

## Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion

### Overview

Activities in the RCI<sup>1</sup> sectors produce carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) emissions when fuels are combusted to provide space heating, water heating, process heating, cooking, and other energy end-uses. Carbon dioxide accounts for about 98% of these emissions on a million metric tons (MMt) of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) basis in Arkansas. In addition, since these sectors consume electricity, one can also attribute emissions associated with electricity generation to these sectors in proportion to their electricity use.<sup>2</sup> Direct use of oil, natural gas, coal, and wood in the RCI sectors accounted for an estimated 15.1 MMtCO<sub>2</sub>e of gross greenhouse gas (GHG) emissions in 2005.<sup>3</sup>

### Emissions and Reference Case Projections

Emissions from direct fuel use were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for RCI fossil and wood fuel combustion.<sup>4</sup> The default data used in SIT for Arkansas are from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED). The SIT files were updated to include 2004 and 2005 SED information for Arkansas for natural gas, petroleum, and coal for each of the RCI sectors and for wood for the residential and industrial sectors.<sup>5</sup>

Note that the EIIP methods for the industrial sector exclude from CO<sub>2</sub> emission estimates the amount of carbon that is stored in products produced from fossil fuels. For example, the methods account for carbon stored in petrochemical feedstocks, and in liquefied petroleum gases (LPG) and natural gas used as feedstocks by chemical manufacturing plants (i.e., not used as fuel), as

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<sup>1</sup> The industrial sector includes emissions associated with agricultural energy use and fuel combustion by natural gas transmission and distribution (T&D) and oil and gas production industries.

<sup>2</sup> Emissions associated with the electricity supply sector (presented in Appendix A) have been allocated to each of the RCI sectors for comparison of those emissions to the fuel-consumption-based emissions presented in Appendix B. Note that this comparison is provided for information purposes and that emissions estimated for the electricity supply sector are not double-counted in the total emissions for the state. One could similarly allocate GHG emissions from natural gas T&D fugitives, other fuels production, and transport-related GHG sources to the RCI sectors based on their direct use of gas and other fuels, but we have not done so here due to the difficulty of ascribing these emissions to particular end-users. Estimates of emissions associated with the transportation sector are provided in Appendix C, and estimates of emissions associated with natural gas T&D are provided in Appendix E.

<sup>3</sup> Emissions estimates from wood combustion include only N<sub>2</sub>O and CH<sub>4</sub>. Carbon dioxide emissions from biomass combustion are assumed to be "net zero," consistent with US EPA and Intergovernmental Panel on Climate Change (IPCC) methodologies, and any net loss of carbon stocks due to biomass fuel use should be accounted for in the land use and forestry analysis.

<sup>4</sup> GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," August 2004, and Chapter 2 "Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion," August 2004.

<sup>5</sup> EIA, *State Energy Consumption, Price, and Expenditure Estimates (SEDS)*, ([http://www.eia.doe.gov/emeu/states/seds\\_updates.html](http://www.eia.doe.gov/emeu/states/seds_updates.html)).

well as carbon stored in asphalt and road oil produced from petroleum. The carbon storage assumptions for these products are explained in detail in the EIIP guidance document.<sup>6</sup> The fossil fuel types for which the EIIP methods are applied in the SIT software to account for carbon storage are: asphalt and road oil, coking coal, distillate fuel, feedstocks (naphtha with a boiling range of less than 401 degrees Fahrenheit), feedstocks (other oils with boiling ranges greater than 401 degrees Fahrenheit), LPG, lubricants, miscellaneous petroleum products, natural gas, pentanes plus,<sup>7</sup> petroleum coke, residual fuel, still gas, and waxes. Data on annual consumption of the fuels in these categories as chemical industry feedstocks were obtained from the EIA.<sup>5</sup>

Table B1 shows historic and projected growth rates for electricity sales by sector. The 1990-2005 electricity sales data by RCI sector were obtained from EIA.<sup>8</sup> For 2005 to 2025, the annual growth rate in electricity sales for each sector was estimated from the sector growth rates projected for the Southwest Power Pool and Southeastern Electric Reliability Council regions as reported in EIA's *Annual Energy Outlook 2007* (AEO2007).<sup>9</sup> The proportion of each RCI sector's sales to total sales was used to allocate emissions associated with the electricity supply sector to each of the RCI sectors.

Table B2 shows historic and projected growth rates for energy use by sector and fuel type. Reference case emissions from direct fuel combustion were estimated by applying growth rates computed from fuel consumption forecasts from AEO2007 to 2005 historical emissions. For the RCI sectors, annual growth rates for natural gas, oil, wood, and coal were calculated from the AEO2007 forecasts that EIA prepared for the West South Central modeling region. For the residential sector, the AEO2007 annual fuel consumption growth rates were normalized using a combination of the AEO2007 regional population forecasts and Arkansas' population forecasts. Arkansas' annual rate of population growth is expected to average about 0.81% between 2005 and 2025.<sup>10</sup> CCS was unable to obtain from EIA the regional employment forecast data for AEO2007, which would have allowed a similar normalization of the regional forecasts for the commercial and industrial sectors. The AEO2007 estimates of growth reflect expected responses of the economy — as simulated by the EIA's National Energy Modeling System — to changing fuel and electricity prices and changing technologies, as well as to structural changes within each sector (such as shifts in subsectoral shares and in energy use patterns).

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<sup>6</sup> EIIP, *Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," August 2004.

<sup>7</sup> A mixture of hydrocarbons, mostly pentanes and heavier fractions, extracted from natural gas.

<sup>8</sup> Energy Information Administration, "Arkansas Electricity Profile,"

[http://www.eia.doe.gov/cneaf/electricity/st\\_profiles/arkansas.html](http://www.eia.doe.gov/cneaf/electricity/st_profiles/arkansas.html).

<sup>9</sup> EIA, *Annual Energy Outlook 2007 with Projections to 2030* (<http://www.eia.doe.gov/oiaf/aeo07/index.html>).

<sup>10</sup> Center for Business and Economic Research, University of Arkansas,

<http://cber.uark.edu/default.asp?show=population>

**Table B1. Electricity Sales Annual Growth Rates, Historical and Projected**

Sector	1990-2005*	2005-2025**
Residential	3.3%	1.5%
Commercial	4.3%	2.2%
Industrial	3.8%	0.6%
<b>Total</b>	<b>3.5%</b>	<b>1.4%</b>

\* 1990-2005 compound annual growth rates calculated from Arkansas electricity sales by year from EIA state electricity profiles (Table 8), [http://www.eia.doe.gov/cneaf/electricity/st\\_profiles/arkansas.html](http://www.eia.doe.gov/cneaf/electricity/st_profiles/arkansas.html).

\*\* 2005-2025 growth rates calculated from AEO2007 projections for Southwest Power Pool and Southeastern Electric Reliability Council.

**Table B2. Historical and Projected Average Annual Growth in Energy Use in Arkansas, by Sector and Fuel, 1990-2025**

	1990-2005 <sup>a</sup>	2005-2010 <sup>b</sup>	2010-2015 <sup>b</sup>	2015-2020 <sup>b</sup>	2020-2025 <sup>b</sup>
<b>Residential</b>					
natural gas	-1.0%	0.45%	0.17%	-0.10%	-0.21%
petroleum	-1.5%	1.1%	1.5%	1.4%	1.2%
wood	-1.6%	2.9%	-0.92%	0.16%	-0.05%
coal	0.0%	-4.4%	-1.0%	-1.0%	-1.2%
<b>Commercial</b>					
natural gas	1.5%	1.9%	2.0%	1.2%	1.4%
petroleum	3.3%	-0.07%	1.5%	0.59%	0.72%
wood	5.7%	0.00%	0.00%	0.00%	0.00%
coal	0.00%	0.00%	0.00%	0.00%	0.00%
<b>Industrial</b>					
natural gas	-2.3%	4.6%	-0.30%	0.90%	0.47%
petroleum	6.0%	0.54%	0.60%	0.21%	0.77%
wood	0.44%	2.2%	1.5%	1.3%	1.4%
coal	3.1%	0.74%	-0.31%	-0.02%	0.14%

<sup>a</sup> Compound annual growth rates calculated from EIA SED historical consumption by sector and fuel type for Arkansas. Petroleum includes distillate fuel, kerosene, and liquefied petroleum gases for all sectors plus residual oil for the commercial and industrial sectors.

<sup>b</sup> Figures for growth periods starting after 2005 are calculated from AEO2007 projections for EIA's West North Central region. Regional growth rates for the residential sector are adjusted for Arkansas's projected population.

## Results

Figures B1, B2, and B3 show historical and projected emissions for the RCI sectors in Arkansas from 1990 through 2025. These figures show the emissions associated with the direct consumption of fossil fuels and, for comparison purposes, show the share of emissions associated with the generation of electricity consumed by each sector. The residential sector's share of total RCI emissions from direct fuel use and electricity was 30% in 1990, decreased to 29% in 2005, and is projected to be 30% in 2025. The commercial sector's share of total RCI emissions from direct fuel use and electricity was 19% in 1990, increased to 21% in 2005, and is projected to increase to 25% by 2025. The industrial sector's share of total RCI emissions from direct fuel use and electricity was 51% in 1990, decreased to 50% in 2005, and is projected to

decrease to 45% in 2025. Emissions associated with the generation of electricity to meet RCI demand accounts for about 81% of the emissions for the residential sector, 77% of the emissions for the commercial sector, and 47% of the emissions for the industrial sector, on average, over the 1990 to 2025 time period. From 1990 to 2025, natural gas consumption is the next highest source of emissions for the residential and commercial sectors, accounting, on average, for about 16% and 20% of total emissions, respectively. For the industrial sector, emissions associated with the combustion of coal, natural gas, and petroleum account for about 4%, 29%, and 20% respectively, on average, over the 1990 to 2025 period.

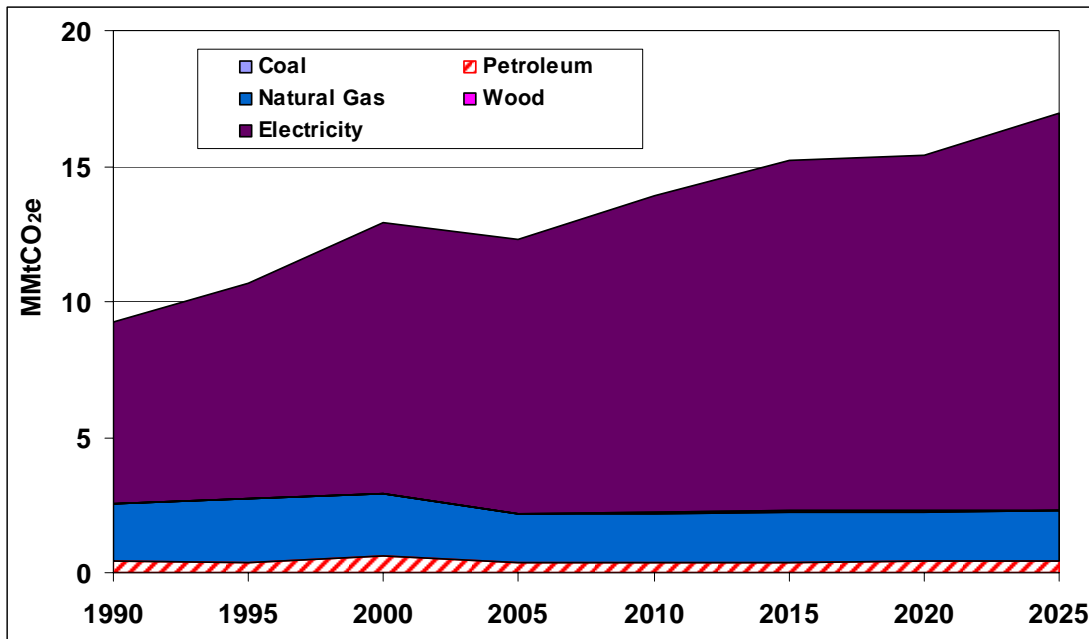
### *Residential Sector*

Figure B1 presents the emission inventory and reference case projections for the residential sector. Figure B1 was developed from the emissions data in Table B3a. Table B3b shows the relative contributions of emissions associated with each fuel type to total residential sector emissions.

For the residential sector, emissions from electricity and direct fossil fuel use in 1990 were about 9.3 MMtCO<sub>2e</sub>, and are estimated to increase to almost 16 MMtCO<sub>2e</sub> by 2025. Emissions associated with the generation of electricity to meet residential energy consumption demand accounted for about 73% of total residential emissions in 1990, and are estimated to increase to 87% of total residential emissions by 2025. In 1990, natural gas consumption accounted for about 23% of total residential emissions, and is estimated to account for about 11% of total residential emissions by 2025. Residential-sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 0.5 MMtCO<sub>2e</sub> combined, and accounted for about 5% of total residential emissions. Emissions from these fuels decreased to 0.4 MMtCO<sub>2e</sub> in 2005. Emissions associated with the consumption of these three fuels in 2025 are estimated to be 0.5 MMtCO<sub>2e</sub>, accounting for 3% of total residential sector emissions by that year.

For the 20-year period 2005 to 2025, residential-sector GHG emissions associated with the use of electricity and petroleum are expected to increase at average annual rates of about 1.9% and 1.3% respectively. Emissions associated with the use of natural gas and wood are expected to increase slightly by about 0.08% and 0.5%, respectively. Total GHG emissions for this sector increase by an average of about 1.6% annually over the 20-year period.

**Figure B1. Residential Sector GHG Emissions from Fuel Consumption**



Source: CCS calculations based on approach described in text.

Note: Emissions associated with coal and wood combustion are too small to be seen on this graph.

**Table B3a. Residential Sector Emissions Inventory and Reference Case Projections (MMtCO<sub>2e</sub>)**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum	0.43	0.35	0.63	0.35	0.37	0.40	0.42	0.45
Natural Gas	2.10	2.37	2.29	1.80	1.84	1.85	1.84	1.82
Wood	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Electricity Consumption	6.73	7.92	9.99	10.14	11.69	12.97	13.12	14.67
Total	9.28	10.67	12.93	12.30	13.92	15.24	15.40	16.96

Source: CCS calculations based on approach described in text.

**Table B3b. Residential Sector Proportions of Total Emissions by Fuel Type**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Petroleum	4.7%	3.3%	4.8%	2.8%	2.6%	2.6%	2.7%	2.6%
Natural Gas	22.6%	22.2%	17.7%	14.6%	13.2%	12.2%	12.0%	10.8%
Wood	0.2%	0.3%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Electricity Consumption	72.5%	74.2%	77.3%	82.4%	84.0%	85.1%	85.2%	86.5%

Source: CCS calculations based on approach described in text.

Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B3a.

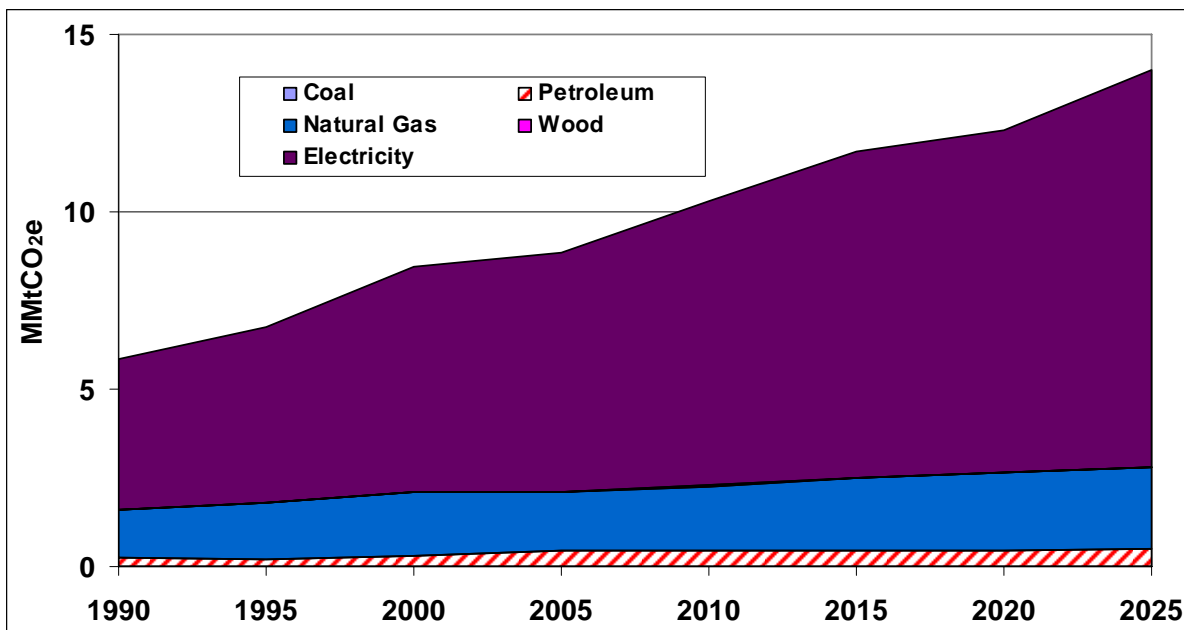
*Commercial Sector*

Figure B2 presents the emission inventory and reference case projections for the commercial sector. Figure B2 was developed from the emissions data in Table B4a. Table B4b show the relative contributions of emissions associated with each fuel type to total commercial sector emissions.

For the commercial sector, emissions from electricity and direct fossil fuel use in 1990 were about 6 MMtCO<sub>2e</sub>, and are estimated to increase to about 14 MMtCO<sub>2e</sub> by 2025. Emissions associated with the generation of electricity to meet commercial energy consumption demand accounted for about 73% of total commercial emissions in 1990, and are estimated to increase to 80% of total commercial emissions by 2025. In 1990, natural gas consumption accounted for about 23% of total commercial emissions and is estimated to account for about 17% of total commercial emissions by 2025. Commercial sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 0.3 MMtCO<sub>2e</sub> combined, and accounted for about 4% of total commercial emissions. By 2025, emissions associated with the consumption of these three fuels are estimated to be 0.5 MMtCO<sub>2e</sub> and to account for 4% of total commercial sector emissions.

For the 20-year period 2005 to 2025, commercial-sector GHG emissions associated with the use of electricity, natural gas, and petroleum are expected to increase at average annual rates of about 2.6%, 1.6%, and 0.7% respectively. Emissions associated with the use of coal and wood are not expected to change relative to 2005. Total GHG emissions for this sector increase by an average of about 2.3% annually over the 20-year period.

**Figure B2. Commercial Sector GHG Emissions from Fuel Consumption**



Source: CCS calculations based on approach described in text.

Note: Emissions associated with coal and wood combustion are too small to be seen on this graph.

**Table B4a. Commercial Sector Emissions Inventory and Reference Case Projections (MMtCO<sub>2</sub>e)**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum	0.26	0.20	0.28	0.43	0.43	0.46	0.47	0.49
Natural Gas	1.35	1.58	1.80	1.68	1.85	2.04	2.16	2.32
Wood	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Electricity Consumption	4.26	4.95	6.36	6.73	8.03	9.22	9.65	11.17
Total	5.86	6.74	8.44	8.84	10.31	11.72	12.29	13.98

Source: CCS calculations based on approach described in text.

**Table B4b. Commercial Sector Proportions of Total Emissions by Fuel Type**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Petroleum	4.4%	3.0%	3.3%	4.8%	4.1%	3.9%	3.8%	3.5%
Natural Gas	23.0%	23.4%	21.3%	19.1%	17.9%	17.4%	17.6%	16.6%
Wood	0.04%	0.07%	0.03%	0.06%	0.06%	0.05%	0.05%	0.04%
Electricity Consumption	72.6%	73.5%	75.4%	76.1%	77.9%	78.7%	78.5%	79.9%

Source: CCS calculations based on approach described in text.

Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B4a.

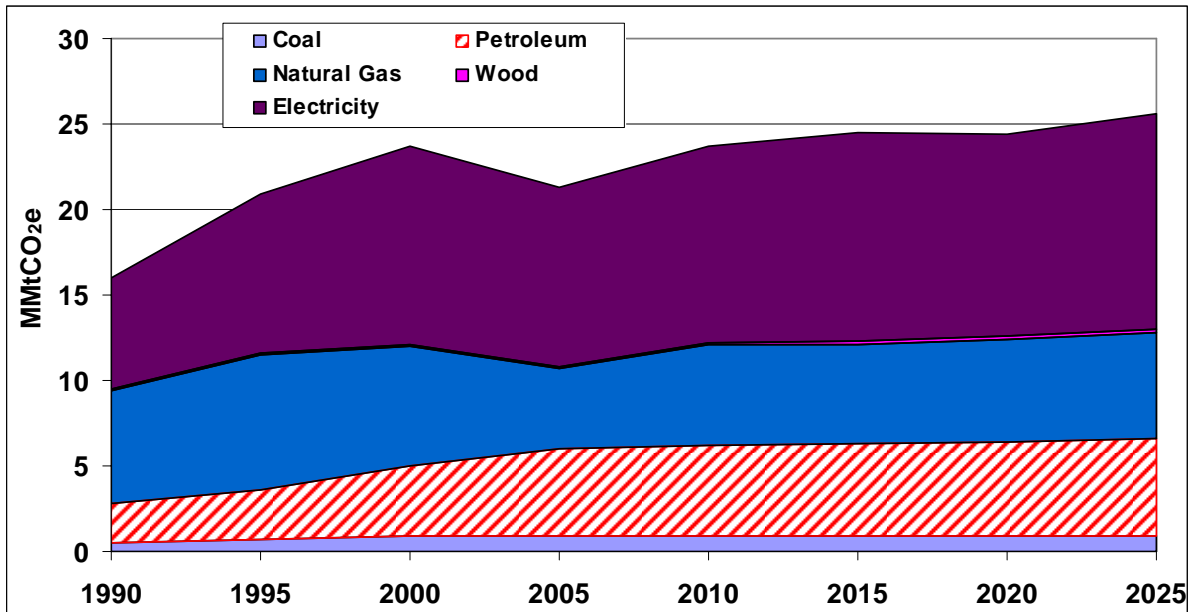
### *Industrial Sector*

Figure B3 presents the emission inventory and reference case projections for the industrial sector. Figure B3 was developed from the emissions data in Table B5a. Table B5b show the relative contributions of emissions associated with each fuel type to total industrial sector emissions.

For the industrial sector, emissions from electricity and direct fuel use in 1990 were about 16 MMtCO<sub>2</sub>e and are estimated to increase to about 26 MMtCO<sub>2</sub>e by 2025. Emissions associated with the generation of electricity to meet industrial energy consumption demand accounted for about 40% of total industrial emissions in 1990, and are estimated increase to about 49% of total industrial emissions by 2025. In 1990, natural gas consumption accounted for about 42% of total industrial emissions, and is estimated to decrease to about 24% of total industrial emissions from 2005 to 2025. Petroleum consumption accounted for about 14% of total industrial emissions in 1990, and is estimated to increase to about 22% of total industrial emissions by 2025. In 1990, coal consumption accounted for about 3.4% of total industrial emissions, and is estimated to be about 3.5% of total industrial emissions in 2025. Emissions associated with wood consumption by the industrial sector are about 1% of total emissions in from 1990 to 2025.

For the 20-year period 2005 to 2025, industrial-sector GHG emissions associated with the use of electricity, natural gas, and wood are expected to increase at average annual rates of about 1.0%, 1.4%, and 1.6% respectively. Emissions associated with the use of petroleum and coal are expected to increase annually by about 0.5% and 0.1%, respectively. Total GHG emissions for the industrial sector increase by an average of about 1.0% annually over the 20-year period.

**Figure B3. Industrial Sector GHG Emissions from Fuel Consumption**



Source: CCS calculations based on approach described in text.

Note: Emissions associated with wood combustion are too small to be seen on this graph.

**Table B5a. Industrial Sector Emissions Inventory and Reference Case Projections (MMtCO<sub>2e</sub>)**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.55	0.73	0.90	0.87	0.90	0.89	0.89	0.90
Petroleum	2.21	2.87	4.12	5.15	5.29	5.45	5.51	5.72
Natural Gas	6.68	7.89	6.95	4.69	5.87	5.78	6.04	6.19
Wood	0.12	0.14	0.14	0.13	0.14	0.15	0.16	0.17
Electricity Consumption	6.45	9.23	11.60	10.46	11.53	12.23	11.83	12.66
Total	16.00	20.87	23.73	21.29	23.73	24.51	24.43	25.64

Source: CCS calculations based on approach described in text.

**Table B5b. Industrial Sector Proportions of Total Emissions by Fuel Type**

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	3.4%	3.5%	3.8%	4.1%	3.8%	3.6%	3.6%	3.5%
Petroleum	13.8%	13.8%	17.4%	24.2%	22.3%	22.2%	22.5%	22.3%
Natural Gas	41.7%	37.8%	29.3%	22.0%	24.7%	23.6%	24.7%	24.1%
Wood	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.7%	0.7%
Electricity Consumption	40.3%	44.2%	48.9%	49.1%	48.6%	49.9%	48.4%	49.3%

Source: CCS calculations based on approach described in text.

Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B5a.

**Key Uncertainties**

Key sources of uncertainty underlying the estimates above are as follows:

- Population and economic growth are the principal drivers for electricity and fuel use. The reference case projections are based on regional fuel consumption projections for EIA's West South Central modeling region. Consequently, there are significant uncertainties associated with the projections. Future work should attempt to base projections of GHG emissions on fuel consumption estimates specific to Arkansas to the extent that such data become available.
- The AEO2007 projections assume no large long-term changes in relative fuel and electricity prices, relative to current price levels and to US DOE projections for fuel prices. Price changes would influence consumption levels and, to the extent that price trends for competing fuels differ, may encourage switching among fuels, and thereby affect emissions estimates.