Appendix C. Transportation Energy Use

Overview

Transportation is one the largest greenhouse gas (GHG) source sectors in Iowa. The transportation sector includes light- and heavy-duty (onroad) vehicles, aircraft, rail engines, and marine engines. Carbon dioxide (CO_2) accounts for about 97% of the transportation sector's GHG emissions in 1990 and is projected to increase to about 98% of transportation GHG emissions by 2025. 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 onroad 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 (2004 and 2005) from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED) added.[3] The default VMT data in SIT were replaced with annual VMT from the Iowa Department of Transportation (DOT).[4] Default data from the Federal Highway Administration (FHWA)[5] were used to allocate the state-level VMT to vehicle types.

Onroad Vehicles

Iowa DOT provided statewide VMT data for the years from 1990 through 2006.[6] These data were used to replace the default SIT VMT data for 1990 through 2005 for calculating CH_4 and N_2O emissions. These VMT data were distributed by vehicle type in the same proportion as the default VMT data in the SIT. The default EIA SED data were used to calculate the CO_2 emissions from onroad 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 Iowa increased from

[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] Iowa historical VMT data provided by Donald Howe, Iowa Department of Transportation.
[5] Highway Statistics, Federal Highway Administration, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.
[6] Iowa historical VMT data provided by Donald Howe, Iowa Department of Transportation.

2.0% of the gasoline consumption on a Btu basis in 1990 to 5.6% in 2005. For the reference case projections, ethanol consumption was assumed to remain at the 2005 level.

Table C-1. 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 (1990-2005)** US EPA SIT and fuel consumption from EIA SED **Reference Case Projections (2005-2025)** Gasoline and diesel fuel use projected with VMT projections based on 1990-2005 historical trends adjusted by fuel efficiency improvement projections from EPA. Other onroad fuels projected using West North Central Region fuel consumption projections from EIA AEO2007 adjusted using state-to-regional ratio of population growth.
Onroad gasoline and diesel vehicles – CH_4 and N_2O	**Inventory (1990-2005)** State total VMT replaced with VMT provided by Iowa DNR, VMT allocated by vehicle type using default VMT by vehicle type data in SIT. **Reference Case Projections (2006-2020)** State total VMT projections were based on 1990-2005 historical trends 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. **Reference Case Projections (2006-2020)** Aircraft projected using aircraft operations projections from provided by Iowa DOT. No growth assumed for rail diesel. Marine gasoline projected based on historical data.

Projections of state VMT to 2025 were not available from Iowa DOT or Iowa Department of Natural Resources (DNR); therefore, total annual VMT was projected based on a linear regression of the 1990 through 2005 historical data. Forecasting the total annual VMT based on the 1990-2005 historical data yields an average annual growth rate of 1.8% for 2005-2025. The resulting total annual VMT data for 2006-2025 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 Iowa estimates of VMT by vehicle type. These VMT data were then proportionally adjusted to total to the projected statewide VMT totals for each year. 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 onroad 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. Onroad 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 onroad fuel consumption growth rates are shown in Table C-4. Growth rates for projecting CO_2 emissions from natural gas and LPG vehicles were calculated by allocating the AEO2007 consumption of these fuels in the West North Central region and allocating this to Iowa based on the ratio of the State's projected population to the region's projected population. Growth rates for projecting CO_2 emissions from lubricants consumption were calculated based on total VMT growth.

Table C-2. Iowa Projected Vehicle Miles Traveled Estimates (million miles)

Vehicle Type	2005	2010	2015	2020	2025
Heavy-Duty Diesel Vehicle	3,634	4,376	5,028	5,649	6,308
Heavy -Duty Gasoline Vehicle	537	529	545	579	634
Light-Duty Diesel Truck	299	379	489	648	904
Light-Duty Diesel Vehicle	90	114	147	195	272
Light-Duty Gasoline Truck	9,932	10,881	11,840	12,781	13,653
Light-Duty Gasoline Vehicle	16,842	18,452	20,078	21,672	23,152
Motorcycle	235	257	280	302	323
Total	31,569	34,988	38,408	41,827	45,247

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

Vehicle Type	2005-2010	2010-2015	2015-2020	2020-2025
Heavy-Duty Diesel Vehicle	3.8%	2.8%	2.4%	2.2%
Heavy-Duty Gasoline Vehicle	-0.3%	0.6%	1.2%	1.8%
Light-Duty Diesel Truck	4.9%	5.2%	5.8%	6.9%
Light-Duty Diesel Vehicle	4.9%	5.2%	5.8%	6.9%

[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/aeo/index.html.

Light-Duty Gasoline Truck	1.8%	1.7%	1.5%	1.3%
Light-Duty Gasoline Vehicle	1.8%	1.7%	1.5%	1.3%
Motorcycle	1.8%	1.7%	1.5%	1.3%

Table C-4. Iowa Onroad Fuel Consumption Compound Annual Growth Rates

Fuel Growth Factors	2005-2010	2010-2015	2015-2020	2020-2025
Onroad gasoline	1.5%	1.5%	1.5%	1.3%
Onroad diesel	3.5%	2.9%	2.5%	2.5%
Natural Gas	15.4%	5.9%	2.7%	2.3%
LPG	5.0%	1.8%	1.3%	1.2%

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 provided by Iowa DOT,[8] military operations projections from the Federal Aviation Administration's (FAA) Terminal Area Forecast System,[9] and national aircraft fuel efficiency forecasts. To estimate changes in jet fuel consumption, 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 general aviation aircraft operations in Iowa, which was obtained from the Iowa DOT source noted above. The resulting compound annual average growth rates are displayed in Table C-5.

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

Fuel	2005-2010	2010-2015	2015-2020	2020-2025
Aviation Gasoline	2.4%	1.1%	0.6%	0.6%
Jet Fuel	1.2%	-0.4%	-1.4%	-1.5%

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.

[8] Michelle McEnany, Office of Aviation, Iowa Department of Transportation.
[9] Terminal Area Forecast, Federal Aviation Administration, http://www.apo.data.faa.gov/main/taf.asp.

For the commercial marine sector (marine diesel and residual fuel), 1990-2005 emission estimates are based on SIT emission rates applied to estimates of Iowa 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 Iowa marine vessel fuel consumption. Iowa fuel consumption estimates were developed by allocating 1990-2005 national diesel and residual oil vessel bunkering fuel consumption estimates obtained from EIA.[10] Marine vessel fuel consumption data were allocated to Iowa using the marine vessel activity allocation methods/data compiled to support the development of EPA's National Emissions Inventory (NEI).[11] 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 Iowa 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."[12]

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, including nonroad vehicles such as snowmobiles and dirt bikes, 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.

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

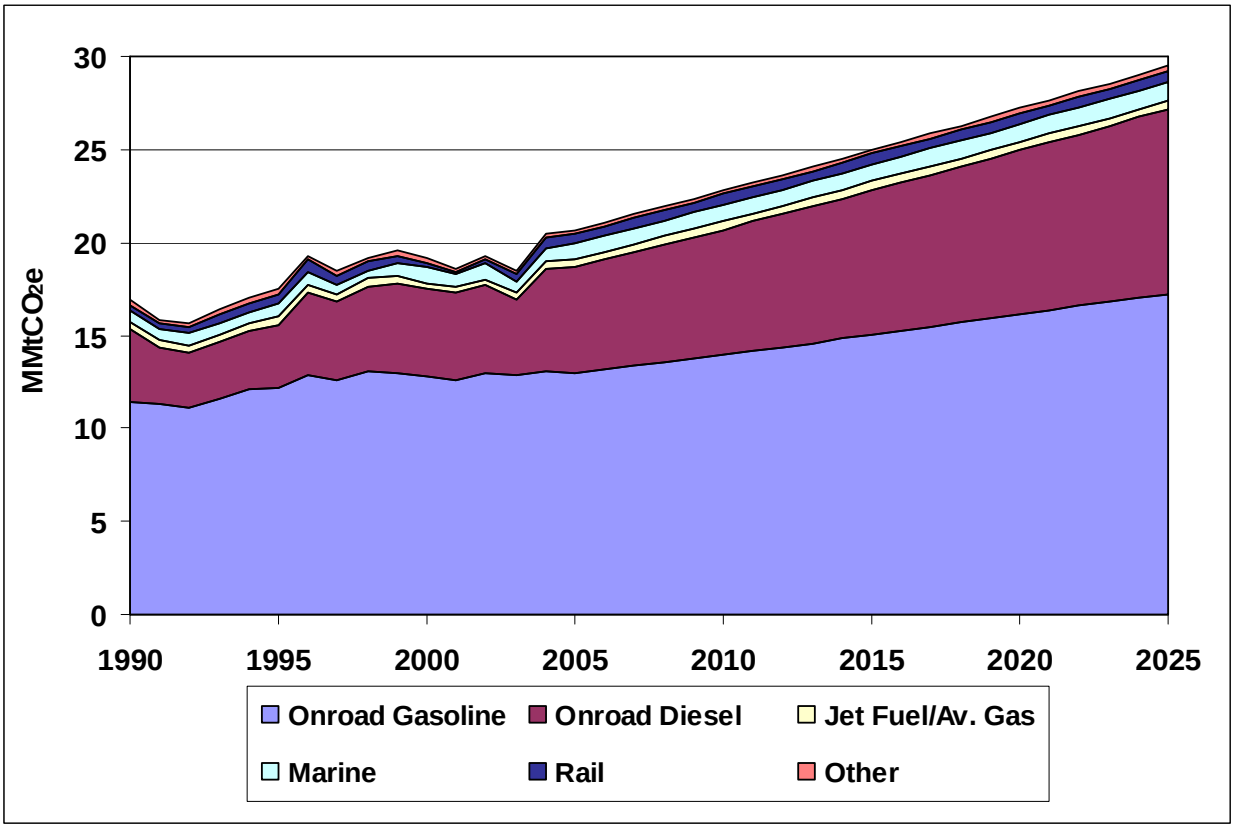
As shown in Figure C-1 and in Table C-7, onroad gasoline consumption accounts for the largest share of transportation GHG emissions. Emissions from onroad gasoline vehicles increased by about 14% from 1990 to 2005, accounting for 63% of total transportation emissions in 2005.

[10] 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).
[11] See methods described in ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf
[12] "Waterborne Commerce of the United States" http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm. Note that it was necessary to estimate 1990-1996 values by applying the available 1997 Iowa percentage of national waterborne tonnage.

GHG emissions from onroad diesel fuel consumption increased by 44% from 1990 to 2005, and by 2005 accounted for 28% of GHG emissions from the transportation sector. Emissions from marine vessels grew by 44% from 1990 to 2005, accounting for 4.1% of GHG transportation emissions in Iowa in 2005. Emissions from locomotives varied from a high of 0.69 $MMtCO_2e$ in 1996 to a low of 0.16 $MMtCO_2e$ in 2001 and accounted for 2.7% of transportation emissions in 2005 (0.56 $MMtCO_2e$). Emissions from all other categories combined (aviation, natural gas and liquefied petroleum gas (LPG), and oxidation of lubricants) contributed to about 3% of total transportation emissions in 2005.

GHG emissions from onroad gasoline consumption are projected to increase by about 33%, and emissions from onroad diesel consumption are expected to increase by 75% between 2005 and 2025. Emissions from aviation are projected to decrease by 6% from 2005 to 2025, while marine emissions are projected to increase by 23% from 2005 to 2025. Overall, the transportation sector GHG emissions in Iowa are expected to increase to 29 $MMtCO_2e$ by 2025, a 42% increase over 2005 emission levels.

Figure C-1. Transportation Gross GHG Emissions by Category, 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
Onroad Gasoline	11.40	12.22	12.81	12.96	13.94	15.03	16.16	17.23
Onroad Diesel	3.96	3.35	4.66	5.69	6.76	7.78	8.80	9.94
Jet Fuel/Aviation Gas	0.39	0.45	0.34	0.45	0.48	0.47	0.45	0.42
Marine Vessels	0.58	0.70	0.84	0.84	0.85	0.91	0.97	1.03
Rail	0.31	0.54	0.26	0.56	0.56	0.56	0.56	0.56
Other	0.23	0.22	0.23	0.20	0.23	0.25	0.27	0.29
Total	***16.88***	***17.48***	***19.13***	***20.69***	***22.82***	***25.00***	***27.20***	***29.47***

Key Uncertainties

Uncertainties in Onroad Fuel Consumption
A major uncertainty in this analysis is the conversion of the projected VMT to fuel consumption. These are based on first allocating Iowa's total VMT by vehicle type using national vehicle type growth projections from AEO2007 modeling, which may not reflect Iowa conditions. The conversion of the VMT data to fuel consumption also includes national assumptions regarding fuel economy by vehicle type.

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 CO2 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 Iowa to the total national freight tonnage reflects the proportion of national marine fuel that is consumed in Iowa.