

Changes in This Year's Inventory Report

Each year the U.S. Greenhouse Gas Inventory Program not only recalculates and revises the emission and sink estimates for all years that are presented in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* but also attempts to improve the analyses themselves through the use of better methods or data as well as the overall usefulness of the report. A summary of this year's changes is presented in the following sections and includes changes in methodology in addition to updates to historical data. The magnitude of each change is also described. Table Changes-1 summarizes the quantitative effect of these changes on U.S. greenhouse gas emissions and Table Changes-2 summarizes the quantitative effect on U.S. sinks, both relative to the previously published U.S. Inventory (i.e., 1990-1999 report). These tables present the magnitude of these changes in units of teragrams of carbon dioxide (CO₂) equivalents (Tg CO₂ Eq.).

A number of significant methodological and data revisions have been made to this year's Inventory. Fuel consumption for electricity generation by non-utilities was removed from the industrial end-use sector and instead combined with electric utility consumption - thus creating a comprehensive "electricity generation" sector. A series of improvements were made to the estimate of CO₂ emissions and carbon storage from the non-energy use (NEU) of fossil fuels, including an enhanced analysis of storage and emissions for a set of fuels used as raw material inputs in petrochemicals production, as well as reallocating emissions from non-energy fuel uses in industrial processes to the Industrial Processes chapter (e.g., Iron and Steel Production), and, finally, accounting for the oxidation of non-combustion, non-biogenic fossil sources of methane. Methane emission estimates for industrial wastewater now include food processing, whereas they previously included only the pulp and paper industry. The Land-Use Change and Forestry chapter now includes estimates on changes in carbon stocks in urban trees. Significant revisions have also been made to estimates of SF₆ emissions from Magnesium Production and Processing and from Electric Power Transmission and Distribution Systems, based on newly reported data from industry. These revisions are among numerous others explained in detail below.

Changes in historical data are generally the result of changes in statistical data supplied by other agencies. Data sources are provided for further reference.

For methodological changes, differences between the previous Inventory report and this report are explained. In general, when methodological changes have been implemented, the entire time series (i.e., 1990 through 1999) has been recalculated to reflect the change.

Table Changes-1: Revisions to U.S. Greenhouse Gas Emissions (Tg CO₂ Eq.)

Gas/Source	1990	1995	1996	1997	1998	1999
CO₂	85.6	86.1	80.5	89.3	85.4	107.3
Fossil Fuel Combustion	(55.8)	(36.2)	(36.3)	(35.4)	(30.6)	(4.5)
Natural Gas Flaring	0.4	(4.9)	(4.8)	(4.5)	(4.6)	(5.0)
Cement Manufacture	NC	NC	NC	NC	NC	0.1
Lime Manufacture	+	+	+	NC	NC	+
Limestone and Dolomite Use	0.1	+	0.1	0.1	0.1	0.8
Soda Ash Manufacture and Consumption	+	+	+	(0.1)	NC	NC
Carbon Dioxide Consumption	NC	NC	NC	NC	NC	+
Waste Combustion	(3.5)	(4.5)	(4.4)	(4.3)	(4.9)	(4.1)
Titanium Dioxide Production ^a	1.3	1.7	1.7	1.8	1.8	1.9
Aluminum Production ^a	6.3	5.3	5.6	5.6	5.8	5.9
Iron and Steel Production ^a	85.4	74.4	68.3	76.1	67.4	64.4
Ferroalloys ^a	2.0	1.9	2.0	2.0	2.0	2.0
Indirect CO ₂ Emissions from CH ₄ Oxidation ^a	30.9	29.5	28.9	28.4	28.2	27.0
Ammonia Manufacture ^a	18.5	18.9	19.5	19.5	20.1	18.9
International Bunker Fuels	(0.1)	+	0.1	0.1	0.1	(2.0)
CH₄	6.8	7.1	5.8	1.3	2.9	0.9
Stationary Sources	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.8)
Mobile Sources	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)
Coal Mining	(0.7)	(1.0)	(1.0)	(0.6)	1.4	1.9
Natural Gas Systems	+	1.5	0.8	0.1	0.1	(3.2)
Petroleum Systems	(0.8)	(0.3)	+	+	0.1	0.4
Petrochemical Production	NC	+	+	+	+	+
Silicon Carbide Production	NC	NC	NC	NC	NC	+
Enteric Fermentation	(1.6)	(3.1)	(2.6)	(2.8)	(2.6)	(2.7)
Manure Management	2.8	3.8	3.5	3.2	2.8	3.2
Rice Cultivation	(1.6)	(1.9)	(1.8)	(2.1)	(2.2)	(2.4)
Agricultural Residue Burning	0.2	0.1	0.2	0.2	0.2	0.2
Landfills	(3.9)	(6.3)	(7.6)	(11.4)	(12.6)	(11.5)
Wastewater Treatment	13.1	15.0	15.1	15.5	15.7	16.1
International Bunker Fuels	0.1	0.1	0.1	0.1	0.1	0.1
N₂O	(9.6)	(12.2)	(11.1)	(14.3)	(7.4)	(9.0)
Stationary Sources	(0.8)	(0.8)	(0.8)	(0.8)	(0.7)	(1.1)
Mobile Sources	(3.4)	(6.4)	(5.2)	(5.5)	(5.1)	(4.7)
Adipic Acid	(3.4)	(2.4)	(3.0)	(5.6)	0.5	(1.3)
Nitric Acid	NC	NC	NC	NC	NC	(0.1)
Manure Management	+	+	+	+	+	+
Agricultural Soil Management	(1.9)	(1.9)	(2.0)	(2.3)	(1.9)	(2.0)
Agricultural Residue Burning	+	+	+	+	+	+
Human Sewage	(0.1)	(0.5)	+	+	+	0.2
Waste Combustion	NC	NC	NC	NC	NC	+
International Bunker Fuels	+	+	+	+	+	+
HFCs, PFCs, and SF₆	9.7	(0.5)	(3.2)	(6.4)	(10.9)	(15.8)
Substitution of Ozone Depleting Substances	NC	(2.2)	(3.4)	(4.1)	(4.8)	(5.4)
Aluminum Production	(1.2)	0.6	0.9	0.1	(1.1)	(1.1)
HCFC-22 Production	0.2	(0.1)	(0.1)	(0.1)	0.2	+
Semiconductor Manufacture	+	0.4	(1.6)	(0.5)	0.5	0.9
Electrical Transmission and Distribution	10.7	0.8	1.1	(1.2)	(5.6)	(10.2)
Magnesium Production and Processing	NC	+	(0.1)	(0.6)	(0.1)	+
Net Change in Total Emissions^b	92.5	80.5	71.9	70.0	69.4	83.4
Percent Change	1.5%	1.3%	1.1%	1.0%	1.0%	1.2%

+ Absolute value does not exceed 0.05 Tg CO₂ Eq.^a New source category relative to previous inventory.^b Excludes emissions from land-use change and forestry.

NC (No Change)

Note: Totals may not sum due to independent rounding.

Table Changes-2: Revisions to Net CO₂ Sequestration from Land-Use Change and Forestry (Tg CO₂ Eq.)

Component	1990	1995	1996	1997	1998	1999
Forests	19.1	(40.7)	(36.3)	144.5	145.6	143.0
Urban Trees ^a	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)
Agricultural Soils ^a	3.1	8.6	8.6	8.6	10.1	9.2
Landfilled Yard Trimmings	(1.3)	(0.2)	(0.1)	(0.1)	0.4	0.4
Net Change in Total Flux	(37.8)	(90.9)	(86.5)	94.4	97.4	94.0
Percent Change	3.6%	8.9%	8.5%	-9.6%	-9.9%	-9.5%

NC (No Change)

Note: Numbers in parentheses indicate an *increase* in estimated net sequestration, or a decrease in net flux of CO₂ to the atmosphere. In the “percent change” row, negative numbers indicate that the sequestration estimate has decreased, and positive numbers indicate that the sequestration estimate has increased. Totals may not sum due to independent rounding.

^aNew source category relative to previous inventory.

Methodological Changes

Emissions and Storage from Non-Energy Uses of Fossil Fuels

The following section addresses changes associated with estimation of CO₂ emissions from non-energy uses (NEU) of fossil fuels. These changes affect a number of source categories in both the Energy and Industrial Processes chapters, including:

- CO₂ from Fossil Fuel Combustion
- Waste Combustion
- Titanium Dioxide Production
- Aluminum Production
- Iron and Steel Production
- Ferroalloy Production
- Ammonia Manufacture

Among the most significant methodological changes made in last year’s inventory were a series of improvements in the estimation of CO₂ emissions and carbon storage from NEU of fossil fuels. This year, as in years past, these NEU emissions are addressed in the Energy chapter, as an adjustment to total potential energy emissions. This year’s inventory introduces several new improvements, and better integrates the characterization of non-energy fuel use with the estimation of emissions from industrial processes.

Most of the changes relate to an improved analysis of storage and emissions for a set of fuels used as raw material inputs in petrochemicals production: petrochemical

feedstocks, liquefied petroleum gas, pentanes plus, and natural gas (for “other uses”). For these fuels—collectively referred to as “feedstocks”—an empirically determined storage factor was developed. The storage factor is equal to the ratio of (a) carbon stored in the final products to (b) total carbon content of the feedstocks used as inputs to non-energy uses. Last year’s inventory used a storage factor for these fuels of 91 percent; revisions made this year changed the estimate by first accounting for net exports (i.e., approximately 9 percent of non-energy fuel consumption), and then applying a revised storage factor of 63 percent.

In addition, this year’s inventory makes several changes in its approach for handling non-energy fuel uses in industrial processes. In past years, most of the emissions from these processes were captured as part of the NEU storage and emissions calculations, and addressed in the Energy chapter of the inventory.¹ This year, the emissions are included in the Industrial Processes chapter in keeping with IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997).

These changes are summarized below, first addressing the feedstocks storage factor calculation, and then the changes in the integration of non-energy uses into the Industrial Processes chapter. The complete methods are described in the Energy and Industrial Processes chapters, and in Annex B.

¹ For example, petroleum coke used to produce carbon anodes for aluminum production was previously considered as non-energy fossil fuel use, and carbon emissions from aluminum production were accounted for in the Energy chapter.

Feedstocks Storage Factor

The approach for characterizing emissions from non-energy uses of feedstocks relies on a mass balance approach, in which total carbon is allocated between long-term storage in products and losses through emissive processes. The overall balance is expressed as a storage factor. This year's storage factor for feedstocks incorporates several new analyses:

- *Imports and Exports of Chemical Intermediates and Products.* To some degree, the energy flows tracked by the Energy Information Administration do not capture fossil-derived materials once they leave refineries labeled as “feedstocks,” and are thus no longer valued for their energy content. Although direct imports and exports of primary chemicals are included in EIA's statistics, imports and exports of some chemical intermediates and products produced by the chemical industry (e.g., xylenes, vinyl chloride, and polypropylene resins) are not covered. This year's analysis accounts for these flows—which results in an adjustment for net exports, thus lowering potential emissions—based on data collected by the National Petroleum Refiners' Association.
- *Energy Recovery from NEU Byproducts.* The chemical reactions in which fuel feedstocks are used are not 100 percent efficient, and unreacted feedstocks or byproducts of production may be combusted for energy recovery in industrial boilers. This year's inventory includes an estimate of CO₂ released by industrial boilers as a result of combustion of these byproducts. The estimate is based on newly available data from EIA's Manufacturers Energy Consumption Survey (MECS) for 1998. The survey includes data on the consumption for energy recovery of “other” fuels in the petroleum and coal products, chemicals, primary metals, nonmetallic minerals, and other manufacturing sectors. Of the improvements to the methodology made this year, this component has the greatest effect, increasing the amount of carbon emitted (versus stored).

- *Solvent Evaporation.* Some feedstocks are used to produce solvents. Most solvents are organic (thus containing carbon), and when emitted to the atmosphere, eventually oxidize into CO₂. Carbon emissions are the product of (a) total solvent tonnage released and (b) the average carbon content of the solvents. This year's inventory incorporates a more accurate estimate of the latter factor, based on newly available data categorizing solvent emissions by chemical species (last year's estimate was based on an assumed average carbon content).
- *Non-Combustion CO.* Similarly, some processes using feedstocks for non-energy uses emit CO, which eventually oxidizes to CO₂ in the atmosphere. This year's inventory includes emissions from non-combustion sources in the mass balance on carbon (combustion sources are accounted for as part of the fossil fuel combustion analysis).
- *Waste Combustion.* Last year's inventory addressed combustion of fossil-derived waste materials in the Waste chapter. This year waste combustion is incorporated in the Energy chapter because the vast majority of waste combustion is performed with energy recovery. Hazardous waste combustion is considered one of the processes through which feedstock carbon is emitted, and is among the components of the mass balance calculation of the storage factor.² Municipal waste combustion is addressed separately in the Energy chapter.
- *Assumed Fate of “Unaccounted for” Carbon.* As with last year, it was not possible to account for all reported feedstock carbon by tallying all carbon in products and emissions. Last year's inventory assumed that the “unaccounted for” carbon had the same proportions, in terms of storage and emissions, as the “accounted” for carbon. This year, most of the unaccounted for carbon was “found” through further investigation—primarily in the analysis of exports and energy recovery. To be conservative, and to reflect the fact that most of

² In last year's inventory, hazardous waste combustion was subdivided into energy recovery and incineration (i.e., combustion without energy recovery). This year's calculation included a large flow of carbon in the form of “Energy Recovery of NEU Byproducts”; a subset of this would involve combustion of hazardous waste. Thus, the storage factor for this year specifically incorporates only incineration of hazardous waste. See Annex B for details.

the newly “found” carbon was emitted—rather than stored—this year’s inventory assumes that all remaining carbon that is unaccounted for is emitted.

Integration of Non-Energy Uses and Industrial Processes

In some cases, it is difficult to make a distinction between CO₂ emissions from fossil fuels used in non-energy applications and CO₂ emissions from industrial processes. This year, five sources previously characterized as non-energy uses—and addressed in the Energy chapter—were recharacterized as Industrial Process emissions in keeping with the IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997):

- *Natural Gas used in Ammonia Production.* Ammonia is produced from natural gas, which is used as both a raw material feedstock and as a fuel for process heat in the ammonia production process. In previous inventory calculations, carbon emissions from the portion used as a raw material feedstock were accounted for under the non-energy use portion of the Energy chapter. In the current inventory, these emissions are calculated based on multiplying a newly developed emission factor by reported annual ammonia production. This year, natural gas used for ammonia production was classified as an industrial process, resulting in an average transfer of emissions of 19.2 Tg CO₂ Eq. from the Energy chapter to the Industrial Processes chapter from 1990 to 1999.
- *Industrial Coking Coal used in Iron and Steel Production.* Iron and steel production is an industrial process in which coal coke is used as a raw material (i.e., reducing agent) in the blast furnace process. In this year’s Inventory, production and use of coal coke for iron and steel production was classified as an industrial process use rather than a fuel use. Iron and steel production accounts for the major portion of consumption of coal coke in the United States. This year the total non-energy use of industrial coking coal, as reported by EIA, was adjusted downward to account for the consumption by the industry, as reported by the U.S. Geological Survey. The remaining industrial non-energy uses of coal coke—accounting for less than 5 percent of total consumption—have not been recharacterized as industrial process uses, and are still reported in the Energy chapter as non-energy use of

industrial coking coal. This change resulted in an average transfer of emissions of 73.1 Tg CO₂ from the Energy chapter to the Industrial Processes chapter from 1990 to 1999.

- *Petroleum Coke used in Ferroalloy Production.* In previous years, ferroalloy production data were adjusted such that production of miscellaneous alloys (i.e., 32-65 percent silicon) were not included in the emission calculation. This year’s calculation has been revised to include production of these miscellaneous alloys. The ferroalloy process uses metallurgical coke as a raw material. In previous years, consumption of coke in the ferrosilicon production process was not calculated explicitly. Emissions from coke consumption for ferroalloy production were accounted for in the calculations for industrial coking coal under fossil fuel combustion in the Energy chapter. This year, coke used for ferroalloy production was classified as an industrial process, resulting in an average transfer of emissions of 2.0 Tg CO₂ Eq. from the Energy chapter to the Industrial Processes chapter from 1990 to 1999.

In past years, metallurgical coke used in the production of ferrosilicon was assumed to be coal coke. However, it is now assumed that 100 percent of U.S. ferroalloy production is produced using petroleum coke using an electric arc furnace process, although it is possible that some ferroalloys may be produced with coking coal, wood, other biomass, or graphite carbon inputs. Carbon dioxide emissions from ferroalloy production for this inventory were calculated based on IPCC emission factors and annual ferroalloy production data. Consumption of petroleum coke for ferroalloy production was calculated from the CO₂ emissions based on the carbon content of petroleum coke. The calculated petroleum coke consumption for ferroalloy production was then subtracted from total non-energy consumption of petroleum coke reported by EIA.

- *Petroleum Coke used in Aluminum Production.* The aluminum production process uses carbon anodes that are manufactured from coal tar pitch and petroleum coke. In past years, consumption of petroleum coke and coal tar pitch for carbon anodes for aluminum production was considered as non-energy fossil fuel use, and carbon emissions from aluminum production

were accounted for in the Energy chapter. This year, emissions from petroleum coke and coal tar pitch used for aluminum production were reported under the Industrial Processes chapter. This resulted in an average transfer of emissions of 5.8 Tg CO₂ from the Energy chapter to the Industrial Processes chapter.

Carbon dioxide emissions from aluminum production were calculated based on IPCC emission factors and annual aluminum production data. Consumption of petroleum coke and coal tar pitch for aluminum production was calculated from the CO₂ emissions based on the petroleum coke and coal tar pitch content of the carbon anodes used in the process. The petroleum coke consumption was then subtracted from the total non-energy consumption of petroleum coke reported by EIA. The calculated coal tar pitch consumption was also factored into the mass balance calculation for Iron and Steel Production.

Additional changes to the estimates of CO₂ and PFC emissions for 1990 through 1999 are explained below in the section entitled Aluminum Production.

- *Petroleum Coke used in Titanium Dioxide Production.* The titanium dioxide production process (i.e., chloride process), which uses petroleum coke as a raw material, was not previously included in the Inventory. Previously, petroleum coke consumed in the titanium dioxide process was embedded in the reported non-energy use of petroleum coke in the Energy chapter, and the associated CO₂ emissions were included in the Inventory only indirectly through application of a storage factor to the non-energy use of petroleum coke. For the current Inventory, carbon emissions from titanium dioxide production are calculated based on an emission factor and titanium dioxide production data. The petroleum coke consumed for titanium dioxide production was then subtracted from the total non-energy consumption of petroleum coke reported by EIA. This year, petroleum coke used for titanium dioxide production was classified as an industrial process, resulting in an average transfer of emissions of 1.6 Tg CO₂ from the Energy chapter to the Industrial Processes chapter from 1990 to 1999.

Mobile Combustion (excluding CO₂)

The N₂O emission factors for light-duty gasoline trucks (LDGT), heavy-duty gasoline vehicles (HDGV), and motorcycles (MC) found in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997) have been revised. In the previous Inventory, N₂O emission factors for these vehicle types were estimated by using data on grams of CO₂/km (as a proxy for fuel consumption) taken from the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997) for each vehicle type as a scaling factor, and applying this factor to the passenger car N₂O emission factors to derive the LDGT, HDGV, and MC factors. This CO₂/km data, however, was found to contain inconsistencies and potential errors. To correct for these errors and use more country-specific information, U.S. miles per gallon (MPG) data were applied as proxy data for this Inventory. Fuel economy data were derived from a number of sources, including DOE's *Transportation Energy Data Book* (DOE 1993 through 2001), FHWA's *Highway Statistics* (FHWA 1996 through 2001), EPA and DOE's *Fuel Economy 2001 Datafile* (EPA, DOE 2001), and the *Vehicle Inventory and Use Survey* (Census 1997).

Previously, a static 8.7 percent of U.S. vehicle miles traveled (VMT) was assumed to be attributable to California for each year. (Due to stricter motor vehicle control technologies standards in California, the VMT in California is treated separately from national VMT to estimate emissions.) This assumption has been replaced using the percent of U.S. VMT represented by California for each year, as obtained from the Federal Highway Administration (FHWA 1996 through 2001).

Historically U.S. VMT data were obtained from EPA's Office of Air Quality Planning and Standards (OAQPS), as they redistribute FHWA VMT data into the vehicle categories for which emission factors exist. This redistribution was recalculated using fuel economy and consumption data from FHWA's Highway Statistics.³ Fuel economy and consumption data were disaggregated by fuel type using a number of sources, including DOE's *Transportation Energy Data Book* (DOE 1993 through 2001), FHWA's *Highway Statistics* (FHWA 1996 through 2001), EPA and DOE's *Fuel Economy 2001 Datafile* (EPA,

³ The existing VMT data from OAQPS was believed to contain some inconsistencies.

DOE 2001), and the Vehicle Inventory and Use Survey (Census 1997). These data were used to distribute national VMT estimates across vehicle categories. All of the revisions discussed above resulted in an annual average decrease of 0.1 Tg of CO₂ Eq. (2.2 percent) in CH₄ emissions and an annual average decrease of 5.2 Tg of CO₂ Eq. (8.2 percent) in N₂O emissions for 1990 through 1999.

Coal Mining

The methodology used to estimate emissions avoided at underground coal mines has changed from the previous Inventory. For most mines with recovery systems, coal mine operators and state agencies provided individual well production data for all coalbed methane wells. Previously, the amount of methane recovered was estimated based on reported gas sales and a pre-drainage timing factor. The new methodology produces a more realistic estimate of emissions avoided for mines that utilize pre-drainage wells for two reasons. First, the new methodology takes into account the location of a well to determine if the well should be included in the emissions avoided estimate. Many of the pre-drainage wells within a degas field adjacent to a coal mine were never inside the footprint of the mine workings. Second, the entire cumulative production of a pre-drainage well is credited toward emissions avoided for only the year in which it is mined through, and not spread out over several years. Recent research showed that the life of a well within the same degas field can vary greatly. Although the data used for annual gas sales was accurate, the methodology resulted in an overestimation due to the inclusion of production from pre-drainage wells that did not contribute to emissions avoided at the coal mine. This methodological revision resulted in average decrease of 0.1 Tg of CO₂ Eq. (less than 0.1 percent) in annual CH₄ emissions from coal mining for 1990 through 1999.

Petroleum Systems

In the Petroleum systems section of the Energy chapter, this year's inventory corrects the activity factors for thirteen methane emissions activities. The thirteen activities include separators (heavy and light crude oil), heater/treaters and compressors, pneumatic devices (high and low bleeds), vessel blowdowns, compressor blowdowns, compressor starts, chemical injection pumps, headers (heavy and light crude oil), and gas engines. Two changes were made in

how activity data were estimated. First, the base year for activity data estimation was changed. In the previous report, the activity data were based on Radian (1996a-e), which represented activity data for the year 1995. However, Radian activity data for these thirteen activities were found to be based on 1993 data rather than 1995 data. Therefore, this year's inventory applies Radian's activity data to the correct year, which is 1993, not 1995. Secondly, the drivers used to estimate activity data outside the base year were refined. In the previous inventory report, non-base year activity data were related only to changes in crude production. This year's inventory follows the Radian approach, which estimated the annual activity data by calculating arithmetic mean of component estimates based on oil well counts and oil production for the years 1990 through 1992 and 1994 through 2000. The magnitude of the combined changes was small. For example, the activity data for pneumatic devices used in this year's Inventory is 3.4 percent lower for the years 1990 to 1995 compared to the 1999 Inventory, but the same data have been increased by an average of 2.9 percent over the period 1996 to 1999 for this year's Inventory. These methodological revisions, together with the data changes described below, resulted in average decrease of 0.2 Tg of CO₂ Eq. (0.8 percent) in annual CH₄ emissions from petroleum systems for 1990 through 1999.

Natural Gas Flaring and Ambient Air Pollutant Emissions in Oil and Gas Activities

Estimates of natural gas flaring have been modified. The amount of natural gas flared was previously calculated by subtracting the vented gas emissions from the total amount of natural gas reported as vented and flared (EIA 2001a). However, for the current Inventory, it was assumed that all reported vented and flared gas was flared. This assumption is consistent with that used by EIA in preparing their emission estimates, under the assumption that many states require flaring of natural gas (EIA 2000b). Additionally, one facility in Wyoming had been incorrectly reporting CO₂ vented as CH₄. EIA has corrected these data in the *Natural Gas Annual* (EIA 2001a) for the years 1998 and 1999 only; data for previous years were corrected for this Inventory by assuming a proportionate share of CO₂ in the flare gas for those years as

for 1998 and 1999. These changes resulted in average decrease of 3.2 Tg of CO₂ Eq. (28.7 percent) in annual CO₂ emissions for 1990 through 1999.

The *National Air Pollutant Emission Trends Report 2000* revised the data for nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compound (NMVOC) emissions. These changes resulted in an average increase of 1,073 Gg (4.6 percent) in annual NO_x emissions, an average decrease of 196 Gg (0.2 percent) in annual CO emissions, and an average decrease of 4 Gg (0.1 percent) in annual NMVOC emissions for 1990 through 1999.

Indirect CO₂ from CH₄ Oxidation

Indirect CO₂ emissions from CH₄ oxidation originating from non-combustion fossil sources—coal mining, natural gas systems, petroleum systems, petrochemical production, and silicon carbide production—have been added to this year's report to account for the global warming properties of methane that occur in the atmosphere after the gas oxidizes. These indirect emissions of CO₂ are not accounted for in the GWP of CH₄. Emissions from this source category added an average of 29.3 Tg of CO₂ Eq. to total Energy chapter emissions.

Limestone and Dolomite Use

The method for estimating carbon dioxide emissions from limestone and dolomite use has been revised to include the thermic reduction of dolomite (CaMg (CO₃)₂) to magnesium metal vapor. This change, combined with the data changes described below, resulted in an increase in CO₂ emissions for 1999 of 1.0 Tg of CO₂ Eq. (9.9 percent). For the years 1990 through 1998, these updates resulted in an average increase in CO₂ emissions of 0.1 Tg CO₂ Eq. (1.8 percent).

Aluminum Production

The estimates of PFC emissions for 1990 through 1999 have been revised due to the receipt of additional smelter-specific information on aluminum production and anode effect frequency and duration. In addition, the estimates reflect updated information on the average frequency and duration of anode effects throughout the industry as reported in the 2000 International Aluminum Institute survey on

anode effects. The revision of Aluminum Production led to an average decrease of 0.4 Tg of CO₂ Eq. (2.8 percent) in annual CF₄ and C₂F₆ emissions for 1990 through 1999.

The estimates of CO₂ emissions for 1990 through 1999 have been revised to use emission factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997). These factors are 1.5 tons CO₂/ton Aluminum for Prebake and 1.8 tons CO₂/ton Aluminum for Soderberg. (Production in the United States is estimated to be split approximately 80/20 for Prebake/Soderberg.) Previously, a single emission factor of 1.47 tons CO₂/ton Aluminum was used. Other revisions to estimates of CO₂ emissions for 1990 through 1999 are explained above in the section entitled Emissions and Storage from Non-Energy Uses of Fossil Fuels. These revisions led to an average increase of 5.8 Tg of CO₂ Eq. in annual CO₂ emissions for 1990 through 1999.

Semiconductor Manufacturing

The estimates for 1990 through 1999 have been revised, reflecting a change in method. Both the previous method and the new method are based on the total annual emissions reported by the participants in the PFC Emission Reduction Partnership for the Semiconductor Industry. However, while the previous method used plant-specific emission factors, the new method uses layer-weighted capacities of plants and a per-layer emission factor to estimate total U.S. emissions. By considering both the average number of layers per chip and the silicon capacities of each plant, the new method more closely reflects the activity associated with PFC emissions. The methodological changes resulted in an average decrease of 0.1 Tg of CO₂ Eq. (1.5 percent) in annual HFCs, PFCs, and SF₆ emissions for 1990 through 1999.

Electric Power Transmission and Distribution Systems

Estimates of SF₆ emissions from electrical equipment have been revised based on two new pieces of information: (1) the reported 1999 and 2000 SF₆ emissions from EPA's utility partners in the SF₆ Emissions Reduction Partnership for Electric Power Systems, and (2) updated aggregate world sales of SF₆ to utilities between 1990 and 1999 as reported by the RAND Corporation for seven major world producers

of SF₆. These new data, which rely on industry statistics for SF₆ emission and consumption, have reduced the uncertainty in the reported emission estimates.

The revised emissions trajectory differs from the previously estimated trend both in magnitude and in direction. The earlier trend showed estimated emissions rising from 20.5 Tg CO₂ Eq. in 1990 to 25.7 Tg CO₂ Eq. in 1995, plateauing thereafter. The revised estimates show a trend in the opposite direction, with estimated emissions fluctuating around 32 Tg CO₂ Eq. between 1990 and 1994, and then steadily falling to 14.4 Tg CO₂ Eq. in 2000.

The previous estimates were based on estimated U.S. SF₆ production capacity in 1994, along with the assumption that 90 percent of this capacity was utilized, 75 percent of produced SF₆ was sold for electrical equipment, and 50 percent of this gas replaced emitted gas as of 1994. Although these estimates were consistent with industry norms and with current research regarding usage of SF₆ world wide, they were highly uncertain, particularly the estimate that 50 percent of the gas sold into the electric equipment sector replaced emitted gas. In addition, they did not account for imports, exports, or year-to-year changes in actual sales for electrical equipment. Information on these factors was not available. Instead, the estimates were simply grown at rates intended to match the growth rate of the electrical power industry. (The exception to this was during the years 1997 through 1999, when emissions estimates were held steady in recognition of the fact that emissions had probably fallen during the mid 1990s in response to the sharp rise in the price of SF₆. At that time, there was not sufficient information available to develop alternative estimates.) These revisions lead to an average increase of 3.1 Tg of CO₂ Eq. (15.0 percent) in annual SF₆ emissions from electric power systems for 1990 through 1999.

Magnesium Production and Processing

The emissions estimates for 1993 through 1999 were revised slightly to reflect changes to the estimated emission factors for different segments of the magnesium industry. The revisions result in an average decrease of 0.1 Tg CO₂ Eq. (1.6 percent) in annual SF₆ emissions for the years 1993 through 1999.

Manure Management

This Inventory includes an improvement to the calculations of MCFs for liquid/slurry and deep pit systems for the entire time series. Previously, these MCFs were calculated using the van't Hoff-Arrhenius equation and an annual average temperature. The calculation now uses a monthly average temperature to better represent seasonal variations that affect the production of methane.

The calculation of MCFs for all liquid systems (liquid/slurry, anaerobic lagoon, and deep pit) are based on the van't Hoff-Arrhenius equation and a monthly ambient temperature used to represent the temperature of the system throughout the year. Some areas of the United States experience extremely cold temperatures and the use of this equation results in insignificant biological activity or methane generation below 5°C. However, there is evidence to suggest that a minimum level of biological activity continues to occur in the manure management system even in cold ambient temperatures, and that the minimum temperatures experienced at depth in these systems is higher than the surrounding ambient temperature. Anaerobic lagoons are therefore modeled with a minimum temperature of 5°C and other covered or partially covered liquid/slurry and deep pit systems are assumed to have a minimum temperature of 7.5°C.

These changes, combined with the data changes described below, resulted in an average increase of 3.3 Tg of CO₂ Eq. (10.9 percent) in annual CH₄ emissions, and an average decrease of less than 0.1 Tg of CO₂ Eq. (0.2 percent) in annual N₂O emissions, from 1990 through 1999.

Rice Cultivation

The method for calculating methane emissions from rice cultivation has been revised to follow the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997). Emissions are now estimated from annual areas harvested and U.S.-specific, area-based, seasonally integrated emission factors; previously, these emissions were based on annual areas harvested, flooding season lengths, and daily average emission factors. This revision, in combination with the revision to the historical data described below, resulted in an average decrease of 1.9 Tg CO₂ Eq. (20.0 percent) in estimated annual CH₄ emissions from rice cultivation over the entire time series.

Agricultural Soil Management

The methodology used to estimate emissions from agricultural soil management includes two changes. First, the calculation of N₂O emissions from cultivated histosols has been revised to take into account the climate of the cropland area. The areas are now split into temperate and sub-tropical categories with different N₂O emission factors. Second, the calculation of indirect emissions from leaching and runoff of manure nitrogen has been corrected so that the portion of manure that is not applied or deposited on soils (i.e., the poultry manure used as a feed supplement—less than 1 percent of total manure nitrogen) is excluded. These two methodological changes, in combination with the revisions to historical data described below, resulted in an average annual decrease of 2.0 Tg of CO₂ Eq. (0.7 percent) in total N₂O emissions from agricultural soil management for 1990 through 1999.

Agricultural Residue Burning

The emission ratio for methane from agricultural residue burning was revised from 0.004 to 0.005 to reflect the correct IPCC default value from the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997).

The calculation of rice straw burning was revised for the entire time series. Instead of applying area-weighted percent burned figures to national production numbers, state estimates of percent residue burned were applied to state production numbers. These calculations were then summed over all the states to yield the national estimates of rice residue burned. These two methodological changes, in combination with the revisions to historical data described below, resulted in average increases in agricultural residue burning emissions of 0.2 Tg CO₂ Eq. (27.9 percent) for methane, less than 0.1 Tg CO₂ Eq. (1.9 percent) for nitrous oxide, 15.8 Gg (2.3 percent) for CO, and 0.6 Gg (1.9 percent) for NO_x for 1990 through 1999.

Land-Use Change and Forestry

The Land-Use Change and Forestry chapter comprises four sections: 1) Forests; 2) Urban Trees; 3) Agricultural Soils; and 4) Landfilled Yard Trimmings. The section on urban trees is new to this year's Inventory. The methodologies used in the first and third sections have changed relative to the previous Inventory. The changes to each section are described below.

- *Forests.* In this year's Inventory, down dead wood from both logging and mortality were counted explicitly. In addition, new volume-to-carbon conversion factors and new forest floor carbon equations were used. Soil carbon densities (carbon per hectare) were assumed constant over time, so that soil carbon changed only if forest type changed or if forest land area changed.
- *Agricultural Soils.* The method for calculating mineral soil carbon changes for cropping systems containing rice and rice in rotation was modified this year. In last year's Inventory, mineral soil carbon stock changes were slightly overestimated due to a programming error that resulted in a double-counting of soil carbon increases for systems containing rice. The corrected program, combined with revisions to the historical data described below, resulted in an average decrease of 10 percent in total net sequestration from mineral and organic soils for 1990 through 1999.
- *Urban Trees.* A new section on changes in carbon stocks in urban trees has been added. The primary input data were obtained from Nowak and Crane (2001).

These changes, combined with the revisions to historical data described below, resulted in an average increase of 75.4 Tg CO₂ Eq. (7 percent) in annual carbon sequestration from land-use change and forestry for 1990 through 1996, and an average decrease of 95.3 Tg CO₂ Eq. (10 percent) in annual carbon sequestration from land-use change and forestry for 1997 through 1999.

Landfills

The methodology used to estimate CH₄ emissions avoided through flaring was modified in the following ways. First, emissions avoided for all flares were based on reported flow range or fit to standard flow ranges established by one of the vendors. In many cases, vendors reported only a flow rate without establishing whether the reported flow rate represented the minimum, average, or maximum flow rate. In previous year's the flow rate was used. To improve consistency across vendors, for this year's inventory individual flare flow rates were mapped into standard flow ranges provided by one of the vendors. The midpoint of this range was then used to calculate emissions avoided. Second, multiple flares for landfills were tracked, while previously only one flare per landfill was included. Finally,

emission reductions at utility flares were included as long as they were not affiliated with a landfill-gas-to-energy project. In past inventories, all utility flares were excluded as it was unclear whether they corresponded to a landfill-gas-to-energy project. This year's flaring estimate reflects emission reductions taking place at 585 flares nationwide, as compared to 487 flares in the previous inventory. These methodological changes, together with the data changes described below, resulted in an average decrease in annual methane emissions from landfills of 7.2 Tg CO₂ Eq. (3.3 percent). This decrease is mainly the result of the incorporation of additional data on the national population of flares.

Wastewater Treatment

In the Wastewater Treatment section of the Waste chapter, the fraction of domestic wastewater that degrades anaerobically was changed to reflect the use of septic tanks in addition to treatment plants. Recent research has shown that twenty five percent of domestic wastewater is disposed into septic tanks. The new factor is 16.25 percent, an increase from the 15 percent used in the previous Inventory.

The industrial wastewater estimate was changed to reflect new information on pulp & paper wastewater. Estimates from vegetables, fruits, and juice processing and the meat and poultry industry were also included for the first time. The pulp and paper estimates were revised to account for secondary treatment lagoons, which, in this industry, are more prone to anaerobic conditions.

These changes to wastewater treatment emissions, coupled with the data changes described below, resulted in an average increase of 14.6 Tg of CO₂ Eq. (124.6 percent) in annual CH₄ emissions for 1990 through 1999, primarily due to the expansion of the categories of industrial wastewater covered by the estimate.

Human Sewage

In the Human Sewage section of the Waste chapter, a change was made to the 1990 through 1999 sewage sludge applications. In previous years, the sewage sludge applied to soils was subtracted from the amount discharged into aquatic environments. In this year's Inventory, the amount landfilled is also subtracted from the amount discharged into aquatic environments. This revision, in combination

with the revision to the historical data described below, resulted in an average decrease of 0.1 Tg CO₂ Eq. (0.8 percent) in estimated annual N₂O emissions from human sewage over the entire time series.

Changes in Historical Data

- In the CO₂ Emissions from Fossil Fuel Combustion section of the Energy chapter, energy consumption data have been updated by the Energy Information Administration (EIA 2001a) for selected years (see above for detail on methodological changes). To highlight one significant revision, EIA removed fuel consumption for electricity generation by non-utilities from the industry end-use sector, and combined it with electric utility consumption—thus creating a comprehensive electric power industry sector. This sector is referred to in this report as “electricity generation.” In another instance, Puerto Rico began consuming natural gas in 2000, which has been reflected in the CO₂ estimates from U.S. Territories for 2000. Puerto Rico began importing liquefied natural gas (LNG) in August 2000 to fuel its new natural gas-fired electricity generation plant. This consumption estimate provided by the EIA is based on available data on LNG shipments to Puerto Rico from Trinidad. Additionally, the carbon storage factor for miscellaneous products under other petroleum for U.S. territories, originally assumed as ten percent has been modified to 100 percent. This revision is based on the assumption that the carbon consumption for miscellaneous products is used for asphalt and road oil. These changes, along with the methodological changes in “Emissions and Storage from Non-Energy Uses of Fossil Fuels” (which affect this sector), resulted in an average decrease of 36.0 Tg CO₂ Eq. (0.7 percent) in annual CO₂ emissions from fossil fuel combustion for 1990 through 1999.
- In the Stationary Combustion (excluding CO₂) section of the Energy chapter, changes to emission estimates were entirely due to revised data from EIA (2001a). These revisions are explained in more detail in the section above on CO₂ Emissions from Fossil Fuel Combustion [and] Carbon Stored in Products from Non-Energy Uses of Fossil Fuels. On average, annual stationary combustion

methane emissions estimates decreased by 0.6 Tg of CO₂ Eq. (7.4 percent), and annual stationary combustion N₂O emissions increased by 0.8 Tg of CO₂ Eq. (5.8 percent) for 1990 through 1999.

- In the Natural Gas Systems section of the Energy chapter, methane emission estimates have been revised to incorporate new activity driver data for distribution mains and services for 1993 through 2000 (OPS 2001). These data changes resulted in an average increase of 0.4 Tg of CO₂ Eq. (0.3 percent) in annual methane emissions from natural gas systems from 1990 through 1999. Furthermore, the emissions reduction estimates for 1999, as reported by EPA's Natural Gas STAR partners, were updated to incorporate more recent data. This change has resulted in a decrease in annual methane emissions of 3.2 Tg of CO₂ Eq. (2.6 percent) in 1999.
- In the Petroleum Systems section of the Energy chapter, this year's inventory reflects one historical data change. A different data source for the number of producing wells has been used. In the previous report, the data source for producing wells was the American Petroleum Institute's (API), *Petroleum Data Book 1999*. Although published annually, the API's data lags two years behind the publication year. In this year's Inventory, data for producing wells were taken from the Energy Information Administration's (EIA), *Annual Energy Review 2001*, which has data for 2000, unlike the API publication. This change, combined with the methodological changes described above, results in an average emissions decrease of 0.2 Tg of CO₂ Eq. (0.8 percent) across the entire period.
- In the International Bunker Fuels section of the Energy chapter, the CH₄ emission factor for marine fuels was revised from 0.03 to 0.315 g CH₄/kg fuel. In addition, DESC (2001) revised their estimates of marine and aviation jet fuel consumption for international bunkers for 2000. The military international bunker fuel data provided by DESC for 2000 are from a data set developed by the Navy Fuels and Logistics office, which is more consistent with the 1995 to 1999 DESC maritime data. An additional marine fuel, intermediate fuel oil (IFO 180 and IFO 380), is included in the estimates for this inventory providing consumption data for 1996 through 2000. IFO is a blend of distillate and residual fuels and is used by some Military Sealift Command vessels. These revisions result in average emission decreases of 0.2 Tg CO₂ Eq. and less than 0.1 Tg CO₂ Eq. of CO₂ and N₂O, respectively, and an average increase of 0.1 Tg CO₂ Eq. of CH₄.
- In the Cement Manufacture section of the Industrial Processes chapter, the clinker production data was altered to reflect the information in the *Cement Annual Report 2001* (USGS 2001a). The revisions increased the annual CO₂ emissions by 0.1 Tg of CO₂ Eq. (0.2 percent) for 1999.
- In the Lime Manufacture section of the Industrial Processes chapter, the activity data was altered to incorporate revised production numbers (USGS 2001b) for dolomitic quicklime and high-calcium hydrated lime. The revisions increased the total lime production and sugar refining data for 1999 leading to an emissions increase of 0.04 Tg of CO₂ Eq. (0.3 percent) for that year. These revisions also decreased total emissions from lime manufacture by less than 0.001 Tg of CO₂ Eq. (0.01 percent) for 1990 through 1996.
- In the Limestone and Dolomite Use section of the Industrial Processes chapter, the activity data used to calculate CO₂ emissions have been changed to incorporate revised numbers for the total flux stone consumption numbers for both limestone and dolomite (USGS 2001c). This change, combined with the methodological change described above, resulted in an increase in CO₂ emissions for 1999 of 1.0 Tg of CO₂ Eq. (9.9 percent). For the years 1990 through 1998, these updates resulted in an average increase in CO₂ emissions of 0.1 Tg CO₂ Eq. (1.8 percent).
- In the Soda Ash Manufacture and Consumption section of the Industrial Processes chapter, the activity data used to calculate CO₂ emissions have been revised to incorporate published 2001 data (USGS 2001d). Trona Production was changed for 1990 and 1991 while soda ash consumption changed 1990 through 1997 according to the *Soda Ash Annual Report 2001*. These updates resulted in a decrease in annual CO₂ emissions by less than 0.1 Tg of CO₂ Eq. (0.4 percent) for 1990 through 1997.

- In the Carbon Dioxide Consumption section of the Industrial Processes chapter, the activity data used to calculate CO₂ emissions has been revised reflect an updated 1999 figure published by the Freedonia Group. This resulted in a change of less than 0.01 Tg CO₂ Eq. in CO₂ emissions from this source for 1999.
- In the Petrochemical Production section of the Industrial Processes chapter, the activity data used to calculate CH₄ emissions were revised to reflect modified data from the American Chemistry Council 2001. The production data was altered for dichloroethylene, styrene, methanol for the years 1995 through 1999. Carbon black and ethylene data was revised for 1999 only. The revisions increased CH₄ emissions on average less than 0.1 Tg of CO₂ Eq. (0.5 percent) for the years 1995 through 1999.
- In the Adipic Acid Production section of the Industrial Processes chapter, information on emission estimates for 1990 to 2000 was directly obtained from two of the four adipic acid plants. These data were updated for the whole time series for these plants. These revisions resulted in an average decrease of 3.5 Tg of CO₂ Eq. (18.9 percent) in annual N₂O emissions from 1990 through 1999.
- In the Nitric Acid Production section of the Industrial Processes chapter, 1999 production data were revised using updated estimates from *Chemical and Engineering News* (C&EN 2001). The revision resulted in a decrease of 0.1 Tg CO₂ Eq. (0.6 percent) in N₂O emissions from nitric acid production in 1999.
- In the Substitution of Ozone Depleting Substances section of the Industrial Processes chapter, a review of the current chemical substitution trends, together with input from industry representatives, resulted in updated assumptions for the Vintaging Model, particularly in the precision cleaning solvents, stationary refrigeration, and fire extinguishing sectors. These revisions resulted in an average decrease of 3.6 Tg CO₂ Eq. (10.6 percent) in HFC, PFC, and SF₆ emissions from substitution of ozone depleting substances for 1994 through 1999.
- For emissions of HFC-23 from HCFC-22 Production within the Industrial Processes chapter, the emission estimates for 1990 to 1998 were changed to correct a small error in the conversion from Gg of HFC-23 to Tg of CO₂ equivalent. None of the changes were greater than ± 0.2 Tg CO₂. The revision lead to an average increase of less than 0.1 Tg of CO₂ Eq. (less than 0.1 percent) in annual HFC-23 emissions from the production of HCFC-22.
- In the Enteric Fermentation section of the Agriculture chapter, the emission estimates have been recalculated using updated animal population data. Specifically, horse population data for 1990 through 1999 were updated by the Food and Agriculture Organization (FAO 2001). Additionally, population data for swine, goats, and sheep were adjusted to match the most updated data from USDA. Some cattle population data were also revised to reflect updated USDA estimates. Lastly, stocker and feedlot numbers were modified to include animals at feedlots with less than 1000 head. These data modifications caused an average decrease of 2.5 Tg of CO₂ Eq. (1.9 percent) in annual CH₄ emissions from enteric fermentation for 1990 through 1999.
- In the Manure Management section of the Agriculture chapter, four changes have been incorporated into the emission estimates. Each of these major changes is discussed in more detail below.
 - USDA updated the quarterly estimates for swine population for the years 1998 and 1999; therefore, population data for these years changed slightly. The volatile solids and nitrogen excretion estimates for these years have changed accordingly.
 - The Food and Agriculture Organization of the United Nations (FAO) has an online database that is used for horse population estimates. These data, from 1990 through 2000, have been updated. Therefore, all N₂O and CH₄ emission estimates for horses have changed relative to the previous Inventory. The effect of the population changes on the predicted CH₄ emissions is less than the effect on the predicted N₂O emissions due to the nonlinear effect of the change on the CH₄ calculations.
 - The beef cattle population data used to calculate N₂O emissions for the previous inventory were slightly different than the data used to calculate CH₄ emissions. The N₂O population data excluded

a small portion of the population, which were animal counts from states with a very small number of animals, compared to the U.S. total population. The CH₄ populations included these counts. In order to be consistent between the N₂O and CH₄ emission calculations, the N₂O populations were changed to include population from these states.

- The supporting documentation for the previous inventory indicated that the relationship of volatile solids excretion and milk production in dairy cows was estimated using a polynomial fit curve. These estimates were actually calculated using a logarithmic curve.

The CH₄ emission estimates for horses decreased an average of 4 percent across the time series. The N₂O emission time series for horses decreased emissions by an average of 12 percent across the time series. These changes, combined with the methodological changes described above, changes in total resulted in an average increase of 3.3 Tg of CO₂ Eq. (10.9 percent) in annual CH₄ emissions, and an average decrease of less than 0.1 Tg of CO₂ Eq. (0.2 percent) in annual N₂O emissions, from 1990 through 1999.

- In the Rice Cultivation section of the Agriculture chapter, one change has been made to the historical data. Revised harvested rice areas for the primary crops in Arkansas and California have been incorporated for the years 1998 and 1999, based on the latest statistics from USDA (2001d). These changes resulted in a less than 2 percent decrease in rice area harvested for each of the affected years. This revision, together with the methodological revision described above, resulted in an average decrease of 1.9 Tg CO₂ Eq. (20.0 percent) in estimated annual CH₄ emissions from rice cultivation over the entire time series.
- The estimates of N₂O emissions from agricultural soil management include several data changes, as described below:
 - Fertilizer consumption data for 1990 through 1999 were revised using the most recent estimates for each year provided by TVA and AAPFCO (TVA 1990, 1991, 1992, 1993, 1994, and AAPFCO 1995,

1996, 1997, 1998, 1999, 2000b). Also, for the commercial organic fertilizers, fertilizer type-specific nitrogen contents were used to estimate total nitrogen applied. These nitrogen contents were obtained from TVA (1991, 1992, 1993, 1994) and AAPFCO (1995; 1996; 1997; 1998; 1999; 2000a,b).

- New manure data were incorporated based on updated swine and horse population estimates, and a regrouping of the beef cattle and cattle-not-on-feed animal groups (USDA 2001a; FAO 2001; USDA 2001b,c).
- The estimates of sewage sludge production and land application were refined through new data sources. Additional annual figures and projections from EPA (1999) were incorporated, reducing the amount of interpolation necessary. The nitrogen content of the sludge was also revised from 4 percent to 3.3 percent based upon information in Metcalf and Eddy, Inc. (1991).
- Crop production figures for 1990 through 1999 were revised using the most recent estimates for each year provided by USDA (1994, 1998c, 2001a). This change resulted in a less than 1 percent revision in crop production for a few crops. In the crop residue calculations, the rice component was revised to include Florida data, which had been omitted previously. Histosol area estimates were revised, as they were extracted from NRI incorrectly last year, and disaggregated into broad climatic regions.

These revisions, in combination with the methodological revisions described above, resulted in an average annual 2.0 Tg CO₂ Eq. (0.7 percent) decrease in total N₂O emissions from agricultural soil management for 1990 through 1999.

- The emission estimates for agricultural residue burning include several changes. Crop production figures for the time series from 1990 through 1999 were revised using the most recent estimates from USDA (1994, 1998c, 2001). This change resulted in less than a 1 percent revision in crop production for a few crops.⁴

⁴ The production statistics presented in Table 5-19 of the Agriculture chapter were also revised to include Florida rice production, which had been omitted previously. However, this had no effect on the emission estimates because rice residue burning does not occur in Florida.

Agricultural extension agents in each rice-growing state, and the California Air Resources Board, were contacted to verify, and update as needed, the historical estimates of rice acreage burned in each state. Estimates for California, Mississippi and Missouri were revised. For California, a new estimate of 1999 rice area burned in Sacramento Valley was obtained from California Air Resources Board (2001), resulting in a 13 percent increase in California's burned acreage for that year. New estimates of the percentage of rice area burned in Mississippi were obtained from Street (2001), as the previous estimates are now thought to be too low. The 1990 to 1998 estimates were revised from 5 to 10 percent, and the 1999 estimate from 10 to 40 percent. The previous 1990 to 1998 estimates for Missouri were also revised from 3.5 to 5 percent (Guethle 2001). These revisions, in combination with the methodological revisions described above, resulted in average increases in agricultural residue burning emissions of less than 0.2 Tg CO₂ Eq. (27.9 percent) for CH₄, less than 0.1 Tg CO₂ Eq. (1.9 percent) for N₂O, 15.8 Gg (2.3 percent) for CO, and 0.6 Gg (1.9 percent) for NO_x for 1990 through 1999.

- In the Land-Use Change and Forestry chapter, the following changes were made:
 - In the Forest Carbon section, results from the USDA Forest Service Forest Sector Modeling System were used to develop a projected stock estimate for 2001. In last year's Inventory, results from the modeling system were used to develop both carbon flux and stock estimates for 1990 through 1999. This year, the USDA Forest Service, Forest Inventory & Analysis data were used directly as the base data (i.e., areas, volumes, growth, land-use changes, and other forest characteristics) for 1987 and 1997. For areas with limited survey data on volume (i.e., Reserved Forest Land and Other Forest Land), average volumes were estimated using the Timberland data for the appropriate forest type and region.
 - In the Agricultural Soils section, the soil carbon stock data were obtained from the updated (final release) 1997 *National Resources Inventory* (NRI) data. Last year's estimates were based on the initial

(unofficial) 1997 NRI data. Use of the final 1997 NRI data, in combination with the agricultural soils methodological revisions described above, resulted in an average decrease of 10 percent in total net sequestration from mineral and organic soils for the 1990 to 1999 period.

- In the Agricultural Soils section, the 1999 carbon dioxide emission estimates for liming were revised based on the U.S. Geological Survey's latest estimates of limestone and dolomite use in 1999 (Tepordei 2000). This decreased the 1999 emission estimate for that source by about 9 percent.
- In the Landfilled Yard Trimmings section, the landfilled yard trimmings data were revised to correct incorrect data entry from last year's inventory. These revisions resulted in an average annual 10 percent decrease in yard trimmings carbon storage for 1990 through 1999.

These changes, combined with the methodological revisions described above, resulted in an average increase of 75.4 Tg CO₂ Eq. (7.4 percent) in annual carbon sequestration from land-use change and forestry for 1990 through 1996, and an average decrease of 95.3 Tg CO₂ Eq. (9.7 percent) in annual carbon sequestration from land-use change and forestry for 1997 through 1999.

- In the Landfills section of the Waste chapter, this year's inventory reflects an updated 1999 waste generation and percent-landfilled estimate published by BioCycle (2000). This revision caused the 1999 CH₄ generation estimate to decrease from 214.6 to 203.1 Tg CO₂ Eq. In addition, EPA used an updated database on landfill-gas-to-energy projects. The methane mitigated from these projects changed from 1990 through 1999. The most recent data indicated a smaller quantity of CH₄ mitigated in 1999 than last year's landfill gas-to-energy database. For 1999, this year's landfill gas-to-energy data showed 1.1 Tg CO₂ Eq. less mitigated CH₄ than last year's data. The difference is primarily attributed to revised estimates of municipal waste capacity for electricity projects and landfill gas flow for direct use projects. Finally, new data from an additional vendor of landfill gas flares was obtained. These revisions, coupled with the methodological changes described

above, resulted in an average decrease of 7.2 Tg CO₂ Eq. (3.3 percent) in annual CH₄ emissions from landfills for 1990 through 1999.

- In the Wastewater Treatment section of the Waste chapter, small changes were made to the 1990 through 1999 population data based on new estimates provided by the U.S. Census. Along with the more substantive methodological changes mentioned above, these revisions resulted in an average increase of 14.6 Tg of CO₂ Eq. (125 percent) in annual CH₄ emissions.
- In the Human Sewage section of the Waste chapter, small changes were made to the 1990 to 1999 per capita protein consumption data based on new estimates provided by the FAO. These revisions, together with the new census population data mentioned previously and the methodological changes described above, resulted in an annual average decrease of 0.1 Tg CO₂ Eq. (0.8 percent) in N₂O emissions from 1990 through 1999.