

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

## **Chapter 2**

### **Trends in CO<sub>2</sub> Emissions from Fossil Fuel Combustion in Missouri, 1990-96**



## Chapter 2: Trends in CO<sub>2</sub> emissions from fossil fuel combustion in Missouri, 1990-96

|   |           |
|---|-----------|
| <i>Part 1: Overview .....</i>   | <i>63</i> |
| <i>Part 2: Trends in combustion of coal and associated CO<sub>2</sub> emissions .....</i>               | <i>67</i> |
| <i>Section 1: Trends in energy sources used to generate electricity in Missouri.....</i>                | <i>67</i> |
| <i>Section 2: Trends in Missouri coal consumption .....</i>   | <i>70</i> |
| <i>Section 3: Trends in CO<sub>2</sub> emissions from use of coal in Missouri .....</i>                 | <i>73</i> |
| <i>Section 4: Trends in the source and carbon content of coal consumed by Missouri utilities .....</i>  | <i>79</i> |
| <i>Part 3: Trends in combustion of petroleum and associated CO<sub>2</sub> emissions .....</i>          | <i>83</i> |
| <i>Section 1: Petroleum consumption.....</i>  | <i>83</i> |
| <i>Section 2: CO<sub>2</sub> emissions from petroleum.....</i>  | <i>85</i> |
| <i>Part 4: Trends in combustion of natural gas and resulting CO<sub>2</sub> emissions .....</i>         | <i>87</i> |
| <i>Part 5: Allocation of Missouri utility CO<sub>2</sub> emissions to end users of electricity.....</i> | <i>91</i> |
| <i>Part 6: Methods used to estimate CO<sub>2</sub> emissions from fossil fuel combustion.....</i>       | <i>95</i> |



## List of Tables

|  |    |
|--|----|
| Table 1 - Estimated CO <sub>2</sub> emissions from fossil fuel combustion in Missouri, summary by sector, 1990-96 .....  | 63 |
| Table 2 - Net changes in Missouri fossil fuel energy consumption, 1990-96 .....  | 64 |
| Table 3 - Estimated CO <sub>2</sub> emissions from fossil fuel combustion in Missouri, detail by sector, 1990-96 .....   | 65 |
| Table 4 - Estimated CO <sub>2</sub> emissions from fossil fuel combustion in Missouri, by fuel type, 1990-96 ....  | 66 |
| Table 5 - Electric power generated by Missouri utilities, by source, 1990-96 .....   | 69 |
| Table 6 - Share by energy source of electric power generated by Missouri utilities, 1990-96 .....  | 69 |
| Table 7 - Electricity generated from coal-fired utility plants, by ownership class, 1990-96 .....  | 69 |
| Table 8 - Estimated coal use in Missouri, 1990-96 .....  | 70 |
| Table 9 - Missouri utility consumption of fossil fuels, 1990-96 .....  | 72 |
| Table 10 - Estimated CO <sub>2</sub> emissions from coal combustion in Missouri, by sector, 1990-96 .....  | 73 |
| Table 11 - Estimated CO <sub>2</sub> emissions from Missouri utilities' use of fossil fuels to generate electricity, by fuel and ownership class, 1990-96 .....                                  | 74 |
| Table 12 - Percent change in CO <sub>2</sub> emissions from MO utilities' use of fossil fuels to generate electricity compared to the 1990 base year, by fuel and ownership class, 1990-96 ..... | 74 |
| Table 13 - Estimated CO <sub>2</sub> emissions from Missouri utilities' use of fossil fuels to generate electricity, by ownership class and fuel, 1990-96 .....                                  | 77 |
| Table 14 - Estimated CO <sub>2</sub> emissions from coal burned to generate electricity, by utility plant, 1990-96 .....   | 77 |
| Table 15 - Estimated use of petroleum products for energy in Missouri, 1990-96 .....   | 84 |
| Table 16 - Estimated Missouri industry use of petroleum products for energy, 1990-96 .....   | 85 |
| Table 17 - Estimated CO <sub>2</sub> emissions from petroleum combustion in Missouri, by sector, 1990-96 .....   | 86 |
| Table 18 - Estimated CO <sub>2</sub> emissions from industrial petroleum combustion in Missouri, 1990-96 .....   | 86 |
| Table 19 - Estimated combustion of natural gas in Missouri's end-use sectors, 1990-96 .....  | 87 |
| Table 20 - Estimated CO <sub>2</sub> emissions from natural gas combustion in Missouri's end-use sectors, 1990-96 .....  | 89 |
| Table 21 - Comparison of primary-use and end-use sectors .....   | 91 |
| Table 22 - Allocation of estimated electric utility CO <sub>2</sub> emissions to Missouri's end-use sectors, 1990-96 .....   | 91 |

Table 23 - Estimated aggregate CO<sub>2</sub> emissions from electricity use and direct combustion of fossil fuels by Missouri's end-use sectors, 1990-96..... 92

Table 24 - Data and methods used to estimate fossil fuel combustion and CO<sub>2</sub> emissions ..... 96

## List of Charts

|   |    |
|---|----|
| Chart 1 - Missouri primary energy-use sector shares of CO <sub>2</sub> emissions from fossil fuel combustion, 1990-96 .....         | 66 |
| Chart 2 - Missouri utilities' consumption of energy resources to generate electricity, 1960-96 .....                                | 68 |
| Chart 3 - Coal burned by Missouri utilities to generate electricity, 1960-96 .....  | 71 |
| Chart 4 - CO <sub>2</sub> emissions from Missouri utilities' use of coal to generate electricity, by ownership class, 1990-96 ..... | 76 |
| Chart 5 - Missouri utilities' shift from Eastern coal to Western coal, 1990-96 .....  | 80 |
| Chart 6 - Estimated increase in average carbon content of coal received by Missouri utilities, 1990-96 .....                        | 81 |
| Chart 7 - Missouri end-use sector shares of CO <sub>2</sub> emissions from fossil fuel combustion, 1990-96 .....                    | 93 |



## Chapter 2: Trends in CO<sub>2</sub> emissions from fossil fuel combustion in Missouri, 1990-96

### Part 1: Overview

Between 1990 and 1996, Missouri CO<sub>2</sub> emissions from fossil fuel combustion grew by about 22 million tons, an increase of about 20 percent. As Table 1 indicates, the increase occurred during the last three years of the period. During these three years, total CO<sub>2</sub> emissions from energy use grew about 23 million tons, more than offsetting a reduction in CO<sub>2</sub> emissions that had occurred between 1990 and 1993.

**Table 1 - Estimated CO<sub>2</sub> emissions from fossil fuel combustion in Missouri, summary by sector, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                          | 1990             | 1991             | 1992             | 1993             | 1994             | 1995             | 1996             | Change from 1990 base |       |
|--------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-----------------------|-------|
| Transportation           | 36,782.4         | 36,636.2         | 37,812.6         | 39,542.0         | 41,109.7         | 42,351.5         | 44,206.8         | 7,424.4               | 20.2% |
| Commercial               | 4,625.1          | 4,897.8          | 4,729.7          | 5,300.3          | 5,071.1          | 4,991.2          | 5,464.6          | 839.5                 | 18.2% |
| Industrial               | 10,283.9         | 9,414.1          | 9,573.8          | 10,240.7         | 10,633.8         | 10,497.3         | 10,612.4         | 328.5                 | 3.2%  |
| Residential              | 8,242.3          | 8,833.2          | 8,514.8          | 9,683.6          | 8,949.7          | 9,073.5          | 9,838.4          | 1,596.1               | 19.4% |
| Utility                  | 51,538.6         | 51,856.7         | 50,346.2         | 45,752.0         | 53,843.2         | 60,242.6         | 63,287.7         | 11,749.1              | 22.8% |
| <b>Total all sectors</b> | <b>111,472.3</b> | <b>111,638.0</b> | <b>110,977.1</b> | <b>110,518.6</b> | <b>119,607.5</b> | <b>127,156.1</b> | <b>133,410.0</b> | 21,937.7              | 19.7% |

The sectors used in Table 1 and the remainder of Parts 1 through 4 of this chapter are defined as users of *primary* energy resources. Table 1 lists five sectors including utilities that use primary energy resources. Examples of primary energy resources are coal, petroleum and natural gas. Utilities are a unique sector in that they use primary energy resources to produce electricity, which is a *secondary* energy resource.

Part 5 of the chapter employs an alternative classification of sectors. This alternative classification includes only end users of electricity and therefore excludes utilities as a separate sector. It allocates emissions from fossil fuel burned by utilities to the four end use sectors in proportion to their use of electricity. Further explanation of the difference in approach is provided by Table 21 in this chapter.

The primary factor determining changes in energy-based CO<sub>2</sub> emissions from 1990 to 1996 was changing levels of fossil fuel combustion.<sup>1</sup> Table 2 indicates the pattern of energy consumption during the period. Through 1993 there was little change in net fossil fuel energy consumption, but after 1993, energy use increased from about 1,335 trillion Btus to 1,573 trillion Btus, an 18 percent increase in three years.

**Table 2 - Net changes in Missouri fossil fuel energy consumption, 1990-96**

Units: Trillion Btus

|                                    | 1990  | 1991  | 1992  | 1993  | 1994  | 1995  | 1996  |
|------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| <b>Total</b>                       | 1,322 | 1,332 | 1,321 | 1,335 | 1,422 | 1,497 | 1,569 |
| <i>Change from previous period</i> |       | 0.7%  | -0.8% | 1.1%  | 6.6%  | 5.3%  | 4.8%  |
| <i>Change from 1990 base year</i>  |       | 0.7%  | -0.1% | 1.0%  | 7.6%  | 13.3% | 18.7% |

CO<sub>2</sub> emissions increased by almost 12 million tons in the utility sector and more than 7 million tons in the transportation sector between 1990 and 1996. As Table 3 indicates, these two sectors accounted for 88 percent of the increase during the period. CO<sub>2</sub> emissions from coal accounted for more than 99 percent of the utility sector increase, and CO<sub>2</sub> emissions from petroleum-based fuels accounted for more than 99 percent of the increase in the transportation sector.

CO<sub>2</sub> emissions increased 1.6 million tons in the residential sector, 0.8 million tons in the commercial sector and 0.3 million tons in the industrial sector from 1990 to 1996. Together, these three sectors accounted for about 12 percent of the increase during the period, with most of the increase coming from use of natural gas. In the industrial sector, the rise in CO<sub>2</sub> emissions from natural gas use was largely offset by decreased emissions from coal use.

For each sector, Table 3 indicates each fuel's contribution to that sector's net change in CO<sub>2</sub> emissions between 1990 and 1996. For example, transportation CO<sub>2</sub> emissions increased 33 percent between 1990 and 1996. About 36 percent of that net change was due to an increase in jet fuel emissions, 34 percent due to diesel emissions and 30 percent due to emissions from gasoline use. Thus, by 1996 personal travel (gasoline) was still the primary source of CO<sub>2</sub> emissions in transportation, but commercial travel (diesel and jet fuel) was the fastest growing component of the sector's emissions.

---

<sup>1</sup> In the utility sector, a change in the source of coal also played a role, as described in Part 2 of this chapter.

**Table 3 - Estimated CO<sub>2</sub> emissions from fossil fuel combustion in Missouri, detail by sector, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                                | 1990    | 1991    | 1992    | 1993    | 1994    | 1995    | 1996    | Change from Base |
|--------------------------------|---------|---------|---------|---------|---------|---------|---------|------------------|
| <b>Energy end-use sectors</b>  | 59,934  | 59,781  | 60,631  | 64,767  | 65,764  | 66,913  | 70,122  |                  |
| <i>Transportation</i>          | 36,782  | 36,636  | 37,813  | 39,542  | 41,110  | 42,351  | 44,207  | 34%              |
| Gasoline                       | 25,826  | 25,810  | 26,109  | 26,454  | 27,125  | 27,364  | 28,044  | 30%              |
| Diesel                         | 7,578   | 7,245   | 8,132   | 8,397   | 8,959   | 9,423   | 10,131  | 34%              |
| Jet fuel                       | 2,971   | 3,353   | 3,362   | 4,040   | 4,752   | 5,204   | 5,672   | 36%              |
| Other                          | 408     | 227     | 210     | 652     | 274     | 360     | 359     | -1%              |
| <i>Commercial</i>              | 4,625   | 4,898   | 4,730   | 5,300   | 5,071   | 4,991   | 5,465   | 4%               |
| Natural gas                    | 3,494   | 3,710   | 3,555   | 4,071   | 3,876   | 3,788   | 4,258   | 91%              |
| Petroleum                      | 721     | 823     | 844     | 844     | 865     | 871     | 881     | 19%              |
| Coal                           | 410     | 365     | 330     | 385     | 330     | 333     | 325     | -10%             |
| <i>Industrial</i>              | 10,284  | 9,414   | 9,574   | 10,241  | 10,634  | 10,497  | 10,612  | 1%               |
| Natural gas                    | 3,077   | 3,220   | 3,270   | 3,417   | 4,021   | 3,865   | 3,921   | 257%             |
| Petroleum                      | 4,107   | 3,263   | 3,580   | 3,985   | 4,101   | 4,044   | 4,127   | 6%               |
| Coal                           | 3,100   | 2,932   | 2,725   | 2,839   | 2,512   | 2,589   | 2,564   | -163%            |
| <i>Residential</i>             | 8,242   | 8,833   | 8,515   | 9,684   | 8,950   | 9,073   | 9,838   | 7%               |
| Natural gas                    | 6,822   | 7,085   | 6,802   | 7,839   | 7,177   | 7,281   | 7,986   | 73%              |
| Petroleum                      | 1,200   | 1,552   | 1,534   | 1,636   | 1,595   | 1,612   | 1,680   | 30%              |
| Coal                           | 221     | 196     | 178     | 209     | 178     | 180     | 173     | 5%               |
| <b>Electric utility sector</b> | 51,539  | 51,857  | 50,346  | 45,752  | 53,843  | 60,243  | 63,288  | 54%              |
| Natural gas                    | 207     | 746     | 137     | 285     | 252     | 743     | 284     | 1%               |
| Petroleum                      | 93      | 113     | 85      | 182     | 133     | 138     | 117     | 0%               |
| Coal                           | 51,238  | 50,997  | 50,124  | 45,284  | 53,458  | 59,362  | 62,887  | 99%              |
|                                | 111,472 | 111,638 | 110,977 | 110,519 | 119,608 | 127,156 | 133,410 | 100%             |

Table 4 categorizes CO<sub>2</sub> emissions from fossil fuel combustion into emissions from use of coal, petroleum and natural gas. Between 1990 and 1996, CO<sub>2</sub> emissions from coal use increased by about 11 million tons, petroleum by about 8.1 million tons and natural gas by about 2.8 million tons. As Table 4 indicates, this amounted to about a 20 percent increase for each of the three major fuel types.

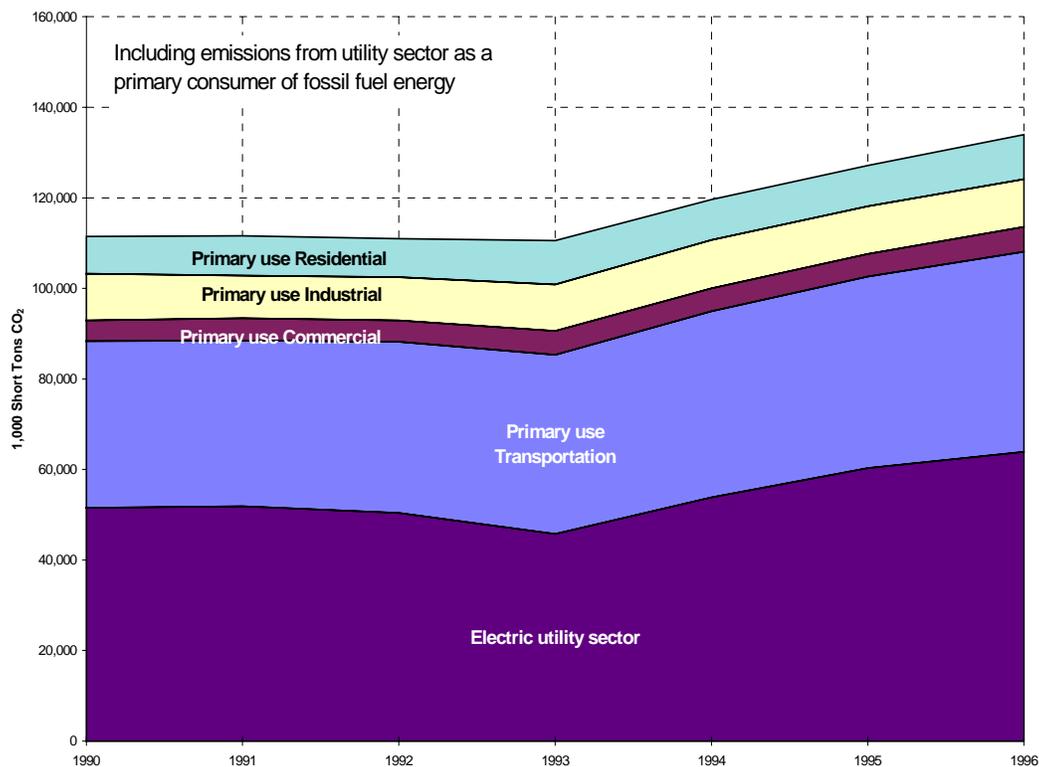
Thus, emissions from the three fuel types between 1990 and 1996 increased in rough proportion to their relative importance in 1990. In 1990, about 49.3 percent of energy-based CO<sub>2</sub> emissions came from coal, 38.2 percent from petroleum and 12.5 percent from natural gas. In 1996, these proportions remained about the same.

**Table 4 - Estimated CO<sub>2</sub> emissions from fossil fuel combustion in Missouri, by fuel type, 1990-96**

|                            | Units: 1,000 Short Tons Carbon Dioxide (CO <sub>2</sub> ) |           |           |           |           |           |           |                       |       |  |
|----------------------------|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------------------|-------|--|
|                            | 1990  | 1991      | 1992      | 1993      | 1994      | 1995      | 1996      | Change from 1990 base |       |  |
| Coal                       | 54,969.3  | 54,490.2  | 53,356.8  | 48,717.0  | 56,479.1  | 62,463.8  | 65,949.1  | 10,979.8              | 20.0% |  |
| Petroleum                  | 42,590.9  | 42,236.7  | 43,721.4  | 45,613.7  | 47,634.2  | 48,738.9  | 50,734.3  | 8,143.4               | 19.1% |  |
| Natural Gas                | 13,912.1  | 14,911.1  | 13,898.9  | 16,187.9  | 15,494.2  | 15,953.4  | 16,726.6  | 2,814.5               | 20.2% |  |
|                            | 111,472.3   | 111,638.0 | 110,977.1 | 110,518.6 | 119,607.5 | 127,156.1 | 133,410.0 | 21,937.7              | 19.7% |  |
| <i>Change - prev. year</i> |   | 0.1%      | -0.6%     | -0.4%     | 8.2%      | 6.3%      | 4.9%      |                       |       |  |

Chart 1 illustrates the distribution of CO<sub>2</sub> emissions during the period across the five primary energy use sectors in Missouri.

**Chart 1 - Missouri primary energy-use sector shares of CO<sub>2</sub> emissions from fossil fuel combustion, 1990-96**



Parts 2, 3 and 4 of this chapter discuss CO<sub>2</sub> emissions trends from coal, petroleum and natural gas respectively between 1990 and 1996. Part 2 focuses on electric utilities, and Parts 3 and 4 discuss Missouri's other primary energy use sectors. Part 5 switches to an end-use sector framework for summarizing trends in Missouri CO<sub>2</sub> emissions between 1990 and 1996, and Part 6 summarizes methodology used for the estimates.

## **Part 2: Trends in combustion of coal and associated CO<sub>2</sub> emissions**

Utility coal use was the state's leading source of greenhouse gas emissions from 1990 to 1996. Utility CO<sub>2</sub> emissions increased by about 12 million tons during this period, and more than 99 percent of Missouri utility CO<sub>2</sub> emissions came from coal-fired boilers.

### ***Section 1: Trends in energy sources used to generate electricity in Missouri***

Coal combustion is the leading source of baseload<sup>2</sup> electric generation in Missouri. As Table 6 indicates, coal's overall role fluctuated somewhat between 1990 and 1996. The share of electricity generated from coal decreased between 1990 and 1993, from about 82 percent to 77 percent, but increased to about 84 percent between 1994 and 1996.

Nuclear and hydroelectric generation are also significant sources of baseload electric generation in Missouri. As Table 6 indicates, between 1990 and 1996, the share of nuclear generation fluctuated between 13 percent and 17 percent, and the share of hydroelectric generation fluctuated between 2 percent and 6 percent. Despite their importance as sources of electric generation, nuclear and hydroelectric generation receive relatively little attention in this report because, following methodology used in the *1990 Inventory*, they are assumed to result in no CO<sub>2</sub> emissions.<sup>3</sup>

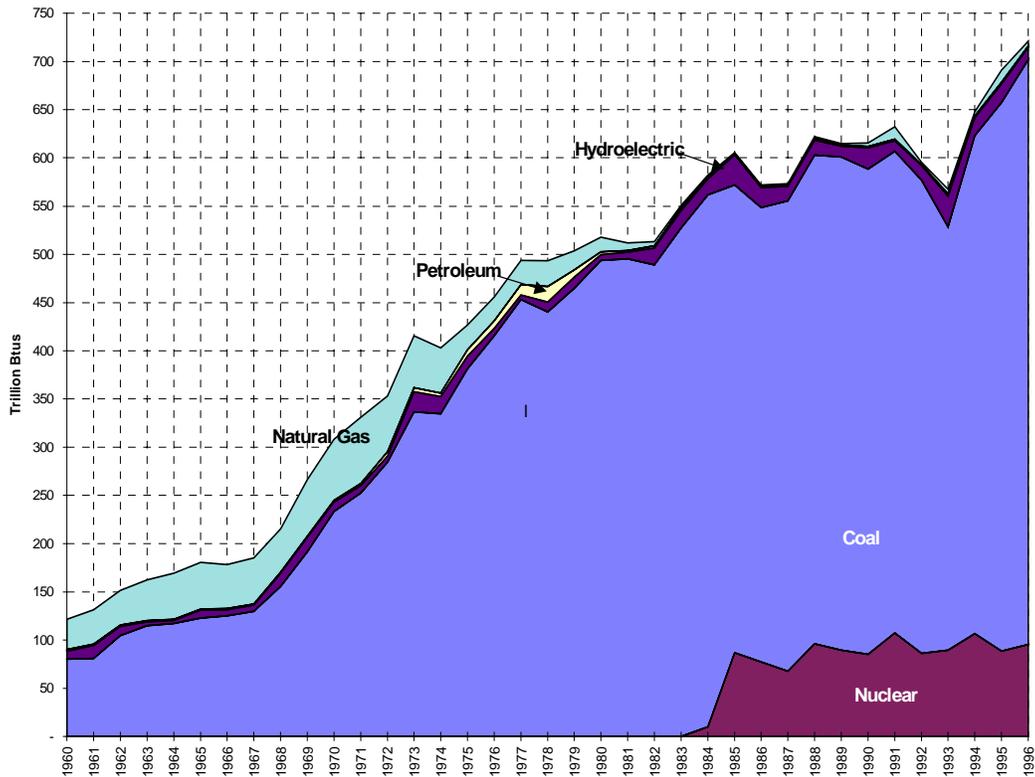
Chart 2 depicts the relative role of coal, other fossil fuels, and nuclear and hydroelectric power as energy inputs for electric generation in Missouri.

---

<sup>2</sup> A baseload plant is normally operated to provide all or part of the minimum electric load of a utility system. Baseload units are generally run continuously to produce electricity at a constant rate, allowing for planned maintenance and forced outages.

<sup>3</sup> See Chapter 1, Section 5 of the *1990 Inventory*.

**Chart 2 - Missouri utilities' consumption of energy resources to generate electricity, 1960-96**



As the following tables indicate, electric generation from Missouri coal-fired utility plants increased about 18 percent between 1990 and 1996, from about 48.5 million to about 57.2 million megawatt-hours.

**Table 5 - Electric power generated by Missouri utilities, by source, 1990-96**

Units: 1,000 kWhs

|               | 1990              | 1991              | 1992              | 1993              | 1994              | 1995              | 1996              |
|---------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Nuclear       | 7,998,039         | 9,979,371         | 8,083,975         | 8,381,333         | 10,006,491        | 8,241,833         | 8,890,377         |
| Hydroelectric | 2,192,175         | 1,119,576         | 1,481,265         | 3,184,483         | 1,916,316         | 1,918,507         | 1,304,084         |
| Coal          | 48,501,751        | 47,907,503        | 46,829,678        | 41,167,635        | 49,207,156        | 54,146,815        | 57,192,971        |
| Petroleum     | 86,606            | 118,645           | 80,522            | 155,493           | 116,430           | 117,717           | 92,062            |
| Natural Gas   | 265,870           | 1,043,653         | 183,411           | 386,378           | 338,101           | 1,015,384         | 371,859           |
| <b>Total</b>  | <b>59,044,441</b> | <b>60,168,748</b> | <b>56,658,851</b> | <b>53,275,322</b> | <b>61,584,494</b> | <b>65,440,256</b> | <b>67,851,353</b> |

**Table 6 - Share by energy source of electric power generated by Missouri utilities, 1990-96**

Units: 1,000 kWhs

|               | 1990  | 1991  | 1992  | 1993  | 1994  | 1995  | 1996  |
|---------------|-------|-------|-------|-------|-------|-------|-------|
| Nuclear       | 13.5% | 16.6% | 14.3% | 15.7% | 16.2% | 12.6% | 13.1% |
| Hydroelectric | 3.7%  | 1.9%  | 2.6%  | 6.0%  | 3.1%  | 2.9%  | 1.9%  |
| Coal          | 82.1% | 79.6% | 82.7% | 77.3% | 79.9% | 82.7% | 84.3% |
| Petroleum     | 0.1%  | 0.2%  | 0.1%  | 0.3%  | 0.2%  | 0.2%  | 0.1%  |
| Natural Gas   | 0.5%  | 1.7%  | 0.3%  | 0.7%  | 0.5%  | 1.6%  | 0.5%  |

Of the 57.2 million megawatt-hours generated from coal in 1996, investor-owned plants generated about two-thirds, cooperatively-owned plants about 26 percent and municipal plants the remaining 7 percent.

**Table 7 - Electricity generated from coal-fired utility plants, by ownership class, 1990-96**

Units: 1,000 kWhs

|              | 1990              | 1991              | 1992              | 1993              | 1994              | 1995              | 1996              |
|--------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| <b>Total</b> | <b>48,501,751</b> | <b>47,907,503</b> | <b>46,829,678</b> | <b>41,167,635</b> | <b>49,207,156</b> | <b>54,146,815</b> | <b>57,192,971</b> |
| Investor     | 34,274,766        | 34,413,598        | 33,322,418        | 31,059,658        | 35,638,142        | 36,194,017        | 38,263,463        |
| Co-op        | 10,993,738        | 10,572,940        | 10,491,953        | 6,999,029         | 10,198,637        | 14,669,769        | 14,826,778        |
| Municipal    | 3,233,247         | 2,920,965         | 3,015,307         | 3,108,948         | 3,370,377         | 3,283,029         | 4,102,730         |

## Section 2: Trends in Missouri coal consumption

In 1996, Missouri utilities consumed more than 600 trillion Btus of coal, a historic high and about 20 percent more than in 1990. Utilities were the only sector where coal consumption grew during the 1990s.<sup>4</sup> Coal use declined by about 6 trillion Btus in the commercial, industrial and residential sectors<sup>5</sup> but increased by about 103 trillion Btus in the utility sector, for a net increase of about 97 trillion Btus during the period. The utility sector's share of total state coal consumption grew from about 93 percent in 1990 to 95 percent in 1996.

**Table 8 - Estimated coal use in Missouri, 1990-96**

Units: Trillion Btus

|   | 1990         | 1991         | 1992         | 1993         | 1994         | 1995         | 1996         |
|---|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Commercial                              | 4.0          | 3.6          | 3.2          | 3.8          | 3.2          | 3.3          | 3.2          |
| Industrial                              | 30.4         | 28.7         | 26.6         | 27.8         | 24.6         | 25.4         | 25.1         |
| Residential                             | 2.2          | 1.9          | 1.7          | 2.0          | 1.8          | 1.8          | 1.7          |
| Utility                                 | 502.9        | 499.6        | 490.7        | 438.7        | 516.2        | 568.8        | 606.2        |
| <b>Total coal use</b>                   | <b>539.5</b> | <b>533.9</b> | <b>522.3</b> | <b>472.3</b> | <b>545.8</b> | <b>599.2</b> | <b>636.2</b> |
| <i>Change from previous period</i>      |              | -1.0%        | -2.2%        | -9.6%        | 15.6%        | 9.8%         | 6.2%         |
| <i>Change from 1990 base year</i>       |              | -1.0%        | -3.2%        | -12.5%       | 1.2%         | 11.1%        | 17.9%        |
| <b>Share of total coal consumption:</b> |              |              |              |              |              |              |              |
| Commercial                              | 0.8%         | 0.7%         | 0.6%         | 0.8%         | 0.6%         | 0.5%         | 0.5%         |
| Industrial                              | 5.6%         | 5.4%         | 5.1%         | 5.9%         | 4.5%         | 4.2%         | 3.9%         |
| Residential                             | 0.4%         | 0.4%         | 0.3%         | 0.4%         | 0.3%         | 0.3%         | 0.3%         |
| Utility                                 | 93.2%        | 93.6%        | 93.9%        | 92.9%        | 94.6%        | 94.9%        | 95.3%        |

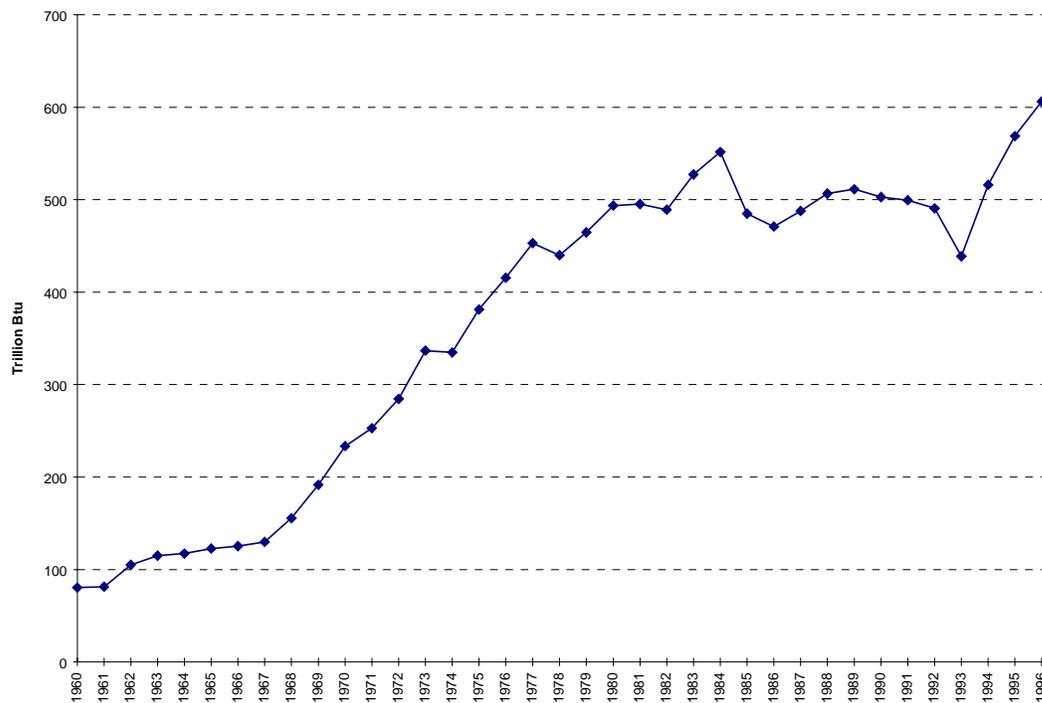
Utility coal use did not increase constantly throughout the period. It decreased by about 64 trillion Btus between 1990 and 1993, then increased by about 167 trillion Btus between 1993 and 1996.

<sup>4</sup> The estimates for the commercial and industrial sectors include coal use and emissions from several non-utilities such as university campuses or industrial plants that generate or co-generate electricity from coal. Because non-utilities are not required to report coal consumption to USDOE, data on their coal consumption is not readily available, and it is uncertain what portion of commercial and industrial coal use is for electric generation.

<sup>5</sup> Coal consumption for these three sectors in 1995 and 1996 had to be estimated; 1990 to 1994 data was taken from the EIA State Energy Data System. The coal consumption estimates for the utility sector were derived from required reports submitted by the utilities.

Chart 3 depicts the growth pattern in utility use of coal from 1990 to 1996 in the context of trends since 1960. Missouri utility coal use increased more or less steadily from 1960 through 1984, decreased from 1984 to 1986 as Union Electric’s Callaway Nuclear Plant came on line, and resumed a pattern of gradual increase between 1986 and 1990 before declining from 1990 to 1993 and beginning its sharp rise in 1994.

**Chart 3 - Coal burned by Missouri utilities to generate electricity, 1960-96**



As Table 9 indicates, utilities in all three utility ownership categories increased their coal consumption between 1990 and 1996. Although some municipal utilities rely heavily on natural gas, the fastest growth in coal use between 1995 and 1996 occurred among municipal utilities.

**Table 9 - Missouri utility consumption of fossil fuels, 1990-96**

Units: Million Btus

|                  | 1990               | 1991               | 1992               | 1993               | 1994               | 1995               | 1996               |
|------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| <b>Total</b>     | <b>507,618,786</b> | <b>513,905,198</b> | <b>494,111,874</b> | <b>445,917,459</b> | <b>522,233,151</b> | <b>583,367,648</b> | <b>608,065,356</b> |
| <i>Investor</i>  | 355,836,824        | 363,298,447        | 351,033,970        | 336,806,879        | 377,851,788        | 387,628,268        | 406,766,620        |
| Coal             | 354,202,346        | 359,747,840        | 349,631,781        | 331,755,926        | 374,625,017        | 378,437,732        | 401,938,881        |
| Natural Gas      | 819,502            | 2,516,395          | 652,232            | 3,216,083          | 1,921,081          | 7,781,900          | 3,531,345          |
| Petroleum        | 814,976            | 1,034,211          | 749,957            | 1,834,869          | 1,305,690          | 1,408,636          | 1,296,394          |
| <i>Co-op</i>     | 112,178,635        | 107,279,831        | 107,214,424        | 73,539,779         | 104,937,525        | 154,656,393        | 153,971,702        |
| Coal             | 112,048,219        | 107,137,572        | 107,071,100        | 73,295,909         | 104,780,867        | 154,547,815        | 153,875,910        |
| Petroleum        | 130,416            | 142,258            | 143,324            | 243,869            | 156,658            | 108,578            | 95,792             |
| <i>Municipal</i> | 39,603,327         | 43,326,921         | 35,863,480         | 35,570,802         | 39,443,839         | 41,082,987         | 47,327,034         |
| Coal             | 36,619,786         | 32,717,166         | 33,974,081         | 33,661,135         | 36,822,403         | 35,829,914         | 45,891,399         |
| Natural Gas      | 2,761,935          | 10,370,335         | 1,718,068          | 1,714,454          | 2,429,735          | 5,047,718          | 1,379,575          |
| Petroleum        | 221,606            | 239,419            | 171,331            | 195,213            | 191,701            | 205,355            | 56,060             |

### Section 3: Trends in CO<sub>2</sub> emissions from use of coal in Missouri

Trends in CO<sub>2</sub> emissions from utility coal combustion mirrored those in utility consumption of coal. CO<sub>2</sub> emissions decreased by almost 6 million tons between 1990 and 1993, then increased between 1993 and 1996 by nearly 18 million tons, for a net increase of nearly 12 million tons. CO<sub>2</sub> emissions from utility coal use in 1996 were about 37 percent higher than in 1993.

The increase in utility CO<sub>2</sub> emissions from coal combustion was partly offset by a decrease in CO<sub>2</sub> emissions from coal use by the commercial, industrial and residential sectors.<sup>6</sup> Utility CO<sub>2</sub> emissions from coal grew about 23 percent between 1990 and 1996, and emissions from coal use in all sectors increased by about 20 percent.

**Table 10 - Estimated CO<sub>2</sub> emissions from coal combustion in Missouri, by sector, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                     | 1990            | 1991            | 1992            | 1993            | 1994            | 1995            | 1996            | Change from 1990 base |        |
|---------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------------|--------|
| Commercial          | 410.4           | 364.6           | 330.4           | 385.3           | 330.4           | 332.6           | 325.2           | (85.2)                | -20.8% |
| Industrial          | 3,099.9         | 2,931.8         | 2,724.6         | 2,839.0         | 2,512.2         | 2,588.8         | 2,564.1         | (535.7)               | -17.3% |
| Residential         | 221.0           | 196.3           | 177.9           | 208.6           | 178.3           | 180.5           | 173.0           | (48.0)                | -21.7% |
| Utility             | 51,238.0        | 50,997.5        | 50,124.0        | 45,284.0        | 53,458.3        | 59,362.0        | 62,886.8        | 11,648.8              | 22.7%  |
| <b>Total coal</b>   | <b>54,969.3</b> | <b>54,490.2</b> | <b>53,356.8</b> | <b>48,717.0</b> | <b>56,479.1</b> | <b>62,463.8</b> | <b>65,949.1</b> | 10,979.8              | 20.0%  |
| Change - prev. year |                 | -0.9%           | -2.1%           | -8.7%           | 15.9%           | 10.6%           | 5.6%            |                       |        |
| Change - 1990 base  |                 | -0.9%           | -2.9%           | -11.4%          | 2.7%            | 13.6%           | 20.0%           |                       |        |

As the following tables indicate, the trend for utility CO<sub>2</sub> emissions from fossil fuel combustion was influenced primarily by increases and decreases in emissions from coal. Utility emissions from fossil fuel combustion increased about 23 percent between 1990 and 1996, with emissions from coal contributing most of the increase. Throughout the period, about 99.4 percent of utility CO<sub>2</sub> emissions were from coal combustion. There were large temporary increases in natural gas use by some utilities in 1991 and 1995 in response to lower natural gas prices, but these increases did not change the dominance of coal combustion as an emissions source. Although CO<sub>2</sub> emissions from petroleum and natural gas increased between 1990 and 1996, this contributed less than 1 percent of the total increase in emissions during the period.

<sup>6</sup> Coal consumption for these three sectors in 1995 and 1996 had to be estimated; 1990 to 1994 data was taken from the EIA State Energy Data System. The coal consumption estimates for the utility sector were derived from required reports submitted by the utilities.

**Table 11 - Estimated CO<sub>2</sub> emissions from Missouri utilities' use of fossil fuels to generate electricity, by fuel and ownership class, 1990-96**

Units: Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                  | 1990              | 1991              | 1992              | 1993              | 1994              | 1995              | 1996              |
|------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| <b>Total</b>     | <b>51,538,570</b> | <b>51,856,655</b> | <b>50,346,224</b> | <b>45,751,983</b> | <b>53,843,243</b> | <b>60,242,644</b> | <b>63,287,710</b> |
| <i>Coal</i>      | 51,238,014        | 50,997,460        | 50,123,968        | 45,284,048        | 53,458,252        | 59,361,956        | 62,886,778        |
| Investor         | 36,295,050        | 36,953,152        | 35,954,884        | 34,341,986        | 38,858,533        | 39,391,378        | 42,021,612        |
| Co-op            | 11,250,533        | 10,747,621        | 10,744,949        | 7,491,839         | 10,818,351        | 16,256,945        | 16,182,801        |
| Municipal        | 3,692,431         | 3,296,688         | 3,424,135         | 3,450,223         | 3,781,368         | 3,713,633         | 4,682,365         |
| <i>Nat. Gas</i>  | 207,360           | 746,122           | 137,237           | 285,471           | 251,906           | 742,816           | 284,335           |
| Investor         | 47,448            | 145,696           | 37,763            | 186,206           | 111,228           | 450,560           | 204,460           |
| Municipal        | 159,912           | 600,427           | 99,474            | 99,264            | 140,678           | 292,255           | 79,875            |
| <i>Petroleum</i> | 93,196            | 113,073           | 85,020            | 182,464           | 133,086           | 137,872           | 116,598           |
| Investor         | 65,084            | 82,592            | 59,892            | 147,399           | 105,266           | 112,801           | 104,471           |
| Co-op            | 10,415            | 11,361            | 11,446            | 19,475            | 12,511            | 8,671             | 7,650             |
| Municipal        | 17,697            | 19,120            | 13,682            | 15,590            | 15,309            | 16,400            | 4,477             |

**Table 12 - Percent change in CO<sub>2</sub> emissions from MO utilities' use of fossil fuels to generate electricity compared to the 1990 base year, by fuel and ownership class, 1990-96**

|                  | 1990        | 1991        | 1992         | 1993          | 1994        | 1995         | 1996         |
|------------------|-------------|-------------|--------------|---------------|-------------|--------------|--------------|
| <b>Total</b>     | <b>0.0%</b> | <b>0.6%</b> | <b>-2.3%</b> | <b>-11.2%</b> | <b>4.5%</b> | <b>16.9%</b> | <b>22.8%</b> |
| <i>Coal</i>      | 0.0%        | -0.5%       | -2.2%        | -11.6%        | 4.3%        | 15.9%        | 22.7%        |
| Investor         | 0.0%        | 1.8%        | -0.9%        | -5.4%         | 7.1%        | 8.5%         | 15.8%        |
| Co-op            | 0.0%        | -4.5%       | -4.5%        | -33.4%        | -3.8%       | 44.5%        | 43.8%        |
| Municipal        | 0.0%        | -10.7%      | -7.3%        | -6.6%         | 2.4%        | 0.6%         | 26.8%        |
| <i>Nat. Gas</i>  | 0.0%        | 259.8%      | -33.8%       | 37.7%         | 21.5%       | 258.2%       | 37.1%        |
| Investor         | 0.0%        | 207.1%      | -20.4%       | 292.4%        | 134.4%      | 849.6%       | 330.9%       |
| Municipal        | 0.0%        | 275.5%      | -37.8%       | -37.9%        | -12.0%      | 82.8%        | -50.1%       |
| <i>Petroleum</i> | 0.0%        | 21.3%       | -8.8%        | 95.8%         | 42.8%       | 47.9%        | 25.1%        |
| Investor         | 0.0%        | 26.9%       | -8.0%        | 126.5%        | 61.7%       | 73.3%        | 60.5%        |
| Co-op            | 0.0%        | 9.1%        | 9.9%         | 87.0%         | 20.1%       | -16.7%       | -26.5%       |
| Municipal        | 0.0%        | 8.0%        | -22.7%       | -11.9%        | -13.5%      | -7.3%        | -74.7%       |

Although utility CO<sub>2</sub> emissions from utility coal combustion increased nearly 23 percent between 1990 and 1996, the increase occurred primarily during the final three years of the period, as Chart 4 illustrates.

Utility CO<sub>2</sub> emissions from coal decreased by nearly 6 million tons between 1990 and 1993. About 1 million tons of this decrease occurred between 1990 and 1992 and the remaining 5 million occurred in 1993.

In 1991, utility emissions from coal use decreased slightly despite a 4.5 percent increase in electricity sales. The decrease occurred because municipal utilities substituted natural gas for coal generation in response to low natural gas prices, and co-op utilities substituted wholesale power purchases for generation from coal.

In 1992, in response to an unusually cool summer, residential and commercial electricity sales decreased to a level slightly below 1990 sales, resulting in decreases in fossil fuel use and emissions by all three utility classes (investor, co-op and municipal). Utility CO<sub>2</sub> emissions in 1992 were about 2 percent below 1990 levels.

In 1993, with the return of normal summer weather, electricity sales to residential and commercial customers rebounded. Total electricity sales in 1993 were about 8.4 percent higher than in 1990. Nevertheless, utility coal use and CO<sub>2</sub> emissions decreased to about 88 percent of the 1990 level due to several factors, including flooding that cut off Eastern coal supplies and other transportation routes for coal, a labor strike in Eastern coal mining states that also decreased the supply of coal, increased availability of inexpensive hydroelectric power and relatively low prices for natural gas.

From 1993 through 1996, following this 3-year decline in CO<sub>2</sub> 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.<sup>7</sup> 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.<sup>8</sup>

On the supply side, the average delivered cost of coal to Missouri utilities decreased rapidly after 1992, as Missouri utilities switched from coal mined in Missouri and imported from Eastern states to coal imported from Wyoming and other western states. The average delivered price of coal to utilities decreased about 7 percent in 1993, 11 percent in 1994, 11 percent in 1995 and 3 percent in 1996. The average delivered price in 1996, 95.5 cents per million Btu, was nearly 30 percent lower than in 1992, 133.6 cents per million Btu.<sup>9</sup>

---

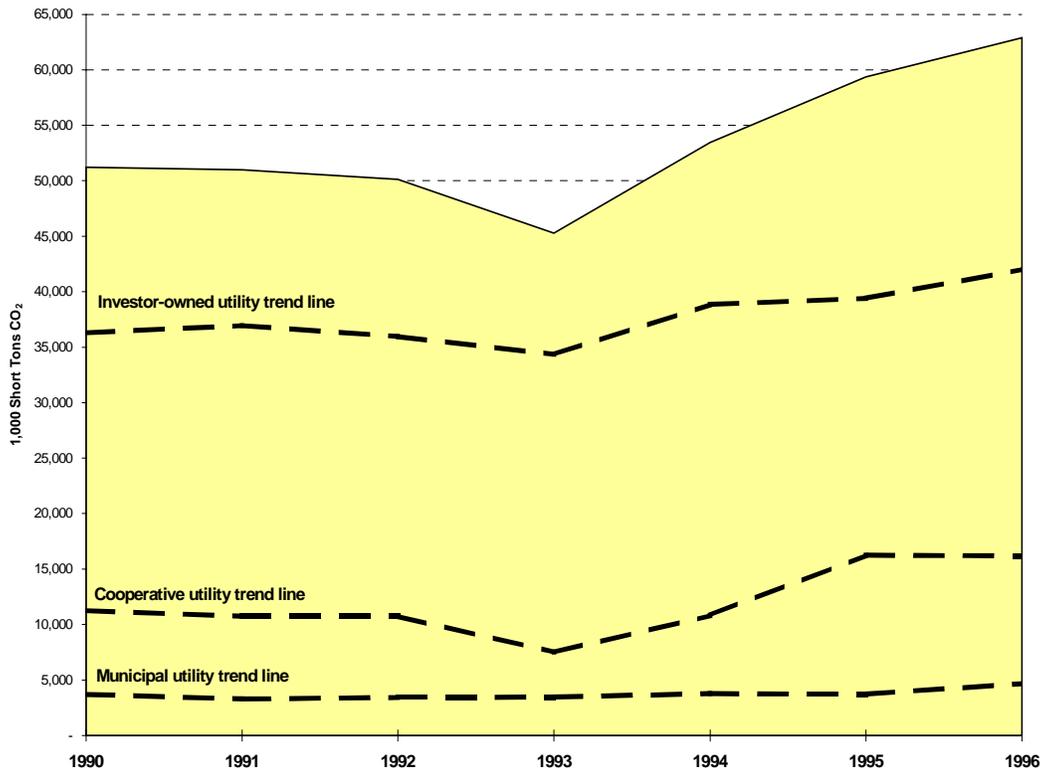
<sup>7</sup> Due to variations in the weather, the growth of electricity sales in Missouri slowed too only about 0.5 percent in 1997 but increased to about 7.8 percent during the first half of 1998.

<sup>8</sup> 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.

<sup>9</sup> USDOE/EIA, *Cost and Quality of Fuels for Electric Utility Plants*, 1992 and 1996, Table 2.

The steady increase in utility generation from coal between 1993 and 1996 led to a rapid increase in CO<sub>2</sub> emissions. CO<sub>2</sub> emissions from utility coal use increased by more than 18 million tons between 1994 and 1996. The level of utility CO<sub>2</sub> emissions from coal in 1996, 62.9 million tons, was about 23 percent higher than in 1990 and 39 percent higher than in 1993.

**Chart 4 - CO<sub>2</sub> emissions from Missouri utilities' use of coal to generate electricity, by ownership class, 1990-96**



CO<sub>2</sub> emissions trends varied among investor-owned, cooperatively owned and municipal utilities. CO<sub>2</sub> emissions from investor-owned, coal-fired plants increased about 5.7 million tons (about 16 percent) between 1990 and 1996. However, on a percentage growth basis, there were larger increases in CO<sub>2</sub> emissions in cooperative and municipal coal-fired plants — a 44 percent increase for cooperatives and a 27 percent increase for municipals. Accordingly, investor-owned utilities' share of total coal-fired CO<sub>2</sub> emissions fell between 1990 to 1996, from 70 percent in 1990 to 66 percent in 1996. Table 13 summarizes the relative role of investor-owned, cooperative and municipal utilities as sources of CO<sub>2</sub> emissions between 1990 and 1996

**Table 13 - Estimated CO<sub>2</sub> emissions from Missouri utilities' use of fossil fuels to generate electricity, by ownership class and fuel, 1990-96**

Units: Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                  | 1990              | 1991              | 1992              | 1993              | 1994              | 1995              | 1996              |
|------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| <b>Total</b>     | <b>51,538,570</b> | <b>51,856,655</b> | <b>50,346,224</b> | <b>45,751,983</b> | <b>53,843,243</b> | <b>60,242,644</b> | <b>63,287,710</b> |
| <i>Investor</i>  | 36,407,582        | 37,181,439        | 36,052,539        | 34,675,592        | 39,075,027        | 39,954,739        | 42,330,542        |
| Coal             | 36,295,050        | 36,953,152        | 35,954,884        | 34,341,986        | 38,858,533        | 39,391,378        | 42,021,612        |
| Natural Gas      | 47,448            | 145,696           | 37,763            | 186,206           | 111,228           | 450,560           | 204,460           |
| Petroleum        | 65,084            | 82,592            | 59,892            | 147,399           | 105,266           | 112,801           | 104,471           |
| <i>Coop</i>      | 11,260,948        | 10,758,981        | 10,756,395        | 7,511,314         | 10,830,861        | 16,265,616        | 16,190,451        |
| Coal             | 11,250,533        | 10,747,621        | 10,744,949        | 7,491,839         | 10,818,351        | 16,256,945        | 16,182,801        |
| Petroleum        | 10,415            | 11,361            | 11,446            | 19,475            | 12,511            | 8,671             | 7,650             |
| <i>Municipal</i> | 3,870,040         | 3,916,235         | 3,537,291         | 3,565,077         | 3,937,355         | 4,022,288         | 4,766,718         |
| Coal             | 3,692,431         | 3,296,688         | 3,424,135         | 3,450,223         | 3,781,368         | 3,713,633         | 4,682,365         |
| Natural Gas      | 159,912           | 600,427           | 99,474            | 99,264            | 140,678           | 292,255           | 79,875            |
| Petroleum        | 17,697            | 19,120            | 13,682            | 15,590            | 15,309            | 16,400            | 4,477             |

CO<sub>2</sub> emissions trends also varied for the 21 different utility plants burning coal in Missouri. Table 14 lists plants in descending order based on CO<sub>2</sub> emissions levels in 1996.

**Table 14 - Estimated CO<sub>2</sub> emissions from coal burned to generate electricity, by utility plant, 1990-96**

Units: Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                            | 1990       | 1991       | 1992       | 1993       | 1994       | 1995       | 1996       | 1990-96 |
|----------------------------|------------|------------|------------|------------|------------|------------|------------|---------|
| UE - Labadie               | 11,673,913 | 11,294,043 | 11,734,823 | 10,288,919 | 12,419,696 | 13,785,217 | 13,357,925 | 14.4%   |
| AEC - Thomas Hill          | 4,285,879  | 3,876,425  | 4,245,410  | 1,447,144  | 4,278,811  | 8,089,601  | 8,284,256  | 93.3%   |
| AEC - New Madrid           | 6,660,830  | 6,636,641  | 6,315,138  | 5,794,581  | 6,169,648  | 7,920,858  | 7,480,771  | 12.3%   |
| UE - Rush Island           | 5,527,194  | 5,804,567  | 5,177,976  | 5,119,321  | 6,103,978  | 6,305,635  | 7,333,896  | 32.7%   |
| KCPL - Iatan               | 4,503,759  | 4,653,070  | 4,359,896  | 3,890,295  | 5,119,203  | 4,900,284  | 5,150,289  | 14.4%   |
| UE - Sioux                 | 4,393,579  | 4,300,082  | 3,721,272  | 3,545,205  | 3,076,942  | 3,649,300  | 4,285,061  | -2.5%   |
| Utilicorp - Sibley         | 1,770,180  | 2,198,368  | 2,367,636  | 2,132,456  | 2,866,505  | 2,789,146  | 3,001,152  | 69.5%   |
| KCPL - Montrose            | 2,476,327  | 2,445,530  | 2,595,719  | 3,082,051  | 3,069,836  | 2,843,901  | 2,893,500  | 16.8%   |
| KCPL - Hawthorn            | 2,413,820  | 2,704,536  | 2,319,878  | 2,246,180  | 2,541,467  | 2,067,642  | 2,647,784  | 9.7%    |
| Sikeston                   | 1,466,101  | 1,678,826  | 1,238,018  | 1,360,613  | 1,555,781  | 1,602,408  | 1,756,911  | 19.8%   |
| UE - Meramac               | 1,790,251  | 1,942,061  | 1,776,193  | 2,044,024  | 1,785,329  | 1,268,922  | 1,747,552  | -2.4%   |
| Springfield - James River  | 880,627    | 228,786    | 792,173    | 765,398    | 862,036    | 1,055,455  | 1,448,710  | 64.5%   |
| Empire - Asbury            | 1,471,915  | 1,357,492  | 1,669,525  | 1,667,648  | 1,611,778  | 1,598,023  | 1,268,717  | -13.8%  |
| Springfield - Southwest    | 1,035,048  | 1,102,715  | 1,130,582  | 993,645    | 1,021,741  | 780,379    | 1,162,080  | 12.3%   |
| Central EC - Chamois       | 303,825    | 234,554    | 184,401    | 250,114    | 369,891    | 246,486    | 417,773    | 37.5%   |
| St. Joseph - Lake Road     | 274,113    | 253,402    | 231,965    | 325,888    | 263,799    | 183,309    | 335,736    | 22.5%   |
| Independence - Blue Valley | 106,539    | 95,739     | 88,910     | 133,862    | 127,756    | 93,803     | 123,535    | 16.0%   |
| Columbia                   | 78,335     | 143,879    | 112,024    | 108,489    | 128,870    | 96,902     | 113,286    | 44.6%   |
| Marshall                   | 93,820     | 18,960     | 34,000     | 59,492     | 44,840     | 57,568     | 61,152     | -34.8%  |
| Chillicothe - Beardmore    | 31,855     | 27,782     | 25,765     | 28,723     | 40,344     | 27,117     | 15,447     | -51.5%  |
| Independence - Missouri    | 106        | -          | 2,661      | -          | -          | -          | 1,244      |         |
|                            | 51,238,014 | 50,997,460 | 50,123,968 | 45,284,048 | 53,458,252 | 59,361,956 | 62,886,778 | 22.7%   |

CO<sub>2</sub> emissions from coal use at some plants increased sufficiently to move them higher in the rankings on Table 14. For example, CO<sub>2</sub> emissions from Associated Electric Cooperative's (AEC) Thomas Hill plant were about 93 percent higher in 1996 than 1990, with most of the increase coming in 1994 and 1995. CO<sub>2</sub> emissions from coal combustion at Springfield's James River municipal power plant increased about 65 percent between 1990 and 1996, with most of the increase occurring in 1994 through 1996.<sup>10</sup>

The largest percentage increases in CO<sub>2</sub> emissions among the investor-owned plants occurred at Utilicorp's Sibley plant and Union Electric's Rush Island plant where emissions increased about 70 percent and 33 percent respectively. More than half of the increase at the Rush Island plant occurred during 1995 and 1996.

Despite changes within the rankings of different plants, the top-heavy distribution of CO<sub>2</sub> emissions in 1996 was nearly identical to that in 1990, with the seven leading plants producing about 76 to 77 percent of the CO<sub>2</sub> emissions, the middle third producing about 22 to 23 percent, and the final third producing only about 1 percent.

---

<sup>10</sup> It should not be inferred that overall emissions from the Springfield utility increased by this amount. Boilers operated by Springfield Municipal Utility in its James River plant can burn either coal or natural gas. The James River Plant's CO<sub>2</sub> emissions from coal combustion were unusually high in 1996 because the utility substituted coal for natural gas during that year in response to high natural gas prices. In 1995, the James River Plant burned only about a third as much natural gas as in 1990 and about 60 percent as much natural gas as in 1995. Springfield Municipal Utility's CO<sub>2</sub> emissions from all fossil fuel combustion grew by about 30 percent between 1990 and 1996, a substantial increase but much less than 65 percent.

## **Section 4: Trends in the source and carbon content of coal consumed by Missouri utilities**

Between 1990 and 1996, there was a shift in the source of Missouri utility coal purchases, which resulted in an increase in the average carbon content of coal burned in Missouri coal-fired plants. Utility emissions from coal use would have been about 1.6 million tons lower in 1996 if Missouri utilities had burned the same quantity of coal using the same sources that they were using in 1990.

Coal has the highest carbon content of commonly used fossil fuels, although coal from different states varies in its carbon content. On the average, natural gas contains about 55 percent of the carbon contained in coal. Petroleum carbon content varies widely by product but generally falls between that of coal and natural gas.

Shifts between different fossil fuels can affect the level of CO<sub>2</sub> emissions independently of the level of total energy use. An example for Missouri occurred in 1992 and 1993, when the state's net energy consumption increased by about 10 trillion Btus while CO<sub>2</sub> emissions from energy use decreased. Increases in total state consumption of natural gas and petroleum more than offset reductions in coal consumption, but the reduction in coal use weighed more heavily on net CO<sub>2</sub> emissions because of coal's high carbon content.

Shifts between different coal sources can also affect the level of CO<sub>2</sub> emissions independently of the level of total energy use, and this occurred in Missouri during 1990 through 1996. During this period, as indicated by Chart 5, Missouri utilities largely shifted from burning coal mined in Eastern states such as Missouri and Illinois to coal mined in Western states, especially Wyoming.<sup>11</sup> Receipts of Wyoming coal nearly quadrupled from 7.6 million short tons, 31 percent of total receipts in 1990, to 26.8 million short tons, 87 percent of total receipts in 1996.

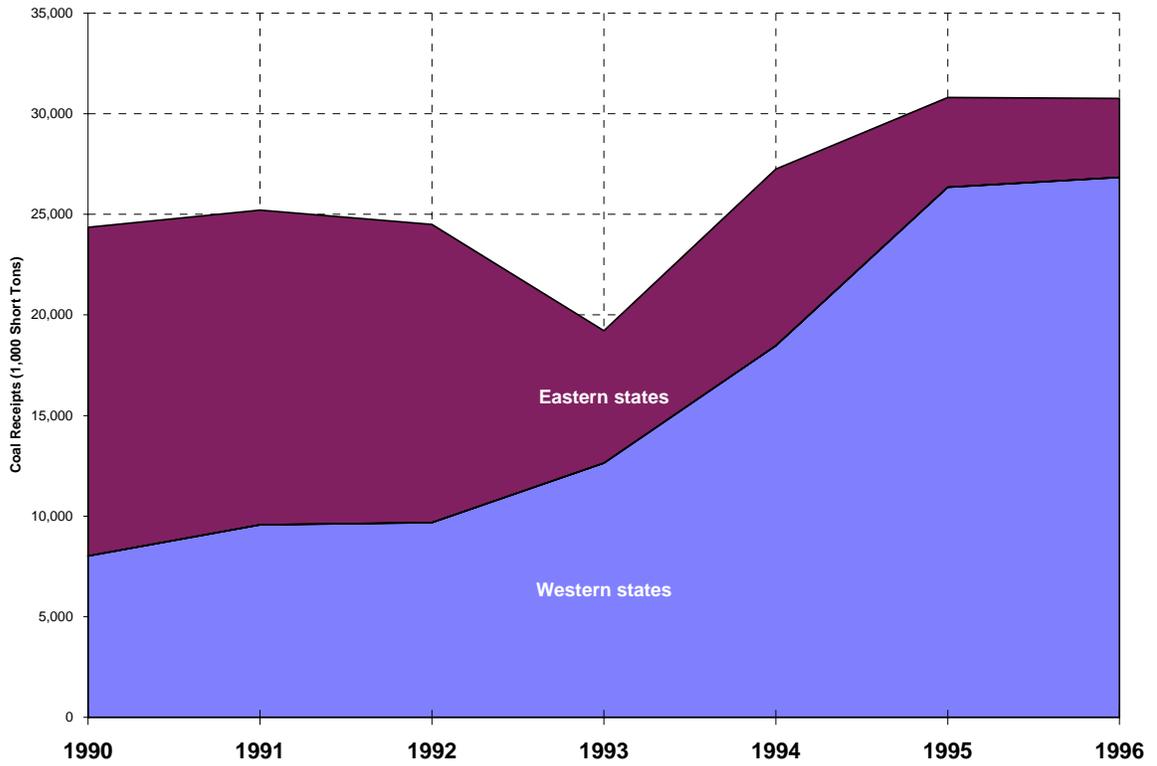
The shift took place because Western coal was priced lower and contained less sulfur than eastern coal. However, because the average carbon content per Btu of Western coal exceeds that for eastern coal, the shift of coal source also contributed to higher CO<sub>2</sub> emissions than would otherwise have occurred.<sup>12</sup> Chart 6 illustrates the increase in average carbon content of utility coal that took place from 1990 to 1996.

---

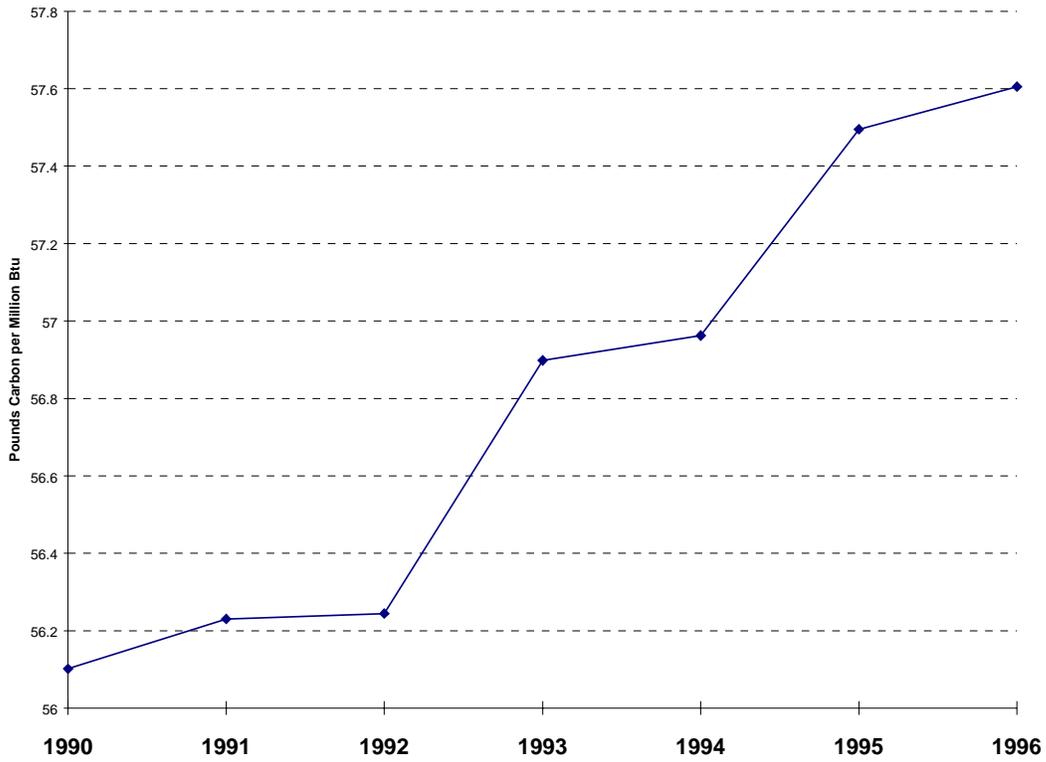
<sup>11</sup> Receipts data is from the 1990 to 1996 editions of the annual USDOE/ EIA, series *Cost and Quality of Fuels for Electric Utility Plants*, Tables 24 and 36.

<sup>12</sup> For example, Wyoming coal contains about 58.01 pounds of carbon per MBtus compared to 55.5 for Illinois coal and 54.9 for Missouri coal. Estimates of carbon content are from Hong, B.D. and E.R. Slatick, Carbon Dioxide Emissions Factors for Coal, USDOE/EIA, *Quarterly Coal Report, January-March 1994*, pp. 1-8.

**Chart 5 - Missouri utilities' shift from Eastern coal to Western coal, 1990-96**



**Chart 6 - Estimated increase in average carbon content of coal received by Missouri utilities, 1990-96**





## **Part 3: Trends in combustion of petroleum and associated CO<sub>2</sub> emissions**

### ***Section 1: Petroleum consumption***

As Table 15 indicates, the transportation sector consumed about 86 percent of petroleum in Missouri during the period from 1990 to 1996. Petroleum use grew in every sector during the period, but most of the growth and the most dramatic shifts occurred in the transportation sector.

Gasoline, primarily used in personal vehicles, accounts for more than half of the petroleum used for energy in the state. However, its share fell from about 61 percent of petroleum energy in 1990 to about 56 percent in 1996.<sup>13</sup> The share lost by gasoline went to jet fuel (a 3.7 percent increase) and diesel fuel (a 1.5 percent increase), used primarily for commercial transportation.

Consumption of the “other” transportation petroleum products included in Table 15 — aviation gasoline, residual fuel and LPG — remained small during the period.

---

<sup>13</sup> Gasoline consumption is defined in the USDOE/EIA State Energy Data System (SEDS) as the sum of highway and marine gasoline use. The estimate for this study is the sum of the SEDS estimate of marine gasoline use and the Missouri Department of Transportation’s (MoDOT) estimate of highway gasoline use. USDOE/EIA State Energy Data System data indicates that gasoline use increased between 1990 and 1991, but MoDOT data indicates that gasoline use decreased between 1990 and 1991. The reason for the discrepancy is not known.

**Table 15 - Estimated use of petroleum products for energy in Missouri, 1990-96**

Units: Trillion Btus

|  | 1990         | 1991         | 1992         | 1993         | 1994         | 1995         | 1996         |
|--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <i>Transportation</i>                        | 466.2        | 466.4        | 481.5        | 497.8        | 522.9        | 537.2        | 560.8        |
| Gasoline                                     | 332.4        | 332.2        | 336.0        | 340.5        | 349.1        | 352.2        | 360.9        |
| Diesel                                       | 94.9         | 90.7         | 101.8        | 105.2        | 112.2        | 118.0        | 126.9        |
| Jet fuel                                     | 37.6         | 42.5         | 42.6         | 51.2         | 60.2         | 65.9         | 71.8         |
| Other  | 1.3          | 1.1          | 1.0          | 1.0          | 1.4          | 1.1          | 1.1          |
| <i>Commercial</i>                            | 9.5          | 10.9         | 11.1         | 11.1         | 11.4         | 11.5         | 11.6         |
| <i>Industrial</i>                            | 48.9         | 40.2         | 43.6         | 49.2         | 50.8         | 50.1         | 51.3         |
| <i>Residential</i>                           | 17.4         | 22.6         | 22.3         | 23.8         | 23.2         | 23.4         | 24.4         |
| <i>Utility</i>                               | 1.2          | 1.4          | 1.1          | 2.3          | 1.7          | 1.7          | 1.4          |
| <b>Total petroleum use</b>                   | <b>543.2</b> | <b>541.5</b> | <b>559.6</b> | <b>584.2</b> | <b>610.0</b> | <b>624.0</b> | <b>649.5</b> |
| Change from previous period                  |              | -0.3%        | 3.3%         | 4.4%         | 4.4%         | 2.3%         | 4.1%         |
| Change from 1990 base year                   |              | -0.3%        | 3.0%         | 7.5%         | 12.3%        | 14.9%        | 19.6%        |
| <b>Share of total petroleum consumption:</b> |              |              |              |              |              |              |              |
| <i>Transportation</i>                        | 85.8%        | 86.1%        | 86.0%        | 85.2%        | 85.7%        | 86.1%        | 86.3%        |
| Gasoline                                     | 61.2%        | 61.3%        | 60.0%        | 58.3%        | 57.2%        | 56.4%        | 55.6%        |
| Diesel                                       | 17.5%        | 16.8%        | 18.2%        | 18.0%        | 18.4%        | 18.9%        | 19.5%        |
| Jet fuel                                     | 6.9%         | 7.8%         | 7.6%         | 8.8%         | 9.9%         | 10.6%        | 11.1%        |
| Other  | 0.2%         | 0.2%         | 0.2%         | 0.2%         | 0.2%         | 0.2%         | 0.2%         |
| <i>Commercial</i>                            | 1.7%         | 2.0%         | 2.0%         | 1.9%         | 1.9%         | 1.8%         | 1.8%         |
| <i>Industrial</i>                            | 9.0%         | 7.4%         | 7.8%         | 8.4%         | 8.3%         | 8.0%         | 7.9%         |
| <i>Residential</i>                           | 3.2%         | 4.2%         | 4.0%         | 4.1%         | 3.8%         | 3.8%         | 3.8%         |
| <i>Utility</i>                               | 0.2%         | 0.3%         | 0.2%         | 0.4%         | 0.3%         | 0.3%         | 0.2%         |

**Breakdown of transportation “other petroleum” consumption**

Units: Trillion Btus

|                        |    |    |    |    |     |    |    |
|------------------------|----|----|----|----|-----|----|----|
| <i>Other petroleum</i> | 96 | 77 | 75 | 76 | 105 | 84 | 81 |
| Aviation gasoline      | 48 | 45 | 44 | 36 | 43  | 44 | 42 |
| Residual fuel          | 19 | 0  | 9  | 18 | 12  | 10 | 8  |
| LPG                    | 29 | 32 | 22 | 22 | 50  | 31 | 30 |

After transportation, industry was the second most important consumer of petroleum. Petroleum products used by Missouri industry for their heat content include distillate and residual fuel, kerosene, LPG, gasoline, and some of the products classified jointly by EIA as “other petroleum.” The particular “other petroleum” products used for energy in Missouri are pentanes plus, petroleum coke and a portion of “miscellaneous” petroleum products.

**Table 16 - Estimated Missouri industry use of petroleum products for energy, 1990-96**

Units: Trillion Btus

|                 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|-----------------|------|------|------|------|------|------|------|
| Distillate      | 17.5 | 17.2 | 19.0 | 16.3 | 20.3 | 20.1 | 20.3 |
| Kerosene        | 0.0  | 0.1  | 0.0  | 0.0  | 0.1  | 0.1  | 0.1  |
| LPG (Energy)    | 6.5  | 7.3  | 6.6  | 9.2  | 9.1  | 8.8  | 9.9  |
| Gasoline        | 3.5  | 4.0  | 3.5  | 7.7  | 8.5  | 8.5  | 8.5  |
| Residual        | 3.3  | 3.0  | 3.9  | 6.4  | 2.9  | 2.9  | 2.0  |
| Other Petroleum | 18.1 | 8.7  | 10.6 | 9.5  | 9.9  | 9.8  | 10.4 |
|                 | 48.9 | 40.2 | 43.6 | 49.2 | 50.8 | 50.1 | 51.3 |

The decline in use of “other” petroleum products between 1990-91 is an artifact of a USDOE/EIA “re-estimate” of consumption for this series in the SEDS database.<sup>14</sup>

A portion of industry LPG use (1.7 percent) and petroleum coke use (25 percent) is devoted to non-energy purposes. This and other instances of industry non-energy petroleum consumption do not appear in Table 16. They are included in a section of Chapter 4 discussing CO<sub>2</sub> emissions from non-energy uses of fossil fuels.

Among electric utilities, petroleum consumption was fairly constant over the period from 1990 to 1996, peaking in 1993 when investor-owned consumption was about 50 percent higher than average. However, use of petroleum increased among investor-owned utilities and decreased among the other two sectors.

## ***Section 2: CO<sub>2</sub> emissions from petroleum***

The transportation sector was the largest source of CO<sub>2</sub> emissions from petroleum from 1990 to 1996, and CO<sub>2</sub> emissions from the sector grew about 19 percent during the period. About 92 percent of this growth was due to increased emissions from gasoline, diesel and jet fuel used for transportation. CO<sub>2</sub> emissions from jet fuel grew an estimated 2.7 million tons, followed by diesel (2.6 million tons) and motor gasoline (2.2 million tons).

---

<sup>14</sup> USDOE/EIA, State Energy Data Report 1994, Appendix G, p. 527.

**Table 17 - Estimated CO<sub>2</sub> emissions from petroleum combustion in Missouri, by sector, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                        | 1990            | 1991            | 1992            | 1993            | 1994            | 1995            | 1996            | Change from 1990 base |        |
|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------------|--------|
| <i>Transportation:</i> | 36,470.5        | 36,485.7        | 37,677.9        | 38,966.8        | 40,941.1        | 42,075.2        | 43,929.6        | 7,459.1               | 20.5%  |
| Gasoline               | 25,826.2        | 25,810.1        | 26,109.2        | 26,454.2        | 27,125.4        | 27,364.2        | 28,044.0        | 2,217.8               | 8.6%   |
| Diesel                 | 7,577.5         | 7,245.5         | 8,131.8         | 8,396.6         | 8,958.5         | 9,423.1         | 10,131.3        | 2,553.7               | 33.7%  |
| Jet fuel               | 2,970.7         | 3,353.3         | 3,361.9         | 4,039.5         | 4,752.0         | 5,204.0         | 5,672.1         | 2,701.5               | 90.9%  |
| Other                  | 96.1            | 76.8            | 75.0            | 76.4            | 105.1           | 83.9            | 82.2            | (13.9)                | -14.5% |
| <i>Commercial</i>      | 720.7           | 823.4           | 844.4           | 844.2           | 864.6           | 870.6           | 881.3           | 160.6                 | 22.3%  |
| <i>Industrial</i>      | 4,106.9         | 3,262.6         | 3,579.6         | 3,984.7         | 4,100.8         | 4,043.6         | 4,127.3         | 20.3                  | 0.5%   |
| <i>Residential</i>     | 1,199.5         | 1,552.0         | 1,534.4         | 1,635.5         | 1,594.6         | 1,611.6         | 1,679.6         | 480.0                 | 40.0%  |
| <i>Utility</i>         | 93.2            | 113.1           | 85.0            | 182.5           | 133.1           | 137.9           | 116.6           | 23.4                  | 25.1%  |
| <b>Total petroleum</b> | <b>42,590.9</b> | <b>42,236.7</b> | <b>43,721.4</b> | <b>45,613.7</b> | <b>47,634.2</b> | <b>48,738.9</b> | <b>50,734.3</b> | 8,143.4               | 19.1%  |
| Change - prev. year    |                 | -0.8%           | 3.5%            | 4.3%            | 4.4%            | 2.3%            | 4.1%            |                       |        |

As Table 17 indicates, the growth in CO<sub>2</sub> emissions from combustion of petroleum, while not steady, was more even from 1990 to 1996 than the growth in CO<sub>2</sub> emissions from combustion of coal. Industrial emissions from petroleum use are summarized in Table 18.

**Table 18 - Estimated CO<sub>2</sub> emissions from industrial petroleum combustion in Missouri, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                 | 1990  | 1991  | 1992  | 1993  | 1994  | 1995  | 1996  |
|-----------------|-------|-------|-------|-------|-------|-------|-------|
| Distillate      | 1,399 | 1,371 | 1,515 | 1,304 | 1,620 | 1,607 | 1,619 |
| Kerosene        | 3     | 10    | 3     | 2     | 5     | 5     | 5     |
| LPG (Energy)    | 445   | 499   | 454   | 632   | 624   | 604   | 682   |
| Gasoline        | 269   | 309   | 273   | 599   | 663   | 660   | 663   |
| Residual        | 285   | 258   | 336   | 549   | 252   | 247   | 175   |
| Other Petroleum | 1,705 | 816   | 998   | 899   | 938   | 920   | 983   |
|                 | 4,107 | 3,263 | 3,580 | 3,985 | 4,101 | 4,044 | 4,127 |

During 1993, the year of their peak petroleum consumption, Missouri utilities generated about 0.1 million megawatt-hours of electricity from petroleum, about 0.4 percent of that generated from coal. The resulting CO<sub>2</sub> emissions were only about 0.3 percent of those from coal; petroleum contains less carbon per Btus than coal.

## Part 4: Trends in combustion of natural gas and resulting CO<sub>2</sub> emissions

As Table 19 indicates, 95 percent of Missouri's use of natural gas for energy occurs in the residential, commercial and industrial sectors.

A small portion (4.1 percent) of total natural gas consumption by industry is for non-energy purposes. Industry consumption of natural gas for non-energy purposes does not appear in the table, but is included in Chapter 4's discussion of CO<sub>2</sub> emissions from non-energy uses of fossil fuels.

**Table 19 - Estimated combustion of natural gas in Missouri's end-use sectors, 1990-96**

Units: Trillion Btus

|  | 1990         | 1991         | 1992         | 1993         | 1994         | 1995         | 1996         |
|--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Transportation                                 | 5.4          | 2.6          | 2.3          | 9.9          | 2.9          | 4.7          | 4.8          |
| Commercial                                     | 60.0         | 63.7         | 61.1         | 69.9         | 66.6         | 65.1         | 73.2         |
| Industrial                                     | 52.9         | 55.3         | 56.2         | 58.7         | 69.1         | 66.4         | 67.4         |
| Residential                                    | 117.2        | 121.7        | 116.9        | 134.7        | 123.3        | 125.1        | 137.2        |
| Utility  | 3.6          | 12.9         | 2.4          | 4.9          | 4.4          | 12.8         | 4.9          |
| <b>Total natural gas use</b>                   | <b>239.1</b> | <b>256.3</b> | <b>238.8</b> | <b>278.2</b> | <b>266.2</b> | <b>274.2</b> | <b>287.4</b> |
| Change from previous period                    |              | 7.2%         | -6.8%        | 16.5%        | -4.3%        | 3.0%         | 4.8%         |
| Change from 1990 base year                     |              | 7.2%         | -0.1%        | 16.4%        | 11.4%        | 14.7%        | 20.2%        |
| <b>Share of total natural gas consumption:</b> |              |              |              |              |              |              |              |
| Transportation                                 | 2.2%         | 1.0%         | 1.0%         | 3.6%         | 1.1%         | 1.7%         | 1.7%         |
| Commercial                                     | 25.1%        | 24.9%        | 25.6%        | 25.1%        | 25.0%        | 23.7%        | 25.5%        |
| Industrial                                     | 22.1%        | 21.6%        | 23.5%        | 21.1%        | 25.9%        | 24.2%        | 23.4%        |
| Residential                                    | 49.0%        | 47.5%        | 48.9%        | 48.4%        | 46.3%        | 45.6%        | 47.7%        |
| Utility  | 1.5%         | 5.0%         | 1.0%         | 1.8%         | 1.6%         | 4.7%         | 1.7%         |

Unlike utility petroleum consumption, utility natural gas consumption was volatile over the period between 1990 and 1996, peaking at 12.9 trillion Btus in 1991, dropping to 2.4 trillion Btus in 1992, and continuing to vary during the following years. The volatility of natural gas consumption reflected both year-to-year changes in peaking requirements and the volatility of natural gas prices.<sup>15</sup>

The average price of natural gas to utilities rose from \$1.51 per 1,000 cubic feet in 1991 to \$1.89 in 1992, peaked at \$2.34 in 1993, then dropped again to \$1.69 in 1995.

As Table 20 indicates, increases in CO<sub>2</sub> emissions from combustion of natural gas occurred primarily in the residential, commercial and industrial sectors. Emissions increased about 27 percent in the industrial sector, 22 percent in the commercial sector and 17 percent in the residential sector. However, the pattern of growth was not consistent; consumption and emissions fell and rose with the rise and fall of natural gas prices.

---

<sup>15</sup> A mild summer in 1992 reduced peaking requirements in that year. Utility natural gas consumption in 1993 was buoyed by a large increase in natural gas-fired generation at the Union Electric Meramec plant during the summer of 1993.

**Table 20 - Estimated CO<sub>2</sub> emissions from natural gas combustion in Missouri's end-use sectors, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|  | 1990            | 1991            | 1992            | 1993            | 1994            | 1995            | 1996            |
|--|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Transportation                                 | 311.9           | 150.4           | 134.6           | 575.2           | 168.6           | 276.3           | 279.5           |
| Commercial                                     | 3,494.0         | 3,709.9         | 3,554.9         | 4,070.7         | 3,876.1         | 3,788.0         | 4,258.1         |
| Industrial                                     | 3,077.1         | 3,219.7         | 3,269.6         | 3,417.0         | 4,020.8         | 3,864.9         | 3,921.0         |
| Residential                                    | 6,821.8         | 7,085.0         | 6,802.5         | 7,839.5         | 7,176.9         | 7,281.4         | 7,985.9         |
| Utility  | 207.4           | 746.1           | 137.2           | 285.5           | 251.9           | 742.8           | 284.3           |
| <b>Total natural gas us</b>                    | <b>13,912.1</b> | <b>14,911.1</b> | <b>13,898.9</b> | <b>16,187.9</b> | <b>15,494.2</b> | <b>15,953.4</b> | <b>16,728.8</b> |
| Change from previous period                    |                 | 7.2%            | -6.8%           | 16.5%           | -4.3%           | 3.0%            | 4.9%            |
| Change from 1990 base year                     |                 | 7.2%            | -0.1%           | 16.4%           | 11.4%           | 14.7%           | 20.2%           |
| <b>Share of total natural gas consumption:</b> |                 |                 |                 |                 |                 |                 |                 |
| Transportation                                 | 2.2%            | 1.0%            | 1.0%            | 3.6%            | 1.1%            | 1.7%            | 1.7%            |
| Commercial                                     | 25.1%           | 24.9%           | 25.6%           | 25.1%           | 25.0%           | 23.7%           | 25.5%           |
| Industrial                                     | 22.1%           | 21.6%           | 23.5%           | 21.1%           | 26.0%           | 24.2%           | 23.4%           |
| Residential                                    | 49.0%           | 47.5%           | 48.9%           | 48.4%           | 46.3%           | 45.6%           | 47.7%           |
| Utility  | 1.5%            | 5.0%            | 1.0%            | 1.8%            | 1.6%            | 4.7%            | 1.7%            |

During 1991, the year of their peak natural gas consumption, Missouri utilities generated about 1 million megawatt-hours of electricity from natural gas, about 2 percent of that generated from coal. The resulting CO<sub>2</sub> emissions were only about 1.5 percent of those from coal.



## Part 5: Allocation of Missouri utility CO<sub>2</sub> emissions to end users of electricity

To this point, the analytic framework for discussing sectoral energy use and CO<sub>2</sub> emissions has been based on primary energy use in five sectors — transportation, commercial, industrial, residential and electric utilities. An alternative analytic framework used in this chapter is based on four energy end-use sectors, excluding utilities. Table 21 summarizes the difference between the two frameworks.

**Table 21 - Comparison of primary-use and end-use sectors**

|   | Primary energy use sectors   | Energy end-use sectors   |
|---|--|--|
| <b>Sectors included</b>   | 5 sectors, including utilities   | 4 sectors, excluding utilities   |
| <b>Method used to account for CO<sub>2</sub> emissions from fossil fuel combustion by utilities</b> | Included under utility sector  | Allocated to end-use sectors based on their consumption of electricity |
| <b>Purposes for which the framework is useful</b>   | To estimate total consumption of fossil fuels and total CO <sub>2</sub> emissions from their use | To analyze consumption decisions by electricity end users              |

Table 22 shows the allocation of utility CO<sub>2</sub> emissions to Missouri's electricity end-use sectors based on their consumption of electricity from 1990 to 1996. Allocated emissions increased 31 percent in the commercial sector, 23 percent in the residential sector and 10 percent in the industrial sector.

**Table 22 - Allocation of estimated electric utility CO<sub>2</sub> emissions to Missouri's end-use sectors, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                                      | 1990   | 1991   | 1992   | 1993   | 1994   | 1995   | 1996   | Change 1990-96 |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|----------------|
| <i>Utility emissions to allocate</i> | 51,539 | 51,857 | 50,346 | 45,752 | 53,852 | 60,246 | 63,288 | 23%            |
| Commercial                           | 18,479 | 18,365 | 18,207 | 16,251 | 19,415 | 21,777 | 22,986 | 24%            |
| Industrial                           | 12,365 | 12,033 | 12,436 | 10,628 | 12,726 | 13,865 | 14,372 | 16%            |
| Residential                          | 20,694 | 21,459 | 19,703 | 18,873 | 21,703 | 24,600 | 25,930 | 25%            |
| Transportation                       | 0      | 0      | 0      | 0      | 8      | 3      | 3      |                |

Table 23 indicates total CO<sub>2</sub> emissions from the end-use sectors after utility emissions are allocated to the four energy end-use sectors. The allocation increases the prominence of the residential and commercial sectors relative to the industrial sector, and the prominence of all three relative to the transportation sector as a source of CO<sub>2</sub> emissions. Table 23 depicts emissions estimates by end-use sector.

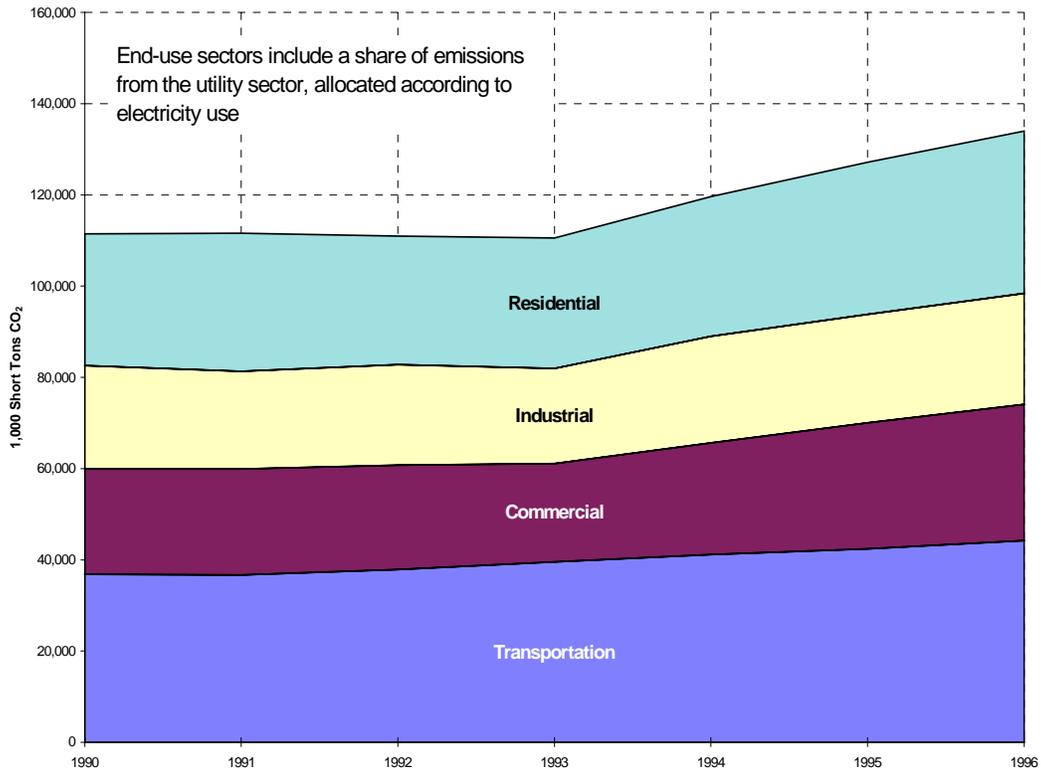
**Table 23 - Estimated aggregate CO<sub>2</sub> emissions from electricity use and direct combustion of fossil fuels by Missouri's end-use sectors, 1990-96**

Units: 1,000 Short Tons Carbon Dioxide (CO<sub>2</sub>)

|                               | 1990    | 1991    | 1992    | 1993    | 1994    | 1995    | 1996    |
|-------------------------------|---------|---------|---------|---------|---------|---------|---------|
| <b>Energy end-use sectors</b> | 111,472 | 111,638 | 110,977 | 110,519 | 119,616 | 127,159 | 133,413 |
| <i>Transportation</i>         | 36,782  | 36,636  | 37,813  | 39,542  | 41,118  | 42,354  | 44,210  |
| Gasoline                      | 25,826  | 25,810  | 26,109  | 26,454  | 27,125  | 27,364  | 28,044  |
| Diesel                        | 7,578   | 7,245   | 8,132   | 8,397   | 8,959   | 9,423   | 10,131  |
| Jet fuel                      | 2,971   | 3,353   | 3,362   | 4,040   | 4,752   | 5,204   | 5,672   |
| Other                         | 408     | 227     | 210     | 652     | 274     | 360     | 359     |
| Transportation                | 0       | 0       | 0       | 0       | 8       | 3       | 3       |
| <i>Commercial</i>             | 23,104  | 23,262  | 22,937  | 21,551  | 24,486  | 26,768  | 28,450  |
| Electricity                   | 18,479  | 18,365  | 18,207  | 16,251  | 19,415  | 21,777  | 22,986  |
| Natural gas                   | 3,494   | 3,710   | 3,555   | 4,071   | 3,876   | 3,788   | 4,258   |
| Petroleum                     | 721     | 823     | 844     | 844     | 865     | 871     | 881     |
| Coal                          | 410     | 365     | 330     | 385     | 330     | 333     | 325     |
| <i>Industrial</i>             | 22,649  | 21,447  | 22,010  | 20,869  | 23,359  | 24,362  | 24,985  |
| Electricity                   | 12,365  | 12,033  | 12,436  | 10,628  | 12,726  | 13,865  | 14,372  |
| Natural gas                   | 3,077   | 3,220   | 3,270   | 3,417   | 4,021   | 3,865   | 3,921   |
| Petroleum                     | 4,107   | 3,263   | 3,580   | 3,985   | 4,101   | 4,044   | 4,127   |
| Coal                          | 3,100   | 2,932   | 2,725   | 2,839   | 2,512   | 2,589   | 2,564   |
| <i>Residential</i>            | 28,937  | 30,292  | 28,218  | 28,557  | 30,653  | 33,674  | 35,768  |
| Electricity                   | 20,694  | 21,459  | 19,703  | 18,873  | 21,703  | 24,600  | 25,930  |
| Natural gas                   | 6,822   | 7,085   | 6,802   | 7,839   | 7,177   | 7,281   | 7,986   |
| Petroleum                     | 1,200   | 1,552   | 1,534   | 1,636   | 1,595   | 1,612   | 1,680   |
| Coal                          | 221     | 196     | 178     | 209     | 178     | 180     | 173     |

Chart 7 summarizes energy end-use sector contributions to CO<sub>2</sub> emissions in Missouri between 1990 and 1996. As the contrast between this chart and Chart 1 indicates, an end-use sector framework emphasizes the prominence of the residential, commercial and industrial sectors as CO<sub>2</sub> emissions sources relative to the transportation sector. This contrast is because nearly all electricity generated by utilities is consumed in these three sectors.

**Chart 7 - Missouri end-use sector shares of CO<sub>2</sub> emissions from fossil fuel combustion, 1990-96**





## **Part 6: Methods used to estimate CO<sub>2</sub> emissions from fossil fuel combustion**

The estimation of CO<sub>2</sub> emissions summarized in this chapter closely followed the methodological procedures described in the *1990 Inventory*. The estimation of CO<sub>2</sub> emissions from fossil fuel combustion requires estimating the physical quantity (tons, barrels, cubic feet, etc.) of the fuel burned, its heat content (Btus) 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<sub>2</sub> 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.

Table 24 summarizes the data and methods used to estimate fossil fuel combustion and CO<sub>2</sub> emissions.

**Table 24 - Data and methods used to estimate fossil fuel combustion and CO<sub>2</sub> emissions**

|   | <b>Source</b>   | <b>Methodological notes</b>   |
|---|---|---|
| <b>Estimates of fossil fuel consumption (physical units of measure) by electric utilities for 1990-96</b> | Electronic database supplied by EIA containing data reported by utilities using Form EIA759   | The estimate is based on fossil fuel used to generate electricity at utility plants located in Missouri. Non-utility use of fossil fuels to generate electricity is included in primary fossil fuel use by the commercial and industrial sectors.   |
| <b>Estimates of fossil fuel consumption (Btus) by utilities prior to 1990</b>                             | State Energy Data System (SEDS) electronic data supplied by EIA   |   |
| <b>Estimates of coal consumption in other sectors</b>   | State Energy Data System (SEDS) electronic data supplied by EIA   | Estimates for 1995 and 1996 are based on AEO projections.   |
| <b>Estimates of natural gas consumption in other sectors</b>  | State Energy Data System (SEDS) electronic data supplied by EIA; EIA, Natural Gas Annual 1995, Table 73; EIA, State Energy Data Report 1994, Appendix D | <p>(1) EIA SEDS provided consumption of natural gas (Btus) for the years 1960 to 1994. EIA, Natural Gas Annual provided consumption of natural gas (physical units of measure) for 1995 and 1996, which was converted to Btus using thermal conversion factors from EIA, State Energy Data Report 1994, Appendix D.</p> <p>(2) SEDS data for industrial natural gas use includes some consumption for non-energy purposes. Non-energy use results in some sequestration of carbon, which otherwise would be released if the natural gas had been burned for energy. This study assumes the percentage of natural gas consumed for non-energy uses from 1991 to 1996 equaled the percentage (4.1%) in the 1990 baseline year. The estimate of CO<sub>2</sub> emissions from non-energy use of natural gas is documented in Chapter 4, Section 1 of this study.</p> |

|  | <b>Source</b>  | <b>Methodological notes</b>   |
|--|--|---|
| <b>Estimates of motor gasoline consumption by the transportation sector</b>  | Data supplied by EIA and Missouri Department of Transportation (MoDOT)                                 | EIA's SEDS classification for transportation motor gasoline includes highway and marine use. For highway consumption, SEDS data was used for 1960 to 1965 and MoDOT data for 1965 to 1996. (Annual FHWA Highway Statistics is derived from MoDOT data.) EIA supplied unpublished SEDS electronic data estimating marine consumption.  |
| <b>Estimates of other petroleum consumption by the transportation sector</b> | State Energy Data System (SEDS) electronic data supplied by EIA, Fuel Oil and Kerosene Sales, Table 16 | EIA's SEDS provided data for 1960 to 1994. Unpublished prime supplier sales data supplied by EIA was used to estimate 1995 and 1996 growth rates of jet and diesel fuel; these were applied to the SEDS data for 1994 consumption.  |
| <b>Estimates of petroleum consumption in other sectors</b>                   | State Energy Data System (SEDS) electronic data supplied by EIA  | <p>(1) SEDS data for industrial petroleum consumption between 1990 and 1991 is discontinuous due to revisions described in EIA, State Energy Data Report 1994, Appendix G, pg. 527. The apparent reduction in industrial CO<sub>2</sub> emissions from petroleum use between 1990 and 1991 is an artifact of these revisions.</p> <p>(2) SEDS data includes some consumption of petroleum fuels for non-energy purposes. Non-energy use results in some sequestration of carbon, which otherwise would be released if the fossil fuel had been burned for energy. The fuels affected are transportation lubricants, industry lubricants, a portion of industry LPG and a portion of "other" petroleum. This study assumes that the percentage of these fuels consumed for non-energy uses from 1991 to 1996 equaled</p> |

|  | Source   | Methodological notes   |
|--|--|--|
| <p><b>Thermal conversion factors (Btus/ton) for coal consumed by utility plants, 1990-96</b></p> | <p>EIA, Cost and Quality of Fuels for Electric Utility Plants: Table 36 for 1990 and 1991, Table 24 for 1992 to 1996</p> | <p>the percentage in the 1990 baseline year. Estimates of CO<sub>2</sub> emissions from non-energy uses are documented in Chapter 4, Section 1 of this study.</p> <p>(3) SEDS provides consumption data through 1994. Regression on 1982 to 1994 consumption trends was used to estimate industrial, in residential and commercial petroleum consumption for 1995 and 1996. The apparent reduction in residential and commercial CO<sub>2</sub> emissions from petroleum use between 1994 and 1995 is an artifact of this methodology.</p> <p>(1) These thermal conversion factors are specific for each plant and year.</p> <p>(2) The thermal conversion factor for coal burned by a plant during the year was assumed to equal the thermal conversion factor for coal received by the plant during that year.</p> <p>(3) For each plant and year, the thermal conversion factor for coal receipts was estimated as a weighted average of thermal conversion factors for coal from each state of origin, weighted by quantity of coal received from that state.</p> <p>(4) The weighted average thermal conversion factor for all plants was used to estimate Btu consumption for several small municipal plants that reported no cost-and-quality data.</p> |

|  | <b>Source</b>  | <b>Methodological notes</b>   |
|--|--|---|
| <b>Thermal conversion factors for coal consumed by other sectors and for natural gas</b>                           | EIA, State Energy Data Report 1994, Appendix D   | Appendix D provides thermal conversion factors by sector for the years 1960 to 1994. The 1994 thermal conversion factors were used for years after 1994.  |
| <b>Thermal conversion factors for petroleum</b>  | State Workbook, Chapter 1  |   |
| <b>Carbon coefficients (lbC/MBtus) to estimate CO<sub>2</sub> emissions from coal burned by utilities, 1990-96</b> | EIA, Cost and Quality of Fuels for Electric Utility Plants: Table 36 for 1990 and 1991, Table 24 for 1992 through 1996; and Hong, B.D. and E.R. Slatick, Carbon Dioxide Emissions Factors for Coal, EIA, Quarterly Coal Report, January-March, 1994, pp. 1-8 | <p>(1) These coefficients are specific for each plant and year.</p> <p>(2) The carbon coefficient for coal burned by a plant during the year was assumed to equal the thermal conversion factor for coal received by the plant during that year.</p> <p>(3) For each plant and year, the carbon coefficient for coal receipts was estimated as a weighted average of carbon coefficients for coal from each state of origin, weighted by the quantity of coal received from that state.</p> <p>(4) The weighted average carbon coefficient for all plants was used to estimate CO<sub>2</sub> emissions for several small municipal plants that reported no cost-and-quality data.</p> <p>(5) Strictly speaking, carbon content of coal is not determined by which state the coal is mined in, but rather by the organic material the coal originated from, as well as the burial conditions of the material and the temperatures to which the material was subjected in the subsurface. Coals of different carbon contents may originate in the same state; it is the coal seam being mined that determines the carbon content. However,</p> |

|   | Source  | Methodological notes  |
|---|---|---|
| <p><b>Carbon coefficients (lbC/MBtus) to estimate CO<sub>2</sub> emissions from coal combustion by utilities prior to 1990 and by other sectors for all years</b></p> | <p>EIA, State Energy Data Report 1994, Appendix F</p> | <p>data on the origin and carbon content of coal used by utilities does not exist at the coal seam level; therefore, it was necessary to use the state-level estimates provided by EIA.</p> <p>Appendix F provides statewide carbon coefficients by sector for the years 1980 to 1994. The 1980 coefficients were used for years prior to 1980, and the 1994 coefficients were used for years after 1994.</p> |