Appendix C. Transportation Energy Use

Overview

Transportation is one the largest greenhouse gas (GHG) source sectors in South Carolina. The transportation sector includes light- and heavy-duty (onroad) vehicles, aircraft, rail engines, and marine engines. Carbon dioxide (CO_2) accounts for about 96 percent of transportation GHG emissions from fuel use. Most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from gasoline engines.

Emissions and Reference Case Projections

Greenhouse gas emissions for 1990 through 2002 were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SGIT) 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 C1. The default fuel consumption data within SGIT were used to estimate emissions, with the most recently available fuel consumption data (2002) from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED) added.[3] The default VMT data for 1993, 1994, and 1997-2002 in SGIT were replaced with annual VMT from the South Carolina Department of Transportation (SCDOT).[4] Default data from the Federal Highway Administration (FHWA) were used for the remaining years. The SCDOT VMT was broken-down by road types. This data was then allocated to vehicle types using vehicle mix by road type from the FHWA.[5]

Onroad Vehicles

Onroad vehicle gasoline and diesel emissions were projected based on VMT forecasts from SCDOT[4] and growth rates developed from national vehicle type VMT forecasts reported in EIA's *Annual Energy Outlook* 2006 (AEO2006). The AEO2006 data were incorporated because they indicate significantly different VMT growth rates for certain vehicle types (e.g., 34 percent growth between 2002 and 2020 in heavy-duty gasoline vehicle VMT versus 284 percent growth in light-duty diesel truck VMT over this period). The procedure first applied the AEO2006 vehicle type-based national growth rates to 2002 South Carolina estimates of VMT by vehicle type. These data were then used to calculate the estimated proportion of total VMT by vehicle type in each year. Next, these proportions were applied to the SCDOT estimates for total VMT in

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[1] CO_2 emissions were calculated using SGIT, 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 SGIT, 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] SCDOT VMT forecast data provided by Carla Bedenbaugh, South Carolina Department of Health and Environmental Control.

[5] Highway Statistics, Federal Highway Administration, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.

the State for each year to yield the vehicle type VMT estimates and compound annual average growth rates are displayed in Tables C2 and C3, respectively.

Table C1. Key Assumptions and Methods for the Transportation Inventory and Projections

Vehicle Type and Pollutants	Methods
Onroad gasoline, diesel, natural gas, and liquefied petroleum gas (LPG) vehicles – CO_2	**Inventory (1990 – 2002)** US EPA SGIT and fuel consumption from EIA SED **Reference Case Projections (2003 – 2020)** Gasoline and diesel fuel projected using VMT projections provided by SCDOT adjusted by fuel efficiency improvement projections from AEO2006. Other onroad fuels projected using South Atlantic Region fuel consumption projections from EIA AEO2006 adjusted using state-to-regional ratio of population growth.
Onroad gasoline and diesel vehicles – CH_4 and N_2O	**Inventory (1990 – 2002)** US EPA SGIT, onroad vehicle CH_4 and N_2O emission factors by vehicle type and technology type within SGIT were updated to the latest factors used in the US EPA's *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2003.* State total VMT replaced with VMT provided by SCDOT, VMT allocated to vehicle types using default data in SGIT. **Reference Case Projections (2003 – 2020)** VMT projections from SCDOT allocated to vehicle types using vehicle specific growth rates from AEO2006.
Non-highway fuel consumption (jet aircraft, gasoline-fueled piston aircraft, boats, locomotives) – CO_2, CH_4 and N_2O	**Inventory (1990 – 2002)** US EPA SGIT and fuel consumption from EIA SED. Commercial marine based on allocation of national fuel consumption, offshore emissions pulled from Commission for Environmental Cooperation in North America (CEC) inventory. **Reference Case Projections (2003 – 2020)** Aircraft projected using aircraft operations projections from Federal Aviation Administration (FAA). No growth assumed for rail diesel. Marine gasoline projected based on historical data.

Table C2. South Carolina Vehicle Miles Traveled Estimates (millions)

Vehicle Type	2002	2005	2010	2015	2020
Heavy Duty Diesel Vehicle	3,978	4,566	5,306	6,181	7,087
Heavy Duty Gasoline Vehicle	517	571	616	699	784
Light Duty Diesel Truck	465	557	766	1,072	1,494
Light Duty Diesel Vehicle	140	168	231	324	452
Light Duty Gasoline Truck	15,446	16,382	17,747	19,539	21,174
Light Duty Gasoline Vehicle	26,360	27,959	30,287	33,346	36,136
Motorcycle	169	179	194	213	231
Total	47,074	50,381	55,147	61,373	67,359

Table C3. South Carolina Vehicle Miles Traveled Compound Annual Growth Rates

Vehicle Type	2002-2005	2005-2010	2010-2015	2015-2020
Heavy Duty Diesel Vehicle	4.70%	3.05%	3.10%	2.77%
Heavy Duty Gasoline Vehicle	3.40%	1.53%	2.55%	2.34%
Light Duty Diesel Truck	6.20%	6.59%	6.96%	6.87%
Light Duty Diesel Vehicle	6.20%	6.59%	6.96%	6.87%
Light Duty Gasoline Truck	1.98%	1.61%	1.94%	1.62%
Light Duty Gasoline Vehicle	1.98%	1.61%	1.94%	1.62%
Motorcycle	1.98%	1.61%	1.94%	1.62%

For forecasting GHG emissions, growth in fuel consumption is also needed along with VMT. Onroad gasoline and diesel fuel consumption were forecasted by developing a set of growth factors that adjusted the VMT projections to account for improvements in fuel efficiency. Fuel efficiency projections were taken from AEO2006. These projections suggest average onroad fuel consumption growth rates of 1% per year for gasoline and 3.3% per year for diesel between 2002 and 2020.

Gasoline consumption estimates for 1990-2002 were adjusted by subtracting ethanol consumption. While the historical ethanol consumption suggests continued growth, projections for ethanol consumption in South Carolina were not available. Therefore, ethanol consumption was assumed to remain at the 2002 level in the reference case projections. Current biodiesel consumption is less than 1% of total diesel consumption in the State and estimates of future consumption of biodiesel were not available. Therefore, biodiesel consumption was not considered in this inventory.

Aviation

For the aircraft sector, emission estimates for 1990 to 2002 are based on SGIT methods and fuel consumption from EIA. Emissions were projected from 2002 to 2020 using general aviation and commercial aircraft operations for 2002 and 2020 from the Federal Aviation Administration's Terminal Area Forecast System[6] and national aircraft fuel efficiency forecasts. To estimate

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

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-2002 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 AEO2006. Because AEO2006 does not estimate fuel efficiency changes for general aviation aircraft, forecast changes in aviation gasoline consumption were based solely on the projected number of itinerant general aviation aircraft operations in South Carolina, which was obtained from the Federal Aviation Administration (FAA) source noted above. The resulting compound annual average growth rates are displayed in Table C4. The negative growth for aviation gasoline for the 2002-2005 period is supported by prime supplier sales volumes from EIA, which shows sales of 6.1 thousand gallons per day in 2002 and 3 thousand gallons per day in 2005.[7]

Table C4. South Carolina Aviation Fuels Compound Annual Growth Rates

Fuel	2002-2005	2005-2010	2010-2015	2015-2020
Aviation Gasoline	-2.80%	0.78%	0.75%	0.52%
Jet Fuel	4.12%	0.97%	0.67%	0.61%

Rail and Marine Vehicles

For the rail and recreational marine sectors, 1990 – 2004 estimates are based on SGIT methods and fuel consumption from EIA. The default annual consumption data for marine gasoline was much higher for 1990-1992 than for the years 1993-2004. Since the consumption data for these two time periods are not comparable, possibly due to a difference in estimation methods, marine gasoline consumption for 1990-1992 was estimated by projecting the 1993-2004 data back to 1990. Marine gasoline consumption was projected to 2020 using historical data, which shows an average annual growth rate of 3.2%. 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), 1990-2004 emission estimates are based on SGIT emission rates applied to estimates of South Carolina marine vessel diesel and residual fuel consumption. Because the SGIT 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 South Carolina marine vessel fuel consumption. South Carolina fuel consumption estimates were developed by allocating 1990-2004 national diesel and residual oil vessel bunkering fuel consumption estimates obtained from EIA.[8] Marine vessel fuel consumption was allocated to South Carolina using the marine vessel activity allocation methods/data compiled to support the development of EPA's National Emissions Inventory (NEI).[9] In keeping with the NEI, 75 percent of each year's distillate fuel and 25 percent of each

[7] US Department of Energy, Energy Information Administration, "Petroleum Navigator", http://tonto.eia.doe.gov/dnav/pet/hist/c400013451a.htm.

[8] 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).

[9] See methods described in ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf

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 South Carolina based on year-specific freight tonnage data for the top 150 ports in the nation as reported in "Waterborne Commerce of the United States, Part 5 – Waterways and Harbors National Summaries."[10] Offshore CO_2 and hydrocarbon (HC) emissions for South Carolina's exclusive economic zone (EEZ) was taken from a study by Corbett for the Commission for Environmental Cooperation in North America (CEC).[11] Offshore CH_4 emissions were estimated by speciating the HC emissions using the California Air Resources Board's total organic gas (TOG) profile (#818).[12] Offshore N_2O emissions were estimated by applying the ratio of N_2O to CH_4 emission factors to the CH_4 emission estimate. The 2002 offshore emissions from the CEC inventory were scaled to other historic years based on the estimated port fuel consumption. Port and offshore commercial marine emissions were projected based on the 1990-2004 growth rates.

Nonroad Engines

It should be noted that fuel consumption data from EIA includes nonroad gasoline and diesel fuel consumption in the commercial and industrial sectors. Emissions from these nonroad engines are included in the inventory and forecast for the residential, commercial, and industrial (RCI) sectors. Table C5 shows how EIA divides gasoline and diesel fuel consumption between the transportation, commercial, and industrial sectors.

Table C5. 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 C1, onroad gasoline consumption accounts for the largest share of transportation GHG emissions. Emissions from onroad gasoline vehicles increased by about 25% from 1990-2002 to cover 70% of total transportation emissions in 2002. GHG emissions from onroad diesel fuel consumption increased by 52% from 1990 to 2002, and by 2002 accounted for 21% of GHG emissions from the transportation sector. Emissions from boats and ships grew by 104% from 1990-2002 to cover 6% of transportation emissions in 2002. Emissions from all other categories combined (aviation, locomotives, natural gas and liquefied petroleum gas (LPG), and oxidation of lubricants) contributed less than 4% of total transportation emissions in 2002.

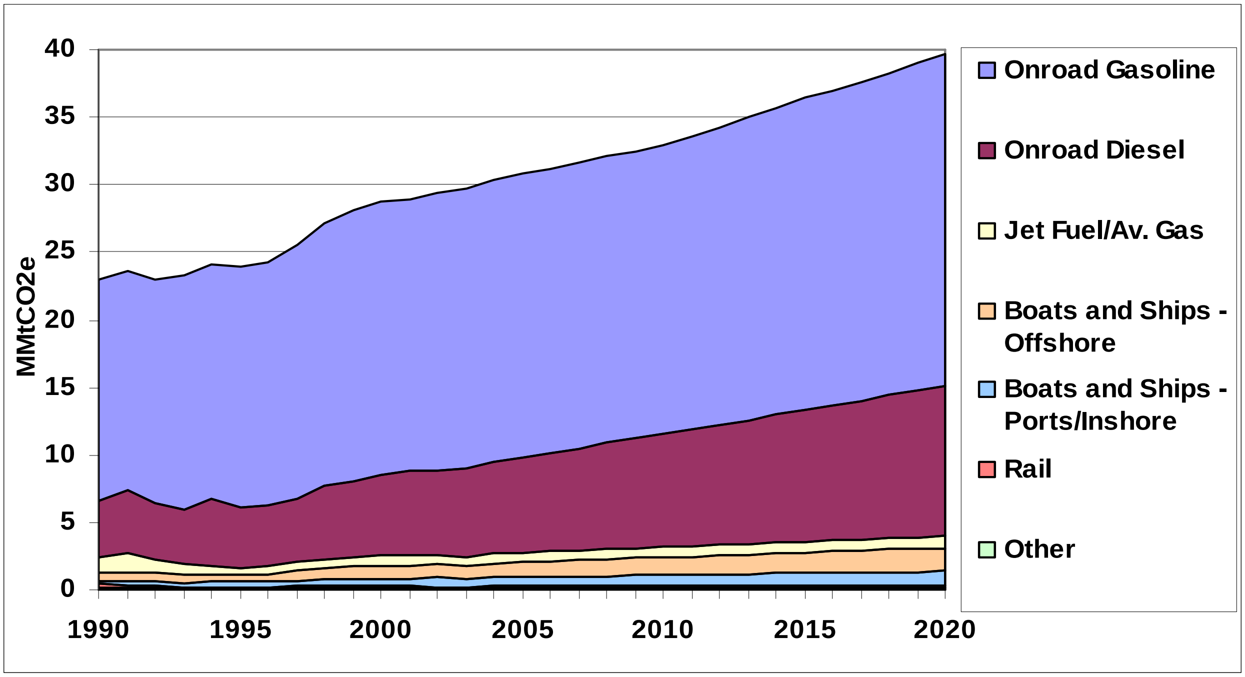
[10] Note that it was necessary to estimate 1991-1995 values by interpolating between the available 1990 and 1996 estimates.

[11] Estimate, Validation, and Forecasts of Regional Commercial Marine Vessel Inventories, submitted by J. Corbett, prepared for the California Air Resources Board, California Environmental Protection Agency, and Commission for Environmental Cooperation in North America, http://coast.cms.udel.edu/NorthAmericanSTEEM/.

[12] California Air Resources Board, Speciation Profiles, http://www.arb.ca.gov/ei/speciate/speciate.htm.

GHG emissions from onroad gasoline consumption are projected to increase by about 19%, and emissions from onroad diesel consumption are expected to increase by 79% between 2002 and 2020. Marine fuel (gasoline, diesel, and residual) consumption is projected to increase by 65% between 2002 and 2020.

Figure C1. Transportation GHG Emissions by Fuel, 1990-2020



Source: CCS calculations based on approach described in text.

Key Uncertainties

Projections of Vehicle Miles of Travel (VMT) and Biofuels Consumption

One source of uncertainty is the future year vehicle mix, which was calculated based on national growth rates for specific vehicle types. These growth rates may not reflect vehicle-specific VMT growth rates for the State. Also, onroad gasoline and diesel growth rates may be slightly overestimated because increased consumption of biofuels between 2005 and 2020 was not taken into account (due to a lack of data).

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 the Ports of Charleston and Georgetown to the total freight tonnage for the top 150 US ports reflects the proportion of national marine fuel that is consumed in South Carolina.