Agricultural Sector

Part 6 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

Agricultural Sector

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6.0 Agricultural 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 has been developed in cooperation with the U.S. Department of Agriculture (USDA) and which relates the general guidance to the issues, methods, and data specific to the agricultural sector. Other supporting documents address the electricity supply sector, the residential and commercial buildings sector, the industrial sector, the transportation sector, and the forestry 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, S.W., Washington, DC 20585.

6.1 Agriculture: Overview

Agriculture is a complex sector that deals with soil, water, plant, air, and animal resources in relation to economic considerations that affect the use of agricultural chemicals, fuels, and timing of operations. Rarely is an agricultural operation directed toward the production of only one commodity. Rather, the operation is really a system geared to multiple-commodity production, depending on the global economy. Given the myriad of combinations that the inputs to production may take, collecting and reporting reliable data are challenges.

For agriculture, the risks of global climate change are considerable. Shifting precipitation patterns and increased variability of moderate to extreme climate events would require adaptation of management techniques, application of technologies, and perhaps strategies to compensate for or prevent lower yields. All of these risks make mitigation actions of interest to the agricultural sector.

The agricultural sector includes both activities that reduce greenhouse gas emissions and sequester carbon. In the context of the earth's carbon cycle, carbon sequestering is the capture and storage of carbon. Carbon sequestration is reversible, depending upon agricultural management. It is a two-step process; carbon dioxide is first withdrawn from the atmosphere through the photosynthetic process, then stored in organic materials and perhaps underground over a period of time. The sequestration process ends when the carbon is released back into the atmosphere, principally as carbon dioxide and other carbon compounds, because of either combustion or decay. In this sense, carbon sequestration is defined by flows of carbon among the atmosphere, plants, animals, and soil. Carbon sequestration in agriculture is increased when the amount of carbon flow from the atmosphere to plants exceeds the flow from plants to the atmosphere.

The complexities of agricultural systems may present challenges to knowledgeable reporters when assessing specific effects of individual conservation or agronomic applications. Even more important will be understanding the integration of these efforts in the context of ecosystems-based management as well as impacts upon the atmospheric natural resource.

6.1.1 Reporting Entities

This sector includes not only family farms, but also any individual or group involved in producing crops or animals. Reporting entities could be classified into three groups: individual farmers or ranchers; associations or third parties; and local bodies of government, such as soil conservation districts, that could be third-party reporters.

Individual Agricultural Operation

Individual farmers, ranchers, consultants, management firms, manufacturers of agricultural products (such as fertilizer), and food producers (for their agricultural operations) may wish to report how their activities or those of their clients have affected greenhouse gas emissions. Many changes in agricultural practices are originally motivated by the needs to conserve soil and water and to use resources more efficiently. However, these same changes may reduce emissions, sequester carbon, or both, and thus may be reported under the EPAct 1605(b) program.

Individual agricultural operations may use tools such as the Erosion Productivity Index Calculator (EPIC), a process simulation model that takes into account farm management practices over 8-10 years and can show the effect of these practices on carbon sequestration. The model is very site-specific and data-intensive.

Associations and Third Parties

Agricultural operators often are members of groups, such as cooperatives, that share information and resources. These groups or associations may have the resources to collect, aggregate, and summarize the data to report under this program and may wish to report jointly, aggregating their data for greater impact and sharing the reporting burden. For example, an association of rangeland grazers could sequester carbon by increasing rangeland quality from poor/fair to good/excellent condition. Such an association might use the 1991 Simulation of Production and Utilization of Rangelands (SPUR) (USDA 1987) model to compare soil organic carbon (SOC) before and after the change in range conditions.

Third parties might also report under this program. Third-party reporters might include food production businesses that contract out to individual farmers and thus control many aspects of production on those farms. These reporters should identify the individual farms as other potential reporters. Another third-party reporter might be a farming consultant who reports practices initiated at client farms; again, the consultant should identify the clients as other potential reporters.

Local Government (Conservation Districts)

Conservation districts, usually at the county level, are in a unique position because they collect and report relevant data under a USDA voluntary reporting program. As part of their current function, they cooperate closely with the individual operations in their counties in order to gather data on agricultural management and conservation activities. The districts possess information on the majority of the farms/ranches in the United States. Since conservation district supervisors are elected officials of county governments, they are answerable to their constituents for the accuracy of the data.

These data are aggregated to the county level and could be used to calculate greenhouse emissions impacts, primarily relying on computer processing. Representative values for the majority of the agricultural operations in a county could be reduced by multiple runs of the models to produce order of magnitude multipliers. For example, using the Cost and Return Evaluator (CARE), a conservation district could calculate the reduction of energy use brought about by the improvement of irrigation water efficiency, or the reduction of fuel use caused by changes in tillage practices or residue management. This may be the most economical method to get a large representation of the agricultural sector. Data could be aggregated to the state or national level.

As the science of carbon sequestration improves, the physical data gathered by the districts can be reanalyzed to more precisely assess the impact over time of agriculture and varying agricultural practices on greenhouse gas emissions.

6.1.2 Sector-Specific Issues

The agricultural sector includes numerous, highly varied activities and many sources of information that can be reported under this program. The sector encompasses crops and animals. Some overlap may occur with the industrial sector in activities involving the food and agricultural chemical industries, and agricultural energy sources.

The sector is unique in the variety of activities that contribute both to greenhouse gas emissions and to carbon sequestration; in the range of possible reporters, from small individual farms to cooperatives and associations to governmental organizations at all levels; and in the understanding of interactions among activities in living organic systems, leading to complex project definitions and estimation methods.

You may encounter complexities in every step of your project analysis. In defining projects and determining effects, you may need to consider carefully what activities to include. An activity that has some straightforward, intended effects may lead to other effects in the life cycle of a crop, in off-site (downstream) impacts on resources surrounding your land, or in other practices that affect greenhouse gas emissions. Similarly, quantifying effects may be a challenge when so many elements need to be accounted for. Furthermore, some effects may interact with each other, either increasing or decreasing the overall effects.

6.2 Reporting Greenhouse Gas Emissions

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 emissions for your entire agricultural operation, you should consider providing a comprehensive accounting so that your audience can gain a clear understanding of your overall activities.

You may report your emissions by either estimating emissions only (from fuel use, fertilizer use, manure lagoons, etc.) or by accounting for carbon flows to and from the atmosphere (capture of carbon, perhaps offsetting some portion of emissions to arrive at net amounts of emissions).

You may not be able to develop a comprehensive emissions report. However, you may be able to report one or more of the following emissions-related activities, which are arranged roughly in increasing order of complexity:

- Carbon emissions from fuel use. To report fuel-related emissions, you may determine the amount and type of energy consumed in the reporting year and, for each fuel, multiply the amount by the corresponding emissions factor in Appendix B. (Emission from fuel use are discussed more extensively in the supporting documents for the electricity supply, residential and commercial buildings, industrial, and transportation sectors.)

- Carbon dioxide emissions from electricity use. To calculate emissions resulting from electricity purchases, you may use the state-level default emissions factors in Appendix C. (Emissions from electricity use are discussed more extensively in the supporting documents for electricity supply and residential and commercial buildings.)

- Methane emissions from manure. These may be measured from a covered lagoon or estimated using the procedure and default factors in Section 6.4.3.

- Nitrous oxide emissions from fertilizer and nitrogen use. Although the application of nitrogen leads to emissions of nitrous oxide, these emissions are difficult to quantify.

- Adjustments to carbon dioxide emissions from calculations of carbon flows. To accomplish this, you may estimate carbon captured by and released from the soil, above- and below-ground biomass, and windbreaks and shelterbelts. Your estimates of carbon flows should include negative flows (capture of carbon from the atmosphere) and positive flows (release of carbon to the atmosphere). That estimate of carbon must be multiplied by 3.67 in order to convert carbon to carbon dioxide. (See Appendix D.) If your activities are capturing more carbon than they are releasing, your carbon dioxide emissions will be lowered. (A more detailed discussion of calculating carbon flows is contained in Section 5.2 of the supporting document for the forestry sector.)

The following example illustrates the decision-making process for determining categories of emissions to report under the voluntary reporting program.

Example 6.1 - Reporting Emissions

Grundvig Chickens, Inc., operated several chicken farms that delivered poultry to a local processing plant. GC had made several improvements to its operations since 1990 in order to become more competitive. As results of these efficiency improvements, the farms were using less fuel for heating and transportation, and less electricity. The farms were also managing the chicken manure to capture methane for on-farm use.

Although reducing greenhouse gas emissions had not been a goal of these activities, GC realized that reporting emissions under the EPAct 1605(b) program would be good public relations for the organization—and lay the basis for reports of emissions reductions.

Since the company had records of fuel use and electricity use, GC decided to report emissions from these activities, using the default emissions factors for natural gas and gasoline, and an emissions factor developed by the local rural electric company. In addition, GC could estimate the amount of natural gas displaced by using recovered methane, since only one heating system was involved. The company had no way to determine actual methane emissions for their reporting years; however, these emissions must have been more than the amount recovered. Therefore, GC decided to report methane emissions at the level that could be substantiated, that is, the amount recovered in a subsequent project. GC reported

Example 6.1 - (cont'd)

emissions of carbon dioxide and methane for 1987-1990 and carbon dioxide for each year thereafter. (Since the company was now recovering methane and did not measure the amount that was not recovered, methane could not be included in the emissions report.)

GC also reported data on tillage practice and crop management to the local conservation district, which aggregated data and determined flows for all cooperators in the district. This became the basis for an emissions report from the conservation district to EIA under the EPAct 1605(b) program.

The primary process of estimation must be documented and be based upon acceptable science from industry, academia, or other research and development sources. The process can include direct measurements, or the method may be based upon simulations of the appropriate resource management models (carbon sequestered from the SPUR or EPIC models, or fuel use from the CARE model), or engineering computations based upon average or normal conditions.

6.3 Performing Project Analysis

The analysis of emission reductions and carbon flow reductions in the agriculture sector follows the process described in the General Guidelines ("How Should I Analyze Projects I Wish to Report?"):

- Establish the reference case.
- Identify the effects of the project.
- Estimate carbon flows for the reference case and the project.

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 project not been undertaken—and the project—the carbon flows and greenhouse gas emissions with the project in place. You must identify the effects of the project. Finally, you must estimate the emissions associated with the reference case and the project, and calculate the difference between them as an estimate of your project accomplishment.

The starting point for any reporting will be gathering the physical data about the operators' activities on any piece of land over time. Science will provide acceptable methods to compute effects of such activities on atmospheric greenhouse gases. As science evolves, new techniques can be applied directly to these physical data. DOE expects that database users will have the opportunity to use the reported information to reevaluate estimated effects in the future, as better data or estimation methods become available.

Well-documented procedures are required to illustrate how the data can show the impact of agriculture on the atmosphere. Integrated applications can be summarized and reported in terms of tons of greenhouse gases sequestered or not emitted within the time frame and spatial extent, depending upon how you define a specific project.

6.3.1 Define the Reference Case

Defining the effects of the agricultural activity starts with defining a reference case. This reference case describes the physical parameters of the activity and the emission effects without the activity. Once you have established the reference case, it serves as the basis for evaluating the effects of the reported activity (the project). In simple terms, the net effects of the activity are defined by the emission levels or carbon flows for the reference case minus the emission levels or carbon flows for the project case.

If you can develop a basic (historic) reference case specific to your operation, that case will probably be the most credible for your audiences. In some situations, your farming operation may be stable, including over the baseline years (1987-1990). Even where your operation has changed from year to year, identifying a typical year or using the year just prior to your project may well be both convenient and credible.

For other situations, you may have difficulty in defining a reference case because no record of historic farm/ranch operations exists, because you have no data or no reliable data, or because you have good reason to believe that greenhouse gas emissions even without the project would have been different from historic emissions. For example, agricultural practices may change rapidly in response to market and other conditions, and your farm's production may change completely within several years. Your range of choices for a reference case might include regional averages, alternative scenarios available in models (for example, in the EPIC program), or projections of trends (such as additional carbon sequestration in the soil, projected as a continuation of past years' activity). For a few well-defined projects, you may wish to use default factors, documenting the source for any such factors. Similarly, you may be able to find data on land similar to yours and refine that information to develop a reference case.

If you use such a reference case, called a modified reference case, keep in mind that your audiences may need to be convinced of the comparability of your reference and project cases. In this situation, the construction of a reference case can involve considerable analysis and the best estimate of knowledgeable technical people. You will need to state both the methods and assumptions that you used to arrive at the reference case. For example, if you use modeled data or regional averages, you should exercise care in applying the data to your specific site(s).

6.3.2 Identify Effects of the Project

In developing your project analysis, you should strive to include all relevant effects of the activity as described in the General Guidelines ("What Effects Did the Project Have?"). The complexities of natural resource systems do not lend themselves well to well-defined project boundaries, and you may need to account for a wide range of possible effects. Actions taken to reduce carbon dioxide emissions may increase emissions of other greenhouse gases. For example, the life-cycle effects of growing biomass include energy and chemical inputs that may partially offset the beneficial effects of alternative fuels made from the biomass crop.

The guidance for analysis of specific activities in Section 6.4 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.

6.3.3 Estimate Emissions for the Reference Case and Project

Your report must include an estimation of emissions effects and carbon sequestration associated with your project. Although this supporting document provides a few default factors, you generally must develop your own estimation process for agricultural projects. Remember that your report will be less credible if you do not use acceptable analytical practices. You may want to review the guidance provided in Section 6.4 that discusses some acceptable procedures for estimating the carbon flow effects for some types of agricultural projects.

Default Factors

For this sector, as for all sectors, you can use default factors to estimate emissions from fuel use (multiply the quantity of each fuel by the relevant factor—see Appendix B) and electricity use (multiply the megawatt hours by your state's emissions factor—see Appendix C).

However, very few default factors exist for uniquely agricultural activities, since, for the most part, emissions from any activity depend upon specific characteristics such as type and condition of the site, management practices, and weather. Field measurements or site-specific estimates are almost always preferred to default factors. Nevertheless, this guidance draws from research some default factors for a few projects, such as methane emissions from livestock manure and carbon dioxide emissions from tillage systems. As the scientific understanding of atmospheric greenhouse gases increases, more default factors will become available for use in specific situations. These default factors may allow you to report projects easily, but they will be less precise than your own data from actual field measurements.

Field Measurements

When appropriately designed and executed, site-specific field studies will provide the highest quality data and thus the highest credibility with users of the database. If you use field measurements, your report should briefly describe the sampling plan and the associated levels of confidence.

Models

Many of the estimation techniques discussed in this supporting document for specific projects rely on the use of models. You should carefully consider the suitability of any model that you use. For example, some models are designed for farm-scale use; to apply them on a district-wide basis may reduce their accuracy. Moreover, the models discussed earlier (EPIC, SPUR, and CARE) were developed originally for different purposes than estimating greenhouse gas emissions and, therefore, may not adequately address issues of many effects, integrated effects, or multiple gases. Finally, the model that is otherwise suitable for your situation may not provide a credible reference case. For example, you could use EPIC to estimate emissions from tillage systems, but if your site's historic use does not fit any of the model's simulation categories, your report may lose credibility because your reference case may then be considered arbitrary.

6.3.4 Reporting by Conservation District

Local communities create soil and water conservation districts (SWCDs) that are in a unique position to be able to collect and aggregate data that may be used to report under the EPAct 1605(b) program. These districts, which often follow county boundaries, can receive funds from the state or may have the power to tax land in their jurisdictions to provide citizens a means of determining which soil and water conservation problems should be addressed and how. District employees work closely with staff from the USDA's Soil Conservation Service (SCS).

These linkages among national, state, and local levels allow conservation districts to use computer databases that are common across the United States. The districts enter data based on their knowledge of local practices and programs for which they assist landowners. A typical district office provides assistance to the extent requested by the landowners in the district and participates in special projects, such as erosion and sediment control work, conservation education, soil survey efforts, and the Small Watershed Protection Program. An important task has been overseeing the implementation of the 1985 and 1990 Farm Bills, which require that farmers develop and apply a conservation plan on their land in order to remain eligible for USDA program benefits.

The data currently gathered and entered into computer databases by both SCS and SWCD personnel at the district level provide most, if not all, the information required to track agricultural practices related to global climate change. The database system records changes to the landscape that SCS or district employees observe and/or initiate with the cooperation of the land users. Projects for EPAct 1605(b) reports can be identified using the district progress reporting codes, shown in Table 6.1. Each of these project codes is associated with a multi-page definition of the activity. For example, the description of Code 328, Conservation Cropping Sequence, begins, "An adapted sequence of crops designed to provide adequate organic residue for maintenance or improvement of soil tilth." This is followed by definitions of the elements of such a practice (including planning) and 32 possible variations.

Table 6.1 Typical State Technical Guide Index of Standards and Specifications

Code	Project	Code	Project	Code	Project
310	Bedding	460	Land Clearing	586	Stripcropping, Field
324	Chiseling and Subsoiling	451	Land Reclamation, Fire Control	589	Stripcropping, Wind
326	Clearing and Snagging	456	Land Reclamation,	587	Structure for Water Control
327	Conservation Cover	453	Land Reclamation, Landslide Treatment	606	Subsurface Drain
328	Conservation Cropping Sequence	452	Land Reclamation, Shaft and Adit Closing	607	Surface Drainage, Field Ditch
329	Conservation Tillage	454	Land Reclamation, Subsidence Treatment	608	Surface Drainage, Main or Lateral
330	Contour Farming	453	Land Reconstruction, Abandoned Mined Land	600	Terrace
340	Cover and Green Manure Crop	544	Land Reconstruction, Currently Mined Land	612	Tree Planting
342	Critical Area Planting	466	Land Smoothing	614	Trough or Tank
344	Crop Residue Use	468	Lined Waterway or Outlet	620	Underground Outlet
349	Dam, Multiple Uses	472	Livestock Exclusion	312	Waste Management System
356	Dike	484	Mulching	425	Waste Storage Pond
362	Diversion	590	Nutrient Management	313	Waste Storage Structure
380	Farmstead and Feedlot Windbreak	500	Obstruction Removal	359	Waste Treatment Lagoon
382	Fencing	582	Open Channel	633	Waste Utilization
386	Field Border	510	Pasture and Hayland Management	638	Water and Sediment Control Basin

Table 6.1 (cont'd)

Code	Project	Code	Project	Code	Project
392	Field Windbreak	512	Pasture and Hayland Planting	641	Water Table Control
393	Filter Strip	595	Pest Management	642	Well
394	Firebreak	516	Pipeline	990	Well Testing
399	Fishpond Management	556	Planned Grazing Systems	657	Wetland Development or Restoration
402	Dam, Flood Water Retarding	378	Pond	645	Wildlife Upland Habitat Management
408	Forest Land Erosion Control System	521A	Pond Sealing and Lining - Flexible Membrane	644	Wildlife Wetland Habitat Management
409	Forest Land Management	521B	Pond Sealing and Lining - Soil Dispersant	652	Woodland Direct Seeding
410	Grade Stabilization Structure	521C	Pond Sealing, Bentonite	654	Woodland Improved Harvesting
412	Grassed Waterway	338	Prescribed Burning	666	Woodland Improvement
411	Grasses and Legumes in Rotation	991	Record Keeping	660	Woodland Pruning
560	Access Road	566	Recreation Land Grading and Shaping	490	Woodland Site Preparation
422	Hedgerow Planting	568	Recreation Trail and Walkway	990	Well Testing
522A	Irrigation Pit	558	Roof Runoff Management	991	Record Keeping
436	Irrigation Storage Reservoir	350	Sediment Basin	333	Cross Slope Farming
442	Irrigation System, Sprinkler	574	Spring Development	342	Critical Area Planting
441	Irrigation System, Trickle	584	Stream Channel Stabilization	331I	Cross Slope Farming
430	Irrigation System Conveyance - Pipeline	580	Streambank and Shoreline Protection	318I	Dead Poultry Composting
449	Irrigation Water Management	585B	Stripcropping, Buffer		
561	Heavy Use Protection Area	585	Stripcropping, Contour		
Source: *Virginia State Technical Guide*					

These data are shared with the USDA's Agriculture Stabilization and Conservation Service who collect and share data on crop yield and field boundary changes. However, both of these data sets are only the physical data for projects, not the emissions effects of the projects. In order to report under EPAct 1605(b), the district offices would have to apply methods and factors to estimate emissions from both a reference case and a project case.

A reference case could be constructed from data already being collected by the districts. Every five years (for example, 1987 and 1992) the districts, using statistical sampling methods, inventory all the land they have information about. Data for the intervening years represent changes from the previous inventory, for example, acreage that has been taken from conventional tillage and put into conservation tillage during the preceding year. Data can be retrieved from any year and compared to the inventory year.

6.4 Reportable Types of Projects in the Agricultural Sector

If you report emissions for your entire operation (see Section 6.2), you may wish to define your emissions reductions project at that level also. You would then simply report emissions in a reference case year (say, 1990) and emissions in the project year; if the project year emissions are less, you have emissions reductions to report.

This section addresses activities that may be analyzed using either a basic or modified reference case—cropland management (for carbon sequestration or reduced fuel consumption), grazing land improvement, windbreaks and shelterbelts, reduction of manure methane emissions, irrigation water management, efficient nutrient management for crop production, and growing biomass. The objective is to provide an overview of anticipated effects and to suggest published studies that may be useful for framing your estimates. However, reference to a particular study should not be construed as an endorsement of its contents by DOE.

Also, these are only some of the types of projects that could be reported in the agricultural sector. Others could include (but are not limited to) changing the diets or diet supplements of animals, changing the types or amounts of fertilizer used, using more energy-efficient equipment, removing land from production, and switching to less energy-intensive crops. For example, in a large rowcrop operation, the primary activity might be sequestering carbon and reducing the release of nitrous oxide into the atmosphere.

Some projects may be most appropriately analyzed using approaches and data found in other supporting documents. Windbreaks and shelterbelts, for example, can capture carbon in the trees and shrubs themselves and also reduce energy use in buildings; these functions of trees are covered in the supporting document for the forestry sector. (However, because of the mix of vegetation and the species of trees normally used for windbreaks and shelterbelts, these projects would need to be treated as reporter-designed projects, not estimated using default factors found in that document.) Similarly, the forestry sector document discusses establishing short-rotation woody biomass plantations (but not grasses) for biomass energy and agroforestry, the combination of agriculture and silvaculture on the same tract of land. The use of fuels such as ethanol made from biomass is discussed in the transportation sector. Projects that report reductions associated with energy use (fuel reductions) can be analyzed using the approach outlined in the supporting document for the industrial sector, along with the default factors in Appendixes B and C.

6.4.1 Cropland Management

No-till practices appear to increase the amount of organic carbon in the top 4 to 6 inches of the soil profile. Limited research on conservation tillage indicates that this system maintains the existing organic matter equilibrium. Although conventional tillage has been shown in long-term plots to reach an equilibrium, smaller losses have been noted after the initial decline (Kern and Johnson 1993). Based on this study of the impacts of conservation tillage on national soil and organic carbon levels, you may assume that conventional tillage continues to reduce SOC, conservation tillage prevents further loss, and no-till increases SOC. However, different soil types (with different texture, drainage, and erosion status) will respond differently to the same management regimes.

You may report increases in carbon sequestration accomplished through adoption of no-till systems, through the establishment of permanent vegetative cover, and through residue management. You may test any number of fields with applicable soil mapping units or one representative field and its soil mapping units.

You may also report estimated accomplishments from an ecosystem-based management approach to the entire farm to account for areas that are cumbersome to track individually, such as grassed waterways and permanent buffers between fields and streams. You may report the total but specify each practice.

Reference case

For projects involving changing tillage practices, the basic reference case would be the tillage practices in the year(s) before you began no till or conservation till. If you have no site-specific data and you use a model such as EPIC, you can run the model for conventional or conservation tillage, if that is the appropriate reference case.

Effects of the project

The major effect should be to sequester organic carbon in the A soil horizon (the top 4 to 6 inches). Other effects would include increasing the release of nitrous oxide, since residue on the soil surface will increase soil moisture and carbon. (The residue will have other conservation benefits, including reducing soil temperatures, increasing infiltration, and increasing the water-holding capacity of the soil.) If you maintain vegetative cover, carbon sequestration in the soil should increase.

Based on data compiled by the Conservation Technology Information Center,[a] fuel use is reduced by adopting conservation tillage and greatly reduced by using no-till. Producers have also reduced their fuel use by combining pesticide, fertilizer, and planting operations, thereby reducing the number of trips across a field.

Estimation of effects for the reference case and project

The Soil Conservation Service (SCS) Technical Guides, developed by individual states, provide guidance for an appropriate estimation system. The conservation plan that documents the applied resource management system will show the data about how and how often nutrients are applied. You may use this information to calculate the total tons of carbon sequestered.

Soil organic matter content testing could be used to document carbon sequestration in areas of no-till and permanent cover. Your soil carbon testing program would require an initial soil test reading to show the present carbon level or the level before the field was planted to permanent cover or converted to a no-till operation. Then, on a periodic basis (for example, every five years), another test on the same field would be taken and the results input into a soil carbon sequestration database. To control variability in the soil sampling procedure, you should follow your state's SCS technical guidelines.

(a) Conservation Technology Information Center, 1220 Potter Drive, Room 170, Purdue Research Park, West Lafayette, IN 47906-1334.

EPIC, an SCS computer program that models farm management practices (Williams et al. 1984) plus a two-equation model (Kern and Johnson 1993) that estimates organic carbon may be used to quantify the organic carbon level in the soil as a reference case at the beginning of the sequestration process. This same approach can be used to estimate the carbon level in the soil after application of no-till or permanent vegetative cover is implemented. EPIC is a multi-year simulation with daily time-step accounting that considers weather, soils, cropping rotations, planting dates, cultivation dates, fertility dates, herbicide applications, all types of tillage and management practices, and natural wind or water erosion process. It monitors soil fertility, soil organic content, soil moisture, and soil erosion. It has the capability to provide very accurate accounting of "before and after" sequestered soil carbon—the basic reference case and the project case.

Estimates of emission reductions for fuel use could be based upon historical fuel consumption on a per acre basis and then tracked with reports of current use. This information would include tillage reduction figures as well as figures for reducing the number of trips across a field. The total gallons of fuel saved on a farm would be converted to total carbon emission reductions. The SCS CARE computer program or another farm budget program can be used to estimate fuel savings.

If you collect information on total benefits of no-till, then emission reductions could be reported specifically for the type of tillage system used on a farm (See Table 6.2). This approach has the advantage of making reporting relatively easy and providing a standard estimate of emission reductions. Example 6.2 illustrates one project analysis for a conservation tillage project.

Table 6.2. Average Carbon Emitted from Energy Use Associated with Crop Production[a]

Tillage Method	Carbon Emitted (kgC/ha/yr)[b]
Conventional	52.8
Minimum tillage	45.1
No tillage	29.0

(a) Includes carbon for herbicide manufacturing and for machinery and repair. Based upon the energy estimates in liters of diesel fuel per hectare.
(b) kg C/hectare/year, using typical density of #2 diesel fuel of 852 g/liter and a carbon content of 873 g C/kg.

Source: Frye 1984.

Example 6.2 - Conservation District Reporting Conservation Tillage

The John Marshall Soil and Water Conservation District encompasses Fauquier County, an area of 660 square miles (422,400 acres) in Virginia. In 1993, this office assisted 372 landowners and participated in a number of special projects. The office collected data on conservation projects using CAMPS, microcomputer software developed by the Soil Conservation Service (SCS).

This district wished to report under the EPAct 1605(b) program to link its local efforts to national initiatives in a way that would be visible to the local landowners. In order to report, the district obtained agreement from over 300 of the landowners to report their data. The district reported the remaining landowners as other potential reporters. Staff members realized that, because appropriate emissions factors were not available for all their activities, only a limited subset could be reported. Further, they wished to keep the costs of reporting to an absolute minimum. Therefore, they decided to report conservation tillage only for the reporting year, 1993.

Conservation tillage data (code 329) showed three reports during 1993, for a total of 1,339 acres that came under conservation tillage. Using a reference case of conventional tillage, the district staff calculated an annual reduction per hectare of 7.7 kg carbon emitted from energy use associated with crop production (see Table 6.2; 52.8 - 45.1 = 7.7 kgC/ha/yr).

They then computed the emissions reductions by multiplying acres by the carbon savings (1,339 acres • 1 hectare/ 2.47 acres • 7.7 kgC/hectare/yr = 4,174.2 kg C), then multiplying the carbon reduction by 3.67 to obtain the annual carbon dioxide emissions reductions (see Appendix D):

$$4{,}174.2 \bullet 3.67 = 15{,}319 \text{ kg } CO_2$$

For the report, the kilograms may be converted to metric tons, using the tables in Appendix A.

6.4.2 Windbreaks and Shelterbelts

Windbreaks are composed of rows of progressively taller vegetation established perpendicular to the predominate wind flow. The lowest vegetation is on the windward side and the tallest on the downstream, leeward, side of the flow. This vegetation is a mixture of low- to mid-level brush and low- to tall-growing trees. As these plantings mature, they offer significant resistance to wind flow and reduce greenhouse gas emissions as discussed below. Windbreaks and shelterbelts are grown mostly to slow winds during the growing season, thus stopping wind erosion and plant desiccation. They can also be used to shelter the farmstead, thus reducing fuel required to heat and cool the buildings.

Windbreaks and shelterbelts are usually a small component of a larger modern farm operation when computed on a per-acre basis, and they use different species from the trees for which the forestry sector document gives default values (Appendix 5.A). For these two reasons, windbreaks and shelterbelts cannot be estimated as standard forestry projects.

Reference case

The simplest basic reference case is the land without windbreaks and shelterbelts. Your reference case may include the land use without the project and fuel and electricity use by the farmstead before your windbreak project. If you are replacing an existing shelterbelt, computations will prove more difficult.

Effects of the project

The effects of windbreaks and shelterbelts on greenhouse gas emissions have two components: the capture of carbon in the vegetation itself and the reduction in energy requirements for cooling and heating the farmstead.

Estimation of effects for the reference case and project

To estimate carbon storage, the most credible method is field measurement. Although research literature (for example, Brandle, Wardle, and Bratton 1992) may provide carbon storage factors by type of vegetation, your site-specific project may yield quite different results. Although you may report using factors derived from research, you should also use measured data if you can.

Shelterbelts may reduce winter fuel consumption at the farmstead by 10 to 30 percent (USDA 1978). To estimate your reduced energy requirements, you may use fuel and energy bills for both the reference case and project cases, corrected for differences in weather between the two cases. If you have reduced electricity use, you may use your state's default emissions factors (Appendix C) if you do not have data from your electricity supplier about its specific emissions. You may find further guidance on how to estimate emissions reductions for the farm buildings in Part 2 of these supporting documents (Residential and Commercial Buildings Sector).

6.4.3 Reduction and Recovery of Manure Methane Emissions

Methane is produced during the anaerobic decomposition of the organic material in livestock and poultry manure. Large livestock facilities store and treat livestock manure in anaerobic lagoons and pits to comply with the limitations on the legal discharge of manure into surface waters. These lagoons and pits are conducive to the production of methane, which can be captured for energy production. Recovered methane can be used to produce electricity or to fuel gas-fired equipment such as boilers or chillers.

The major approaches for recovering and using livestock manure methane are as follows:

- Covered Anaerobic Lagoon: Anaerobic lagoons are among the simplest manure storage and treatment systems in current use. Methane is produced in the lagoon by the biological process that stabilizes the manure. Covering the lagoon allows the recovery of methane, which then can be used as an on-farm energy source.

- Plug Flow and Complete Mix Digesters: Digesters have been used for many years to produce energy from livestock manure. The digesters are commonly built as tanks (complete mix) or trenches (plug flow). As the manure decomposes in the digester, the methane is recovered and used for fuel.

Alternative manure management systems that reduce methane emissions involve handling manure under aerobic conditions. These include land application, composting, and incineration of the manure.

You may report reductions of methane emissions from manure for your individual operating units or you may combine all your projects into a single report, taking care to account for potential effects within and outside of your organization. (See Example 6.3.)

Reference case

The most credible reference case would be the emissions from manure before the management system was implemented. However, no reliable method exists to estimate these emissions. Therefore, you should estimate your emissions reductions directly as the amount of methane you recover.

Effects of the project

The major effect is to reduce emissions of methane. Possible other effects include substitution of methane for fossil fuels, which reduces emissions from fossil fuel use.

Estimation of effects for the reference case and project

Estimating emissions reductions using actual measurements is possible in the particular case of an existing, covered lagoon from which you recover methane. Emissions reductions in that case equal the amount of methane recovered.

Under other circumstances emissions reductions cannot be estimated from the amount of gas recovered under a new manure management system. Emissions reductions equal the change in emissions resulting from the manure that is handled by the new management system. For example, if half the manure from an animal feeding/holding area (drylot) is transferred to a covered lagoon to recover gas, emissions from this area will also be reduced by half.

Measuring is difficult, but you may estimate emissions in one of two ways:

- If your existing lagoon is covered and the methane is recovered, reference case emissions may be estimated as the amount of methane recovered.

- You may use the set of emissions factors in Table 6.3 to estimate reference case emissions. To use these factors, first calculate total excretion of volatile solids and the amount of volatile solids handled in each manure management system. Next, select a climate region from those in the table, and multiply the amount of volatile solids in each system by the appropriate emissions factor.

Table 6.3. Livestock Manure Methane Emissions Factors[(a)]

Type of Manure Management	Dairy	Beef in Feedlots	Beef Grazing	Swine—Breeder	Swine—Fattening
Anaerobic lagoons—all climates	146	201	104	220	287
Pasture/range and solid storage—cool	1.6	2.2	1.2	2.4	3.2
Pasture/range and solid storage—temperate	2.4	3.4	1.7	3.7	4.8
Pasture/range and solid storage—warm	3.3	4.5	2.3	4.9	6.4
Drylot—cool	1.6	2.2	1.2	2.4	3.2
Drylot—temperate	2.4	3.4	1.7	3.7	4.8
Drylot—warm	8.1	11.2	5.8	12.2	15.9
Daily spread—cool	0.2	0.2	0.1	0.2	0.3
Daily spread—temperate	0.8	1.1	0.6	1.2	1.6
Daily spread—warm	1.6	2.2	1.2	2.4	3.2
Liquid/slurry—cool	16	22	12	24	32
Liquid/slurry—temperate	57	78	40	85	112
Liquid/slurry—warm	106	145	75	159	207
Pit storage < 30 days—cool	8	11	6	12	16
Pit storage < 30 days—temperate	29	40	21	44	57
Pit storage < 30 days—warm	54	74	38	81	105
Pit storage > 30 days—cool	16	22	12	24	32
Pit storage > 30 days—temperate	57	78	40	85	112
Pit storage > 30 days—warm	106	145	75	159	207

(a) in kgs of methane/1000 kgs of volatile solids

Source: EPA 1993.

Example 6.3 - Reporting Methane Emissions Reductions

In 1989 Robert Link began systematically making improvements to his farm to increase the overall economic efficiency of his operation. As one aspect of his efforts, he hired a farm management consultant, Gordon Stillwell, who analyzed energy inputs and recommended several changes that resulted in reducing fuel and electricity use on the farm. During the same year, Link followed the example of a neighbor and covered his manure lagoon so he could use the methane he recovered as on-farm fuel. The methane recovery project was operational by January 1991.

When the EPAct 1605(b) program was implemented, Link was encouraged by a local conservation district employee to submit a report out of his belief in the contribution agriculture could make to solving the problem of increasing greenhouse gas emissions. The conservation district, said the employee, was going to submit a report on changes in cropping and tillage practices. "But you've made other changes," he said, "and you should get all of them on record."

Link wanted to report and wanted his report to be accurate. However, he also wanted to spend as little of his time and energy as possible on reporting. He therefore called Gordon Stillwell to ask if the consultant still had data from his analysis readily available. When he called Stillwell, however, the consultant said that he wished to report the data himself in order to be able to tell his clients that his accomplishments were on the federal record. Link agreed to let Stillwell report the reductions in fuel and electricity use, knowing that he could still report the methane recovered from his covered manure lagoon.

Link had metered his recovered methane, so he could estimate the amount of recovered methane directly as the emissions reduction, following the technical guidance in the EPAct 1605(b) program.

6.4.4 Irrigation Water Management

Only about 3 percent of the nation's energy is used in agriculture and only 23 percent of this quantity (or less than 0.7 percent of the nation's energy use) powers the irrigation pumping plants. However, in those areas where irrigation allows continuous agricultural production, the energy use for irrigation remains a much larger percentage of the on-farm energy requirement, often exceeding two-thirds. Further, in some locations, the peak electrical power generating capacity is often driven by irrigation pumping (ASAE 1990).

Although the energy savings from accelerated irrigation water management is relatively small on a national scale, the savings in selected portions of the 17 western states could be significant, especially in the states of California, Texas, and Nebraska. In recent years, these three states have accounted for one-half the on-farm energy used for irrigation (ASAE 1990).

Energy savings from irrigation may be achieved through any of the following actions:

- Reduced pumping volume which may be achieved through
  - runoff reuse
  - improved application efficiencies and irrigation scheduling
  - improved irrigation systems
    low energy precision application (LEPA)
    low-pressure center pivot
    surge
    trickle
  - moisture stress-limited

- Reduced pumping head

  - reduced pipeline friction losses
  - substitution of surface water for groundwater
  - improved irrigation systems (see above)

- Improved pumping plant efficiency

- Alternative energy sources

Of these, those offering the greatest potential for substantial savings are reduced pumping volume and improved pumping plant efficiency. Agricultural irrigation efficiencies are often 10 to 20 percent less than that reasonably achievable. On-farm pump plant efficiencies are often found to be far below the 75 percent that can be attained with good design, installation, operation and maintenance. In several studies, half the pump plant efficiencies were found to be less than 75 percent, with some plants as low as 40 percent (ASAE 1990).

Reference case

A basic reference case would be an existing system for which the efficiencies and fuel use are known. These data would likely have been gathered in order to determine the costs and benefits of improving the system. A modified reference case is more problematic, for example, the installation of a new system or of equipment that is more energy-efficient or uses alternative fuel. In this situation, you will need to carefully consider what emissions would have been in the absence of the new system. In order to have a credible emissions reductions report, your reference case must be acceptable to your audiences.

Effects of the project

The effect of your irrigation project is likely to be reduction in energy use and/or use of energy sources that have lower emissions. These effects may be increased by improved operation and maintenance procedures.

Estimation of effects for the reference case and project

You may quantify emission reductions from improved irrigation management in the following ways:

- Reductions in energy use could be based on fuel and utility cost reductions and the resultant savings in fuel.

- Where energy is saved by another entity (for example, the Central Arizona Project has nine pumping stations on its canals) because the farmer reduced water volume, estimates of reductions would be based on the equivalent carbon dioxide reduction from the energy saved.

6.4.5 Grazing Land Improvement

Grazing lands worldwide provide a significant opportunity to reduce net emissions of greenhouse gases by capturing carbon in soils and below-ground biomass and by reducing the need for more energy-intensive processed feed for livestock. In the United States, grazing land resources represent 45 percent of non-federal rural lands, including rangelands (63 percent), pasturelands (21 percent), haylands (10 percent) and grazed forestlands (6 percent)—a total area of 634 million acres (USDA,SCS 1987).

The potential for increased carbon sequestration through the improvement of grazing land conditions is supported by numerous studies. Globally, rangeland soils have been determined to contain 150-300 percent as much carbon as does above-ground biomass (Kinsman and Trexler 1993). In U.S. studies at the Jornada Experimental Range (Texas), soil organic carbon (SOC) in rangelands is twice that in croplands (Johnson et al. 1992). Lands in the Conservation Reserve Program (CRP) that were managed for carbon sequestration over five years showed a 5 to 16 percent improvement in the amount of SOC (Gebhart et al. 1992).

A permanent grassland environment stores more SOC than does cropland agriculture, and grazing land stimulates more below-ground biomass that stores more carbon. Grasses, forbs, and shrubs represent the primary vegetative components found on rangelands. Grazed rangelands convert six times more energy to below-ground biomass compared to above-ground biomass. Ungrazed rangelands deliver only three times as much energy to below-ground biomass than was allocated for above-ground biomass (Sims and Singh 1978).

Generally greater above-ground biomass indicates greater below-ground biomass on rangeland sites. Rangelands in good and excellent condition will typically have greater above-ground biomass than these sites in poor or fair condition. Blue grama rangelands were found to correlate to higher organic carbon in near climax or excellent range condition (Spaeth 1990). Studies using the Simulation of Production and Utilization of Rangelands (SPUR) model, 1991 version, on data collected by the SCS/ARS Range Study Team, have shown a definitive trend toward higher organic carbon values on tallgrass sites compared to shortgrass sites.

Improvement of conditions in grazing lands will generally offer effective energy savings to livestock producers. Livestock producers who have integrated state-of-the-art grazing systems in New York have reduced the cost of dairy production by 19 percent (Sweetland 1993). Most of this savings has been achieved though the reduction of feeding harvested or processed feeds. Reducing processed feed in livestock operations places more reliance on low energy pastures from grazing lands, thereby significantly reducing fossil fuel expenditure directly by reducing fuels expended during harvesting, processing of livestock feeds, and spreading manure. Fossil fuels are saved indirectly by a reduction in the use of mineral fertilizers needed in the production of high-yielding grain and silage crops.

Although potential biomass production levels are generally considered least in arid and semiarid environments, long-term sequestration is at a high level because of the low level of natural oxidation that occurs. Annual dry biomass of irrigated halophytes (saline-tolerant plants) has been shown to store large quantities of carbon per hectare (Glenn 1993).

Reference case

The reference case could be cropland, or unmanaged rangeland or grassland, with appropriate measurements or estimates of SOC and perhaps other carbon sequestration data.

Effects of the project

The major effect of improving grazing land conditions (even though it is a slow, 10 to 20+ year process) will be an increase in the sequestration of atmospheric carbon, partitioned in above- and below-ground sectors of grazing land ecosystems. Other effects might be increasing the efficiency of large ruminant livestock production, thereby reducing (per unit of production) methane emissions from livestock and reducing the need for processed feed, thus eliminating or reducing the energy inputs involved in the production of processed feed.

Estimation of effects for the reference case and the project

As an alternative to using direct measurement and/or engineering methodologies to estimate the carbon levels associated with your activities before and after implementing a change in farming operations, you may wish to use a process simulation model such as SPUR (USDA 1987), a comprehensive rangeland ecosystem model that was developed as a tool for both research and management. The SPUR model has five components: climate, hydrology, plant, animal (both domestic and wildlife), and economics. In the plant component, net photosynthesis is the basis for predicting total above-ground biomass. Carbon and nitrogen levels are estimated and tracked by the model through the life-cycle process, including standing green, standing dead, live roots, dead roots, seeds, litter, and soil organic matter.

This model can be used to predict accumulation of SOC in range and grasslands of the United States. Inputs required by the model are initial biomass content, and parameters that describe the species, photosynthesis level, transpiration rate, and nitrogen utilization.

6.4.6 Efficient Nutrient Management for Crop Production

High-yield production agriculture can be sustainable agriculture. They are not mutually exclusive. As conservation and agronomic practices are adapted, nutrient use efficiency increases, erosion is slowed, the potential for nonpoint source water pollution drops, and crop yields go up. More productive plants will require more nutrients—perhaps twice the demand of current plants. As that happens, less land is needed, so more fragile land can be converted to permanent ground cover, set aside for wildlife protection and used for recreational purposes.

Plant nutrients from all sources, including commercial fertilizers, animal manures, human wastes, legumes, native soil fertility, and plant residues can contribute to the total yield of crops. Once in the soil, all nutrient sources undergo various transformations that result in crop uptake and use. These transformations are all subject to other processes, such as potential leaching of nitrate-N into groundwater, denitrification, N volatilization, release of nitrous oxide into the atmosphere, nutrient loss by erosion, and so on.

Adding nitrogen to the soil results in some nitrous oxide emissions, a very effective greenhouse gas. But how much is emitted depends upon many factors, including the quantity, the acreage, the form in which nitrogen is added, the manner of application, and the frequency of application.

Efficient nutrient management helps to maximize the sum of all benefits—economic and environmental. Appropriate trade-offs must be made between using nutrient sources in a manner that results in the greatest economic and agronomic benefit to the farmer, while conserving energy and otherwise protecting the environment. While energy requirements for the production of commercial fertilizers are high, so are energy needs for the use of animal manures, human wastes, and the production of legumes. Other factors must be considered as well.

- Nutrient contents of manures are low compared to commercial fertilizers, so large quantities must be applied to each acre. This requires significant amounts of fuel and is usually labor intensive. Economics prevent the efficient hauling of manure more than about 10 miles from the source.

- Legumes provide nitrogen, but they also require larger amounts of phosphorus, potassium, and other nutrients to be effective nitrogen producers. Each ton of alfalfa, for example, removes more than 60 pounds of potassium oxide per acre if the crop is harvested.

- All forms of nitrogen added to the soil result in the formation of nitrous oxide.

The efficiency of nutrient use in agriculture is greatly improving as a result of farmer implementation of science-based technologies, including conservation tillage practices to reduce erosion, hold more nutrients in the soil, and improve infiltration. Some of the ways farmers can ensure that applied nutrients get into the plant are through testing and plant analysis. Precise application equipment, timing and placement of nutrients also help, by matching nutrient levels to crop needs. In addition, encapsulating fertilizer to slow the release of nitrogen and using nitrification inhibitors will reduce nitrous oxide emissions.

All nutrient sources that are valuable to the farmer can be managed in ways that help to reduce erosion, to reduce nitrate-N in groundwater, and to control emissions of greenhouse gases such as nitrous oxide. Further, as nutrient use and crop yields increase, more carbon can be sequestered.

Reference case

In developing your reference case for nutrient management, you need to list the practices that would have been used, except for the project. For example—

- Crop rotation
- Nutrients in the soil (soil test)
- Seeding rate
- Nitrogen management (number and type of applications)
- Pest control (methods and restrictions).

Changes in any or all of these practices can result in environmental advantages, including soil carbon sequestration.

Effects of the project

If, through good management practices, you apply the needed nitrogen and increase crop productivity, you may decrease nitrous oxide emissions in two ways: (1) you can allow some land to remain uncultivated (because your cropland will be more productive) and (2) the nitrogen you apply will be used more efficiently by the plants if you apply the amount they need where they need it in the root zone. In addition, you will reduce carbon dioxide emissions because less land is under cultivation.

Estimation of effects for the reference case and project

The emissions effects of best nutrient management practices are difficult to estimate. No standard method exists to perform field measurements of nitrous oxide, and factors derived from research literature may be problematic. The reductions in carbon dioxide emissions can be derived from the emissions factors associated with cultivation of certain crops. If you convert the noncultivated land to permanent vegetative cover (grazing land, for example), you may also determine the amount of carbon sequestered by that activity. Example 6.4 illustrates some of the aspects of reporting a nutrient management project.

Example 6.4 - Association Report of a Nutrient Management Project

A group of farmers in central Virginia formed the Best Rural Management Practices Club in order to demonstrate and quantify the benefits of conservation and energy efficiency in nutrient management. They began by calling on university extension service scientists to measure several parameters over one growing season and to work with them in designing and implementing best management practices (BMPs) over the next growing season. Thus, they had the data to develop a historic reference case.

The activities that became defined for basic and project cases included the following:

Example 6.4 - (cont'd)

Practice	**Previous Management (Reference Case)**	**BMP Management (Project Case)**
Rotation	Sometimes	Always
Soil test	Unbalanced nutrients	Balanced nutrients
Seeding rate	1.5 bu/A	22 seeds/ft row
N management	Single application	Tissue test; split applications
Pest control	No integrated pest management or scouting	Use integrated pest management and scouting

Beyond their expectations, they achieved the following results:

- Higher yields: 85 bu/A with BMP vs. 50 bu/A
- Higher N use efficiency: 0.65 bu/lb with BMP vs. 0.50 bu/lb
- Lower production costs: $2.44/bu with BMP vs. $3.20/bu
- Less N left in the soil from BMP: 34 lb/A vs 40 lb/A
- More CO_2 captured: 3.8 more tons in total with BMP.

Although their primary purpose was to increase crop productivity relative to nutrient inputs, the club members noted that they had achieved an increase in carbon sequestration. However, they realized that the increase was part of the carbon flow and would be lost as the plants were used after harvest. As part of their efforts to publicize and extend the use of BMPs, they wanted to submit a report under the EPAct 1605(b) program, but they were puzzled about the relationship between their crop-related accomplishments and possible emissions reductions.

They knew, for example, that applying nitrogen means that nitrous oxide is emitted from the agricultural operation. However, John Johnston, a scientist from the university extension service, informed them that scientists do not know how to measure these emissions in the field and that no default factors existed. Thus, even though the group felt that their more efficient use of nitrogen actually resulted in *fewer* nitrous oxide emissions, they had no basis on which to estimate the reductions.

They decided that the only effect they could estimate with any confidence was less fuel use because they were more efficient about applying nutrients and controlling pests. For the hundred acres, the difference between the reference case and the project case was about the same difference between conventional till and minimum till, as they read the definitions from the conservation district. Using Table 6.2 from the technical support document for agriculture, they estimated 7.7 kilograms of carbon per hectare saved (52.8 - 45.1 = 7.7). One hundred acres was converted to 40 hectares, then multiplied by 7.7 kilograms for a total of 308 kilograms of carbon saved. Multiplying the kilograms of carbon saved by 3.67 (the conversion factor from Appendix D), they estimated an emissions reduction of 1,131 kilograms of carbon dioxide.

After some discussion, the club members agreed to report the carbon sequestration and note separately in the club's report that there were nitrous oxide emissions in both the reference and project cases, but that changes in emissions could not be quantified. They agreed that their report next year would reflect land converted to grass cover and again mention the nitrous oxide. If methods were developed to quantify the nitrous oxide reductions, they could amend their reports in later years.

6.4.7 Growth of Biomass as a Renewable Energy Source

Biomass is currently being used to produce liquid fuels such as ethanol, methanol, and biodiesel as well as a fuel to produce electricity. In order to meet clean air standards in many cities across the nation, the Clean Air Act Amendments require the use of alternative fuels for motor vehicles. The Electric Power Research Institute (EPRI) is promoting the use of biomass as an alternative, renewable source of energy that will reduce the net emissions of greenhouse gasses.

DOE is promoting research to identify a variety of efficient, high-yielding plants as a source of biomass and cost effective technologies to convert biomass to liquid fuels and/or electricity. USDA is supporting research to convert grains and vegetable oils to biofuels. Biomass crops can be woody (trees or short rotation woody biomass), herbaceous perennial (for example, switch grass), or herbaceous annual (such as corn or sorghum).

The production of biomass has an impact on carbon emissions in three different ways. First, it can substitute for fossil fuels. The conversion of biomass to energy releases $C0_2$ into the atmosphere. The photosynthesis process recycles $C0_2$ from the air and converts it into biomass. Therefore, any quantity of biomass substituted for fossils fuels will reduce the net increase of $C0_2$ in the atmosphere that would occur from combustion of the fossil fuel.

Second, the difference in fuel and agricultural chemical requirements to produce biomass versus other crops will have an impact on carbon emissions to the atmosphere.

The third impact of producing biomass is the sequestration of carbon in the soil. On the average, there is less soil disturbance in the production and harvesting of biomass crops than for annual crops. This should reduce oxidation and release of carbon to the atmosphere and help sequester carbon in the soil (except if the biomass crop is an annual such as energy sorghum).

Reference case

The most credible reference case may be what the land was used for in the year before you initiated the biomass project. If you change crops (for example, from a food crop to switch grass), the energy inputs in terms of equipment, fertilizer use, and processing would constitute the major portions of the reference case.

Effects of the project

When examining biofuel projects, you must consider life cycle effects. For example, DeLuchi (1991) states that the growth of corn for biofuels actually increase greenhouse gas emissions because corn production is extremely fuel- and chemical-intensive, though other research analysis (for example, Graham et al. 1992) indicates that life cycle analysis yields emissions reductions.

Estimation of effects for the reference case and project

Estimating project effects, especially on a life cycle basis, is a complex, perhaps time-consuming process. For example, you should take into account fossil fuel requirements for the production of the crop and the production of nitrogenous fertilizers for both the reference and project cases. You need to know the conversion efficiencies to liquid fuel or electricity and the energy substitution properties of various fuels (Graham et al. 1992). The following example illustrates the process of estimating carbon dioxide reductions from growing biomass and using fuels made from that biomass.

Example 6.5 - Report of a Biomass Project

Don Marshall, a Midwestern farmer, harvested his hybrid poplars (a short rotation woody crop) in 1993 and wished to report the resulting emissions reductions under the EPAct 1605(b) program. He had followed management practices reported in the research literature (Turhollow and Perlack 1991) and so felt he could use the assumptions and factors from an associated research article (Graham et al. 1992).

Marshall's yield was 11.3 Mg/ha, or a total of approximately 1500 Mg of biomass that would be converted to ethanol to displace gasoline. The ethanol yield from each megagram of biomass is 344 liters; Marshall's 1500 Mg would thus yield

1500 Mg • 344 L/Mg = 516,000 liters

The current wood-to-ethanol technology produces a surplus of 184 kWh of electricity per dry megagram of wood (taking into account that some electricity is used in processing the feedstock). Marshall's electricity yield was

1500 Mg • 184 kWh/Mg = 276,000 kWh = 276 MWh

To calculate the emissions saved from substituting ethanol for gasoline, Marshall (following Graham et al. 1992) assumed that the carbon content of gasoline is 0.723 kg/L and one liter of ethanol can substitute for 0.8 L of gasoline; therefore, the carbon offset by the fuel substitution is

516,000 L • 0.8 = 412,800 L gasoline
412,800 L gasoline • 0.723 kgC/L = 298,454 kg C

This figure must be adjusted for the carbon emissions involved in producing the woody crops; again, following Graham et al. (1992), Marshall used the carbon emissions calculated for his management regime (0.29 Mg/ha), multiplying that by his 133 hectares:

133 ha • 0.29 MgC/ha = 38.57 Mg C = 38,570 kg C

The final carbon offset figure is thus 298,454 - 38,570 = 259,884 kg C. This figure would be converted to carbon dioxide emissions using the conversion figure in Appendix D:

259,884 kg C • 3.67 = 953,774 kg CO_2

To determine the emissions saved from the electricity generated by the biomass, Marshall used the default emissions factor for his state (Illinois) from Appendix C. The carbon dioxide emissions factor for Illinois is 1137.6 lb/MWh, so the emissions reduction from 276 MWh generated by Marshall's biomass is

276 MWh • 1137.6 lb/MWh = 313,978 lb = 142,394 kg CO_2

Adding the figures for carbon dioxide reductions resulting from fuel substitution and the figure for electricity generation, Marshall arrived at the following total, which he reported under the EPAct 1605(b) program:

953,774 kg CO_2 + 142,394 kg CO_2 = 1,096,168 kg CO_2 = 1,096 metric tons CO_2

In his report, Marshall identified his local utility and the transport company that bought the ethanol as other potential reporters.

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