard Tree Planting Procedures

Appendix 5.A: Tables for Standard Tree Planting Procedures

The tables presented in this appendix were developed using general methods described in Birdsey (1992, p. 255-257). Carbon storage was estimated for each of the four forest ecosystem components defined in Section 5.4.3: trees, soil, forest flow, and understory vegetation. Tree carbon was estimated using timber volume yields for the United States derived from national forest inventories conducted by the U.S. Forest Service. Volumes were converted to carbon storage using ratios that account for tops, branches, foliage, and other material not included in timber volume estimates. These ratios also account for differences in tree sizes and differences among tree species and regions.

Carbon storage estimates for the non-tree components of the forest ecosystem were developed using methods and data available in several published studies. These estimates account for important regional differences owing mainly to differences in precipitation and temperature. For details on all of these methods, refer to Birdsey (1992).

List of Tables:

Table no.	Region	Species	Site Quality	Land Status	Access Code
1.	Southeast	Planted Pine	High	Clearcut forest	1111
2.	Southeast	Planted Pine	High	Cropland	1112
3.	Southeast	Planted Pine	Medium	Clearcut Forest	1121
4.	Southeast	Planted Pine	Medium	Pasture	1123
5.	South Central	Planted Pine	High	Clearcut forest	2111
6.	South Central	Planted Pine	High	Cropland	2112
7.	South Central	Planted Pine	Medium	Clearcut forest	2121
8.	South Central	Planted Pine	Medium	Pasture	2123
9.	Northeast	White/red Pine	All	Clearcut forest	3111; 3121
10.	Northeast	White/red Pine	All	Cropland	3112; 3122
11.	Northeast	White/red Pine	All	Pasture	3113; 3123
12.	Northeast	Spruce-Fir	All	Clearcut forest	3211; 3221
13.	Northeast	Spruce-Fir	All	Cropland	3212; 3222
14.	Northeast	Spruce-Fir	All	Pasture	3213; 3223
15.	Lake States	White/red Pine	All	Clearcut forest	5111; 5121
16.	Lake States	White/red Pine	All	Cropland	5112; 5122
17.	Lake States	White/red Pine	All	Pasture	5113; 5123
18.	Lake States	Spruce-Fir	All	Clearcut forest	5211; 5221
19.	Lake States	Spruce-Fir	All	Cropland	5212; 5222
20.	Lake States	Spruce-Fir	All	Pasture	5213; 5223
21.	Central States	White/red Pine	All	Clearcut forest	6111; 6121
22.	Central States	White/red Pine	All	Cropland	6112; 6122
23.	Central States	White/red Pine	All	Pasture	6113; 6123
24.	Central States	Oak-Hickory	All	Clearcut forest	6211; 6221
25.	Central States	Oak-Hickory	All	Cropland	6212; 6222
26.	Central States	Oak-Hickory	All	Pasture	6213; 6223
27.	Rocky Mtn-North	Ponderosa Pine	All	Clearcut forest	7111; 7121
28.	Rocky Mtn-North	Ponderosa Pine	All	Cropland	7112; 7122
29.	Rocky Mtn-North	Ponderosa Pine	All	Pasture	7113; 7123
30.	Rocky Mtn-South	Ponderosa Pine	All	Clearcut forest	8111; 8121

Table no.	Region	Species	Site Quality	Land Status	Access Code
31.	Rocky Mtn-South	Ponderosa Pine	All	Cropland	8112; 8122
32.	Rocky Mtn-South	Ponderosa Pine	All	Pasture	8113; 8123
33.	Pacific Northwest	Douglas Fir	High	Clearcut Forest	9111
34.	Pacific Northwest	Douglas Fir	Medium	Clearcut Forest	9121
35.	Pacific Northwest	Douglas Fir	High	Cropland	9112
36.	Pacific Northwest	Douglas Fir	Medium	Pasture	9123
37.	Pacific Northwest	Ponderosa Pine	All	Clearcut Forest	9211; 9221
38.	Pacific Northwest	Ponderosa Pine	All	Cropland	9212; 9222
39.	Pacific Northwest	Ponderosa Pine	All	Pasture	9213; 9223

Table 5.E.1. Region: Southeast; Site: High; Access Code: 1111; Species: Southern Pines-Planted; Land Status: Clearcut Forest

		Reference Cases					
		Natural Pine		Oak Pine		Oak Hickory	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	69	69	0	69	0	69	0
5	70	69	1	67	3	67	3
10	74	72	2	64	10	64	10
20	138	101	37	105	33	93	45
30	179	135	44	134	45	138	41
40	202	169	33	156	46	167	35
50	220	200	20	176	44	191	29
60	233	225	8	195	38	214	19
70	243	248	-5	211	32	234	9
80	250	270	-20	228	22	244	6
90	251	278	-27	234	17	248	3
100	252	280	-28	236	16	249	3

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.2. Region: Southeast; Site: High; Access Code: 1112; Species: Southern Pines-Planted; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	35	35	0
5	45	35	10
10	57	35	22
20	109	35	74
30	142	35	107
40	169	35	134
50	193	35	158
60	217	35	182
70	238	35	203
80	247	35	212
90	249	35	214
100	249	35	214

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.3. Region: Southeast; Site: Medium; Access Code: 1121; Species: Southern Pines-Planted; Land Status: Clearcut Forest

		Reference Cases							
		Natural Pine		Oak Pine		Oak Hickory		Bottomland Hardwd	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	69	69	0	69	0	69	0	69	0
5	69	68	1	67	2	67	2	65	4
10	68	68	0	63	5	63	5	60	8
20	116	88	28	90	26	83	33	81	35
30	153	112	41	114	39	118	35	121	32
40	175	135	40	132	43	141	34	144	31
50	191	157	34	145	46	159	32	162	29
60	201	179	22	159	42	176	25	177	24
70	210	198	12	169	41	192	18	190	20
80	215	212	3	178	37	202	13	200	15
90	217	217	0	181	36	206	11	204	13
100	218	218	0	182	36	206	12	205	13

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.4. Region: Southeast; Site: High; Access Code: 1123; Species: Southern Pines-Planted; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	46	46	0
5	54	46	8
10	59	46	13
20	97	46	51
30	127	46	81
40	151	46	105
50	174	46	128
60	192	46	146
70	208	46	162
80	212	46	166
90	214	46	168
100	214	46	168

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.5. Region: South Central; Site: High; Access Code: 1111; Species: Southern Pines-Planted; Land Status: Clearcut Forest

		Reference Cases							
		Natural Pine		Oak Pine		Oak Hickory		Bottomland Hdwd	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	68	68	0	68	0	68	0	68	0
5	69	69	0	66	3	66	3	64	5
10	77	75	2	65	12	64	13	65	12
20	144	110	34	112	32	95	49	119	25
30	187	150	37	148	39	143	44	164	23
40	213	184	29	174	39	172	41	194	19
50	233	212	21	197	36	194	39	218	15
60	244	240	4	220	24	212	32	240	4
70	250	262	-12	239	11	226	24	261	-11
80	254	285	-31	257	-3	238	16	280	-26
90	255	293	-38	264	-9	242	13	287	-32
100	255	295	-40	265	-10	243	12	288	-33

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.6. Region: South Central; Site: High; Access Code: 1112; Species: Southern Pines-Planted; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	34	34	0
5	44	34	10
10	59	34	25
20	116	34	82
30	150	34	116
40	179	34	145
50	204	34	170
60	222	34	188
70	229	34	195
80	233	34	199
90	234	34	200
100	235	34	201

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.7. Region: South Central; Site: Medium; Access Code: 2121; Species: Southern Pines-Planted; Land Status: Clearcut Forest

		Reference Cases							
		Natural Pine		Oak Pine		Oak Hickory		Bottomland Hdwd	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	68	68	0	68	0	68	0		68
5	67	67	0	66	1	66	1		67
10	68	70	-2	63	5	63	5		68
20	121	92	29	93	28	90	31		121
30	160	119	41	122	38	125	35		160
40	185	142	43	144	41	150	35		185
50	201	164	37	158	43	169	32		201
60	211	187	24	172	39	184	27		211
70	217	204	13	183	34	197	20		217
80	221	215	6	193	28	207	14		221
90	223	219	4	197	26	211	12		223
100	223	220	3	198	25	212	11		223

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.8. Region: South Central; Site: Medium; Access Code: 2123; Species: Southern Pines-Planted; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	45	45	0
5	53	45	8
10	59	45	14
20	100	45	55
30	133	45	88
40	159	45	114
50	181	45	136
60	195	45	150
70	201	45	156
80	204	45	159
90	205	45	160
100	205	45	160

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.9. Region: Northeast; Site: All; Access Code: 3111, 3121; Species: White/Red Pine; Land Status: Clearcut Forest

		Reference Cases			
		Spruce - Fir		Maple-Beech-Birch	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	152	152	0	150	2
5	149	147	2	146	3
10	147	140	7	142	5
20	155	142	13	150	5
30	177	160	17	173	4
40	197	179	18	197	0
50	217	198	19	220	-3
60	236	217	19	241	-5
70	253	234	19	262	-9
80	269	249	20	280	-11
90	284	263	21	297	-13
100	297	276	21	312	-15

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.10. Region: Northeast; Site: All; Access Code: 3112, 3122; Species: White/Red Pine; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	72	72	0
5	85	72	13
10	99	72	27
20	126	72	54
30	152	72	80
40	178	72	106
50	203	72	131
60	227	72	155
70	249	72	177
80	268	72	196
90	284	72	212
100	298	72	226

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.11. Region: Northeast; Site: All; Access Code: 3123; 3113; Species: White/Red Pine; Land Status: Pasture

Age	Activity Carbon	Reference Cases	
		Pasture	
		Carbon Stored	Net Effect
0	96	96	0
5	108	96	12
10	121	96	25
20	145	96	49
30	169	96	73
40	193	96	97
50	215	96	119
60	237	96	141
70	255	96	159
80	270	96	174
90	284	96	188
100	296	96	200

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.12. Region: Northeast; Site: All; Access Code: 3211, 3221; Species: Spruce-Fir; Land Status: Clearcut Forest

		Reference Cases			
		White/red Pine		Maple-Beech-Birch	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	152	152	0	150	2
5	147	149	-2	146	1
10	140	147	-7	142	-2
20	142	155	-13	150	-8
30	160	177	-17	173	-13
40	179	197	-18	197	-18
50	198	217	-19	220	-22
60	217	236	-19	241	-24
70	234	253	-19	262	-28
80	249	269	-20	280	-31
90	263	284	-21	297	-34
100	276	297	-21	312	-36

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.13. Region: Northeast; Site: All; Access Code: 3212, 3222; Species: Spruce-Fir; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	72	72	0
5	83	72	11
10	92	72	20
20	113	72	41
30	136	72	64
40	160	72	88
50	185	72	113
60	209	72	137
70	230	72	158
80	248	72	176
90	262	72	190
100	275	72	203

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.14. Region: Northeast; Site: All; Access Code: 3223; 3213; Species: Spruce-Fir; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	96	96	0
5	106	96	10
10	114	96	18
20	132	96	36
30	153	96	57
40	175	96	79
50	197	96	101
60	217	96	121
70	234	96	138
80	249	96	153
90	262	96	166
100	273	96	177

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.15. Region: Lake States; Site: All; Access Code: 5111, 5121; Species: White/Red Pine; Land Status: Clearcut Forest

		Reference Cases							
		Spruce - Fir		Maple-Beech		Aspen-Birch		Bottomland Hdwd	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	124	124	0	122	2	122	2	122	2
5	125	123	2	117	8	121	4	120	5
10	127	121	6	111	16	121	6	119	8
20	148	128	20	110	38	136	12	130	18
30	188	145	43	125	63	168	20	155	33
40	234	161	73	148	86	195	39	181	53
50	281	175	106	175	106	217	64	207	74
60	325	187	138	203	122	235	90	234	91
70	362	197	165	229	133	248	114	259	103
80	395	206	189	252	143	259	136	281	114
90	421	215	206	270	151	267	154	300	121
100	435	221	214	284	151	273	162	334	101

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.16. Region: Lake States; Site: All; Access Code: 5112, 5122; Species: White/Red Pine; Land Status: Cropland

Age	Activity Carbon	Reference Cases Cropland Carbon Stored	Reference Cases Cropland Net Effect
0	58	58	0
5	72	58	14
10	87	58	29
20	123	58	65
30	168	58	110
40	218	58	160
50	269	58	211
60	318	58	260
70	359	58	301
80	393	58	335
90	419	58	361
100	433	58	375

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.17. Region: Lake States; Site: All; Access Code: 5123, 5113; Species: White/Red Pine; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	78	78	0
5	91	78	13
10	105	78	27
20	139	78	61
30	182	78	104
40	230	78	152
50	279	78	201
60	325	78	247
70	363	78	285
80	395	78	317
90	420	78	342
100	433	78	355

NOTE: All carbon figures in 10^3 lbs/acre.

**Table 5.E.18. Region: Lake States; Site: All; Access Code: 5111, 5121;
Species: Spruce-Fir; Land Status: Clearcut Forest**

		Reference Cases							
		White/red Pine		Maple-Beech		Aspen-Birch		Bottomland Hdwd	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	124	124	0	122	2	122	2	122	2
5	123	125	-2	117	6	121	2	120	3
10	121	127	-6	111	10	121	0	119	2
20	128	148	-20	110	18	136	-8	130	-2
30	145	188	-43	125	20	168	-23	155	-10
40	161	234	-73	148	13	195	-34	181	-20
50	175	281	-106	175	0	217	-42	207	-32
60	187	325	-138	203	-16	235	-48	234	-47
70	197	362	-165	229	-32	248	-51	259	-62
80	206	395	-189	252	-46	259	-53	281	-75
90	215	421	-206	270	-55	267	-52	300	-85
100	221	435	-214	284	-63	273	-52	334	-113

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.19. Region: Lake States; Site: All; Access Code: 5212, 5222; Species: Spruce-Fir; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	58	58	0
5	70	58	12
10	80	58	22
20	103	58	45
30	114	58	56
40	124	58	66
50	145	58	87
60	164	58	106
70	181	58	123
80	194	58	136
90	204	58	146
100	213	58	155

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.20. Region: Lake States; Site: All; Access Code: 5213, 5223; Species: Spruce-Fir; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	78	78	0
5	88	78	10
10	98	78	20
20	118	78	40
30	138	78	60
40	157	78	79
50	174	78	96
60	188	78	110
70	198	78	120
80	206	78	128
90	214	78	136
100	219	78	141

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.21. Region: Central States; Site: All; Access Code: 6111, 6121; Species: White/Red Pine; Land Status: Clearcut Forest

		Reference Cases			
		Oak-Hickory		Bottomland Hardwoods	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	78	78	0	78	0
5	80	79	1	81	-1
10	82	82	0	89	-7
20	91	94	-3	107	-16
30	105	112	-7	126	-21
40	118	131	-13	143	-25
50	132	148	-16	158	-26
60	145	165	-20	172	-27
70	158	181	-23	184	-26
80	170	194	-24	195	-25
90	181	207	-26	205	-24
100	193	218	-25	214	-21

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.22. Region: Central States; Site: All; Access Code: 6112, 6122; Species: White/Red Pine; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	37	37	0
5	47	37	10
10	57	37	20
20	76	37	39
30	92	37	55
40	108	37	71
50	125	37	88
60	141	37	104
70	156	37	119
80	169	37	132
90	181	37	144
100	192	37	155

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.23. Region: Central States; Site: All; Access Code: 6123, 6113; Species: White/Red Pine; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	50	50	0
5	59	50	9
10	69	50	19
20	86	50	36
30	101	50	51
40	116	50	66
50	131	50	81
60	145	50	95
70	158	50	108
80	170	50	120
90	182	50	132
100	193	50	143

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.24. Region: Central States; Site: All; Access Code: 6211, 6221; Species: Oak-Hickory; Land Status: Clearcut Forest

		Reference Cases			
		White/red Pine		Bottomland Hardwoods	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	78	78	0	78	0
5	79	80	-1	81	-2
10	82	82	0	89	-7
20	94	91	3	107	-13
30	112	105	7	126	-14
40	131	118	13	143	-12
50	148	132	16	158	-10
60	165	145	20	172	-7
70	181	158	23	184	-3
80	194	170	24	195	-1
90	207	181	26	205	2
100	218	193	25	214	4

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.25. Region: Central States; Site: All; Access Code: 6212, 6222; Species: Oak-Hickory; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	37	37	0
5	46	37	9
10	57	37	20
20	79	37	42
30	100	37	63
40	121	37	84
50	141	37	104
60	161	37	124
70	178	37	141
80	193	37	156
90	205	37	168
100	216	37	179

NOTE: All carbon figures in 10^3 lbs/acre.

Table E.5.26. Region: Central States; Site: All; Access Code: 6223, 6213; Species: Oak-Hickory; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	**Activity Carbon**	**Carbon Stored**	**Net Effect**
0	50	50	0
5	58	50	8
10	68	50	18
20	89	50	39
30	108	50	58
40	128	50	78
50	148	50	98
60	165	50	115
70	181	50	131
80	194	50	144
90	207	50	157
100	217	50	167

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.27. Region: Rocky Mountains - North; Site: All; Access Code: 7111, 7121; Species: Ponderosa Pine; Land Status: Clearcut Forest

		Reference Cases							
		Douglas fir		Fir-Spruce		Lodgepole Pine		Larch	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	86	86	0	93	-7	82	4	103	-17
5	86	86	0	95	-9	83	3	110	-24
10	83	83	0	94	-11	79	4	115	-32
20	86	86	0	98	-12	81	5	131	-45
30	99	98	1	113	-14	91	8	157	-58
40	117	119	-2	134	-17	107	10	190	-73
50	136	149	-13	164	-28	127	9	225	-89
60	155	182	-27	197	-42	146	9	260	-105
70	175	214	-39	229	-54	161	14	291	-116
80	193	245	-52	257	-64	176	17	319	-126
90	211	276	-65	280	-69	189	22	343	-132
100	227	304	-77	299	-72	201	26	360	-133

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.28. Region: Rocky Mountains - North; Site: All; Access Code: 7112, 7122; Species: Ponderosa Pine; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	39	39	0
5	49	39	10
10	54	39	15
20	67	39	28
30	84	39	45
40	106	39	67
50	128	39	89
60	151	39	112
70	173	39	134
80	193	39	154
90	211	39	172
100	228	39	189

NOTE: All carbon figures in 10^3 lbs/acre

Table 5.E.29. Region: Rocky Mountains - North; Site: All; Access Code: 7123, 7113; Species: Ponderosa Pine; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	52	52	0
5	61	52	9
10	71	52	19
20	85	52	33
30	103	52	51
40	124	52	72
50	146	52	94
60	166	52	114
70	185	52	133
80	203	52	151
90	219	52	167
100	234	52	182

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.30. Region: Rocky Mountains - South; Site: All; Access Code: 8111, 8121; Species: Ponderosa Pine; Land Status: Clearcut Forest

		Reference Cases							
		Douglas fir		Fir-Spruce		Lodgepole Pine		Larch	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	74	74	0	82	-8	71	3	103	-29
5	76	76	0	84	-8	72	4	110	-34
10	75	74	1	83	-8	66	9	115	-40
20	77	76	1	87	-10	74	3	131	-54
30	85	84	1	100	-15	85	0	157	-72
40	95	93	2	114	-19	99	-4	190	-95
50	107	104	3	128	-21	115	-8	225	-118
60	121	118	3	145	-24	132	-11	260	-139
70	135	133	2	162	-27	149	-14	291	-156
80	149	146	3	178	-29	164	-15	319	-170
90	162	158	4	193	-31	177	-15	343	-181
100	175	169	6	207	-32	188	-13	360	-185

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.31. Region: Rocky Mountains - South; Site: All; Access Code: 8112, 8122; Species: Ponderosa Pine; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	33	33	0
5	43	33	10
10	49	33	16
20	60	33	27
30	72	33	39
40	85	33	52
50	100	33	67
60	118	33	85
70	135	33	102
80	149	33	116
90	162	33	129
100	175	33	142

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.32. Region: Rocky Mountains - South; Site: All; Access Code: 8123; 8113; Species: Ponderosa Pine; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	44	44	0
5	54	44	10
10	59	44	15
20	69	44	25
30	79	44	35
40	91	44	47
50	106	44	62
60	122	44	78
70	136	44	92
80	150	44	106
90	162	44	118
100	174	44	130

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.33. Region: Pacific Northwest; Site: High; Access Code: 9111; Species: Douglas Fir; Land Status: Clearcut Forest

		Reference Cases					
		Hemlock-Sitka Spruce		Hardwoods		Redwoods	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	95	92	3	93	2	95	0
5	96	93	3	98	-2	99	-3
10	94	91	3	104	-10	102	-8
20	120	103	17	122	-2	119	1
30	193	137	56	147	46	153	40
40	285	185	100	175	110	196	89
50	373	238	135	205	168	244	129
60	449	288	161	234	215	291	158
70	512	335	177	259	253	336	176
80	564	377	187	276	288	374	190
90	609	414	195	287	322	404	205
100	649	446	203	296	353	431	218

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.34. Region: Pacific Northwest; Site: Medium; Access Code: 9121; Species: Douglas Fir; Land Status: Clearcut Forest

		Reference Cases					
		Hemlock-Sitka Spruce		Hardwoods		Redwood	
Age	Activity Carbon	Carbon Stored	Net Effect	Carbon Stored	Net Effect	Carbon Stored	Net Effect
0	95	92	3	93	2	95	0
5	97	93	4	98	-1	99	-2
10	97	91	6	104	-7	102	-5
20	109	103	6	122	-13	119	-10
30	156	137	19	147	9	153	3
40	228	185	43	175	53	196	32
50	299	238	61	205	94	244	55
60	366	288	78	234	132	291	75
70	422	335	87	259	163	336	86
80	468	377	91	276	192	374	94
90	506	414	92	287	219	404	102
100	538	446	92	296	242	431	107

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.35. Region: Pacific Northwest; Site: High; Access Code: 9112; Species: Douglas Fir; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	44	44	0
5	55	44	11
10	63	44	19
20	100	44	56
30	177	44	133
40	273	44	229
50	364	44	320
60	445	44	401
70	510	44	466
80	564	44	520
90	609	44	565
100	649	44	605

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.36. Region: Pacific Northwest; Site: Medium; Access Code: 9123; Species: Douglas Fir; Land Status: Pasture

		Reference Cases	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	58	58	0
5	70	58	12
10	78	58	20
20	100	58	42
30	150	58	92
40	224	58	166
50	298	58	240
60	366	58	308
70	423	58	365
80	468	58	410
90	506	58	448
100	538	58	480

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.37. Region: Pacific Northwest; Site: All; Access Code: 9211, 9221; Species: Ponderosa Pine; Land Status: Clearcut Forest

		Reference Cases	
		Lodgepole Pine	
Age	Activity Carbon	Carbon Stored	Net Effect
0	95	92	3
5	96	92	4
10	94	88	6
20	98	89	9
30	112	101	11
40	129	120	9
50	149	138	11
60	168	153	15
70	187	166	21
80	204	177	27
90	221	187	34
100	237	194	43

NOTE: All carbon figures in 10^3 lbs/acre.

Table 5.E.38. Region: Pacific Northwest; Site: High; Access Code: 9212, 9222; Species: Ponderosa Pine; Land Status: Cropland

		Reference Cases	
		Cropland	
Age	Activity Carbon	Carbon Stored	Net Effect
0	44	44	0
5	55	44	11
10	62	44	18
20	78	44	34
30	96	44	52
40	117	44	73
50	140	44	96
60	163	44	119
70	185	44	141
80	204	44	160
90	221	44	177
100	237	44	193

NOTE: All carbon figures in 10^3lbs/acre.

Table 5.E.39. Region: Pacific Northwest; Site: Medium; Access Code: 9213, 9223; Species: Ponderosa Pine; Land Status: Pasture

		Reference Case	
		Pasture	
Age	Activity Carbon	Carbon Stored	Net Effect
0	58	58	0
5	68	58	10
10	82	58	24
20	97	58	39
30	115	58	57
40	136	58	78
50	159	58	101
60	179	58	121
70	197	58	139
80	213	58	155
90	229	58	171
100	244	58	186

NOTE: All carbon figures in 10^3 lbs/acre.