

4. Carbon Sequestration

Background

Carbon sequestration plays an important role in the global carbon cycle. Green plants remove (sequester) carbon from the atmosphere through photosynthesis, extracting carbon dioxide from the air, separating the carbon atom from the oxygen atoms, returning oxygen to the atmosphere, and using the carbon to make biomass in the form of roots, stems, and foliage.

Every year in the United States and throughout the world a very large amount of carbon dioxide—on the order of 100 billion metric tons—is sequestered in biomass.³⁷ At the same time, carbon is released to the atmosphere from vegetative respiration, combustion of wood as fuel, degradation of manufactured wood products, consumption of biomass for food by animals, and the natural decay of expired vegetation. The net numerical difference, or flux, between carbon sequestration and release can be viewed as a measure of the relative contribution of biomass to the carbon cycle. World flux associated with Earth's living matter is difficult to measure, but biomass is thought to provide a net "sink" equivalent to about 0.7 billion metric tons carbon dioxide per year.³⁸

Forests can play an important role in offsetting human-produced carbon emissions. On average, trees are approximately 25 percent carbon by weight (live trees are approximately 50 percent water by weight, and oven-dried wood is approximately 50 percent carbon by weight).³⁹ The amount of carbon a plant can sequester depends on a number of variables, including species and age, but can be quite large. For example, one large sugar maple tree is capable of removing more than 450 pounds of carbon dioxide from the atmosphere in a year. At that rate, preserving 29 trees per operating automobile in the

United States would offset all U.S. automobile-related carbon dioxide emissions.⁴⁰

Carbon sequestration on a national scale is substantial. The U.S. Environmental Protection Agency, relying heavily on the work of U.S. Forest Service Researchers Richard Birdsey and Linda Heath, estimates annual U.S. carbon sequestration (generally defined according to the guidelines of the Intergovernmental Panel on Climate Change) at 211 million metric tons carbon equivalent,⁴¹ which offsets approximately 11 percent of annual U.S. anthropogenic emissions of greenhouse gases.⁴²

Projects Reported

Sixty-six entities reported projects involving forestry or natural resources that sequestered carbon or reduced emissions in 2000 (Table 14). The reporters included 55 electric utilities, 3 operating subsidiaries of an independent power producer, 3 nonprofit organizations, 2 petroleum companies, a computer chip manufacturer, a real estate company, and a company providing forestry and habitat restoration services. A total of 494 carbon sequestration projects were reported, an increase of 12 percent from the 1999 data year. Forestry projects were the most commonly reported project type, accounting for 26 percent of all the projects reported for 2000 (see Table 2 in Chapter 1). The reported forestry projects were dispersed over a wide geographic area, including 48 States and 7 foreign countries. A total of 422 domestic and 72 international forestry projects were reported. Sixty-four of the foreign projects represent individual equity shares in a single forest preservation project in Belize, the Rio Bravo Carbon Sequestration Pilot Project.

The total sequestration reported on Form EIA-1605 for 2000 declined by 6 percent from the previous year, to

³⁷Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual*, IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 3 (Paris, France, 1995), p. 5.2, web site <http://www.iea.org/ipcc.htm>.

³⁸Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 77.

³⁹R.A. Birdsey, *Carbon Storage and Accumulation in United States Forest Ecosystems* (Washington, DC: USDA Forest Service, 1992), p. 12.

⁴⁰Average mileage and fuel consumption for passenger cars from Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000), p. 53. Carbon dioxide emissions per mile driven and gallon of motor fuel from U.S. Department of Energy, *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*, DOE/PO-0028 (Washington, DC, October 1994), Vol. 2, p. 4.19.

⁴¹U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2000), p. 6-2, web site <http://www.epa.gov/globalwarming/publications/emissions/us2000/index.html>.

⁴²U.S. anthropogenic greenhouse gases emissions were 1,903.6 million metric tons carbon equivalent in 2000. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), p. vii, web site <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

9,010,021 metric tons carbon dioxide (Table 14). Direct emission reductions associated with forest management projects reported for 2000 totaled 1,041 metric tons carbon dioxide. Reductions or sequestration reported on Form EIA-1605EZ declined from 71,048 metric tons carbon dioxide equivalent for 1999 to 5,081 metric tons carbon dioxide equivalent for 2000. The decline resulted largely from the absence of a 2000 submission from a reporter that reported sequestering or reducing emissions of 68,194 metric tons carbon dioxide for 1999 on Form EIA-1605EZ.

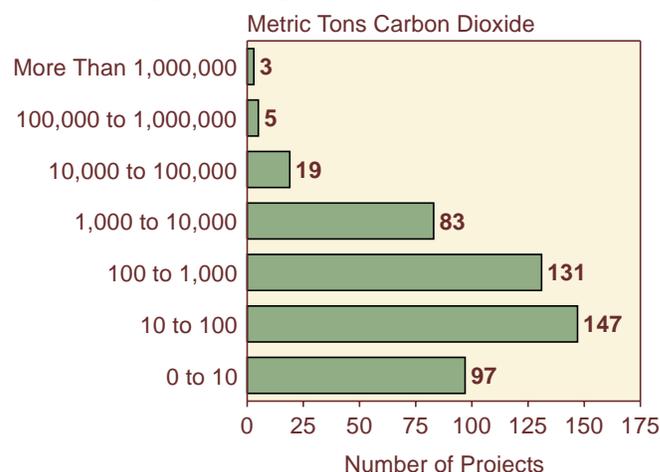
A significant number (11 percent) of the reported projects were urban forestry projects, involving the planting of trees in urban and suburban areas.⁴³ Urban forestry projects are typically much smaller than forestry projects undertaken in rural or wilderness areas. The average carbon dioxide sequestration reported per urban forestry project for 2000 was just 292 metric tons. Projects in rural or wilderness areas are sometimes large: 8 such projects sequestered more than 100,000 metric tons carbon dioxide each in 2000 (Figure 11). For the 469 projects for which data were reported, average sequestration for 2000 was 19,211 metric tons carbon dioxide equivalent per project.

Of the sequestration projects reported for 2000, most (398 or 81 percent) involved some kind of tree planting, which included afforestation, reforestation, urban forestry, and woody biomass production or agroforestry (Table 15).⁴⁴ These projects accounted for 13 percent of the sequestration (and related direct and unspecified emission reductions) reported for 2000. Although only 41 forest preservation projects were reported, they accounted for 85 percent of the sequestration reported

for 2000. Ninety-two percent of the total sequestration for 2000 was reported on behalf of foreign projects, which include some very large forest preservation and agroforestry initiatives.

More than half (58 percent) of the reported forestry projects were undertaken in part to fulfill commitments made under the Climate Challenge program. Thirty of the investors in the UtiliTree Carbon Company each submitted reports on the six projects that were operational in 2000. All but two of the investors also participate in Climate Challenge. In addition, 38 (8 percent) were undertaken as part of the U.S. Initiative on Joint Implementation (USII). Established under the Climate

Figure 11. Carbon Sequestration Projects by Amount of Carbon Sequestered, Data Year 2000



Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

Table 14. Number of Projects and Sequestration and Net Reductions Reported for Sequestration Projects, Data Years 1994-2000

Data Year	Number of Reporters	Number of Projects	Sequestration (Metric Tons Carbon Dioxide)	Net Emission Reductions (Metric Tons Carbon Dioxide)		
				Direct	Indirect	Unspecified ^a
1994	40	78	746,545	189	23,127	2,470
1995	62	199	1,190,754	378	48,730	7,569
1996	67	198	8,676,591	1,291	32,215	2,519
1997	75	309	9,849,807	6,160	—	5,466
1998	73 ^(R)	355 ^(R)	12,490,927	716	—	4,025
1999 ^(R)	70	442	9,623,599	3,406	—	71,048
2000	66	494	9,010,021	1,041	—	5,081

^aUnspecified reductions represent quantities reported on Form EIA-1605EZ, which does not distinguish between direct and indirect emission reductions.

(R) = revised.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

⁴³Urban forestry projects include projects reported as general tree planting projects on Form EIA-1605EZ.

⁴⁴Afforestation is the planting of trees in unforested areas. Reforestation is the planting of trees in forest areas that have recently been harvested. Urban forestry is the planting of trees individually or in small groups in urban or suburban settings. Agroforestry is the cultivation of trees in plantations for fuel or fiber.

Change Action Plan (CCAP),⁴⁵ the USII is a pilot program that seeks to encourage foreign-based emission reduction and carbon sequestration projects conducted by U.S. and non-U.S. partners. The following USII-approved forestry projects were reported to the Voluntary Reporting Program: the Rio Bravo Carbon Sequestration Pilot Project (Belize) and the Noel Kempf Mercado Climate Change Action Project (Bolivia).

Afforestation and Reforestation

Of the sequestration projects reported for 2000, 342 (69 percent) involved either afforestation or reforestation. The carbon sequestration and emission reductions reported for these projects totaled 627,902 metric tons carbon dioxide, representing 7 percent of the total sequestration reported for 2000. All the afforestation and reforestation projects reported for 2000 were domestic.

American Forests, a nonprofit conservation organization, and American Electric Power, Inc. (AEP), a large investor-owned utility, together accounted for more than one-half (56 percent) of the 342 afforestation and reforestation projects reported for 2000. American Forests reported a total of 164 projects under its Global ReLeaf Forests program, 30 of which were initiated in 2000. Global ReLeaf supports the restoration of U.S. forest ecosystems that have been damaged by natural events or human actions. American Forests reported that, through 2000, it has planted a total of 14.4 million trees, which sequestered 108,880 metric tons carbon dioxide in 2000—enough to offset carbon dioxide emissions from more than 100,000 automobiles.⁴⁶ All but 6 of

the Global ReLeaf projects involved reforestation. AEP reported 26 afforestation projects on land owned by its operating companies, which sequestered a reported 90,204 metric tons carbon dioxide in 2000. Two of the projects were initiated in 2000.

Urban Forestry

A total of 55 urban forestry projects were reported for 2000 by 36 reporters, all but two of which were electric utilities. For the 53 urban forestry projects for which estimates were developed, a total of 15,476 metric tons carbon dioxide was sequestered in 2000—an amount that would offset less than 0.1 percent of the emissions from a 1,000-megawatt coal-fired power plant.⁴⁷

Urban forestry projects are unique, in that under some circumstances they can reduce energy consumption as well as sequester carbon. Shade trees planted near buildings reduce summer air conditioning requirements; in addition, trees can also act as windbreaks, reducing heating needs in the winter. Although the emission reductions associated with energy effects of urban forestry can be several times the sequestration benefits on a carbon dioxide equivalent basis, they are difficult to estimate. As a result, only eight reporters submitted information on energy-related emission reductions for eight urban forestry projects (the reductions are included in the energy end-use reduction totals in Chapter 3).

Forest Preservation

Forest preservation projects sequester carbon by avoiding the harvesting of timber or clearing of land and thus

Table 15. Number of Sequestration Projects Reported by Project Type, Data Years 1994-2000

Data Year	1994	1995	1996	1997	1998	1999	2000
Afforestation	26	38	38	91	102	159	179
Reforestation	15	82	80	92	110	139	167
Urban Forestry	27	41	42	48	56 ^(R)	57 ^(R)	55
Modified Forest Management	12	20	10	34	42	43	43
Woody Biomass Production and Other Agroforestry	8	14	2	3	3	3	3
Forest Preservation	2	23	30	40	47	39	41
Conservation Tillage	1	1	1	2	2	2	2
Other Projects	3	4	6	11	4	11	11

(R) = revised.

Notes: Urban forestry includes general tree planting projects reported on Form EIA-1605EZ. Some projects are counted in more than one category. For example, an afforestation project reported by Alliant Energy also included modified forest management activities.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

⁴⁵President William J. Clinton, The Climate Change Action Plan (Washington, DC, October 1993), Appendix II, web site <http://www.gcrio.org/USCCAP/toc.html>.

⁴⁶Average mileage and fuel consumption for passenger cars from Energy Information Administration, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, August 2001), p. 57. Carbon dioxide emissions per mile driven and gallon of motor fuel from U.S. Department of Energy, *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*, DOE/PO-0028 (Washington, DC, October 1994), Vol. 2, p. 4.19.

⁴⁷Assuming a power plant with a heat rate of 12,000 Btu per kilowatt-hour operating at 85 percent availability using subbituminous coal emitting 212.7 pounds of carbon dioxide per million Btu.

preventing the release of stored carbon. A total of 41 forest preservation projects were reported for 2000 by 33 reporters. All but one of the projects were foreign. The two largest forest preservation projects were reported by AES Hawaii and AES Shady Point, subsidiaries of the AES Corporation. Together, these two projects sequestered a reported 5.68 million metric tons carbon dioxide in 2000, representing 72 percent of the total sequestration reported for forest preservation projects.

Two utilities (AEP and PacifiCorp) and a petroleum company (BP) reported on the Noel Kempf Mercado Climate Action Project in Bolivia, which was accepted by the USJI in November 1996. The project, which involves the preservation of 634,286 hectares of land on the southern and western boundary of the Noel Kempf Mercado National Park by incorporating it into the park, includes the following components: (1) carbon dioxide emission reductions through the cessation of logging activities and the protection of forest land from conversion to agricultural use; (2) protection, regeneration, and preservation; and (3) leakage prevention.⁴⁸ The sequestration reported by the three partners in the project totaled 1.88 million metric tons carbon dioxide for 2000.

The Rio Bravo Carbon Sequestration Pilot Project, a forest preservation project in Belize, was included in the reports submitted by 30 utilities, each of which reported its prorated share of the total sequestration for the project. Begun in 1995, the project is being undertaken through a partnership between Cinergy Corporation, DTE/Detroit Edison, PacifiCorp, Wisconsin Electric Power Co., the UtiliTree Carbon Company, the Nature Conservancy, and a Belizean nongovernmental organization (Programme for Belize). The project includes the purchase of a 14,400-acre parcel of endangered forest threatened with conversion to agriculture.

The entire Rio Bravo Carbon Sequestration Pilot Project sequestered an estimated 105,924 metric tons carbon dioxide in 2000, of which 103,468 metric tons (98 percent) was reported to the Voluntary Reporting of Greenhouse Gases Program.⁴⁹ This represents an 83-percent decline from the sequestration reported for 1999, which occurred because the preservation of the forest is nearing completion. The reported carbon sequestration for this project was estimated by defining a reference case that assumes a profile of carbon releases that would

have occurred if the project had not been undertaken and the forest had been converted to agriculture. The estimated carbon sequestration equals the projected avoided carbon releases. Project completion will occur when the conversion to agriculture would have been completed under the reference case scenario.

Only one domestic forest preservation project was reported, by Alliant Energy, which reported sequestering 1,597 metric tons carbon dioxide in 2000 by maintaining forested buffer lands around its power plants.

Modified Forest Management

Of the 43 modified forest management projects reported in 2000, 31 were associated with two related reduced-impact logging initiatives in Malaysia. The first initiative was a pilot project reported by PG&E Corporation.⁵⁰ Started in 1992, this project implemented new logging techniques with the goal of reducing logging damage by 50 percent. The new techniques include pre-cutting of vines, directional felling, and planned extraction of timber on impact-reducing skid trails. Thirty utilities reported their shares in the second initiative—a full-scale project sponsored by the UtiliTree Carbon Company that introduced reduced-impact logging practices to 2,422 acres of forest beginning in 1997. Together, the two initiatives increased sequestration by a reported 36,256 metric tons carbon dioxide equivalent in 2000.

Between 1991 and 2000, AEP selectively harvested more than 5,300 acres of upland central hardwood and bottomland hardwood stands to improve growing space relationships and maximize growth rates. The efforts increased sequestration on the affected tracts by a reported 15,981 metric tons carbon dioxide in 2000. DTE Energy/Detroit Edison conducted similar thinning operations in previously unmanaged wood lots and reported increasing sequestration by 1,398 metric tons in 2000. Enhanced forest management activities were also reported by Alliant Energy as a component of its afforestation project.

Forest Plantations

Forest plantations include woody biomass production and agroforestry. Woody biomass production is the cultivation of trees in intensively managed plantations for the purpose of producing fuel or fiber. Agroforestry

⁴⁸Leakage refers to the migration of logging and land-clearing activities that would have occurred in the preserve to areas outside the preserve, which would offset the sequestration achievements of the project.

⁴⁹Ten UtiliTree participants did not submit reports to the Voluntary Reporting Program for data year 2000, including one Canadian utility that is ineligible to report.

⁵⁰This project was originally sponsored by New England Power Company and reported by its parent company, New England Electric System (NEES) Company. In August 1998, USGen New England, Inc. (USGenNE) completed the acquisition of New England Electric System (NEES) Company's hydroelectric and fossil power generation business previously operated by New England Power. As part of the acquisition, the rights to the emission reductions and carbon sequestration achieved by this and other projects were transferred to USGenNE. For 2000, the activities previously reported by USGenNE were incorporated into the report submitted by its parent, PG&E Corporation.

involves mixing trees with annual crops to provide wind shelter, stabilize soil, and produce fuel wood and fruit crops.

Woody biomass production projects were reported by Minnesota Power and J.M. Gilmer and Company. Minnesota Power has negotiated contracts with land owners for the planting of hybrid poplars, which was conducted on 2,672 acres of cleared land between 1995 and 1997. The trees, which reportedly sequestered more than 22,000 metric tons carbon dioxide in 2000, will be harvested after 12 years for use by the forest products industry or as biomass for energy production. J.M. Gilmer and Company established a short-rotation cottonwood plantation on a river bottom site in Alabama. The cottonwoods will also be harvested on a 12-year rotation and used as biofuel (displacing fossil fuel) or for pulpwood. J.M. Gilmer and Company reported that this plantation sequestered 240 metric tons of carbon dioxide in 2000.

AES Thames reported an agroforestry project in Guatemala that involves establishing a plantation of fruit, pulp, and fuel wood trees. Using a revised estimation method, AES Thames reported that its project sequestered 370,000 metric tons carbon dioxide in 2000.

Conservation Tillage and Other Sequestration Projects

Not all the carbon sequestration projects reported for 2000 involved conventional forestry. Other projects reported involved conservation tillage, reuse of utility poles, and restoration of terrestrial, wetland, and marine habitats. The only new projects reported for 2000 were six marine habitat restoration projects reported by the Greater Caribbean Energy & Environment Foundation, which included planting of marshes, seagrass, coral, and coralline and calcareous algae.

Other previously reported carbon sequestration projects include the following: conservation tillage projects reported by PPL Corporation, and Alliant Energy; Commonwealth Edison's planting of Illinois prairie grasses on company properties and the reuse of utility poles; Conectiv Atlantic Generation's reclamation of 6 acres of wetland; and Entergy Services, Inc.'s wetland reclamation activities in Texas and Louisiana. Together, these projects sequestered a reported 71,005 metric tons of carbon dioxide in 2000.

