Appendix C. Transportation Energy Use

Overview

The transportation sector is one the largest sources of greenhouse gas (GHG) emissions in Arkansas. This sector includes light- and heavy-duty (on-road) vehicles, aircraft, rail engines, and marine engines. Carbon dioxide (CO_2) accounts for about 98% of transportation GHG emissions in 2005. Most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from gasoline engines.

Historical Emissions and Reference Case Projections

Historical GHG emissions 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 the sector.[1,2] For on-road vehicles, the CO_2 emission factors are in units of pounds (lb) per million British thermal unit (MMBtu) and the methane (CH_4) and N_2O emission factors are both in units of grams per vehicle mile traveled (VMT). Key assumptions in this analysis are listed in Table C-1. The default fuel consumption data within SIT were used to estimate emissions, with the most recently available fuel consumption data (2005) from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED) added.[3] The default SIT data was also used to estimate VMT for the years 1990-1992. VMT data from the Arkansas Highway and Transportation Department were used for 1993 to 2005[4]. Default data in the SIT from the Federal Highway Administration (FHWA)[5] were used to allocate the VMT by vehicle type in the State.

On-road Vehicles

SIT default VMT data were used for 1990 through 1992 for calculating CH_4 and N_2O emissions. The Arkansas Highway and Transportation Department provided VMT data for the years 1993 through 2005[6]. These VMT data were distributed by vehicle type in the same proportion as the default VMT data in the SIT. The default EIA SED on-road fuel consumption data were used to calculate the CO_2 emissions from on-road vehicles for the historical years. Gasoline consumption estimates for 1990-2005 were adjusted by subtracting ethanol consumption, per the methodology used in SIT. The historical EIA ethanol consumption data show that use of ethanol in Arkansas decreased between 1990 and 1996. Ethanol consumption remained at or near zero for the years

[1] CO_2 emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 1. "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", August 2004.
[2] CH_4 and N_2O emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 3. "Methods for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion", August 2004.
[3] Energy Information Administration, State Energy Consumption, Price, and Expenditure Estimates (SED), http://www.eia.doe.gov/emeu/states/_seds.html
[4] Arkansas Highway and Transportation Department. Daily VMT Estimates 1993-2005. Provided by Mike Selig and Linda Hargrove on 2/1/08.
[5] Highway Statistics, Federal Highway Administration, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.
[6] Arkansas Highway and Transportation Department. Daily VMT Estimates 1993-2005. Provided by Mike Selig and Linda Hargrove on 2/1/08.

1997-2005. Ethanol consumption ranged from a maximum value of about 0.35% of the gasoline consumption on a Btu basis in 1990, down to 0% in 1997 and thereafter. For the reference case projections, ethanol consumption was assumed to remain at the 2005 level (0% of gasoline consumption on Btu basis).

Table C-1. Key Assumptions and Methods for the Transportation Inventory and Projections

Vehicle Type and Pollutants	Methods
On-road gasoline, diesel, natural gas, and liquefied petroleum gas (LPG) vehicles – CO_2	**Inventory (1990-2005)** US EPA SIT and fuel consumption from EIA SED **Reference Case Projections (2006-2025)** Gasoline and diesel fuel projected using linear regression of state VMT calculated using historical default SIT VMT data (1990-1992) and Arkansas state VMT data (1993-2005) and adjusted for fuel efficiency improvement projections from EPA . Other on-road fuels projected using West South Central Region fuel consumption projections from EIA AEO2007 adjusted using state-to-regional ratio of population growth.
On-road gasoline and diesel vehicles – CH_4 and N_2O	**Inventory (1990-2005)** State VMT calculated using default SIT data (1990-1992) and Arkansas state data (1993-2005). VMT allocated by vehicle type using default data in SIT. **Reference Case Projections (2006-2025)** 1990-2005 state total VMT forecasted through 2025 by linear regression and allocated to vehicle types using vehicle specific growth rates from AEO2007.
Non-highway fuel consumption (jet aircraft, gasoline-fueled piston aircraft, boats, locomotives) – CO_2, CH_4 and N_2O	**Inventory (1990-2005)** US EPA SIT and fuel consumption from EIA SED. Commercial marine based on allocation of national fuel consumption. **Reference Case Projections (2006-2025)** Aircraft projected using aircraft operations projections from Federal Aviation Administration (FAA). No growth assumed for rail diesel. Marine gasoline projected based on linear regression of historical data.

On-road vehicle gasoline and diesel emissions were projected through 2025 based on statewide VMT growth rates developed from linear regression of the historical default SIT 1990-2002 VMT data and the 1993-2005 VMT data provided by the Arkansas Highway and Transportation Department. The resulting total annual VMT data were then allocated by vehicle type based on national VMT forecasts by vehicle type reported in EIA's *Annual Energy Outlook 2007* (AEO2007).[7] The AEO2007 data were incorporated because they indicate significantly different VMT growth rates for certain vehicle types (e.g., 27% growth between 2005 and 2025 in light-duty gasoline vehicle VMT versus 61% growth in heavy-duty diesel truck VMT over this period). The AEO2007 vehicle type-based national growth rates were applied to the 2005 Arkansas estimates of VMT by vehicle type. The resulting vehicle-type VMT estimates and compound annual average growth rates are displayed in Tables C-2 and C-3, respectively. These VMT growth rates were used to forecast the CH_4 and N_2O emissions from on-road gasoline and diesel vehicles. These VMT growth rates were also applied to natural gas vehicles.

For forecasting CO_2 emissions, growth in fuel consumption is needed. On-road gasoline and diesel fuel consumption were forecasted by developing a set of growth factors that adjusted the VMT projections shown in Table C-2 to account for improvements in vehicle fuel efficiency. Projected vehicle fuel efficiency data were obtained from EPA. The resulting on-road fuel consumption growth rates are shown in Table C-4. Growth rates for projecting CO_2 emissions from natural gas vehicles, lubricants, and other fuel consumption were calculated by allocating the AEO2007 consumption of these fuels in the West South Central region and allocating this to Arkansas based on the ratio of the State's projected population to the region's projected population.

[7] US Department of Energy, Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, DOE/EIA-0383(2007), February 2007, available at http://www.eia.doe.gov/oiaf/archive/aeo07/index.html.

Table C-2. Arkansas Vehicle Miles Traveled Estimates (millions)

Vehicle Type	2005	2010	2015	2020	2025
Heavy Duty Diesel Vehicle	2,090	2,501	2,855	3,193	3,549
Heavy Duty Gasoline Vehicle	308	324	346	374	410
Light Duty Diesel Truck	316	402	515	680	946
Light Duty Diesel Vehicle	95	121	155	204	284
Light Duty Gasoline Truck	10,506	11,531	12,487	13,421	14,297
Light Duty Gasoline Vehicle	17,815	19,554	21,174	22,758	24,243
Motorcycle	107	117	127	136	145
Total	31,237	34,549	37,657	40,766	43,874

Table C-3. Arkansas Vehicle Miles Traveled Compound Annual Growth Rates

Vehicle Type	2005-2010	2010-2015	2015-2020	2020-2025
Heavy Duty Diesel Vehicle	3.66%	2.68%	2.26%	2.14%
Heavy Duty Gasoline Vehicle	0.97%	1.32%	1.60%	1.86%
Light Duty Diesel Truck	4.91%	5.10%	5.72%	6.82%
Light Duty Diesel Vehicle	4.91%	5.10%	5.72%	6.82%
Light Duty Gasoline Truck	1.88%	1.60%	1.45%	1.27%
Light Duty Gasoline Vehicle	1.88%	1.60%	1.45%	1.27%
Motorcycle	1.88%	1.60%	1.45%	1.27%

Table C-4. Arkansas On-road Fuel Consumption Compound Annual Growth Rates

Fuel Growth Factors	2005-2010	2010-2015	2015-2020	2020-2025
On-road gasoline	1.39%	1.57%	1.38%	1.29%
On-road diesel	3.49%	2.88%	2.50%	2.55%

Aviation

For the aircraft sector, emission estimates for 1990 to 2005 are based on SIT methods and fuel consumption from EIA. Emissions were projected from 2006 to 2025 using general aviation and commercial aircraft operations for 2006 through 2025 from the Federal Aviation Administration's (FAA) Terminal Area Forecast System[8] and national aircraft fuel efficiency forecasts. To estimate changes in jet fuel consumption, itinerant aircraft operations from air carrier, air taxi/commuter, and military aircraft were first summed for each year of interest. The post-2005 estimates were adjusted to reflect the projected increase in national aircraft fuel efficiency (indicated by increased number of seat miles per gallon), as reported in AEO2007. Because AEO2007 does not estimate fuel efficiency changes for general aviation aircraft, forecast changes in aviation gasoline consumption were based solely on the projected number of

[8] Terminal Area Forecast, Federal Aviation Administration, http://www.apo.data.faa.gov/main/taf.asp.

itinerant general aviation aircraft operations in Arkansas, which was obtained from the FAA source noted above. The resulting compound annual average growth rates are displayed in Table C-5.

Table C-5. Arkansas Aviation Fuels Compound Annual Growth Rates

Fuel	2005-2010	2010-2015	2015-2020	2020-2025
Aviation Gasoline	1.05%	0.78%	0.69%	0.76%
Jet Fuel	-1.14%	0.25%	0.32%	0.51%

Rail and Marine Vehicles

For the rail and recreational marine sectors, 1990-2005 estimates are based on SIT methods and fuel consumption from EIA. Marine gasoline consumption was projected to 2025 based on a linear regression of the 1990 through 2005 historical data. The historic data for rail shows no significant positive or negative trend; therefore, no growth was assumed for this sector.

For the commercial marine sector (marine diesel and residual fuel), 1990-2005 emission estimates are based on SIT emission rates applied to estimates of Arkansas marine vessel diesel and residual fuel consumption. Because the SIT default relies on marine vessel fuel consumption estimates that represent the State in which fuel is sold rather than consumed, an alternative method was used to estimate Arkansas marine vessel fuel consumption. Arkansas fuel consumption estimates were developed by allocating 1990-2005 national diesel and residual oil vessel bunkering fuel consumption estimates obtained from EIA.[9] Marine vessel fuel consumption was allocated to Arkansas using the marine vessel activity allocation methods/data compiled to support the development of EPA's National Emissions Inventory (NEI).[10] In keeping with the NEI, 75% of each year's distillate fuel and 25% of each year's residual fuel were assumed to be consumed within the port area (remaining consumption was assumed to occur while ships are underway). National port area fuel consumption was allocated to Arkansas based on year-specific freight tonnage data by state as reported in "Waterborne Commerce of the United States, Part 5 – Waterways and Harbors National Summaries."[11]

Non-road Engines

It should be noted that fuel consumption data from EIA includes non-road gasoline and diesel fuel consumption in the commercial and industrial sectors. Emissions from these non-road engines are included in the inventory and forecast for the residential, commercial, and industrial (RCI) sectors. Table C-6 shows how EIA divides gasoline and diesel fuel consumption between the transportation, commercial, and industrial sectors.

[9] US Department of Energy, Energy Information Administration, "Petroleum Navigator" (diesel data obtained from http://tonto.eia.doe.gov/dnav/pet/hist/kd0vabnus1a.htm; residual data obtained from http://tonto.eia.doe.gov/dnav/pet/hist/kprvatnus1a.htm).
[10] See methods described in ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf
[11] Note that it was necessary to estimate 1990-1996 values by applying the available 1997 AR percentage of national waterborne tonnage.

Table C-6. EIA Classification of Gasoline and Diesel Consumption

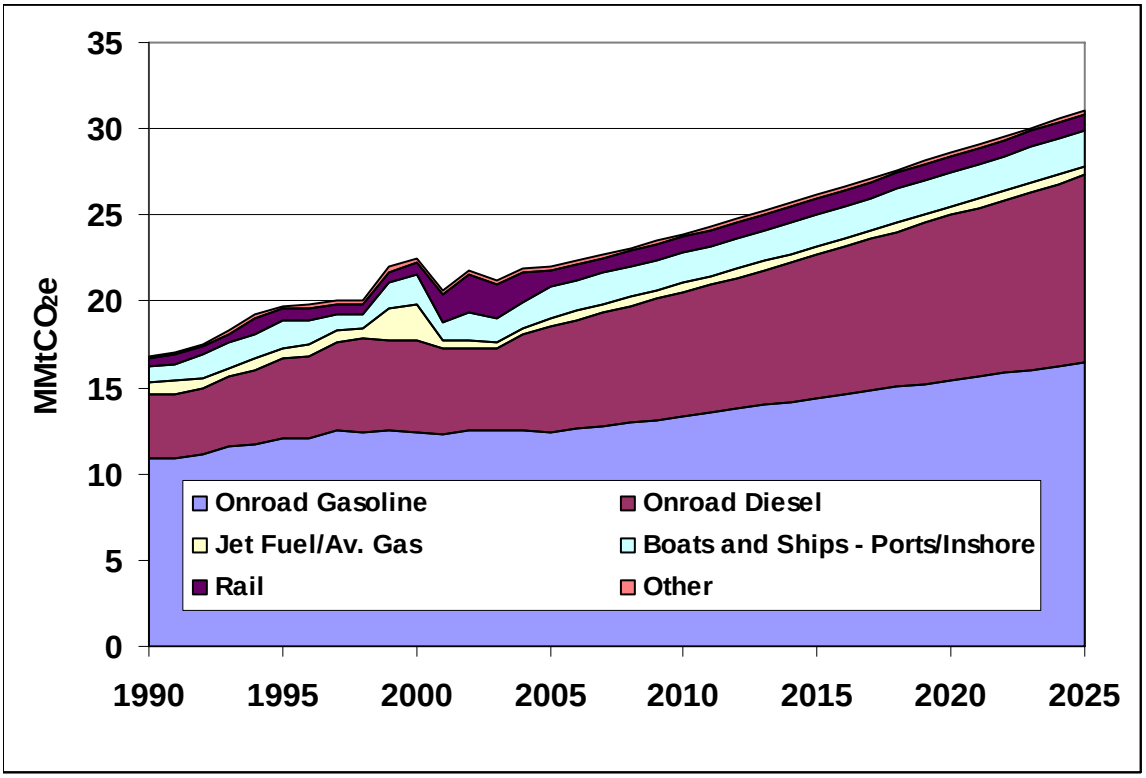
Sector	Gasoline Consumption	Diesel Consumption
Transportation	Highway vehicles, marine	Vessel bunkering, military use, railroad, highway vehicles
Commercial	Public non-highway, miscellaneous use	Commercial use for space heating, water heating, and cooking
Industrial	Agricultural use, construction, industrial and commercial use	Industrial use, agricultural use, oil company use, off-highway vehicles

Results

As shown in Figure C-1 and in Table C-7, on-road gasoline consumption accounts for the largest share of transportation GHG emissions throughout the historical and forecast periods. Emissions from on-road gasoline vehicles increased by about 15% from 1990 to 2005, and accounted for 57% of total transportation emissions in 2005. GHG emissions from on-road diesel fuel consumption increased by 61% from 1990 to 2005, and by 2005 accounted for 28% of GHG emissions from the transportation sector. Emissions from boats and ships increased by 97% from 1990 to 2005. These account for 8% of transportation emissions in 2005. Emissions from all other categories combined (aviation, locomotives, natural gas and liquefied petroleum gas (LPG), and oxidation of lubricants) contributed to about 7% of total transportation emissions in 2005.

GHG emissions from on-road gasoline consumption are projected to increase by about 32%, and emissions from on-road diesel consumption are expected to increase by 78% between 2005 and 2025. Aviation emissions are projected to remain relatively constant between 2005 and 2025, while marine emissions are projected to increase by 15% between the same period. By 2025, the share of transportation emissions from on-road gasoline decreases to 53% while the share of transportation emissions from on-road diesel increases to 35%. Overall, the transportation sector GHG emissions in Arkansas are expected to increase to 31 $MMtCO_2e$ by 2025, a 41% increase over 2005 emission levels.

Figure C-1. Transportation Gross GHG Emissions by Fuel, 1990-2025



Source: CCS calculations based on approach described in text.

Table C-7. Gross GHG Emissions from Transportation ($MMtCO_2e$)

Source	1990	1995	2000	2005	2010	2015	2020	2025
On-road Gasoline	10.86	12.10	12.41	12.44	13.34	14.42	15.44	16.46
On-road Diesel	3.78	4.63	5.37	6.08	7.22	8.29	9.55	10.84
Jet Fuel/Aviation Gas	0.72	0.53	2.01	0.53	0.50	0.51	0.52	0.53
Boats and Ships - Ports/Inshore	0.93	1.63	1.79	1.84	1.73	1.86	1.98	2.11
Rail	0.37	0.64	0.66	0.92	0.92	0.92	0.92	0.92
Other	0.20	0.19	0.21	0.18	0.18	0.19	0.21	0.22
Total	***16.85***	***19.72***	***22.44***	***21.99***	***23.90***	***26.19***	***28.63***	***31.08***

Key Uncertainties

Uncertainties in On-road Fuel Consumption

A major uncertainty in this analysis is the conversion of the projected VMT to fuel consumption. These are based on first allocating the Arkansas total VMT values by vehicle type using national vehicle type growth projections from AEO2007 modeling, which may not reflect Arkansas conditions. The conversion of the VMT data to fuel consumption also includes national assumptions regarding fuel economy by vehicle type. If the Arkansas vehicle fleet turns over at a slower rate than the rest of the nation, these fuel economy values may not reflect conditions in Arkansas.

Energy Independence and Security Act of 2007

The reference case projections documented here do not include the corporate average fuel economy (CAFÉ) or biofuels provisions (or any other provisions) of the Energy Independence and Security Act of 2007. Increases in vehicle fuel economy resulting from this act would lead to reduced CO_2 emissions from onroad vehicles. Reductions attributable to the CAFÉ and biofuels provisions of this Act will be separately quantified at a later date.

Uncertainties in Aviation Fuel Consumption

The jet fuel and aviation gasoline fuel consumption from EIA is actually fuel *purchased* in the State, and therefore, includes fuel consumed during state-to-state flights and international flights. The fuel consumption associated with international air flights should not be included in the State inventory; however, data were not available to subtract this consumption from total jet fuel estimates. Another uncertainty associated with aviation emissions is the use of general aviation forecasts to project aviation gasoline consumption. General aviation aircraft consume both jet fuel and aviation gasoline, but fuel specific data were not available.

Uncertainties in Marine Fuel Consumption

There are several assumptions that introduce uncertainty into the estimates of commercial marine fuel consumption. These assumptions include:

- 75% of marine diesel and 25% of residual fuel is consumed in port; and
- The proportion of freight tonnage at ports in Arkansas to the total national freight tonnage reflects the proportion of national marine fuel that is consumed in Arkansas.