Appendix E. Fossil Fuel Industries

Overview

The inventory for this subsector of the Energy Supply sector includes methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) emissions associated with the production, processing, transmission, and distribution of fossil fuels in Arkansas.[1] In 2005, emissions from the subsector accounted for an estimated 2.82 million metric tons (MMt) of CO_2 equivalent (CO_2e) of total gross greenhouse gas (GHG) emissions in Arkansas, and are estimated to increase to about 3.04 $MMtCO_2e$ by 2025.

Emissions and Reference Case Projections

Oil and Gas Production

In 2005, Arkansas' crude oil production totaled 17,000 barrels (bbls) per day, accounting for only 0.3% of US production.[2] Proved crude oil reserves are 40 million bbls, which is similarly about 0.2% of US totals. The peak year of oil production in Arkansas was 1986 (43,000 bbls per day). Production has steadily declined for more than two decades since.[3] Arkansas has two operating petroleum refineries located in the Gulf Coastal Plain in the southern portion of the state, with a crude oil distillation capacity of 76,800 bbls per day.[4]

Arkansas is also responsible for about 1% of the Nation's natural gas production. The productive Arkoma Basin region is located in the western part of the state, and there are a number of gas wells located in the Gulf Coastal Plain to the south. In 2005, Arkansas consumed 214 billion cubic feet (Bcf) of natural gas while it produced 191 Bcf.[4]

The majority of Arkansas oil and gas emissions comes from transportation of natural gas through the state's transmission pipelines. Due to its location near larger natural gas producing states, including Texas and Louisiana, Arkansas is home to thousands of miles of natural gas transmission and distribution pipeline which transports the gas to consumption markets in the Midwest and Northeast.

Oil and Gas Industry Emissions

Emissions can occur at several stages of production, processing, transmission, and distribution of oil and gas. Based on the information provided in the Emission Inventory Improvement Program (EIIP) guidance[5] for estimating emissions for this sector, transmission pipelines are large diameter, high-pressure lines that transport gas from production fields, processing plants, storage facilities, and other sources of supply over long distances to local distribution companies or to

[1] Note that emissions from natural gas consumed as lease fuel (used in well, field, and lease operations) and plant fuel (used in natural gas processing plants) are included in Appendix B in the industrial fuel combustion category..
[2] US Department of Energy (DOE), Energy Information Administration, "Crude Oil Production", accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm, January 2008.
[3] US DOE Energy Information Administration, "Crude Oil Proved Reserves, Reserves Changes, and Production," accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_pres_dcu_SAR_a.htm, January 2008.
[4] "State Energy Profiles: Arkansas", US DOE Energy Information Administration website, January 2008, accessed from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=AR.
[5] Emission Inventory Improvement Program, Volume VIII: Chapter 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems," August 2004.

large volume customers. Sources of CH_4 emissions from transmission pipelines include leaks, compressor fugitives, vents, and pneumatic devices. Distribution pipelines are extensive networks of generally small diameter, low-pressure pipelines that distribute gas within cities or towns. Sources of CH_4 emissions from distribution pipelines are leaks, meters, regulators, and mishaps. Carbon dioxide, CH_4, and N_2O emissions occur as the result of the combustion of natural gas by internal combustion engines used to operate compressor stations.

With 3,500 active gas-producing wells in the state, 5 operational gas processing plants, and nearly 27,000 miles of gas pipelines, there are significant uncertainties associated with estimates of Arkansas' GHG emissions from this sector. This is compounded by the fact that there are no regulatory requirements to track GHG emissions. Therefore, estimates based on emissions measurements in Arkansas are not possible at this time.

The EPA's State Greenhouse Gas Inventory Tool (SIT) facilitates the development of a rough estimate of state-level GHG emissions. GHG emission estimates are calculated by multiplying emissions-related activity levels (e.g., miles of pipeline, number of compressor stations) by aggregate industry-average emission factors. Key information sources for the activity data are the US Department of Energy's Energy Information Administration (EIA)[6] and the US Department of Transportation's Office of Pipeline Safety (OPS).[7] The Arkansas Oil and Gas Commission (AOGC) and Arkansas Public Service Commission (APSC) provided additional activity data and adjustments to OPS distribution pipeline information. Emissions were estimated using the SIT, with reference to methods/data sources outlined in the EIIP guidance document for natural gas and oil systems.[8] Emissions of CO_2, CH_4, and N_2O associated with pipeline natural gas combustion were estimated using SIT emission factors[9] and Arkansas 1990-2005 natural gas data from EIA for the "consumed as pipeline fuel" category.[10]

Unfortunately the OPS has not collected data from pipeline operators using a consistent set of reporting requirements over the 1990-2005 analysis period. In particular, OPS has only required operators to report state-level data for their transmission/gathering pipelines since 2001 and state-level data for their distribution pipelines since 2004. Before these dates, a number of Arkansas pipeline records report data as multi-state totals. As noted above, the APSC was able to provide natural gas distribution pipeline data that avoided these issues. To estimate a complete time-series of natural gas transmission/gathering pipeline data, CCS compiled surrogate data to back-cast the 2001 transmission/gathering pipeline mileage for each year back to 1990.[11]

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[6] "Natural Gas Navigator," US DOE Energy Information Administration website, January 2008, accessed from http://www.eia.doe.gov.

[7] US Department of Transportation, Office of Pipeline Safety, "Distribution and Transmission Annuals Data: 1990 to 2005," accessed from http://ops.dot.gov/stats/DT98.htm, January 2008.

[8] Emission Inventory Improvement Program, Volume VIII: Chapter. 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems", August 2004.

[9] 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.

[10] US DOE, Energy Information Administration, *State Energy Consumption, Price, and Expenditure Estimates (SEDS)*, (http://www.eia.doe.gov/emeu/states/_seds.html).

[11] Note that CCS estimated an additional 964 transmission pipeline miles in 2002 to account for an operator that appeared to be missing from the OPS database (Mississippi River Transmission Corporation).

The AOGC also provided information on the number of associated wells, which are oil wells that also produce natural gas. The AOGC estimates approximately 200 such wells in operation for each year throughout the historical analysis period.

Coal Production Emissions
The US Environmental Protection Agency (EPA) reports nominal coal mining-related GHG emissions in Arkansas throughout the historical analysis period.[12] These estimates were incorporated directly into this inventory.

Table E1 provides an overview of data sources and approaches used to develop fossil fuel sector emission estimates for Arkansas, including a description of the surrogate data that were used to back-cast natural gas transmission/gathering pipeline mileage data for the historical analysis period.

Emission Forecasts
Table E1 provides an overview of data sources and approaches used to develop projected fossil fuel sector emission estimates for Arkansas. The approach to forecasting sector emissions/activity consisted of compiling and comparing two alternative sets of annualized growth rates for each emissions activity – one using *Annual Energy Outlook 2007* forecast data for each 5-year time-frame over the 2005-2025 analysis period, and the other using the historical 1990-2005 activity data for each of 3 periods (i.e., 1990 to 2005, 1995 to 2005, and 2000 to 2005). Because available AEO forecast information is for a broad region that may not reflect Arkansas-specific trends (e.g., AEO forecasts of natural gas production are for the Midcontinent Region, which includes 7 states in addition to Arkansas), the AEO forecast growth rates were only used when they were in-line with the Arkansas historical growth rates. Therefore, some oil and gas production sector projections are based on state-level historical activity/emissions trends. In cases where of each the three historical periods indicated continual growth or decline, the period with the smallest annual rate of growth/decline was used in the projection. This conservative assumption was adopted because of the uncertainty associated with utilizing historical trends to estimate future emission activity levels.

It is important to note that potential improvements to production, processing, and pipeline technologies that could result in GHG emissions reductions are generally not accounted for in the projections analysis.

[12] US Environmental Protection Agency, "Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, USEPA #430-R-07-002, April 2007

Table E1. Approach to Estimating Historical/Projected Emissions from Fossil Fuel Systems

Activity	**Approach to Estimating Historical Emissions**		**Surrogate Data Used to Backcast Activity to 1990**	**Forecasting Approach**
	Required SIT Data	***Data Source***		***Projection Assumption***
Natural Gas Production	Number of gas/ associated wells	Gas wells - EIA[13] Associated wells - AOGC[14]		Used AEO 2007[15] Midcontinent region natural gas production forecast because annualized growth rate over forecast period (0.24%) is in-line with the long-term historical annual growth rate.
Natural Gas Processing	Number of gas processing plants	*Oil and Gas Journal*[16]		Annual growth rate (1.50%) based on smallest annualized rate of growth in number of natural gas processing plants from each of 3 periods analyzed (1990-2005).
	Flaring of Entrained Gas	EIA[17]		No change because no clear historical trend (growth in 1 period; decreases in other 2 historical periods analyzed).
Natural Gas Transmission	Miles of gathering pipeline	Office of Pipeline Safety[7]	AR natural gas production as reported by EIA[18]	Used AEO 2007 West South Central region natural gas pipeline use projections since annualized growth over forecast period (0.47%) is in-line with long-term historical AR transmission emissions growth.
	Miles of transmission pipeline		Average of volume of natural gas transported into AR and transported out of AR, from EIA[19]	
	Number of gas transmission compressor stations	EIIP[20]		
	Number of gas storage compressor stations	EIIP[21]		

[13] US DOE, Energy Information Administration, "Arkansas Natural Gas Number of Gas and Gas Condensate Wells," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1170_sar_8a.htm, January 2008.
[14] Personal communication, "RE: Greenhouse Gas Inventory Contacts," from Lawrence Bengal, Arkansas Oil and Gas Commission, to Andy Bollman, CCS, February 1, 2008.
[15] US DOE, Energy Information Administration, "Annual Energy Outlook 2007 with Projections to 2030," accessed from http://www.eia.doe.gov/oiaf/archive/aeo07/index.html, January 2008.
[16] PennWell Corporation, "Worldwide Gas Processing," *Oil and Gas Journal* (1990-2005 June/July issues).
[17] US DOE, Energy Information Administration, "Arkansas Natural Gas Vented and Flared," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1130_sar_2a.htm , January 2008.
[18] US DOE, Energy Information Administration, "Arkansas Dry Natural Gas Production," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1160_sar_2a.htm, January 2008.
[19] US DOE, Energy Information Administration, "International and Interstate Movements of Natural Gas by State," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_move_ist_a2dcu_SAR_a.htm, January 2008.
[20] Number of gas transmission compressor stations = miles of transmission pipeline x 0.006 – EIIP, Volume VIII: Chapter 5, March 2005.
[21] Number of gas storage compressor stations = miles of transmission pipeline x 0.0015 EIIP. Volume VIII: Chapter 5, March 2005.

Table E1. Approach to Estimating Historical/Projected Emissions from Fossil Fuel Systems (continued)

Activity	**Approach to Estimating Historical Emissions** *Required SIT Data*	*Data Source*	**Surrogate Data Used to Backcast Activity to 1990**	**Forecasting Approach** *Projection Assumption*
Natural Gas Distribution	Miles of distribution pipeline by pipeline material type Total number of services Number of unprotected steel services Number of protected steel services	Office of Pipeline Safety[7] and APSC[22]		Used annual rate of decline (-0.26%) reflecting smallest annualized decrease in distribution emissions from each of 3 periods analyzed (1990-2005).
Natural Gas Pipeline Fuel Use (CO_2, CH_4, N_2O)	Volume of natural gas consumed by pipelines	EIA[10]		Used AEO 2007 projected regional pipeline fuel consumption growth rates since they are in-line with historical AR trends.
Oil Production	Annual production	EIA[23]		Used annual rate of decline (-2.37%) representing smallest annualized decrease in oil production from each of 3 periods analyzed (2000-2005).
Oil Refining	Annual volume refined	EIA[24]		Used AEO 2007 PAD III region refining capacity projections since annual growth over forecast period (0.76%) is in-line with long-term historical AR refining activity growth.
Oil Transport	Annual volume transported	Unavailable (per SIT, assumed oil refined = oil transported)		(same as oil refining)
Coal Mining	Methane emissions in million cubic feet	US EPA[12]		Used AEO 2007 Western Interior coal production projections since annualized growth over forecast period (0.61%) is in-line with recent historical AR coal mining emissions trend.

[22] Personal communication, "RE: Inquiry," from John Bethel, Arkansas Public Service Commission, to Andy Bollman, CCS, February 6, 2008.
[23] US DOE, Energy Information Administration, "Arkansas Crude Oil Production," accessed from http://tonto.eia.doe.gov/dnav/pet/hist/mcrfpar1a.htm, January 2008.
[24] Refining is assumed to be equal to the total input of crude oil into PADD III times the ratio of Arkansas' refining capacity to PADD III's total refining capacity. No data for 1996 and 1998, so linear interpolation used to estimate values in these years. Data are from US DOE, Energy Information Administration, "Petroleum Navigator." PADD capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/moclep32A.htm. PADD crude input data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/mgirip32A.htm. State capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/8_na_8do_sar_4a.htm, January 2008.

Results

Table E2 displays the estimated emissions from the fossil fuel industry in Arkansas for select years over the period 1990 to 2025. Emissions from this sector grew by 4% from 1990 to 2005 and are projected to increase by an additional 8% between 2005 and 2025. Natural gas transmission is the major contributor to both historic emissions and emissions growth.

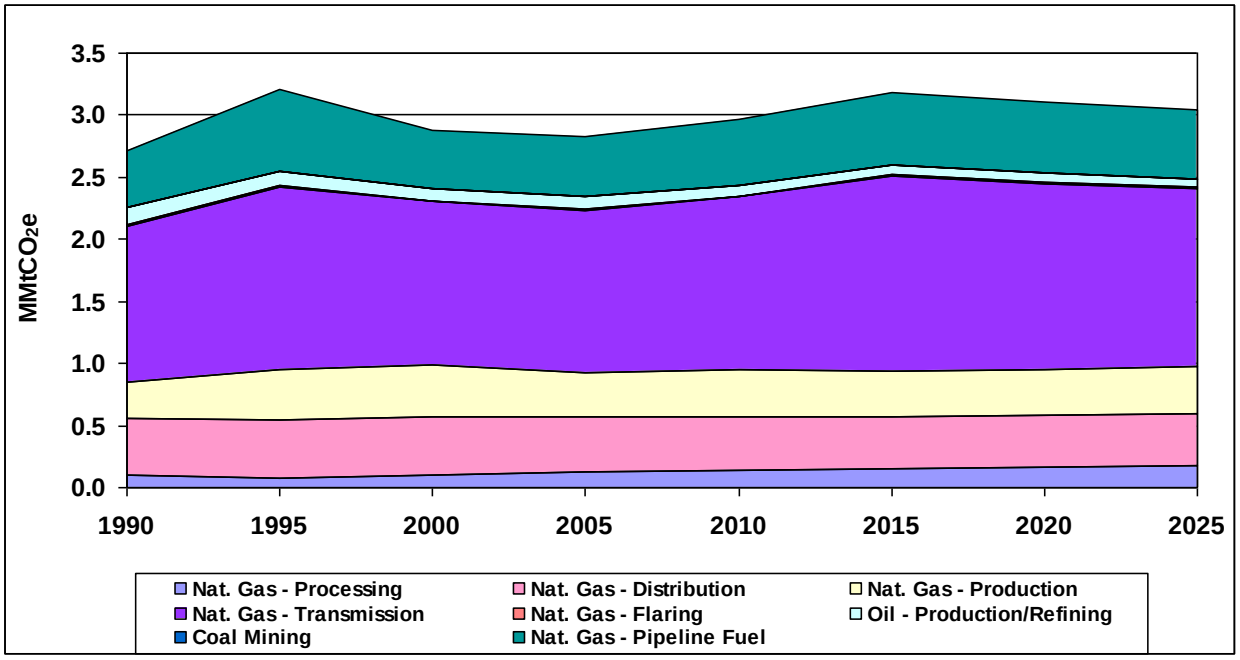
Table E2. Historical and Projected Emissions for the Fossil Fuel Industry

(Million Metric Tons CO_2e)	1990	1995	2000	2005	2010	2015	2020	2025
Fossil Fuel Industry	2.72	3.21	2.88	2.82	2.97	3.18	3.11	3.04
Natural Gas Industry	2.58	3.10	2.79	2.73	2.89	3.10	3.04	2.98
Production	0.30	0.41	0.41	0.36	0.37	0.36	0.37	0.38
Processing	0.10	0.08	0.10	0.13	0.14	0.15	0.16	0.18
Transmission	1.26	1.47	1.31	1.31	1.40	1.57	1.50	1.44
Distribution	0.45	0.46	0.47	0.44	0.43	0.42	0.42	0.41
Flaring	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Pipeline Fuel	0.46	0.66	0.47	0.48	0.53	0.59	0.58	0.56
Oil Industry	0.13	0.12	0.09	0.10	0.09	0.08	0.07	0.06
Production	0.13	0.11	0.09	0.09	0.08	0.07	0.07	0.06
Refining	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004
Coal Mining	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000

Note: Calculations based on approach described in text.

Figure E1 displays process-level emission trends from the fossil fuel industry, on an $MMtCO_2e$ basis.

Figure E1. Fossil Fuel Industry Emission Trends ($MMtCO_2e$)



Source: Calculations based on approach described in text.

Key Uncertainties

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

- Current levels of fugitive emissions. These are based on industry-wide averages, and until estimates are available for local facilities, significant uncertainties remain.
- Due to data limitations associated with OPS reporting, natural gas gathering and transmission pipeline emissions in earlier years were estimated by assuming that changes in each emissions producing activity were related to changes in activity levels for surrogates for the emissions activity.[25]
- Projections of future production of fossil fuels. The assumptions used for the projections do not reflect all potential future changes that could affect GHG emissions, including potential changes in regulations and emissions-reducing improvements in oil and gas production, processing, and pipeline technologies.

[25] For example, gathering pipeline emissions were back-cast to pre-2001 years by applying the ratio of Arkansas natural gas production in each pre-2001 year to Arkansas natural gas production in 2001.