Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015 Technical Report

Chapter 1

Introduction and Overview

Chapter 1: Introduction and Overview

List of Tables

List of Charts

Chapter 1: Introduction & Overview

For several decades, atmospheric scientists and climatologists have been concerned that human activities such as energy use may increase the concentration of greenhouse gases in the atmosphere, enhancing the "greenhouse effect" and thereby altering temperature and other determinants of global climate.[1]

The greenhouse effect itself is well established, but it is difficult to determine whether global climate change is actually taking place and impossible to predict with certainty the timing, magnitude or regional distribution of climatic change that would result from the greenhouse effect. However, a number of supercomputer-based climate models have been developed in recent years to delineate the complex interaction of greenhouse gases and other factors that affect climate.

Many of these models project that increased concentrations of greenhouse gases will result in increased average temperatures by 2 to 4°C and changes in patterns of precipitation in most regions of the world. Natural systems could be disrupted, injuring forests, fisheries, coastal zones, agriculture, water resources, energy demand and supply, air quality, and human health.

Over the past dozen years, concern over the possible consequences of these anthropogenic (human-origin) greenhouse gas (GHG) emissions and their possible consequences has migrated from a relatively small scientific community to the forum of state, national and international policy makers. For example, about 25 states, including Missouri, have completed inventories of their 1990 GHG emissions, and several states, including Missouri, have undertaken projects to analyze possible actions to reduce GHG emissions.

Most of the state inventories, including Missouri's, follow methodological guidelines provided by the U.S. Environmental Protection Agency (USEPA). The common methodology makes it possible to aggregate emissions estimates from different states and compare them to each other and to national emissions estimates.

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[1] The term "greenhouse effect" describes the role of certain atmospheric gases that allow radiation from the sun to reach the Earth's surface but prevent, by absorption and reemission back to the surface, the Earth's surface radiation from loss to space. Scientists generally agree that the "greenhouse effect" is an important determinant of the balance between the Earth's incoming and outgoing radiation. Without the greenhouse effect, the Earth's surface would be too cold to sustain life. Controversy centers over the extent to which human activities are leading to an "enhanced" greenhouse effect by increasing greenhouse gas concentration, and the influence of this "enhanced" greenhouse effect on climate and natural systems.

Atmospheric science employs the term "radiative forcing" to refer to changes in the existing balance between the Earth's incoming and outgoing radiation. This balance can be upset by natural causes such as volcanic eruptions as well as by human activities such as greenhouse gas emissions. In addition to greenhouse gases, sources of radiative forcing include solar radiation, aerosols, and albedo. Albedo refers to the fraction of light or radiation that is reflected by the Earth. For example, polar ice and cloud cover increase the Earth's albedo.

Part 1 of this chapter summarizes and updates the baseline estimate of greenhouse gas emissions previously published in the *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990*,[2] referred to throughout this study as the *1990 Inventory.* Part 2 summarizes methodological procedures and assumptions adopted or modified from the *1990 Inventory*. Parts 3 and 4 summarize Missouri greenhouse gas emissions trends through 1996 and projections through 2015.

The remaining chapters of the study amplify and support points made in Parts 1, 3 and 4 of this chapter. Because carbon dioxide (CO_2) emissions from fossil fuel combustion and especially from electric generation constitute the largest part of Missouri's GHG emissions, this source is treated separately in Chapters 2 through 4. Chapter 2 discusses trends through 1996, while Chapter 3 discusses projections for CO_2 emissions from the utility sector and Chapter 4 discusses emissions from the end-use sectors.

Chapter 5 deals with trends and projections for other sources of GHG emissions, including non-energy sources of CO_2, and sources of methane, nitrous oxide and perfluorinated carbons (PFCs). PFCs, which are minor but highly potent greenhouse gases produced as a byproduct of aluminum manufacture, are described in more detail in the *1990 Inventory*. Chapter 6 deals with CO_2 sequestration by Missouri forests.

[2] Missouri Department of Natural Resources, Division of Energy, Jefferson City, April 1996, Chapter 1.

Part 1: Baseline 1990 estimate of Missouri GHG emissions

Missouri's gross anthropogenic GHG emissions in 1990 totaled about 148 million tons. Energy use and other activities by Missourians emitted about 123 million tons of CO_2 and an additional 25 million tons of methane, nitrous oxide and PFCs.

Net anthropogenic GHG emissions in Missouri in 1990 amounted to about 121 million tons STCDE.[3] Estimated net emissions are lower than gross emissions because biomass growth in Missouri's forests, including below-ground root growth, offset about 27 million tons of GHG emissions in 1990.[4]

Section 1: GHG emissions from energy use

Table 1 provides detailed estimates of Missouri GHG emissions from energy use and other sources in 1990. For each source, Table 1 shows its percentage share of total GHG emissions. For example, fossil fuel combustion for energy use accounted for about 75 percent of total estimated GHG emissions.

For Missouri in 1990, coal combustion contributed about 49 percent of energy-related GHG emissions, petroleum about 39 percent and natural gas only about 12 percent. For the U.S. as a whole in 1990, coal accounted for only about 36 percent of energy-related GHG emissions, petroleum about 43 percent and natural gas about 20 percent. These differences between the share of coal, petroleum and natural gas at the national and state level reflect Missouri's reliance on coal to generate electricity and relatively low consumption of natural gas. Coal has the highest, and natural gas has the lowest, carbon content of any major fossil fuel.

In 1990, the utility sector accounted for about 46 percent of total CO_2 emissions from fossil fuel combustion. More than 99 percent of total utility CO_2 emissions were from combustion of coal.

Table 1 lists the utility sector separate from the four energy "end-use" sectors — transportation, commercial, industrial and residential sectors — because the utility sector consumes primary fossil fuel energy resources, such as coal, to generate electricity for these four "end-use" sectors.

In addition to electricity, the four end-use sectors listed in Table 1 use both primary fossil fuel energy resources, such as natural gas and petroleum, and electricity, which is a secondary form of energy. Examples of primary fossil fuel consumption in the end-use sectors are the use of motor gasoline and diesel fuel for highway travel in the transportation sector and the use of natural gas for heating and cooking in the residential and commercial sectors.

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[3] Emissions of methane, nitrous oxide and PFCs are reported in Short Tons Carbon Dioxide Equivalent (STCDE). The derivation of this unit of common measure is based on Global Warming Potential (GWP) factors for the different gases, as explained later in this section.

[4] In order to grow, trees and other perennial plants remove and store (sequester) carbon dioxide (CO_2). Following the methodology of the *1990 Inventory*, this removal is considered to be a result of forest management practices and therefore to offset an equivalent quantity of GHG emissions.

Table 1 - Missouri GHG sources in 1990, showing each source's estimated share of total gross GHG emissions

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

Carbon dioxide emissions	123,129	83.2%
CO_2 from fossil fuel combustion	111,472	75.3%
Energy end-use sectors	59,934	40.5%
Transportation	36,782	24.8%
Gasoline	25,826	17.4%
Diesel	7,578	5.1%
Jet fuel	2,971	2.0%
Other	408	0.3%
Commercial	4,625	3.1%
Natural gas	3,494	2.4%
Petroleum	721	0.5%
Coal	410	0.3%
Industrial	10,284	6.9%
Natural gas	3,077	2.1%
Petroleum	4,107	2.8%
Coal	3,100	2.1%
Residential	8,242	5.6%
Natural gas	6,822	4.6%
Petroleum	1,200	0.8%
Coal	221	0.1%
Electric utility sector	51,539	34.8%
Natural gas	207	0.1%
Petroleum	93	0.1%
Coal	51,238	34.6%
Other sources of CO_2	11,656	7.9%
Oxidation of carbon monoxide	1,460	1.0%
Non-energy uses of fossil fuels	1,345	0.9%
Limestone use	4,445	3.0%
Land use changes	4,407	3.0%
Methane emissions	16,527	11.2%
Agriculture	10,463	7.1%
Municipal waste	5,419	3.7%
Fossil fuel prod'n & distribution	501	0.3%
Highway travel	143	0.1%
Nitrous oxide emissions	3,805	2.6%
Agriculture	2,333	1.6%
Highway travel	1,080	0.7%
Nitric acid production	391	0.3%
PFCs from aluminum production	4,611	3.1%
Total greenhouse gas sources	***148,071***	***100.0%***

Table 2 reports the same CO_2 emissions from fossil fuel combustion that are reported in Table 1, however, Table 2 drops utilities as a separate sector and allocates utility CO_2 emissions to the end-use sectors in proportion to their consumption of electricity. Estimated Tons of emissions per capita are shown for all sources, and estimated tons per $1 million Gross State Product (GSP) are shown for those sources whose level of emissions is closely related to the production and transportation of goods and services. The table also shows each source's percentage of total CO_2 emissions from fossil fuel combustion.

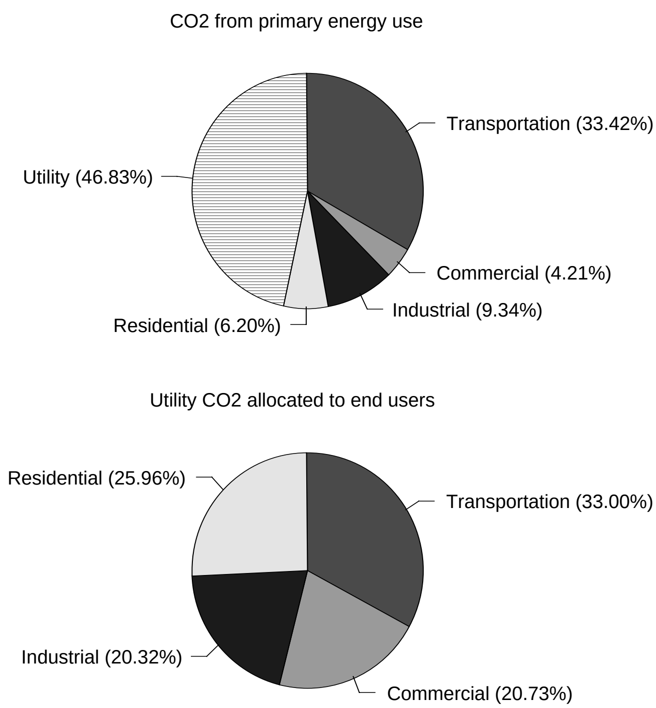
Table 2 - Estimated Missouri CO_2 emissions from fossil fuel combustion in 1990

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	CO_2 emissions (1,000 Tons)	Tons per person	Tons per $1 million GSP	Percent of total emissions
Energy end-use sectors	111,472	21.8		100.0%
Transportation	36,782	7.2		33.0%
Gasoline	25,826	5.0		23.9%
Diesel	7,578	1.5	82.2	6.9%
Jet fuel	2,971	0.6	32.2	2.8%
Other	408	0.1		0.4%
Electricity	0	0.0		0.0%
Commercial	23,104	4.5		20.7%
Electricity	18,479	3.6		16.6%
Natural gas	3,494	0.7		3.1%
Petroleum	721	0.1		0.6%
Coal	410	0.1		0.4%
Industrial	22,649	4.4	245.7	20.3%
Electricity	12,365	2.4	134.2	11.1%
Natural gas	3,077	0.6	33.4	2.7%
Petroleum	4,107	0.8	44.6	3.7%
Coal	3,100	0.6	33.6	2.8%
Residential	28,937	5.7		26.0%
Electricity	20,694	4.0		18.6%
Natural gas	6,822	1.3		6.1%
Petroleum	1,200	0.2		1.1%
Coal	221	0.0		0.2%
Electricity	51,539	10.1		46.2%
Commercial	18,479	3.6		16.6%
Industrial	12,365	2.4		11.1%
Residential	20,694	4.0		18.6%

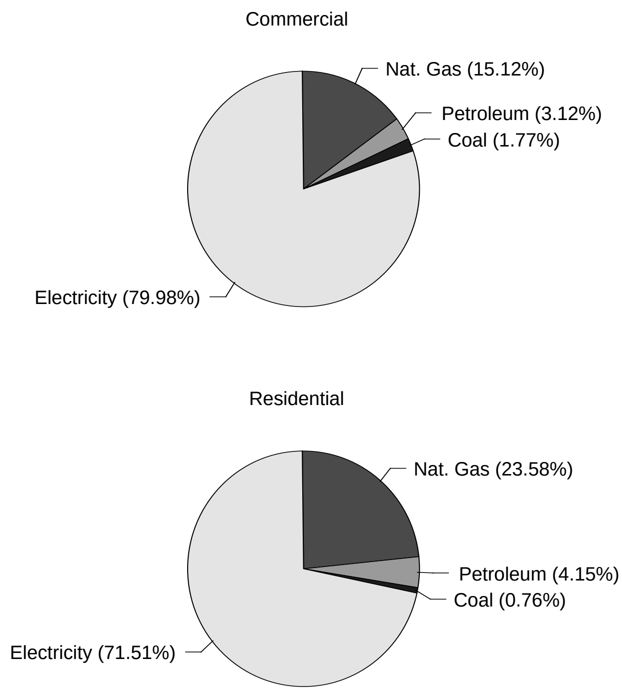
Since the transportation sector used virtually no electricity in 1990, Table 2 shows a much more even distribution of CO_2 emissions across the four end-use sectors than in Table 1. In 1990, transportation accounted for about 37 million tons of emissions from primary fossil fuel use. This amounts to more than 60 percent of total emissions from primary fossil fuel use as reported in Table 1. However, Table 2 indicates that transportation accounts for only about 33 percent of total CO_2 emissions from the end-use sectors after allocating emissions from electricity use to the sectors. The residential sector accounts for about 26 percent, and the commercial and industrial sectors each account for about 20-21 percent.

Chart 1 - Five-sector distribution of CO_2 emissions from primary energy use versus four-sector distribution based on allocating utility CO_2 emissions to end users of electricity, 1990



In 1990, about 76 percent of 1990 CO_2 emissions from electric generation were due to use in the residential and commercial sectors. In these two sectors, electricity is the dominant source of energy, with natural gas a distant second. Electricity use accounted for about 72 percent of residential and 80 percent of commercial CO_2 emissions in 1990. On a per-capita basis, the residential sector emitted about 4.0 tons of CO_2 from electricity use, and the commercial sector about 3.6 tons of CO_2, for each Missourian in 1990.

Chart 2 - CO_2 emissions by energy source in the commercial and residential sectors, 1990



Missouri's industrial sector is less energy-intensive than the national average, and electricity is one of a wide variety of energy resources used in the sector. Nevertheless, electricity use accounted for more than half of industrial CO_2 emissions in 1990. In 1990, the industrial sector emitted about 134 tons of CO_2 from electricity use per $1 million Gross State Product (GSP).

Section 2: GHG emissions from sources other than energy use

About 25 percent of estimated Missouri GHG emissions in 1990 were from sources other than energy use. Land use changes, industrial and agricultural uses of limestone, industrial and transportation use of fossil fuels for purposes other than energy, and oxidation of carbon monoxide emitted by highway vehicles and stationary industrial sources accounted for about 11.7 million tons of CO_2 emissions, about 8 percent of total CO_2 emissions in 1990.

Methane, nitrous oxide and PFC emissions accounted for about 25 million tons of GHG emissions, measured in units of Short Tons Carbon Dioxide Equivalent (STCDE). The leading sources of non-CO_2 emissions were agriculture, industry and municipal waste management, as follows:

1. Agriculture was the leading source of methane and nitrous oxide emissions in the state. In 1990, beef cattle, dairy cattle and swine operations generated more than 10 million tons (STCDE) of methane emissions, and use of nitrogenous fertilizers generated more than 2 million tons (STCDE) of nitrous oxide emissions.

2. Industrial production of aluminum accounted for about 4.6 million tons (STCDE) of PFCs and nitric acid production accounted for an additional 0.4 million tons (STCDE) of nitrous oxide. This amount was in addition to a variety of non-energy-related industrial sources of $CO_{2,}$ including non-energy uses of fossil fuels, production of lime and cement from limestone.

3. Finally, municipal waste management was an important source of methane emissions. Anaerobic decomposition of organic waste deposited in municipal landfills generated more than 5 million tons (STCDE) of methane emissions in 1990.

Short Tons Carbon Dioxide Equivalent (STCDE) is the unit of common measure used throughout this study. Global Warming Potential (GWP) factors developed by the Intergovernmental Panel on Climate Change (IPCC) are the basis for this unit of measure. For example, Table 1 estimates that 16.4 million tons (STCDE) of methane were emitted in Missouri in 1990. This means it would have required 16.4 million short tons of CO_2 to equal the global warming potential (GWP) of the methane that was emitted. Because estimates given using STCDE units weight the emissions estimate for each gas by its GWP factor, it is possible to add or compare the emissions estimates for different greenhouse gases.

Part 2: Methodological assumptions from the *1990 Inventory*

Estimates of GHG emissions in this report closely follow the methodological procedures described in the *1990 Inventory,* which were based, with some refinements, on methodology specified by the U.S. Environmental Protection Agency (USEPA) in its *State Workbook*.[5] For additional discussion of the procedures, the reader is referred to the *1990 Inventory.*

The estimates are limited to the anthropogenic (from human sources) emissions of four greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and perfluorinated carbons (PFCs). Stratospheric and troposphere ozone, carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and other ozone-depleting compounds (ODCs) are omitted as explained in the *1990 Inventory*, Section 1.1.

Estimates of CO_2 emissions from the combustion of fossil fuels are probably the most reliable estimates contained in the *1990 Inventory* and this report. The estimation of CO_2 emissions from fossil fuel combustion requires estimating the physical quantity (tons, barrels, cubic feet, etc.) of the fuel burned, its heat content (Btus)[6] and its carbon content. For fossil fuel usage and quality data, the *1990 Inventory* and this report rely primarily on federal data sources compiled from reports by Missouri state agencies (such as the Missouri Department of Revenue or Missouri Department of Transportation) or producers and consumers of fossil fuels (such as refiners and electric utilities). Most heat and carbon coefficients came from the U.S. Department of Energy's Information Administration (EIA) or from USEPA. Because of the prominence of coal combustion by electric utilities as a source of CO_2 emissions in Missouri, individual heat content coefficients and carbon coefficients were estimated for each coal-fired utility plant in the state using data provided by EIA.

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[5] USEPA, State and Local Outreach Program, *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions,* Washington, DC, 1995.

[6] Although the fuel supply industry regularly reports fuel consumption in physical units (such as tons of coal, cubic feet of natural gas or barrels of oil), the methodology to estimate emissions is based on measuring consumption by a common unit of heat content, the British Thermal Unit (Btu). The factors used to convert physical to thermal units, are listed on page 161 in the *1990 Inventory*.

The use of a standard coefficient to estimate heat content of fossil fuels consumed is one source of error in estimating emissions. The heat content of coal, natural gas and petroleum is variable. For example, the energy content of utilities' coal receipts varies widely, even for the same grade of coal from the same state of origin (EIA, *Cost and Quality of Fuels for Electric Utility Plants*, annual report). The thermal content reported by the utilities is itself based on sampling and therefore subject to error.

Table 1 in the previous section indicates that methane, nitrous oxide and PFCs accounted for about 17 percent of total estimated Missouri GHG emissions in 1990. In contrast, the *1990 Inventory* reported that these gases accounted for about 14 percent. The primary reason for the increase in the share of the three gases is that this report uses higher Global Warming Potential (GWP) factors[7] for methane, nitrous oxide and perfluorinated carbon emissions.

Table 3 lists the Intergovernmental Panel on Climate Change's (IPCC) 1992 and 1995 GWP factors for methane (CH_4), nitrous oxide (N_2O) and perfluorinated carbons (PFCs). This report uses the 1995 GWP factors, which are higher than the 1992 GWP factors used in the *1990 Inventory*. Use of the 1995 factors increases estimated methane emissions by about 11 percent and nitrous oxide emissions by about 19 percent.

Table 3 - IPCC 1992 and 1995 GWP factors

	IPCC 1992 GWP factors	**IPCC 1995 GWP factors**
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	22	24.5
Nitrous oxide (N_2O)	270	320
Perfluorinated carbons (PFCs)	5,400	6,300 (CF_4)* 12,500 (C_2F_6)*

See Chapter 5, Part 4.

In addition to using higher GWP factors, this report makes other minor departures from the methodology used in the *1990 Inventory*. In estimating PFC emissions from aluminum, the *1990 Inventory* averaged two sources, Noranda Aluminum's estimates of PFC emissions and independent estimates based on *State Workbook* methodology. This study drops the averaging procedure and reports only Noranda Aluminum's estimates.

In addition to these methodological revisions, this report has corrected data for several sources of CO_2 and methane emissions. Otherwise, this report uses the same methodology and data used in the *1990 Inventory* for methane (CH_4), nitrous oxide (N_2O) and perfluorinated carbons (PFCs). Table 4 indicates the resulting revisions in emissions estimates for methane (CH_4), nitrous oxide (N_2O) and perfluorinated carbons (PFCs).

[7] The concept of global warming potential, as developed by the Intergovernmental Panel on Climate Change (IPCC), is based on a comparison of the radiative forcing effect of the concurrent emission into the atmosphere of an equal quantity of CO_2 and another greenhouse gas. Each gas has a different instantaneous radiative forcing effect. In addition, the atmospheric concentration attributable to a specific quantity of each gas declines with time; IPCC assumes a 100-year time horizon. For additional discussion, see the *1990 Inventory*, Section 1.2.

Table 4 - Changes in estimates of Missouri's 1990 methane, nitrous oxide and PFC emissions

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	Original estimate (STCDE) weighted by 1992 factors	Revised estimate (STCDE) weighted by 1995 factors	Change in estimate (STCDE)
Methane emissions	14,755	16,527	1,772
Agriculture	9,005	10,463	1,459
Beef cattle	5,098	5,677	579
Dairy cattle	1,624	1,808	185
Swine	2,076	2,747	671
Other livestock	153	170	17
Rice cultivation	55	61	6
Burning crop wastes	0	0	0
Municipal Waste	5,171	5,419	588
Fossil fuel production & distribution	450	501	51
Transportation	129	143	15
Nitrous oxide emissions	3,210	3,805	595
Agriculture	1,969	2,333	365
Transportation	911	1,080	169
Nitric acid production	330	391	61
PFCs from aluminum production	3,625	4,611	982
CF_4 emissions	3,299	3,847	548
C_2F_6 emissions	329	763	434
Total non-CO_2 GHG emissions	***21,590***	***24,942***	***3,348***

Following the example of the 1990 Inventory, this report assumes zero net emissions from use of nuclear fuel and biofuels. Moreover, the report excludes accounting for out-of-state emissions. Because Missouri in 1990 imported nearly all its fossil fuels, nuclear fuel and ethanol, emissions associated with the production and transportation of these fuels occurred primarily out-of-state and therefore are not included in trend estimates for the state's GHG emissions.

Although there is some uncertainty associated with all estimates, the level of uncertainty is greater for some GHG emissions sources than others. In an authoritative discussion, the U.S. Department of Energy's Energy Information Administration (EIA) concludes that estimates of CO_2 emissions from the combustion of fossil fuels are probably reliable within five percent.[8] Because these emissions can be estimated with the greatest reliability and make up the greatest portion (86 percent) of Missouri's GHG emissions, and because there are many possible state actions that could influence the level of these emissions, trends and projections in CO_2 emissions receive the greatest attention in this report.

Estimates of methane emissions are generally more uncertain than for CO_2. Although methane emissions in Missouri are less important than CO_2 emissions, they do constitute about ten percent of total GHG emissions, and there are significant "no regret" actions that may influence the level of methane emissions. Therefore, trends and projections in methane emissions also receive attention in this report.

Estimates of nitrous oxide emissions are highly uncertain. Because nitrous oxide emissions make up the smallest slice of the GHG emissions "pie" and because they are relatively impervious to possible state actions, trends and projections in nitrous oxide emissions receive the least attention in this report.

[8] EIA, *Emissions of Greenhouse Gases in the United States, 1987-1994,* 1985, p. 81. EIA discusses uncertainties in the volume of fuel consumed, characteristics of fuel consumed, emissions coefficients and coverage. For the most part, the estimates in the *1990 Inventory* and this report depend on coefficients estimated by EIA or data reported to EIA by producers and consumers of fossil fuels.

Part 3: Trends in Missouri GHG emissions since 1990

Missouri's gross GHG emissions increased from about 148 million tons in 1990 to 168 million tons in 1996, growing 13 percent at a 2.1 percent annual average growth rate. Gross 1996 emissions included about 145 million tons of CO_2 and 23 million tons of other gases.

Table 5, which is similar in format to Table 1, provides detailed comparisons of Missouri GHG emissions sources in 1990 and 1996. CO_2 emissions from fossil fuel combustion for energy use increased by about 22 million tons, growing about 20 percent at a 3 percent average annual growth rate.[9] Energy-related CO_2 emissions accounted for nearly 80 percent of total estimated GHG emissions in 1996 compared to about 75 percent in 1990.

Table 6 and Table 7 summarize GHG emissions for each year between 1990 and 1996 and indicate percentage increases or decreases in the different emissions categories.

The pattern of increase between 1990 and 1996 was not linear. Net GHG emissions actually dropped by about 3.4 million tons (STCDE) through 1993, but then increased by nearly 24 million tons (STCDE) from 1993 through 1996.

Factors influencing changes in GHG emissions between 1990 and 1996 included:

- 1990-91: Reductions in perfluorinated carbon (PFC) emissions led the 1990 and 1991 decline in net GHG emissions. Reduction in PFCs are produced from aluminum manufacture. Noranda Aluminum has dramatically reduced PFC emissions at its Missouri plant through ongoing efforts to improve the efficiency of its manufacturing processes.

- 1992-93: Decreasing CO_2 emissions from coal-fired utility boilers led the 1992 and 1993 decline.

- 1994-96: Increasing CO_2 emissions from coal-fired utility boilers led the increase in net GHG emissions between 1993 and 1996.

- Other significant sources of the increase in net emissions between 1990 and 1996 were increases in energy-based CO_2 emissions from the transportation, residential and commercial sectors and increases in methane emissions from swine, beef cattle and municipal landfills.

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[9] Nationally, USEPA estimates that energy-related CO_2 emissions grew a little more than 9 percent during this period. USEPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996*, 1998, p. 2-3.

Table 5 - Missouri GHG sources in 1990 and 1996, showing each source's estimated share of total gross GHG emissions and average annual rate of growth

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	Estimated 1990 Gross Emissions		Estimated 1996 Gross Emissions		Rate 1990-96
Carbon dioxide emissions	123,129	83.1%	145,282	86.5%	2.8%
CO_2 from fossil fuel combustion	111,472	75.2%	133,410	79.4%	3.0%
Energy end-use sectors	59,934	40.4%	70,122	41.7%	2.7%
Transportation	36,782	24.8%	44,207	26.3%	3.1%
Gasoline	25,826	17.4%	28,044	16.7%	1.4%
Diesel	7,578	5.1%	10,131	6.0%	5.0%
Jet fuel	2,971	2.0%	5,672	3.4%	11.4%
Other	408	0.3%	359	0.2%	-2.1%
Commercial	4,625	3.1%	5,465	3.3%	2.8%
Natural gas	3,494	2.4%	4,258	2.5%	3.4%
Petroleum	721	0.5%	881	0.5%	3.4%
Coal	410	0.3%	325	0.2%	-3.8%
Industrial	10,284	6.9%	10,612	6.3%	0.5%
Natural gas	3,077	2.1%	3,921	2.3%	4.1%
Petroleum	4,107	2.8%	4,127	2.5%	0.1%
Coal	3,100	2.1%	2,564	1.5%	-3.1%
Residential	8,242	5.6%	9,838	5.9%	3.0%
Natural gas	6,822	4.6%	7,986	4.8%	2.7%
Petroleum	1,200	0.8%	1,680	1.0%	5.8%
Coal	221	0.1%	173	0.1%	-4.0%
Electric utility sector	51,539	34.8%	63,288	37.7%	3.5%
Natural gas	207	0.1%	284	0.2%	5.4%
Petroleum	93	0.1%	117	0.1%	3.8%
Coal	51,238	34.6%	62,887	37.4%	3.5%
Other sources of CO_2	11,656	7.9%	11,872	7.1%	0.3%
Oxidation of carbon monoxide	1,460	1.0%	1,650	1.0%	2.1%
Non-energy uses of fossil fuels	1,345	0.9%	982	0.6%	-5.1%
Limestone use	4,445	3.0%	4,834	2.9%	1.4%
Land use changes	4,407	3.0%	4,407	2.6%	0.0%
Methane emissions	16,712	11.3%	18,290	10.9%	1.5%
Agriculture	10,463	7.1%	11,166	6.6%	1.1%
Municipal waste	5,604	3.8%	6,481	3.9%	2.5%
Fossil fuel prod'n & distribution	501	0.3%	501	0.3%	0.0%
Highway travel	143	0.1%	143	0.1%	0.0%
Nitrous oxide emissions	3,805	2.6%	3,820	2.3%	0.1%
Agriculture	2,333	1.6%	2,348	1.4%	0.1%
Highway travel	1,080	0.7%	1,080	0.6%	0.0%
Nitric acid prodcution	391	0.3%	391	0.2%	0.0%
PFCs from aluminum production	4,611	3.1%	641	0.4%	-28.0%
Total greenhouse gas sources	***148,256***	***100.0%***	***168,033***	***100.0%***	***2.1%***

Table 6 - Summary of Missouri GHG emissions sources, 1990-96

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1991	1992	1993	1994	1995	1996
Greenhouse gas sources	148,256	144,688	144,397	144,229	154,381	161,561	168,033
Carbon dioxide emissions	123,129	122,635	122,326	121,502	131,112	138,482	145,282
Energy	111,472	111,638	110,977	110,519	119,608	127,156	133,410
Energy end-use sectors	59,934	59,781	60,631	64,767	65,764	66,913	70,122
Electric utility sector	51,539	51,857	50,346	45,752	53,843	60,243	63,288
Other	11,656	10,998	11,349	10,983	11,504	11,326	11,872
Methane emissions	16,712	16,762	17,056	17,569	18,343	18,159	18,290
Nitrous oxide emissions	3,805	3,859	3,925	4,001	3,877	3,855	3,820
PFCs - aluminum production	4,611	1,431	1,090	1,157	1,049	1,065	641

Table 7 - Summary of percentage increases in Missouri GHG emissions in 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Greenhouse gas sources	-2.4%	-2.6%	-2.7%	4.1%	9.0%	13.3%
Carbon dioxide emissions	-0.4%	-0.7%	-1.3%	6.5%	12.5%	18.0%
Energy	0.1%	-0.4%	-0.9%	7.3%	14.1%	19.7%
Energy end-use sectors	-0.3%	1.2%	8.1%	9.7%	11.6%	17.0%
Electric utility sector	0.6%	-2.3%	-11.2%	4.5%	16.9%	22.8%
Other	-5.7%	-2.6%	-5.8%	-1.3%	-2.8%	1.9%
Methane emissions	0.3%	2.1%	5.1%	9.8%	8.7%	9.4%
Nitrous oxide emissions	1.4%	3.2%	5.2%	1.9%	1.3%	0.4%
PFCs - aluminum production	-69.0%	-76.4%	-74.9%	-77.3%	-76.9%	-86.1%

The relative share of CO_2 emissions in the total mix of GHG emissions in Missouri increased between 1990 and 1996. In 1990, CO_2 held an estimated 83 percent share of gross GHG emissions in Missouri.[10] By 1996, this share increased to about 86 percent.

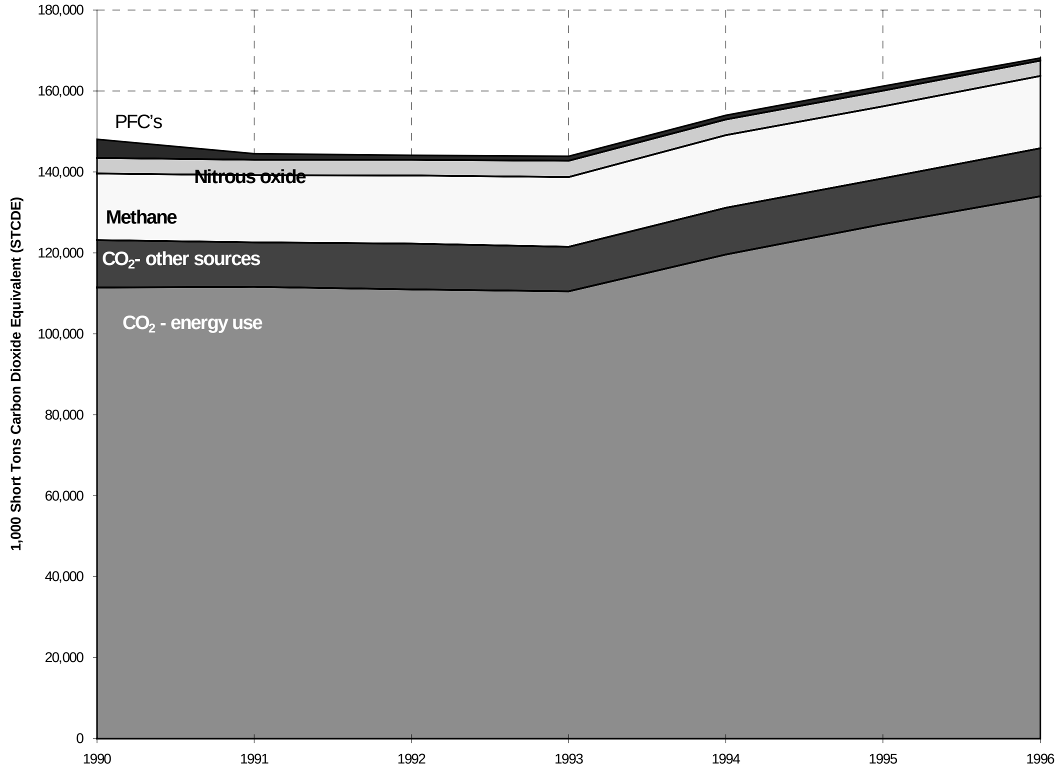
Estimated methane emissions also increased during the period, but not as rapidly as CO_2 emissions. The share of methane emissions in the total mix remained at about 11 percent.

Estimated nitrous oxide emissions remained about constant from 1990 through 1996 and dropped from about 2.6 percent to 2.3 percent of the total mix. The largest reduction was in PFC emissions, which dropped from about 3.1 percent of total emissions in 1990 to less than 1 percent in 1996.

The following chart illustrates the relative shares of CO_2, methane, nitrous oxide and perfluorinated carbons in Missouri gross GHG emissions between 1990 and 1996. Net emissions are lower than gross emissions because they take into account sequestration from forest growth.

[10] As explained in Part 1 of this chapter, this is lower than the 85.5 percent share estimated by the *1990 Inventory* because that study used Global Warming Potential (GWP) factors estimated by IPCC in 1992, whereas this study uses the GWP factors estimated in IPCC in 1995. The 1995 GWP factors ascribe a higher relative Global Warming Potential to methane, nitrous oxide and perfluorinated carbons than the 1992 factors.

Chart 3 - Missouri GHG emissions trends, by gas type, 1990-96



"Net" GHG emissions take into account the impact of carbon sequestration that occurs when there is an increase in the biomass in Missouri forests. Net anthropogenic GHG emissions increased from about 121 million tons (STCDE) in 1990 to about 142 million tons (STCDE) in 1996, growing 17 percent at a 2.7 percent annual average growth rate. The increase in net emissions was due to an increase in gross emissions and a decrease in estimated sequestration by Missouri's forests. Sequestration decreased an estimated 5 percent between 1990 and 1996.

Section 1: Trends in Missouri CO_2 emissions from fossil fuel combustion, 1990-96

CO_2 emissions from fossil fuel combustion increased by about 20 percent, between 1990 and 1996. The leading source of the increase was an expansion in electric utility coal use. Emissions from utility use of coal account for more than 99 percent of utility CO_2 emissions. Utility emissions increased about 23 percent between 1990 and 1996. Net emissions from the other four energy sectors (transportation, commercial, industrial and residential) increased by about 17 percent.

CO_2 emissions from utility coal use led both the 1991 through 1993 decline in Missouri's net GHG emissions and the 1994 through 1996 increase in net GHG emissions. Utility CO_2 emissions from coal decreased by nearly 6 million tons between 1990 and 1993. About 1 million tons of this decrease occurred between 1991 and 1992, and the remaining 5 million occurred in 1993. The decline probably occurred for different reasons in each of the three years: in 1991, because municipal utilities and co-op utilities took advantage of low prices for natural gas and wholesale power to substitute for coal; in 1992, because residential and commercial electricity sales were affected by an unusually cool summer; and in 1993, because flooding and a labor strike cut off Eastern coal supplies and also because natural gas was inexpensive and hydroelectric power was abundant.

From 1994 through 1996, following this 3-year decline in CO_2 emissions from utility coal use, generation from coal steadily increased. Utility coal use in 1996 was 20 percent higher than in 1990 and 37 percent higher than in 1993. The increase came as utilities, responding to growing electricity demand and the decreasing price of coal, took advantage of the existing excess coal generating capacity in Missouri.

Electricity sales in 1996 were about 20 percent higher than in 1990; compared to the previous year, electricity sales increased by about 1.8 percent in 1994, 4.3 percent in 1995 and 4.2 percent in 1996.[11] Residential and commercial electricity sales during this period increased in response to population and economic growth in the state. Industrial electricity sales increased due to these factors as well as steadily decreasing electricity rates for industry.[12]

On the supply side, the average delivered cost of coal to Missouri utilities decreased rapidly after 1992 as Missouri utilities switched to coal imported from Wyoming and other western states. Missouri utilities' average delivered price of coal in 1996 was nearly 30 percent lower than in 1992.

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[11] Due to variations in the weather, the growth of electricity sales in Missouri slowed to only about 0.5 percent in 1997 but increased to about 7.8 percent during the first half of 1998.

[12] During the 20 years prior to 1990, the average price for electricity delivered to Missouri industry increased every year except 1984. Since 1990, the average price to industry has decreased every year. The average price in nominal dollars for electricity delivered to Missouri industry decreased about 8.3 percent between 1990 and 1995, from $14.50 per million Btu in 1990 to $13.29 in 1995. The average price to residential and commercial customers also decreased between 1990 and 1995, but the decrease was smaller (4.1 percent to commercial customers and 1.4 percent to residential customers) and price changes followed a mixed pattern of price increases and decreases from year to year. USDOE/EIA, *State Energy Price and Expenditure Report*, 1995.

The steady increase in utility generation from coal between 1993 and 1996 led to a rapid increase in CO_2 emissions. CO_2 emissions from utility coal use increased by more than 18 million tons between 1994 and 1996. The level of utility CO_2 emissions from coal in 1996, 62.9 million tons, was about 23 percent higher than in 1990 and 39 percent higher than in 1993.

Electric utilities increased their share of energy-related CO_2 emissions from about 46 percent in 1990 to about 47 percent in 1996. With continued growth in transportation emissions during 1990 through 1996, the share of the transportation sector also increased slightly. The residential and commercial sectors' shares remained about constant, and the industrial sector's share decreased from about 10 percent to about 8 percent.

Table 8 and Table 9 summarize sectoral trends between 1990 and 1996 in CO_2 emissions from fossil fuel combustion.

Table 8 - Trends in CO_2 emissions from fossil fuel combustion, by primary energy use sector, 1990-96

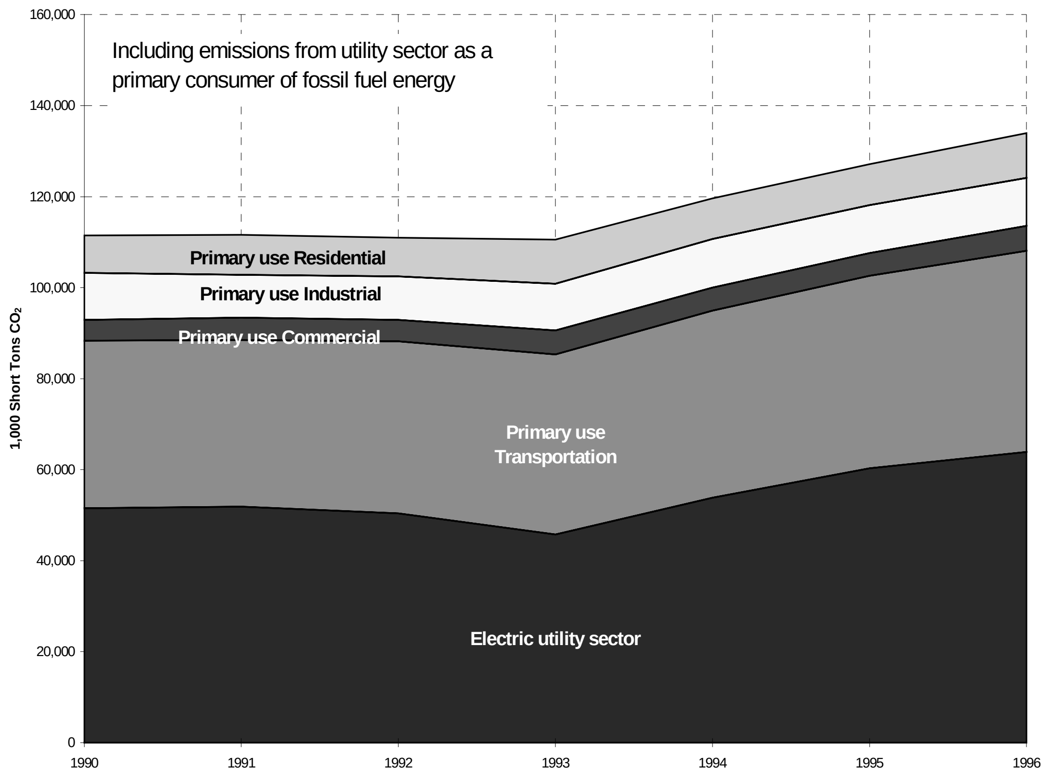
Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	1990	1991	1992	1993	1994	1995	1996
Primary use							
Transportation	36,782	36,636	37,813	39,542	41,110	42,351	44,207
Commercial	4,625	4,898	4,730	5,300	5,071	4,991	5,465
Industrial	10,284	9,414	9,574	10,241	10,634	10,497	10,612
Residential	8,242	8,833	8,515	9,684	8,950	9,073	9,838
Electric utility sector	51,539	51,857	50,346	45,752	53,843	60,243	63,288
Total	***111,472***	***111,638***	***110,977***	***110,519***	***119,608***	***127,156***	***133,410***

Table 9 - Percentage increases in CO_2 emissions from fossil fuel combustion in 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Primary use						
Transportation	-0.4%	2.8%	7.5%	11.8%	15.1%	20.2%
Commercial	5.9%	2.3%	14.6%	9.6%	7.9%	18.2%
Industrial	-8.5%	-6.9%	-0.4%	3.4%	2.1%	3.2%
Residential	7.2%	3.3%	17.5%	8.6%	10.1%	19.4%
Electric utility sector	0.6%	-2.3%	-11.2%	4.5%	16.9%	22.8%
Total	***0.1%***	***-0.4%***	***-0.9%***	***7.3%***	***14.1%***	***19.7%***

Chart 4 - Trends in CO_2 emissions from fossil fuel combustion, 1990-96



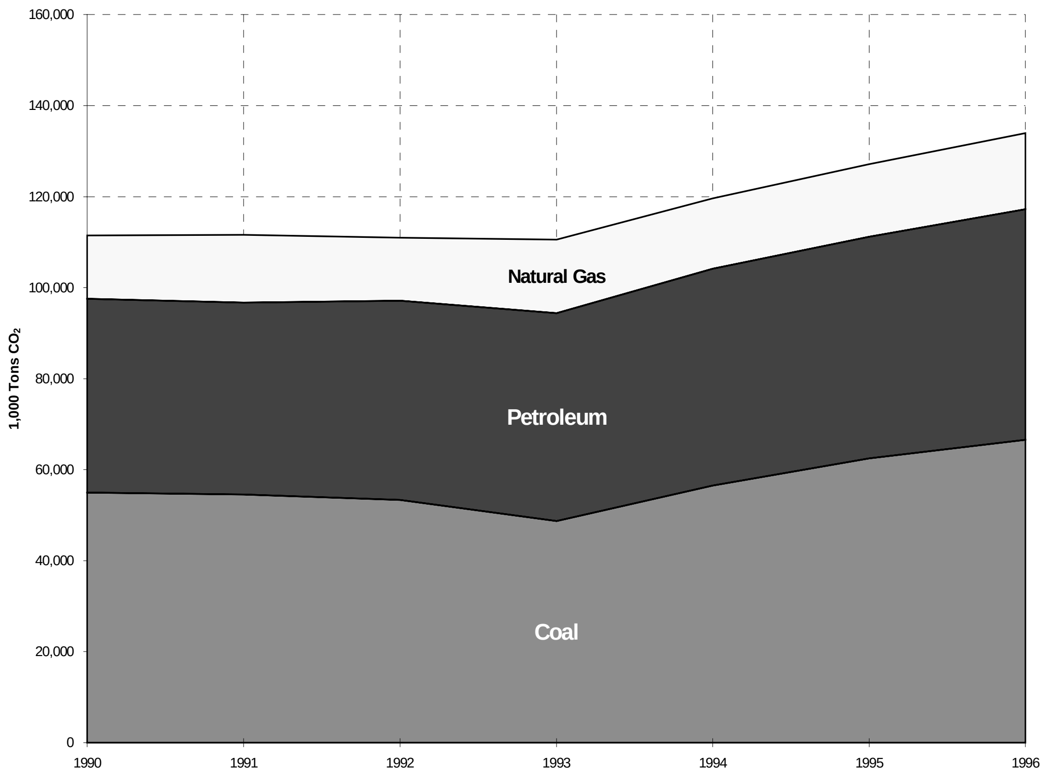
In addition to CO_2 emissions from coal-fired utility boilers, other sources of the large increase of energy-related CO_2 emissions between 1990 and 1996 included:

CO_2 emissions from increased use of gasoline, diesel and jet fuel in the transportation sector, which increased by about 5 million tons (STCDE); and

CO_2 emissions from increased use of natural gas in the commercial, industrial and residential sectors, which increased by about 3 million tons (STCDE).

Thus, as a result of increased coal consumption in the utility sector, petroleum consumption in the transportation sector and natural gas consumption in the other sectors, estimated energy-related CO_2 emissions from all three fuel types increased during 1990 through 1996.

Chart 5 - Trends in CO_2 emissions from fossil fuel combustion, by fuel type, 1990-96



Tables 10 and 11 indicate the emissions increases in the three fuel types.

Table 10 - Trends in CO_2 emissions for coal, petroleum and natural gas, 1990-96

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	1990	1991	1992	1993	1994	1995	1996
Coal	54,969	54,490	53,357	48,717	56,479	62,464	65,949
Petroleum	42,591	42,237	43,721	45,614	47,634	48,739	50,733
Natural Gas	13,912	14,911	13,899	16,188	15,494	15,953	16,729
Total	***111,472***	***111,638***	***110,977***	***110,519***	***119,608***	***127,156***	***133,411***

Table 11 - Percentage increases in CO_2 emissions from coal, petroleum and natural gas in 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Coal	-0.9%	-2.9%	-11.4%	2.7%	13.6%	20.0%
Petroleum	-0.8%	2.7%	7.1%	11.8%	14.4%	19.1%
Natural Gas	7.2%	-0.1%	16.4%	11.4%	14.7%	20.2%
Total	***0.1%***	***-0.4%***	***-0.9%***	***7.3%***	***14.1%***	***19.7%***

As discussed in Chapter 2, Part 3, emissions from fossil fuel-based electricity generation may be allocated to the other four sectors according to the sectors' share of electricity use. In 1996, as in 1990, transportation was the leading sectoral source of emissions among the four end-use sectors. Between 1990 and 1996, the estimated shares of the transportation and industrial sectors dropped slightly, and those of the residential and commercial sectors rose slightly, but the shifts were all less than one percent. Tables 12 and 13 summarize the resulting trends by sector:

Table 12 - Trends in CO_2 emissions, by end-use sector, 1990-96

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	1990	1991	1992	1993	1994	1995	1996
Transportation	36,782	36,636	37,813	39,542	41,118	42,354	44,210
Commercial	23,104	23,262	22,937	21,551	24,486	26,768	28,450
Industrial	22,649	21,447	22,010	20,869	23,359	24,362	24,985
Residential	28,937	30,292	28,218	28,557	30,653	33,674	35,768
Total end-use sectors	***111,472***	***111,638***	***110,977***	***110,519***	***119,616***	***127,159***	***133,413***

Table 13 - Percentage increases in CO_2 emissions from Missouri end-use sectors in 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Transportation	-0.4%	2.8%	7.5%	11.8%	15.1%	20.2%
Commercial	0.7%	-0.7%	-6.7%	6.0%	15.9%	23.1%
Industrial	-5.3%	-2.8%	-7.9%	3.1%	7.6%	10.3%
Residential	4.7%	-2.5%	-1.3%	5.9%	16.4%	23.6%
Total end-use sectors	***0.1%***	***-0.4%***	***-0.9%***	***7.3%***	***14.1%***	***19.7%***

Section 2: Missouri GHG emissions from sources other than energy use, 1990-96

This section reviews changes in CO_2 emissions from non-energy sources, changes in CO_2 sequestration due to forest growth and changes in emissions of gases other than CO_2.

CO_2 from sources other than energy

Between 1990 and 1996, while energy-based CO_2 emissions increased at a 3.1 percent average annual growth rate, total non-energy-based CO_2 emissions increased only about 0.2 million tons (STCDE) over their level in 1990, an average annual growth rate of about 0.3 percent. Between 1990 and 1996, non-energy-based CO_2 emissions for several sources fell below their 1990 level.[13] The share of non-energy emissions as a percentage of total CO_2 emissions decreased from 9.5 percent in 1990 to about 8.2 percent in 1996. Table 14 summarizes estimates for sources of non-energy-related CO_2 emissions during 1990-96, and Table 15 summarizes percentage changes for these sources.

Table 14 - Trends in Missouri CO_2 emissions from sources other than fossil fuel combustion, 1990-96

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	1990	1991	1992	1993	1994	1995	1996
Oxidation of carbon monoxide	1,460	1,433	1,481	1,516	1,570	1,595	1,650
Transportation	1,293	1,279	1,325	1,349	1,396	1,424	1,477
Industrial	168	153	156	167	173	171	173
Non-energy uses of fossil fuels	1,345	849	951	910	960	946	982
Industrial sector uses	1,111	640	737	693	733	720	754
Transportation sector - lubricants	234	210	214	218	227	226	228
Limestone use	4,445	4,309	4,510	4,150	4,568	4,379	4,834
Cement Production	2,260	2,156	2,382	2,255	2,629	2,424	2,562
Lime Manufacture	1,599	1,597	1,579	1,374	1,413	1,413	1,731
Decomposition of agricultural lime	586	555	549	522	526	541	541
Land use changes	4,407	4,407	4,407	4,407	4,407	4,407	4,407
Net loss of above-ground "sinks"	1,613	1,613	1,613	1,613	1,613	1,613	1,613
Soil carbon release	2,793	2,793	2,793	2,793	2,793	2,793	2,793
Total	***11,656***	***10,998***	***11,349***	***10,983***	***11,504***	***11,326***	***11,872***

[13] As explained in Chapter 3, the apparent decrease may be in part an artifact of changes in EIA methodology for reporting industrial consumption of certain petroleum products typically used for non-energy purposes.

Table 15 - Percentage changes in CO_2 emissions from sources other than fossil fuel combustion, 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Oxidation of carbon monoxide	-1.9%	1.4%	3.8%	7.5%	9.2%	13.0%
Transportation	-1.0%	2.5%	4.3%	8.0%	10.1%	14.3%
Industrial	-8.5%	-6.9%	-0.4%	3.4%	2.1%	3.2%
Non-energy uses of fossil fuels	-36.8%	-29.3%	-32.3%	-28.6%	-29.7%	-27.0%
Industrial sector uses	-42.4%	-33.6%	-37.6%	-34.0%	-35.2%	-32.1%
Transportation sector - lubricants	-10.5%	-8.8%	-7.1%	-2.9%	-3.4%	-2.9%
Limestone use	-3.1%	1.5%	-6.6%	2.8%	-1.5%	8.8%
Cement Production	-4.6%	5.4%	-0.2%	16.3%	7.3%	13.4%
Lime Manufacture	-0.1%	-1.2%	-14.1%	-11.6%	-11.6%	8.2%
Decomposition of agricultural lime	-5.3%	-6.4%	-11.0%	-10.2%	-7.6%	-7.7%
Land use changes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	***-5.7%***	***-2.6%***	***-5.8%***	***-1.3%***	***-2.8%***	***1.9%***

Sequestration from forest biomass growth

The total biomass in Missouri forests continued to increase in the 1990s, resulting in substantial annual sequestration of carbon in new biomass. The *1990 Inventory* estimated that biomass growth in Missouri's forests sequestered between 31.3 and 37.8 million tons of CO_2. This study estimates that Missouri's growing forests continued to add new biomass and sequester new carbon in 1996 at nearly the same level as in 1990.

However, this study does estimate that *net* forest sequestration decreased by about 1.3 million tons (STCDE) between 1990 and 1996. Since a 1-ton decrease in carbon sequestration has the same impact as a 1-ton increase in carbon emissions, this is equivalent to a 1.3 million ton increase in CO_2 emissions.

Underlying this decrease in forest sequestration was an increase in the rate of commercial forest harvest and "forest removals" in Missouri between 1990-96. The *State Workbook* recommends a simple methodology for accounting for the carbon impact of forest removals, and the estimate of a 1.3 million ton decrease was derived using this simple methodology.

As discussed in Chapter 6, the methodology recommended in the *State Workbook* and used in this study is based on simplifying assumptions about what happens to carbon in wood and other biomass that is removed from the forest. The net result of these assumptions is that the carbon in forest removals is assumed to be immediately released.

Chapter 6 presents the rational for using this simple methodology despite its limitations. As explained in Chapter 6, researchers are attempting to develop a more sophisticated methodology for use in national studies that attempts to estimate variable rates of carbon release for different portions of the forest removal stream. Use of this more sophisticated methodology would probably result in a smaller estimate (less than 1.3 million tons) of the decrease in Missouri forest sequestration. However, for reasons detailed in Chapter 6, use of the more sophisticated methodology was impractical.

Table 16 - Trends in sequestration of CO_2 emissions due to Missouri forest growth, 1990-96

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	1990	1991	1992	1993	1994	1995	1996
Biomass growth	(34,615)	(34,615)	(34,615)	(34,615)	(34,615)	(34,615)	(34,615)
Forest removals	7541	7,654	7,954	8,256	8,559	8,726	8,883
Total CO_2 Sequestered	***(27,074)***	***(26,961)***	***(26,662)***	***(26,359)***	***(26,056)***	***(25,889)***	***(25,732)***

Emissions of greenhouse gases other than CO_2

Apart from changes in energy-related CO_2 emissions, the most significant change in Missouri's GHG emissions between 1990 and 1996 was a reduction in perfluorinated carbon (PFC) emissions. PFC emissions in 1996 were about 14 percent of the 1990 level. The largest reduction came in 1990 and 1991, when PFC emissions dropped by about 2.5 million tons (STCDE) to about 31 percent of the 1990 level. This reduction was the leading cause of the drop in Missouri's net GHG emissions in 1990 and 1991.[14]

The reductions in PFC emissions were the result of production line improvements by Noranda Aluminum Inc., whose aluminum manufacturing facility is the sole source of PFC emissions in Missouri. Noranda Aluminum is a participant in USEPA's Voluntary Aluminum Industry Partnership program.

Estimated methane emissions increased by about 9.4 percent to total about 18.3 million tons (STCDE) in 1996, an average annual growth rate of 1.5 percent. Increases occurred primarily after 1994. Estimated methane emissions increased about 6.7 percent from agriculture and about 15.9 percent from landfills.

Estimated nitrous oxide emissions from the use of nitrogenous fertilizers were only slightly higher in 1996 than in 1990.

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[14] A portion (about 1.7 MSTCDE) of the reported 1990-91 decline may be an artifact of EIA State Energy Data System data series adjustments for petroleum consumed in the industrial sector. This issue is discussed in Chapter 2, Part 2, Section 3 of this report.

Table 17 summarizes the study's estimates of methane, nitrous oxide and perfluorinated carbons emissions between 1990 and 1996:

Table 17 - Trends in Missouri methane, nitrous oxide and PFC emissions, 1990-96

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1991	1992	1993	1994	1995	1996
Methane emissions	16,712	16,762	17,056	17,569	18,343	18,159	18,290
Agriculture	10,463	10,255	10,410	10,796	11,445	11,140	11,166
Municipal waste	5,604	5,851	5,997	6,135	6,261	6,375	6,481
Fossil fuel prod'n & dist'n	501	513	506	495	494	501	501
Highway transportation	143	143	143	143	143	143	143
Nitrous oxide emissions	3,805	3,859	3,925	4,001	3,877	3,855	3,820
Agriculture	2,333	2,388	2,454	2,530	2,406	2,383	2,348
Highway transportation	1,080	1,080	1,080	1,080	1,080	1,080	1,080
Nitric acid production	391	391	391	391	391	391	391
PFCs aluminum production	4,611	1,431	1,090	1,157	1,049	1,065	641
CF_4 emissions	3,847	1,194	910	965	875	889	535
C_2F_6 emissions	763	237	181	192	174	176	106
Total non-CO_2 emissions	***25,127***	***22,053***	***22,071***	***22,727***	***23,269***	***23,079***	***22,751***

Table 18 - Percentage changes in non-CO_2 emissions in 1991-96 compared to 1990

	1991	1992	1993	1994	1995	1996
Methane emissions	0.3%	2.1%	5.1%	9.8%	8.7%	9.4%
Agriculture	-2.0%	-0.5%	3.2%	9.4%	6.5%	6.7%
Municipal waste	4.4%	7.0%	9.5%	11.7%	13.8%	15.6%
Fossil fuel prod'n & dist'n	2.4%	0.9%	-1.2%	-1.5%	-0.1%	-0.1%
Highway transportation	n/a	n/a	n/a	n/a	n/a	n/a
Nitrous oxide emissions	1.4%	3.2%	5.2%	1.9%	1.3%	0.4%
Agriculture	2.3%	5.2%	8.4%	3.1%	2.1%	0.6%
Highway transportation	n/a	n/a	n/a	n/a	n/a	n/a
Nitric acid production	n/a	n/a	n/a	n/a	n/a	n/a
PFCs aluminum production	-69.0%	-76.4%	-74.9%	-77.3%	-76.9%	-86.1%
CF_4 emissions	-69.0%	-76.4%	-74.9%	-77.3%	-76.9%	-86.1%
C_2F_6 emissions	-69.0%	-76.4%	-74.9%	-77.3%	-76.9%	-86.1%
Total non-CO_2 emissions	***-12.2%***	***-12.2%***	***-9.6%***	***-7.4%***	***-8.2%***	***-9.5%***

Part 4: Projections of Missouri GHG emissions through 2015

Increasing fossil fuel combustion in Missouri is projected to be the driving force behind increases in statewide GHG emissions through 2015. GHG emissions from fossil fuel combustion in Missouri increased between 1990 and 1996 and are projected to increase even further through 2015. Because the amount of increase depends on a variety of factors, Part 4 presents a range of estimates for the amount that fuel-based GHG emissions will increase.

Total GHG emissions from other Missouri sources are not projected to increase significantly between 1996 and 2015. Increases in emissions from some sources such as limestone use and swine and beef operations will, according to this study's projections, be offset by decreases in other sources such as landfills and dairy operations. Combined with pre-1996 decreases in PFC emissions from aluminum manufacture, the net result is that total GHG emissions from non-fuel sources in 2015 are projected to be only slightly higher than they were in 1990.

Section 1: Projected CO_2 emissions from fossil fuel combustion

This study uses scenarios to take into account uncertainties inherent in projecting future greenhouse gas emissions from fossil fuel combustion. Uncertainties influence estimates of future production and consumption of electricity, a secondary form of energy, as well as the consumption of primary forms of energy through combustion of petroleum, coal and natural gas.

In order to accommodate uncertainties affecting the consumption of primary forms of energy, the study projects CO_2 emissions from fossil fuel combustion using three alternative methods, as follows:

- The "steady state" (SS) method assumes that current patterns of energy use will continue in the future. This scenario assumes that in the year 2015 Missouri citizens and businesses will continue to use primary energy resources as they do now. Projections of energy use and GHG emissions under the steady state scenario assume that CO_2 emissions will grow at the same rate as projected population or projected gross state product (GSP).

- The "continuing trends" (CT) method assumes that recent trends in Missouri's energy use continue into the future. The projections rely on estimating future energy use from past energy consumption trends.

- The AEO method assumes that Missouri's future energy consumption will mirror energy use projections made in the *Annual Energy Outlook 1997*, published by the U.S. Department of Energy's Energy Information Administration (USDOE/EIA).

Energy use patterns respond to factors such as economic and demographic shifts, technological change, the discovery or exhaustion of energy resources, and changes in tastes and preferences. Scenarios based on the SS method do not incorporate these factors into projections of energy use or CO_2 emissions sectors. For the sake of completeness, SS projections are presented for all energy use sectors; however, they are useful primarily as reference points rather than reliable projections.

The CT method implicitly incorporates factors that have operated in the past but does not explicitly analyze how changes in these or other factors might affect energy use in the future. CT projections provide a first approximation of future energy use or emissions and help define boundary conditions for more explicit analyses.

The EIA's *Annual Energy Outlook 1997* is based on the National Energy Modeling System (NEMS) developed by the EIA. NEMS provides national- and regional-level "business-as-usual" estimates of energy use that explicitly incorporate assumptions about future economic, demographic and technological change.[15]

Chapter 4 applies the three methods to estimates of future CO_2 emissions from combustion of petroleum, coal and natural gas in each end-use sector, resulting in the projections summarized in Table 19. As Table 19 indicates, the three methods converge for many sector/fuel combinations and also for the CT and AEO estimates for aggregate emissions.

[15] This study draws on the EIA modeling primarily because of the openness of the modeling process and ready availability of its results. The *Annual Energy Outlook 1997* discusses and summarizes projections from other organizations such as DRI, GRI and WEFA. Although these organizations project energy use based on explicit models, the models and results are proprietary and not available to this project.

Table 19 - Projections of end-use sector CO_2 emissions from primary fossil fuel combustion in 2015, by sector

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	CT	SS	AEO
Transportation	58,842	53,303	52,250
Gasoline	33,831	30,186	29,332
Diesel	15,595	14,572	13,612
Jet fuel	9,052	8,158	8,398
Other	365	388	908
Commercial	5,590	5,886	5,341
Natural gas	4,620	4,583	4,214
Petroleum	127	942	784
Coal	843	360	343
Industrial	7,754	15,334	13,202
Natural gas	4,103	5,640	5,091
Petroleum	3,118	5,936	5,272
Coal	533	3,758	2,839
Residential	9,022	10,528	9,563
Natural gas	6,927	8,596	8,558
Petroleum	1,640	1,738	814
Coal	455	194	191
Total end-use sectors	***81,209***	***85,050***	***80,356***

However, Table 19 also reveals significant differences in projections for specific sectors such as transportation and industry. For example, the CT projection for transportation CO_2 emissions in 2015 is about 8 million tons higher than the AEO projection. As Chapter 4 explains, the continuing trend method assumes motor gasoline use will continue growing at a steady rate of about 1 percent per year. In contrast, the national and regional projections in the *Annual Energy Outlook 1997* imply that state motor gasoline use will grow more slowly than during the past, with absolute and per capita consumption decreasing after about 2010. CT projections for diesel and jet fuel growth are also larger than AEO projections.

On the other hand, the CT method projects that industrial CO_2 emissions in 2015 will be lower than in 1990, led by decreases in emissions from petroleum and coal use. AEO projections for the industrial sector indicate that CO_2 emissions from petroleum and coal will increase through 2015. Both methods project that CO_2 emissions from natural gas will increase, but the AEO projection for 2015 is about 1 million tons greater than the CT projection.

Chapter 3 is dedicated to projecting utility CO_2 emissions. The study dedicates a separate chapter to utility sector projections due to the following characteristics of that sector:

1. The utility sector is the largest source of CO_2 emissions in Missouri.

2. Projections of utility energy use and CO_2 emissions are currently subject to high uncertainty due to the prospect of market restructuring. The sector is likely to undergo restructuring within the next few years, but the nature of the restructuring is a political decision that has not yet been determined.

3. Electricity is a secondary form of energy. Projecting energy use in the utility sector requires an additional level of analysis because utility consumption of primary fossil fuel energy is partly derived from end use-demand for electricity.

Table 20 summarizes the result of applying the SS, CT and AEO methods to estimate CO_2 emissions from future utility use of coal, petroleum and natural gas.

Table 20 - "Direct" projections of utility sector CO_2 emissions from primary fossil fuel combustion in 2015

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	AEO	**CT**	**SS**
Utility sector	80,576	73,893	68,516
Coal	78,584	72,957	68,083
Natural gas	1,781	862	308
Petroleum	211	74	125
End-use sectors	80,356	81,209	85,050
Total - all sectors	***160,932***	***155,102***	***153,566***

The direct estimation methods used for Table 20 are probably not adequate to project utility emissions because they do not incorporate electricity users' demand for electricity. Chapter 3 extends the analysis of utility CO_2 emissions, developing four extended scenarios based on the derived nature of utility primary fossil fuel use and CO_2 emissions. These scenarios, summarized in Table 21, are based on a two-step estimation procedure described in Chapter 3.

Table 21 - Extended Method Scenarios for utility sector CO_2 emissions from primary fossil fuel combustion in 2015

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

	AEO Sales		CT Sales	
	High NG	**Low NG**	**High NG**	**Low NG**
Utility sector	74,224	80,877	82,131	88,621
Coal	68,534	78,995	76,468	87,685
Natural gas	5,589	1,781	5,589	862
Petroleum	102	102	74	74
End-use sectors	80,356	80,356	81,209	81,209
Total - all sectors	***154,580***	***161,233***	***163,339***	***169,830***

Future electricity sales is the first differentiating factor in the extended methodology. The two leftmost projections in Table 21 are based on AEO estimates of future electricity sales; the two rightmost are based on CT estimates. The "AEO sales" projections are lower than the "CT sales" projections because the *Annual Energy Outlook 1997* states that utility sales will grow more slowly than in the past. The CT and AEO methods for estimating utility sales are fully described in Chapter 3.

Projected utility investment and use of new natural gas generation is the second differentiating factor in the extended methodology. Substitution of natural gas for coal would decrease CO_2 emissions because coal has higher carbon content than natural gas. The "high NG" projections assume that utilities (or new independent power producers entering the market under deregulation) will increase the rate of investment in natural gas generating facilities and expand the use of natural gas to mid-load or base-load generation. The "low NG" projections assume that Missouri utilities will continue to confine natural gas use to meeting peak load requirements.

The "business-as-usual" projections in Table 21 are based on conservative assumptions about future end user decisions and utility decisions. The electricity sales projections assume growth rates equal or lower than the sales growth rates used by Missouri utilities in their Integrated Resource Plans. The level chosen to represent a "high" use of natural gas is based on *Annual Energy Outlook 1997* projections.

Moreover, the study makes conservative assumptions about the impact of restructuring on external purchases and sales of electricity in order to keep the scope of its analytic effort within reasonable bounds. The projections in Table 21 assume that the close relationship between the quantity of electricity produced and consumed in Missouri will continue. Restructuring could alter this relationship and bring large increases in exports and/or imports of electricity.

The aggregate projections for CO_2 emissions from energy use summarized in Table 20 and Table 21 may be classified into low-, midrange- and high-emissions scenarios, as follows:

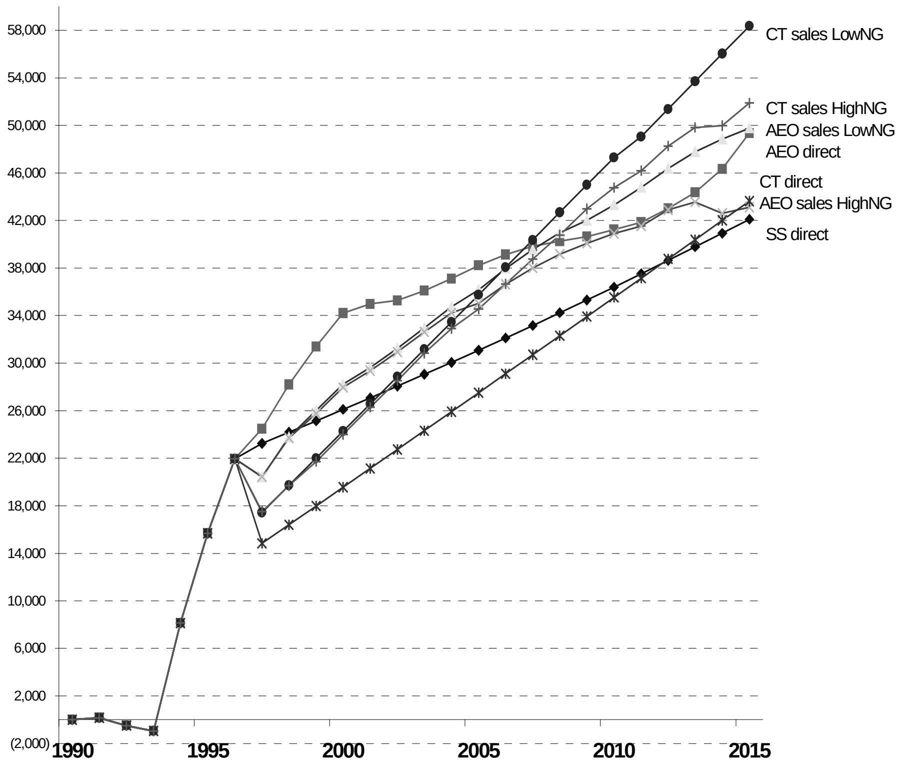
- ***Low-emissions scenario:*** Total emissions of about 154 to 155 million tons of CO_2. The CT direct estimate and the AEO sales/high natural gas estimate, both in Table 21, fit into this scenario.

- ***Midrange-emissions scenario:*** Total emissions of about 161 to 163 million tons of CO_2. The AEO direct estimate in Table 20 and the AEO sales/low natural gas and CT sales/high natural gas estimates in Table 21 fit into this scenario.

- ***High-emissions scenario:*** Total emissions of about 170 million tons of CO_2. The CT sales/low natural gas estimate in Table 21 fit into this scenario.

Under the low emissions scenario, CO_2 emissions from energy use would increase at an average annual growth rate of about 1.3 percent per year between 1990 and 2015, resulting in an increase of 42 to 44 million tons over 1990 levels. The corresponding average annual growth rates for the midrange and high scenarios are about 1.5 percent (an increase of 49 to 51 million tons) and 1.7 percent (58 million tons). Chart 4 depicts projected increases in CO_2 emissions deriving from the different scenarios.

Chart 6 - Projected increase in CO_2 from fossil fuel combustion, 1990-2015



Although the seven different projections for the year 2015 appear to group themselves into low-, midrange- and high-emissions scenarios, this is not necessarily true for earlier years. For example, projections based on the Continuing Trend method are relatively low[16] and those based on EIA's *Annual Energy Outlook 1997* are relatively high for earlier years. However, EIA projects a decreasing growth rate in energy use after the year 2000. Therefore, after the year 2000, the AEO projections are bypassed by the CT projections, which do not assume a decreasing growth rate.

Tables 22 through 24 summarize Missouri greenhouse gas emissions projections for 2005, 2010 and 2015. These tables include all CO_2 sources and sinks, non-energy as well as energy. They also summarize projected emissions of methane, nitrous oxide and PFCs.

[16] The CT projections appear to project a decrease in emissions in the years immediately following 1996. This is an artifact of the use of linear regression. As explained in Chapter 2, the CT method's short-term projections should be disregarded.

Table 22 - Estimated Missouri GHG emissions in 2005, by scenario and method

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	Low emissions scenarios			Midrange			High
	SS Direct	**AEO Sales High NG**	**CT Direct**	**AEO Direct**	**AEO Sales Low NG**	**CT Sales High NG**	**CT Sales Low NG**
Fossil fuel combustion	142,546	146,494	138,974	149,681	147,632	146,019	147,221
Transportation	48,183	49,821	50,326	49,821	49,821	50,326	50,326
Gasoline	29,037	29,305	30,646	29,305	29,305	30,646	30,646
Diesel	12,035	12,461	12,421	12,461	12,461	12,421	12,421
Jet	6,738	7,398	6,897	7,398	7,398	6,897	6,897
Other	373	658	362	658	658	362	362
Commercial	30,587	30,891	31,282	32,055	31,306	34,078	34,554
Electricity	24,925	25,568	25,956	26,733	25,984	28,751	29,228
Nat. Gas	4,409	4,179	4,251	4,179	4,179	4,251	4,251
Petroleum	906	810	438	810	810	438	438
Coal	346	334	637	334	334	637	637
Industrial	27,570	28,853	22,444	29,626	29,129	23,904	24,153
Electricity	14,906	16,980	13,553	17,754	17,256	15,013	15,262
Nat. Gas	4,658	4,623	3,838	4,623	4,623	3,838	3,838
Petroleum	4,903	4,594	3,474	4,594	4,594	3,474	3,474
Coal	3,104	2,655	1,579	2,655	2,655	1,579	1,579
Residential	36,206	36,930	34,921	38,178	37,376	37,711	38,187
Electricity	26,079	27,424	25,904	28,672	27,870	28,694	29,170
Nat. Gas	8,269	8,225	7,108	8,225	8,225	7,108	7,108
Petroleum	1,672	1,099	1,565	1,099	1,099	1,565	1,565
Coal	187	182	344	182	182	344	344
Other sources of CO_2	12,588	12,602	12,604	12,602	12,602	12,604	12,604
Methane emissions	15,357	15,357	15,357	15,357	15,357	15,357	15,357
Nitrous oxide emissions	3,872	3,872	3,872	3,872	3,872	3,872	3,872
PFC emissions	458	458	458	458	458	458	458
Forest sequestration	(24,140)	(24,140)	(24,140)	(24,140)	(24,140)	(24,140)	(24,140)
Total GHG emissions	***150,681***	***154,644***	***147,125***	***157,830***	***155,781***	***154,170***	***155,372***

Table 23 - Estimated Missouri GHG emissions in 2010, by scenario and method

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	Low emissions scenarios			Midrange			High
	SS Direct	AEO Sales High NG	CT Direct	AEO Direct	AEO Sales Low NG	CT Sales High NG	CT Sales Low NG
Fossil fuel combustion	147,869	152,379	146,999	152,711	154,783	156,239	158,771
Transportation	50,641	51,554	54,545	51,554	51,554	54,545	54,545
Gasoline	29,604	29,509	32,199	29,509	29,509	32,199	32,199
Diesel	13,243	13,204	14,008	13,204	13,204	14,008	14,008
Jet	7,414	8,022	7,974	8,022	8,022	7,974	7,974
Other	380	818	364	818	818	364	364
Commercial	31,476	32,174	33,793	32,295	33,052	37,552	38,582
Electricity	25,704	26,845	28,335	26,966	27,723	32,094	33,124
Nat. Gas	4,495	4,193	4,435	4,193	4,193	4,435	4,435
Petroleum	924	798	283	798	798	283	283
Coal	353	339	740	339	339	740	740
Industrial	29,035	30,671	22,191	30,753	31,265	24,031	24,535
Electricity	15,100	18,169	13,869	18,251	18,763	15,708	16,213
Nat. Gas	5,125	4,903	3,970	4,903	4,903	3,970	3,970
Petroleum	5,395	4,893	3,296	4,893	4,893	3,296	3,296
Coal	3,415	2,706	1,056	2,706	2,706	1,056	1,056
Residential	36,717	37,980	36,469	38,109	38,912	40,111	41,108
Electricity	26,392	28,466	27,449	28,594	29,397	31,091	32,089
Nat. Gas	8,430	8,390	7,017	8,390	8,390	7,017	7,017
Petroleum	1,704	938	1,603	938	938	1,603	1,603
Coal	191	187	399	187	187	399	399
Other sources of CO_2	12,995	12,967	13,034	12,967	12,967	13,034	13,034
Methane emissions	15,150	15,150	15,150	15,150	15,150	15,150	15,150
Nitrous oxide emissions	3,870	3,870	3,870	3,870	3,870	3,870	3,870
PFC emissions	437	437	437	437	437	437	437
Forest sequestration	(23,305)	(23,305)	(23,305)	(23,305)	(23,305)	(23,305)	(23,305)
Total GHG emissions	***157,016***	***161,497***	***156,185***	***161,830***	***163,902***	***165,425***	***167,957***

Table 24 - Estimated Missouri GHG emissions in 2015, by scenario and method

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	Low emissions scenarios			Midrange			High
	SS Direct	**AEO Sales High NG**	**CT Direct**	**AEO Direct**	**AEO Sales Low NG**	**CT Sales High NG**	**CT Sales Low NG**
Fossil fuel combustion	153,566	154,580	155,102	160,822	161,233	163,339	169,830
Transportation	53,303	52,250	58,842	52,250	52,250	58,842	58,842
Gasoline	30,186	29,332	33,831	29,332	29,332	33,831	33,831
Diesel	14,572	13,612	15,595	13,612	13,612	15,595	15,595
Jet	8,158	8,398	9,052	8,398	8,398	9,052	9,052
Other	388	908	365	908	908	365	365
Commercial	32,208	32,153	36,275	34,408	34,556	39,696	42,391
Electricity	26,322	26,812	30,685	29,067	29,215	34,106	36,801
Nat. Gas	4,583	4,214	4,620	4,214	4,214	4,620	4,620
Petroleum	942	784	127	784	784	127	127
Coal	360	343	843	343	343	843	843
Industrial	30,630	31,807	21,962	33,371	33,474	23,546	24,794
Electricity	15,297	18,605	14,208	20,170	20,273	15,792	17,040
Nat. Gas	5,640	5,091	4,103	5,091	5,091	4,103	4,103
Petroleum	5,936	5,272	3,118	5,272	5,272	3,118	3,118
Coal	3,758	2,839	533	2,839	2,839	533	533
Residential	37,425	38,370	38,023	40,793	40,952	41,255	43,803
Electricity	26,897	28,807	29,000	31,230	31,389	32,233	34,780
Nat. Gas	8,596	8,558	6,927	8,558	8,558	6,927	6,927
Petroleum	1,738	814	1,640	814	814	1,640	1,640
Coal	194	191	455	191	191	455	455
Other sources of CO_2	13,415	13,310	13,472	13,310	13,310	13,472	13,472
Methane emissions	15,109	15,109	15,109	15,109	15,109	15,109	15,109
Nitrous oxide emissions	3,868	3,868	3,868	3,868	3,868	3,868	3,868
PFC emissions	416	416	416	416	416	416	416
Forest sequestration	(22,503)	(22,503)	(22,503)	(22,503)	(22,503)	(22,503)	(22,503)
Total GHG emissions	***163,872***	***164,781***	***165,465***	***171,024***	***171,434***	***173,702***	***180,193***

Table 25 - Projected average annual growth rate of CO_2 emissions from fossil fuel combustion in Missouri, 1990-2015

Units: 1,000 Short Tons Carbon Dioxide (CO_2)

Projected CO_2 emissions

		1990	1996	2000	2005	2010	2015
Low	SS direct	111,472	133,411	137,577	142,546	147,869	153,566
	AEO sales HighNG	111,472	133,410	139,422	146,494	152,379	154,580
	CT direct	111,472	133,411	131,027	138,974	146,999	155,102
Mid	AEO direct	111,473	133,410	145,672	149,681	152,711	160,822
	AEO sales LowNG	111,473	133,410	139,689	147,632	154,783	161,233
	CT sales HighNG	111,472	133,411	135,473	146,019	156,239	163,339
High	CT sales LowNG	111,472	133,411	135,748	147,221	158,771	169,830

Projected increase in CO_2 emissions

		1996	2000	2005	2010	2015
Low	SS direct	21,939	26,105	31,073	36,396	42,094
	AEO sales HighNG	21,938	27,950	35,022	40,906	43,108
	CT direct	21,939	19,554	27,502	35,527	43,630
Mid	AEO direct	21,937	34,199	38,207	41,238	49,349
	AEO sales LowNG	21,937	28,216	36,159	43,310	49,760
	CT sales HighNG	21,939	24,001	34,547	44,767	51,867
High	CT sales LowNG	21,939	24,276	35,748	47,299	58,357

Projected average annual growth rate

		Growth rate 1990-1996	Growth rate 1996-2000	Growth rate 2000-2005	Growth rate 2005-2010	Growth rate 2010-2015
Low	SS direct	3.0%	0.8%	0.7%	0.7%	0.8%
	AEO sales HighNG	3.0%	1.1%	1.0%	0.8%	0.3%
	CT direct	3.0%	-0.4%	1.2%	1.1%	1.1%
Mid	AEO direct	3.0%	2.2%	0.5%	0.4%	1.0%
	AEO sales LowNG	3.0%	1.2%	1.1%	1.0%	0.8%
	CT sales HighNG	3.0%	0.4%	1.5%	1.4%	0.9%

Section 2: Projected GHG emissions from sources other than energy use

About 25 percent of greenhouse gas emissions come from sources other than fossil fuel combustion. In 1990, these "other" sources emitted a total of about 36.8 million tons (STCDE) of greenhouse gas emissions, consisting of about 11.7 million tons of CO_2, 16.7 million tons (STCDE) of methane (CH_4), 3.8 million tons (STCDE) of nitrous oxide (N_2O) and 4.6 million tons (STCDE) of perfluorinated carbons (PFCs).[17]

By 2015, the share of these sources in total greenhouse gas emissions is projected to decline due to a projected 2.5 million ton (STCDE) decrease in total emissions from these sources as well as projected increases in CO_2 emissions from fossil fuel combustion.

However, increases are projected through 2015 for some of these sources, particularly the following:

1. In 2015, CO_2 emissions from industrial and agricultural uses of limestone are projected at a level about 1.4 million tons higher than in 1990. As shown below, the increase is expected to occur steadily throughout the period.

Units: Short Tons Carbon Dioxide (CO_2)

	1990	2000	2005	2010	2015
Clinker production	2,256,657	2,801,127	3,103,127	3,405,127	3,707,127
Masonry cement	2,845	2,845	2,845	2,845	2,845
Lime Production	1,599,045	1,730,627	1,730,627	1,730,627	1,730,627
Agricultural Lime	586,005	459,109	467,661	461,797	461,797
Total	4,444,551	4,993,707	5,304,259	5,600,395	5,902,395
Growth rate		***1.2%***	***1.2%***	***1.2%***	***1.1%***

2. In 2015, methane emissions from swine operations are projected at a level about 0.9 million tons higher than in 1990. As shown below, emissions from this source are likely to peak around the year 2005 and then decrease as swine numbers decline.

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1995	2000	2005	2010	2015
	2,747	3,401	3,691	3,906	3,776	3,672
Average annual growth rate since 1990			***3.0%***	***2.4%***	***1.6%***	***1.2%***

[17] As explained earlier in this chapter, Short Tons Carbon Dioxide Equivalent (STCDE) as a unit of measure functions to permit comparisons between different greenhouse gases. For example, 1 million tons (STCDE) of methane, released into the atmosphere, is expected to have an effect on average temperature equivalent to the effect of releasing 1 million tons of CO_2.

3. In 2015, methane emissions from beef operations are projected at a level about 0.7 million tons (STCDE) higher than in 1990. Although emissions will be affected by the beef cycle, an increase is expected through most of the period.

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1995	2000	2005	2010	2015
Total	5,677	5,956	5,636	6,074	6,210	6,420
Growth rate			***-0.1%***	***0.7%***	***0.9%***	***1.2%***

The projected increases in GHG emissions from these sources are expected to be more than offset by decreases in GHG emissions from other sources. Chart 7 illustrates the net effect of decreases from some sources, more than offsetting increases from other sources. Sources with major decreases projected through 2015 are as follows:

1. In 2015, PFC emissions from aluminum manufacture are projected at a level about 4.2 million tons (STCDE) lower than 1990 PFC emissions. Most of this decrease was realized between 1990 and 1992, when Noranda Aluminum, whose aluminum manufacturing plant is the sole source of PFC emissions in Missouri, reduced PFC emissions by about 3.5 million tons (STCDE) through improvements in its manufacturing process. Noranda achieved this reduction as part of its participation in the Voluntary Aluminum Industry Partnership (VAIP) program sponsored by USEPA. The emissions estimates below are base estimates of PFC emissions for 1990 through 1996 and projections for 2005 and 2015 provided by Noranda.

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1995	2005	2015
CF_4	3,847	889	382	347
C_2F_6	763	176	76	69
Total PFCs	4,611	1,065	458	416
Growth rate			***-14%***	***-9%***

2. In 2015, methane emissions from landfills are projected at a level about 0.7 million tons (STCDE) lower than emissions in 1990. Landfill emissions have increased since 1990 and are projected to increase until the year 2000, but beginning in that year, federal and state requirements that should affect about half of Missouri's landfills will lead to a large increase in methane flaring and capture. Landfill emissions will also show the effect of efforts to reduce municipal waste disposal, efforts which began in 1991 in response to a state mandate. The complicated pattern of landfill emissions is traced below;

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1995	2000	2005	2010	2015
Low WIP	3,906	4,678	3,803	4,131	4,037	3,792
High WIP	7,374	8,097	6,187	6,368	6,130	5,871
Midpoint	5,501	6,273	4,930	5,205	5,046	4,788
Growth rate			***-1.1%***	***-0.4%***	***-0.4%***	***-0.6%***

3. In 2015, methane emissions from dairy operations are projected at a level about 1.1 million tons (STCDE) lower than emissions in 1990.

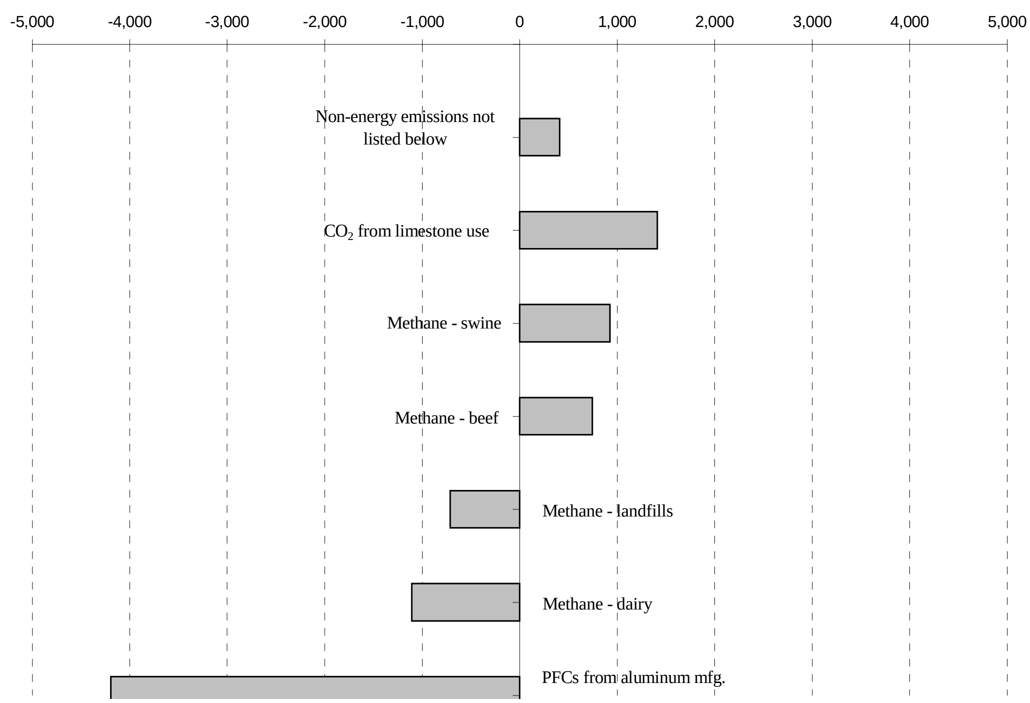
Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1995	2000	2005	2010	2015
Total	1,808	1,552	1,238	1,023	852	700
			-14.1%	***-15.7%***	***-17.3%***	***-18.9%***

While emissions from these three sources are projected to decrease by a total of about 6 million tons (STCDE), most of the decrease in PFC emissions occurred early after 1990, whereas the decrease in landfill emissions is projected to occur after the year 2000.

Chart 7 - Projected change in GHG emissions, for all GHG emissions sources except fossil fuel combustion, 1990-2015

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE), Increase or Decrease



Although the chart illustates that methane emissions in 2015 will be about equal to those in 1990, it is important to recognize that the role that methane sources will play after the year 2000 is different from their role before that year. To date, increases in methane emissions have offset a portion of the decrease in PFC emissions. Through 1996, methane emissions from landfills increased by about 0.9 million tons (STCDE) and methane emissions from swine and beef operations increased by about 1 million tons (STCDE).

After the year 2000, methane sources are projected to drive the decrease in overall emissions. Methane emissions from landfills are projected to decrease by 1.6 million tons (STCDE). Methane emissions from livestock operations are also projected to decrease, with a 0.6 million ton (STCDE) increase in methane emissions from swine and beef operations being offset by a 0.8 million ton decrease from dairy operations. These decreases are expected to occur due to an increase in the flaring and capture of landfill methane, a slowdown in the growth of swine operations in Missouri and continued decline of the state's dairy industry.

Table 26 summarizes the study's net projections for non-energy greenhouse gas emissions from all sources. The projected annual average growth rate for all sources equals about 0.3 percent per year.

Table 26 - Estimated GHG emissions from Missouri sources other than fossil fuel combustion, 1990-2015

Units: 1,000 Short Tons Carbon Dioxide Equivalent (STCDE)

	1990	1996	2000	2005	2010	2015
CO_2 emissions excluding energy	11,656	11,872	12,169	12,595	12,984	13,357
Oxidation of carbon monoxide	1,460	1,650	1,733	1,810	1,857	1,877
Transportation	1,293	1,477	1,549	1,616	1,653	1,662
Industrial sector	168	173	184	194	204	215
Non-energy uses of fossil fuels	1,345	982	1,036	1,074	1,120	1,171
Industrial sector uses	1,111	754	803	835	875	920
Transportation use of lubricants	234	228	233	239	245	251
Limestone use	4,445	4,834	4,994	5,304	5,600	5,902
Cement Production	2,260	2,562	2,804	3,106	3,408	3,710
Lime Manufacture	1,599	1,731	1,731	1,731	1,731	1,731
Decomposition of agricultural lime	586	541	459	468	462	462
Land use changes	4,407	4,407	4,407	4,407	4,407	4,407
Net loss of above-ground "sinks"	1,613	1,613	1,613	1,613	1,613	1,613
Soil carbon release	2,793	2,793	2,793	2,793	2,793	2,793
Methane emissions	16,712	18,290	16,472	17,185	16,861	16,557
Agriculture	10,463	11,166	10,796	11,234	11,068	11,023
Beef cattle operations	5,677	6,161	5,636	6,074	6,210	6,420
Dairy cattle operations	1,808	1,477	1,238	1,023	852	700
Swine operations	2,747	3,296	3,691	3,906	3,776	3,672
Other livestock operations	170	170	170	170	170	170
Rice cultivation	61	61	61	61	61	61
Disposal of crop wastes by burning	0	0	0	0	0	0
Municipal & industrial waste	5,604	6,481	5,033	5,307	5,149	4,890
Municipal & industrial landfills	5,501	6,378	4,930	5,205	5,046	4,788
Municipal waste-water treatment	103	103	103	103	103	103
Fossil fuel production & distribution	501	501	501	501	501	501
Natural gas leakage	496	495	495	495	495	495
Coal mining	6	6	6	6	6	6
Oil production	0	0	0	0	0	0
Highway transportation	143	143	143	143	143	143
Nitrous oxide emissions	3,805	3,820	3,875	3,872	3,870	3,868
Agriculture	2,333	2,348	2,403	2,401	2,399	2,397
Use of nitrogenous fertilizers	2,333	2,348	2,403	2,401	2,399	2,397
Disposal of crop wastes by burning	0	0	0	0	0	0
Highway transportation	1,080	1,080	1,080	1,080	1,080	1,080
Nitric acid production	391	391	391	391	391	391
PFCs from aluminum production	4,611	641	650	458	437	416
CF_4 emissions*	3,847	535	542	382	365	347
C_2F_6 emissions*	763	106	108	76	72	69

See Chapter 5, Part 4.

Forest growth

In 2015, CO_2 sequestration from Missouri forest growth is projected to decrease compared to 1990 due to projected increases in the commercial harvest of forest products. Assuming the middle case for commercial harvest growth, this is equivalent to an emissions increase of 4.6 million tons of CO_2.

Units: 1,000 Short Tons Carbon Dioxide Equilvalent (STCDE)

	1990	1995	2000	2005	2010	2015
Potential sequestration	34,615	34,615	34,615	34,615	34,615	34,615
Removals						
Low case	7,541	8,726	9,390	10,001	10,588	11,153
Mid point	7,541	8,726	9,606	10,475	11,310	12,112
High case	7,541	8,726	9,822	10,949	12,032	13,071
Net sequestration						
Low case	27,074	25,889	25,225	24,614	24,027	23,462
Mid point	27,074	25,889	25,009	24,140	23,305	22,503
High case	27,074	25,889	24,793	23,666	22,583	21,544
Mid-case growth rate			***-0.8%***	***-0.8%***	***-0.7%***	***-0.7%***

"Net sequestration" in the table refers to the impact of biomass growth minus the impact of forest removals. The rate of net sequestration is projected to decrease because the rate of biomass growth is projected to remain constant and the rate of removals is projected to increase.

The projected 4.6 million ton decrease in net sequestration between 1990 and 2015 is based on a simple methodology that assumes that the carbon in forest removals is immediately released. As discussed above, researchers at the national level are developing a more sophisticated methodology that attempts to estimate variable rates of carbon release for different portions of the forest removal stream. Use of the more sophisticated methodology would probably result in a smaller estimate (less than 4.6 million tons) of the decrease in Missouri forest sequestration. However, as discussed in Chapter 6, use of this more sophisticated methodology was not practical for the present study.