Appendix A. Electricity Supply and Use

Overview

This appendix describes the data sources, key assumptions, and the methodology used to develop an inventory of greenhouse gas (GHG) emissions over the 1990-2005 period associated with the generation of electricity to meet electricity demand in Arkansas. It also describes the data sources, key assumptions, and methodology used to develop a reference case projection (forecast) of GHG emissions over the 2006-2025 period associated with meeting electricity demand in the state. Specifically, the following topics are covered in this Appendix:

- *Data Sources:* This section provides an overview of the data sources that were used to develop the inventory and forecast, including publicly accessible websites where this information can be obtained and verified.
- *Greenhouse Gas Inventory methodology:* This section provides an overview of the methodological approach used to develop the Arkansas GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Methodology – Reference Case:* This section provides an overview of the methodological approach used to develop the Arkansas GHG forecast for the electric supply sector.
- *Greenhouse Gas Inventory Results:* This section provides an overview of key results of the Arkansas GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Results:* This section provides an overview of key results of the Arkansas GHG forecast for the electric supply sector.

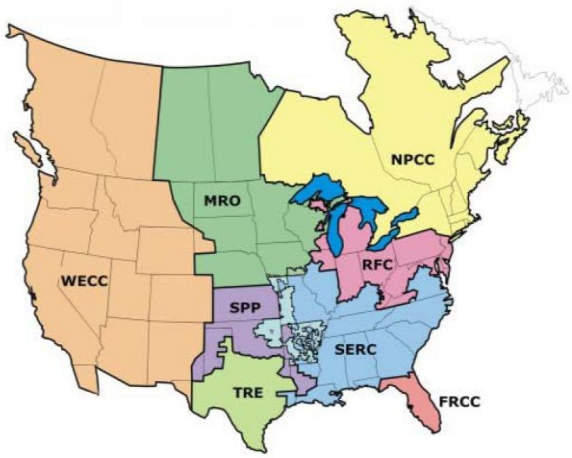
Data Sources

We considered several sources of information in the development of the inventory and forecast of carbon dioxide equivalent (CO_2e) emissions from Arkansas power plants. These are briefly summarized below:

- *2005 EIA-906/920 Monthly Time Series Data.* This is a database file available from the Energy Information Administration (EIA) of the United States (US) Department of Energy (DOE). The information in the database is based on information collected from utilities in Forms EIA-906/920 and EIA-860 for the forecast Base Year of 2005. Data were extracted for Arkansas. Data from these forms provide, among other things, fuel consumption and net generation in power stations located in Arkansas for 2005 by plant type. This information can be accessed from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
- *Annual Energy Outlook 2007.* This is an output of an EIA analysis using the National Energy Modeling System (NEMS), a model that forecasts electric expansion/electricity demand in the US. In particular, regional outputs for the Southwest Power Pool (SPP) region and the Southeastern Reliability Council (SERC) region were used. Arkansas was assumed to be partly (85%) located in the SERC region and partly (15%) located in the SPP region (see map). The SPP and SERC results include forecasts of gross generation, net generation, combustion efficiency, total sales, and exports/imports through the year 2025. This

information is available in supplemental tables that can be accessed directly from http://www.eia.doe.gov/oiaf/aeo/supplement/index.html. The source of the map is http://www.ercot.com/news/mediakit/maps/NERC_Regions.jpg.

North American Electric Reliability Corporation (NERC) Regions



ERCOT - Electric Reliability Council of Texas
FRCC - Florida Reliability Coordinating Council
MRO - Midwest Reliability Organization
NPCC - Northeast Power Coordinating Council
RFC - Reliability*First* Corporation
SERC - Southeastern Electric Reliability Council
SPP - Southwest Power Pool
WECC - Western Electricity Coordinating Council

Note: The Alaska Systems Coordinating Council (ASCC) is an affiliate NERC member.
Source: North American Electric Reliability Corporation.

- *Monthly Cost and Quality of Fuels for Electric Plants.* This information is available from the Federal Energy Regulatory Commission (FERC). The database relies on information collected from utilities in the FERC-423 form. It was used to determine the share of coal type (i.e., whether bituminous, sub-bituminous, anthracite, or lignite) as well as the coal quantity consumed in Arkansas power plants over the period 1990-2005. It was also used to determine the share of oil type (i.e., whether fuel oil #2, #4, #5, or #6) as well as the oil quantity consumed in Arkansas power plants over the period 1990-2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/ferc423.html.
- *State Electricity Profiles.* This information is available from the EIA. The database compiles capacity, net generation, and total retail electricity sales by state. It was used to cross check other data sources regarding Base Year levels for sales, generation, and primary energy use. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.
- *State electricity sales data.* This information is available from the EIA. The database compiles total retail electricity sales by state. It was used to determine total sales of electricity across all sectors for the period 1990 through the Base Year of 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls.
- *State electricity generation data.* This information is available from the EIA. The database compiles total net electricity generation by state. It was used to determine total net generation of electricity across all fuel types for the period 1990 through the Base Year of 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls.
- *State primary energy use for electricity generation data.* This information is available from the EIA. The database compiles total primary energy consumption by state. It was used to determine total primary energy use across all fuel types for the period 1990 through the Base Year of 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/epa/consumption_state.xls.

- *State combined heat and power (CHP) production characteristics.* This information is available from the EIA. The database compiles primary energy consumption by state for combined heat and power facilities, both commercial and industrial. It was used to determine total shares of energy use between commercial and industrial applications across all fuel types for the period 1990 through the Base Year of 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
- *State renewable energy data.* This information is available from the EIA. The database compiles net generation by state for all types of renewable energy. Where 'other wastes' were noted in the EIA data tables, they are assumed to be biomass wastes (e.g., switchgrass, agricultural wastes, paper pellets). It was used to determine total shares of energy use between commercial and industrial applications across all fuel types for the period 1990 through the Base Year of 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/solar.renewables/page/renewelec.html.
- *Energy conversion factors.* This is based on Table Y-2 of Appendix Y in the USEPA's 2003 GHG Inventory for the US. The table is entitled "Conversion Factors to Energy Units (Heat Equivalents)". This information can be accessed directly from the following website: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJTCL/$File/2003-final-inventory_annex_y.pdf.
- *Fuel combustion oxidation factors.* This is based on Appendix A of the USEPA's 2003 US GHG inventory for the US. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.pdf.
- *Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emission factors.* For all fuels except Municipal Solid Waste (MSW), these emission factors are based on Appendix A of the USEPA's 2003 GHG inventory for the US. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.pdf. For MSW, emission factors are based on the EIA's Office of Integrated Analysis and Forecasting, Voluntary Reporting of Greenhouse Gases Program, Table of Fuel and Energy Source: Codes and Emission Coefficients. This information can be accessed directly from http://www.eia.doe.gov/oiaf/1605/coefficients.html.
- *Global warming potentials.* These are based on values proposed by the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report. This information can be accessed directly from http://www.ipcc.ch/pub/reports.htm.

Greenhouse Gas Inventory Methodology

The methodology used to develop the Arkansas inventory of GHG emissions associated with electricity production and consumption is based on methods developed by the IPCC and used by the USEPA in the development of the US GHG inventory. There are four fundamental premises of the GHG inventory developed for Arkansas, as briefly described below:

The GHG inventory should be estimated based on both the production and consumption of electricity. Developing the production estimate involves tallying up the GHG emissions associated with the operation of power plants physically located in Arkansas, regardless of ownership. Developing the consumption estimate involves tallying up the GHG emissions

associated with consumption of electricity in Arkansas, regardless of where the electricity is produced.

The GHG inventory should be estimated based on emissions at the point of electric generation only. That is, GHG emissions associated with the upstream fuel cycle process such as primary fuel extraction, transport to refinery/processing stations, refining, beneficiation, and transport to the power station are not included.

As an approximation, it was assumed that all power generated in Arkansas was consumed in Arkansas. In fact, some power generated in Arkansas is initially exported (through roughly 2004) and then the state becomes a net importer. However, given the similarity in the average carbon intensity of Arkansas power stations and that of power stations in the surrounding SPP and SERC regions, the potential error associated with this simplifying assumption is small, likely on the order of plus or minus 2%.

Several key assumptions were used for making projections of CO_2, CH_4, and N_2O emissions for the electric sector out to 2025. These are summarized in Table A1.

There were several steps in the methodology for the development of the electric sector GHG inventory for the period 1990-2005. These are briefly outlined below:

- Determine the coal quality used in Arkansas power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used).
- Determine the oil quality used in Arkansas power stations (i.e., share of fuel oil #2, #4, #5, and #6 used).
- Determine gross annual primary energy consumption by Arkansas power and CHP stations by plant and fuel type.
- Determine gross annual generation associated with net power imports to satisfy Arkansas electricity demand.
- Multiply gross annual primary energy consumption by Arkansas power and CHP stations by CO_2e emission factors. This provides an estimate of the Arkansas GHG inventory on a production basis.
- Multiply annual gross generation associated with net power imports by the weighted average carbon emission intensity (in units of metric tons of CO_2e per megawatt-hour [tCO_2e/MWh]) of the SPP and SERC regions. This provides an estimate of the additional GHG emissions associated with meeting Arkansas electricity demand in excess of generation from local power plants.
- Add the emissions associated with net power imports to the production-based emissions. This provides an estimate of the GHG inventory on a consumption basis.

Table A1. Key Assumptions used in the GHG Reference Case Projection

Key Assumptions	2005	2025	Average Annual Growth / Change (%)
Arkansas electricity demand (GWh)	46,165	60,612	1.37%
Gross generation to meet Arkansas electricity demand (GWh)			
From Arkansas *power stations*	46,946	62,328	1.43%
From SPP and SERC imports (GWh)	2,880	2,728	-0.27%
Total	49,826	65,056	1.34%
Net generation to meet Arkansas electricity demand (GWh)			
From Arkansas *power stations*	43,991	58,781	1.46%
From SPP and SERC imports (GWh)	2,698	2,573	-0.24%
Total	46,689	61,354	1.38%
Power plant heat rate (Btu/kWh)			
Coal	10,375	9,983	-0.20%
Nuclear	10,582	10,582	0.00%
Natural Gas	7,920	7,601	-0.20%
Oil	9,889	9,062	0.06%
Municipal Solid Waste (MSW)	10,500	10,500	0.00%
Biomass	10,500	10,500	0.00%
Landfill Gas (LFG)	10,500	10,500	0.00%
Wind	10,320	10,320	0.00%
Hydroelectric	10,320	10,320	0.00%
Transmission and Distribution (T&D) Losses (%)	6.3%	5.7%	-0.50%

GWh = gigawatt-hour; Btu/kWh – British thermal unit per kilowatt-hour.

Greenhouse Gas Forecast Methodology – Reference Case

We consider that the most useful methodology for constructing a GHG forecast is one that attempts to build information from the bottom-up. That is, the GHG forecast was developed using detailed state-specific data regarding projected sales, gross in-state generation, supply-side efficiency improvements, planned capacity additions and retirements by plant type/vintage, and changes over time regarding losses associated with on-site use and transmission and distribution (T&D).

While some of this information was available in Arkansas, some key data were not available at the time the forecast was prepared. Therefore, it was necessary to use a top-down approach. A top-down approach uses proxy information regarding future gross in-state generation, supply-side efficiency improvements, and changes over time regarding losses. This approach, while less satisfactory for representing state-specific conditions, nonetheless offers an acceptable starting point for exploring projections of GHG emissions from the electric sector in Arkansas. The methodological steps used for forecasting CO_2e emissions are described below.

New coal stations. An overview of the methodology applied to forecast the generation associated with new coal capacity additions in Arkansas power stations is briefly summarized below:

- There are two new coal stations that are included in the forecast, these are the Plum Point power station (575 megawatts (MW)) and the proposed coal plant in Hempstead County, Arkansas (600 MW).
- It is assumed, in the absence of better information, that Plum Point station comes on line in 2009 and the Hempstead County station comes online in 2011. Both plants are assumed to operate at a capacity factor of 75%, with heat rates comparable to new coal stations in the SPP NERC region.

Coal quality. An overview of the methodology applied to forecast quality of coal used in Arkansas power stations is briefly summarized below:

- For the Base Year of 2005, determine the coal quality used in Arkansas power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used).
- For the period 2006 through and including 2025, assume that the coal quality is the same as the Base Year.

Electricity imports/exports. An overview of the methodology applied to forecast annual net electricity imports or exports to meet Arkansas demand is briefly summarized below:

- For the Base Year of 2005, estimate the sales associated with imports or exports as the difference between total sales in Arkansas and the sales from Arkansas power stations.
- For the period 2006 through and including 2025, assume the sales associated with imported (or exported) electricity equal the average amount of historical imported (or exported) sales from 2001 to 2005.
- For the Base Year of 2005 through and including 2025, estimate the gross generation associated with imports (or exports) by dividing sales from imports (or exports) by one minus the percent losses from on-site usage and T&D in the SPP and SERC regions. Note that Arkansas was a net exporter of electricity from 2001-2004, and was a net importer of electricity in 2005.

Gross generation. An overview of the methodology applied to forecast annual gross electricity generation by Arkansas power stations is briefly summarized below:

- For the Base Year of 2005, estimate losses associated with on-site usage of electricity by plant type for Arkansas power plants. On-site usage losses were assumed to be equal to the SPP and SERC regional average of 0.47% of gross generation.
- For the Base Year of 2005, combine actual net electric generation data (i.e., from the inventory) and assumed average on-site losses (i.e., from the SPP and SERC regions) to estimate gross generation by plant type.
- For the period 2006 through and including 2025, calculate projected total electric generation requirements (electricity sales plus electric system losses) using the annual average sales growth rate as that of the SPP and SERC regions in which the state is located. Subtract projected sales associated with imported electricity from the total electric generation requirements to estimate total net generation by Arkansas power stations to meet the forecasted demand.

- For the period 2006 through and including 2025, estimate total gross generation of Arkansas power stations by dividing the total net generation by one minus the on-site energy usage rate (of the SPP and SERC regions).
- For each year of the period 2006 through and including 2025, allocate total gross generation to each plant and fuel type based on the proportions of each plant and fuel type to total gross generation available from the EIA's modeling forecast for the SPP and SERC regions.

Total sales. An overview of the methodology applied to forecast annual sales of electricity to Arkansas consumers is briefly summarized below:

For the Base Year of 2005, establish total retail sales in Arkansas (i.e. 46,165 gigawatt-hour (GWh).

- For the period 2006 through and including 2025, estimate the Arkansas utility sales to meet the electricity demand in the state by multiplying the total gross generation by one minus the on-site usage percent and the percent losses from T&D (of the SPP and SERC regions).
- For the period 2006 through and including 2025, compute total electricity sales in Arkansas regardless of the origin by adding the sales from imports and the sales from in-state power plants.

Combustion efficiency. An overview of the methodology applied to forecast annual heat rates at Arkansas power stations is briefly summarized below:

- For the Base Year of 2005, estimate gross heat rate of Arkansas power stations by dividing the plant type-specific 2005 gross generation estimate by the plant type-specific 2005 gross primary energy consumption estimate.
- For the period 2006 through and including 2025, estimate the annual average gross plant type-specific heat rate for the SPP and SERC regions.
- For the period 2006 through and including 2025, estimate annual average gross plant type-specific heat rate of Arkansas power stations by multiplying the 2005 value of the annual average gross plant type-specific heat rate of Arkansas power plants by the annual rate of improvement of gross heat rate in the SPP and SERC regions.

Energy use. An overview of the methodology applied to forecast annual primary energy use at Arkansas power stations is briefly summarized below:

- For the Base Year of 2005, establish the actual primary energy consumption for Arkansas power plants as reported by the databases used to develop the inventory.
- For the period 2006 through and including 2025, multiply annual gross generation by annual heat rate for each plant type in Arkansas.

Carbon dioxide-equivalent emissions from Arkansas power stations. An overview of the methodology applied to forecast annual CO_2e emissions from Arkansas power stations is briefly summarized below:

- For the Base Year of 2005 through and including 2025, estimate total CO_2 emissions from Arkansas power stations by multiplying total primary energy use by the CO_2 emission factor and the global warming potential.

- For the Base Year of 2005 through and including 2025, estimate total CH_4 emissions from Arkansas power stations by multiplying total primary energy use by the CH_4 emission factor and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total N_2O emissions from Arkansas power stations by multiplying total primary energy use by the N_2O emission factor and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CO_2e emissions from Arkansas power stations by adding the CO_2e of CO_2, CH_4, and N_2O.

Carbon dioxide-equivalent emissions from imported electricity. An overview of the methodology applied to forecast annual CO_2e emissions from electricity imports is briefly summarized below:

- For the Base Year of 2005 through and including 2025, estimate the average annual GHG emission intensity (i.e., metric tons of CO_2, CH_4, and N_2O per MWh of gross generation) for the SPP and SERC regions from the data sources described earlier.
- For the Base Year of 2005 through and including 2025, estimate total CO_2 emissions associated with imported electricity by multiplying the gross generation associated with these imports by the CO_2 emission intensity and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CH_4 emissions associated with imported electricity by multiplying the gross generation associated with these imports by the CH_4 emission intensity and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total N_2O emissions associated with imported electricity by multiplying the gross generation associated with these imports by the N_2O emission intensity and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CO_2e emissions associated with imported electricity by adding the CO_2e of CO_2, CH_4, and N_2O.

Results

Table A2 and Figure A1 summarize the characteristics of the electric generation system in Arkansas, together with a breakdown in generation and emissions for Arkansas power stations for 2005. The following subsections provide an overview of the results of the GHG emissions inventory and reference case projections estimated using the methodological approach described above.

Primary Energy Consumption

Total primary energy consumption associated with electricity generation in Arkansas is summarized in Figure A2. Primary energy consumption in Arkansas is dominated by coal and nuclear resources.

Gross Generation

Total gross generation by Arkansas power plants is summarized in Figure A3. Gross generation in Arkansas is dominated by steam units, which are primarily based on coal and natural gas fuel.

Imported Electricity

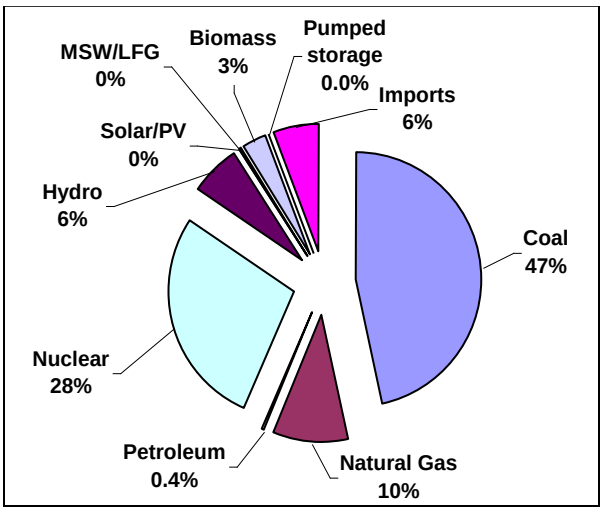
To meet annual demand for electricity in Arkansas, total gross generation by Arkansas power plants needs to be augmented by electricity imports in 2000 and then again in 2005 and for a few years beyond. As indicated earlier, it was assumed that this power is imported from the SPP and SERC regions. Figure A4 summarizes the gross generation within and beyond Arkansas's border needed to satisfy electricity demand in Arkansas.

Table A2. Summary of Arkansas Electric Generator Characteristics for the 2005 Base Year

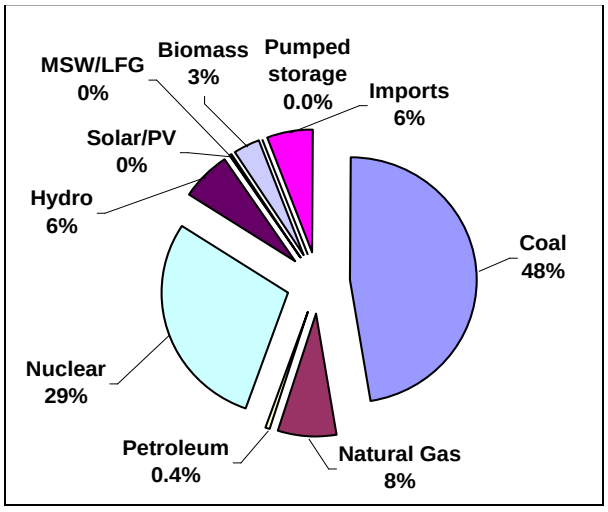
Fuel	Gross Generation (GWh)	Fuel use (Trillion Btu)	Heat rate (Btu/KWh)	Emissions ($MMtCO_2e$)
Coal	23,226	241	10,375	23.30
Natural Gas	4,854	38	7,920	2.06
Other Gases	0	0	0	0.00
Petroleum	208	2	9,889	0.15
Nuclear	13,802	146	10,582	0.00
Hydroelectric	3,108	32	10,320	0.00
Geothermal	0	0	10,500	0.00
Solar/PV	19	0	10,320	0.00
Wind	0	0	10,320	0.00
MSW Landfill gas	153	2	10,500	0.09
Biomass	1,555	16	10,500	0.01
Other wastes	0	0	10,500	0.00
Pumped storage	21	0	10,500	0.02
Imports	2,880	29		1.71
Total	**49,826**	**507**		**25.62**

Figure A1. Arkansas Generation and Emissions; Plus Imports – 2005 Base Year

a. Gross Generation (49,826 GWh)



b. Primary Energy (507 Trillion Btu)



c. Emissions (27.33 MMtCO2e)

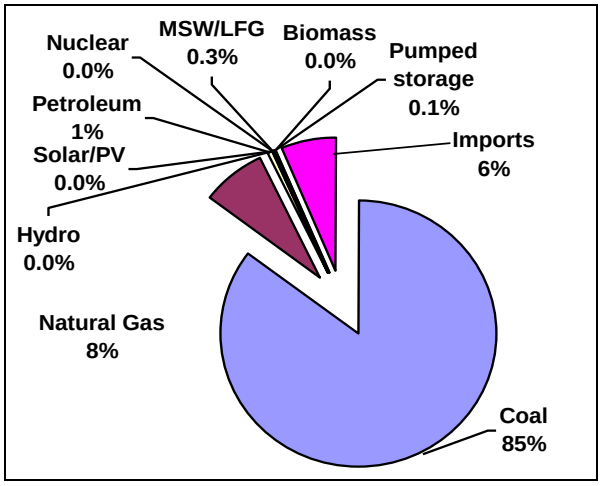
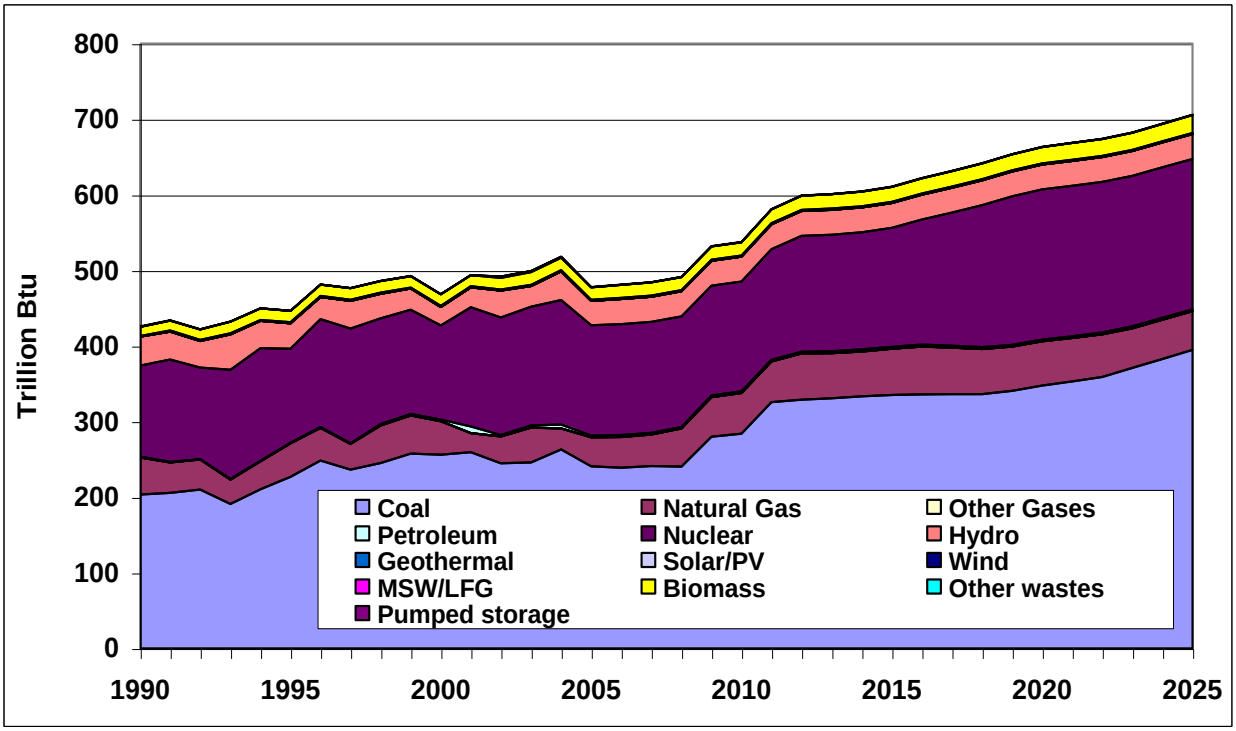
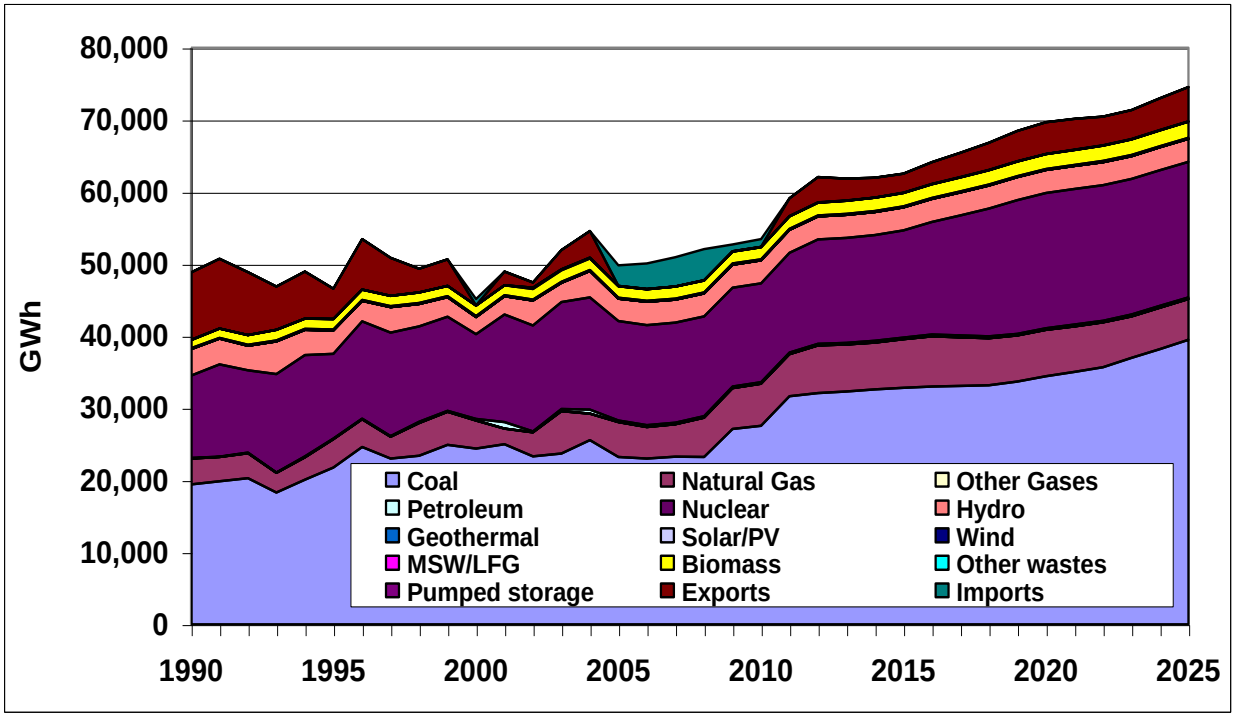


Figure A2. Gross Primary Energy Use at Arkansas Power Stations, Excluding Imports/Exports



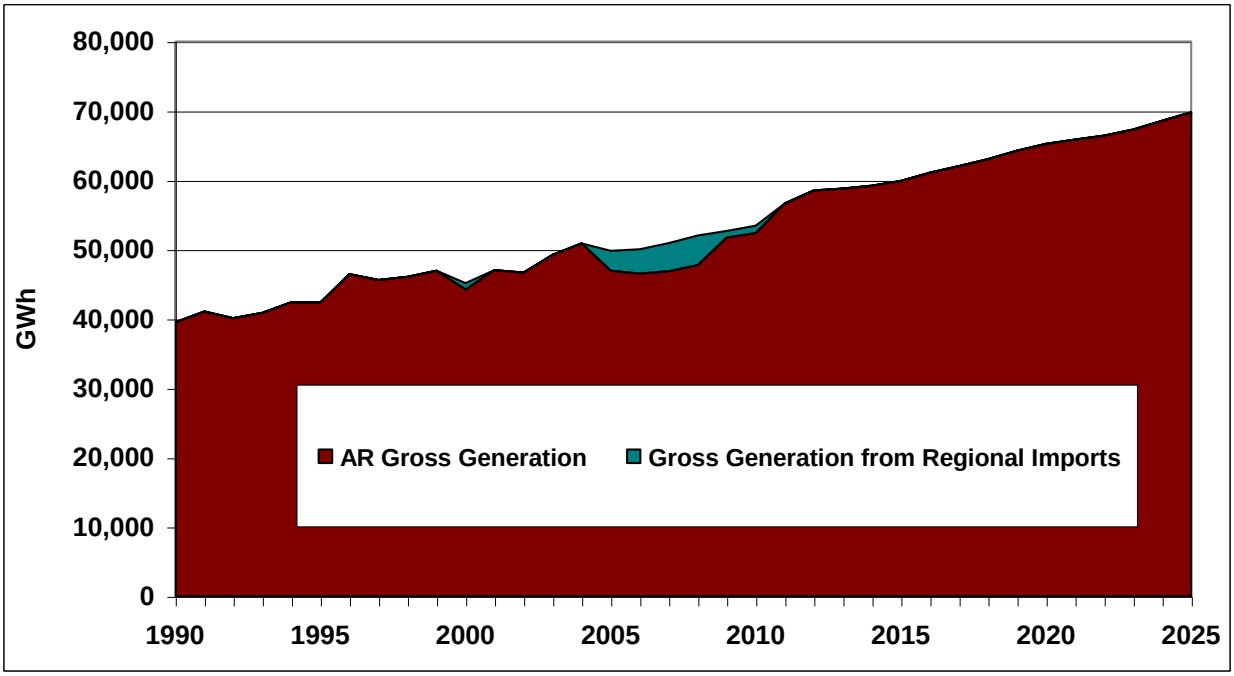
Source: Results in table based on approach described in text.

Figure A3. Gross Generation at Arkansas Power Stations, Including Imports/Exports



Source: Results in table based on approach described in text.

Figure A4. Composition of Gross Generation to Meet Arkansas's Electricity Demand



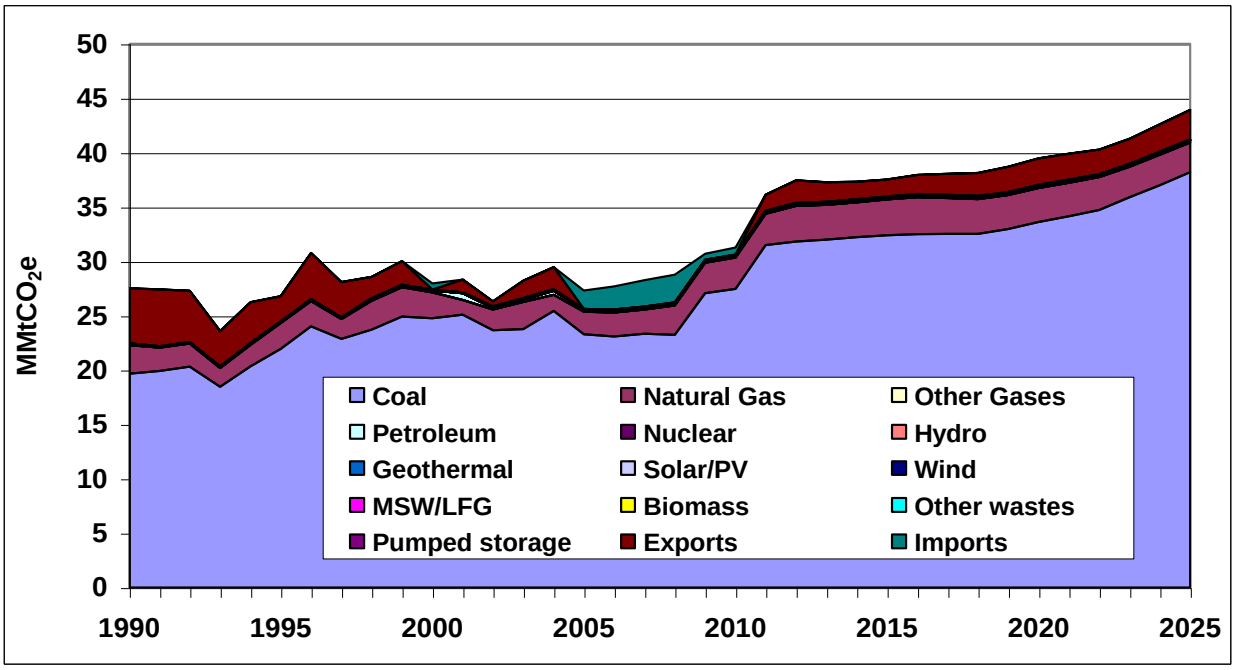
Source: Results in table based on approach described in text.

Total Gross GHG Emissions

Total emissions associated with generation by Arkansas power plants as well as generation by power plants located outside Arkansas to meet electricity demand within Arkansas are summarized in Figure A5 by fuel. Figure A6 compares emissions on a production basis (in-state generation) and consumption basis (in-state generation plus imports, or minus exports, depending on the year).

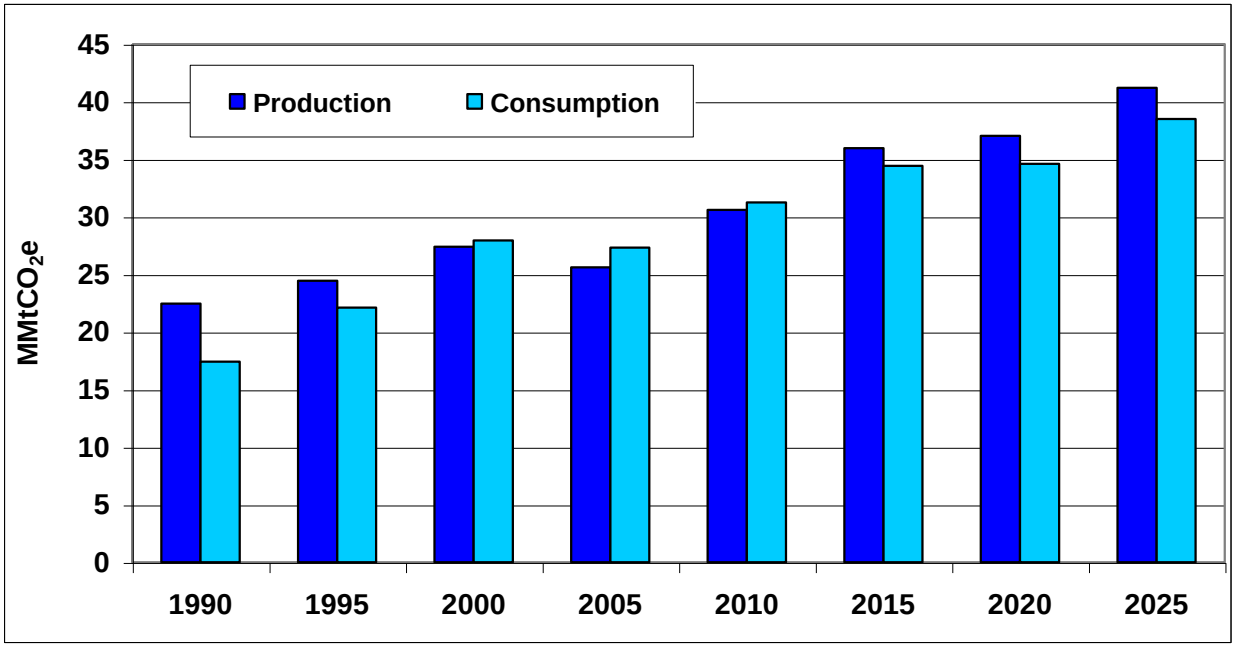
On a consumption basis, emissions were about 27.33 $MMtCO_2e$ in 2005 and are projected to increase to about 38.50 $MMtCO_2e$ in 2025, representing an overall increase of about 41% during this 20-year period. Arkansas was a net exporter of electricity for the historical periods 1990-1999 and 2001-2004, and is projected to be a net exporter for the forecast period of 2011-2025. Arkansas was a net importer of electricity in 2005 and is projected to be a net importer for the forecast period of 2006-2010. Except during 2000, Arkansas has been a net exporter of electricity from 1990 through 2004. Arkansas was a net importer of electricity in 2005 and is expected to continue to be a net importer of electricity through 2010. Beginning in 2011 through 2025, Arkansas is projected to be a net exporter of electricity primarily because of the additional capacity associated with the Plum Point coal station that comes on line in 2009 and the proposed Hempstead County coal station that was assumed to come on line in 2011.

Figure A5. Total Gross GHG Emissions Associated with Arkansas Electric Demand by Fuel Type



Source: Results in table based on approach described in text.
MSW = municipal solid waste; LFG = landfill gas; PV= Photovoltaic.

Figure A6. Electricity Generation Gross GHG Emissions – Production and Consumption Basis (1990-205)



Source: Results in table based on approach described in text.
Electricity consumption emissions are the sum of emissions associated with electricity production and net exported (1990, 1995, 2015, 2020, and 2025) or net imported (2000, 2005, and 2010) electricity.

Key Uncertainties

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

- The methodologies used in this initial preliminary analysis rely on state-specific data on electricity generating units available from the EIA for the historical estimates of GHG emissions. The forecast relies primarily on EIA data available from the AEO2007 forecast for the SPP and SERC regions. Forecasts of GHG emissions associated with imported electricity are based on the assumption that the state will need to import the same amount of electricity from the SPP and SERC regions in the forecast years as the average amount of the past five years (2001-2005). This approach is a top-down approach to estimating historical and future emissions. Future work should focus on improving the inventory and forecast by compiling data that enable a bottom-up approach (unit-by-unit or contract basis) to estimating emissions for the electricity supply sector.
- Electricity on-site usage and T&D loss estimates were used to convert gross generation in the forecast to sales to meet the state demand. The estimated Arkansas utility sales to the customers were less than estimates of electricity demand throughout the forecast period indicating that Arkansas will need to import electricity to fulfill electricity demand that cannot be met by in-state generators. The on-site usage and T&D loss estimates are taken from the EIA AEO2007 for the SPP and SERC regions. Improvements to these estimates (based on input from the state's utilities) could help to get more accurate emissions associated with imported electricity.
- There are uncertainties associated with the statewide fuel mix, emission factors, and conversion factors (to convert electricity from a heat input basis to electricity output) that should be reviewed and revised with data that is specific to Arkansas power generators.
- Fuel price changes influence consumption levels and, to the extent that price trends for competing fuels differ, may encourage switching among fuels, and thereby affect emissions estimates over the forecast period. Although the effects of fuel price changes on the supply and demand of electricity are included in the EIA regional modeling used for this initial analysis, unanticipated events that affect fuel prices could affect the electricity forecast for Arkansas.