Appendix C. Transportation Energy Use

Overview

Fuel use in the transportation sector is the largest source of greenhouse gas (GHG) emissions in Colorado – accounting for 23% of Colorado's gross GHG emissions in 2000. Carbon dioxide (CO_2) accounts for about 96% 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 United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SGIT) 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 expressed in units of pounds per million British Thermal Units (lb/MMBTU), and the methane (CH_4) and N_2O emission factors are both in units of grams per vehicle miles traveled (g/VMT). Key assumptions in this analysis are listed in Table C1. The default data within SGIT were used to estimate emissions, with the most recently available fuel consumption data (2002) from United States Department of Energy (US DOE) Energy Information Administration (EIA) *State Energy Data* (SED) added.[3] The default VMT data in SGIT were replaced with state-level annual VMT data from the Colorado Department of Transportation (CDOT).[4] State-level VMT figures were allocated to vehicle types using the vehicle mix data provided by the Colorado Department of Public Health and Environment (CDPHE).[5]

Onroad gasoline and diesel emissions were forecast based on VMT projections provided by the Denver Regional Council of Governments (DRCOG), the North Front Range Transportation and Air Quality Planning Council (NFRTAQPC), the Pikes Peak Area Council of Governments (PPACG), and CDPHE.[6,7,8] VMT projections from DRCOG were applied to VMT for Adams, Arapahoe, Boulder, Douglas, Denver, and Jefferson counties. Projections from NFRTAQPC were applied to Larimer and Weld counties, and projections from PPACG were applied to El Paso County. Vehicle miles traveled for all other counties were forecast using the 2002-2012 growth rate (assumed to extend to 2020) from the Colorado State Implementation Plan for

---

[1] CO_2 emissions were calculated using SGIT, with reference to EIIP, 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 EIIP, Volume VIII: Chapter. 3. "Methods for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion", August 2004.

[3] EIA, State Energy Consumption, Price, and Expenditure Estimates (SED), http://www.eia.doe.gov/emeu/states/_seds.html

[4] Brad Beckham, Environmental Programs Branch Manager, Colorado Department of Transportation.

[5] Barbara MacRae, Air Pollution Control Division Technical Services Program, Colorado Department of Public Health and Environment.

[6] Erik Sabina, Regional Transportation Modeler, Denver Regional Council of Governments.

[7] Andres Gomez, Regional Transportation Modeler, North Front Range MPO.

[8] 2005-2010 and 2007-2012 Transportation Improvement Programs, PPACG, http://www.ppacg.org/Trans/trans.htm.

Ozone.[9] These VMT projections suggest that the overall state VMT will grow at an average rate of 2.1% per year between 2002 and 2020.[10]

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)** EPA SGIT and fuel consumption from EIA SED **Reference Case Projections (2003 – 2020)** Gasoline and diesel fuel projected using VMT projections provided by Metropolitan Planning Organizations (MPOs) and CDPHE, adjusted by fuel efficiency improvement projections from AEO2006. Other onroad fuels projected using Mountain 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)** 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 CDOT, VMT allocated to vehicle types using data from CDPHE. **Reference Case Projections (2003 – 2020)** VMT projections from MPOs and CDPHE.
Non-highway fuel consumption (jet aircraft, gasoline-fueled piston aircraft, boats, locomotives) – CO_2, CH_4 and N_2O	**Inventory (1990 – 2002)** EPA SGIT and fuel consumption from EIA SED. **Reference Case Projections (2003 – 2020)** Aircraft projected using Colorado airport operations projections provided by CDOT (2005-2025) and EIA prime supplier sales volumes for aviation gasoline (2002-2005), no growth assumed for rail and marine vessels.

The state-level VMT projections were allocated to vehicle types based on national VMT forecasts by vehicle type 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% growth between 2002 and 2020 in heavy-duty gasoline vehicle VMT versus 284% growth in light-duty diesel truck VMT over this period). The procedure first applied the AEO2006 vehicle-type-based national growth rates to 2002 Colorado estimates of VMT by vehicle type. These data were then used to calculate the estimated

[9] Colorado State Implementation Plan for Ozone, Colorado Air Pollution Control Divisions, http://apcd.state.co.us/documents/eac/ms-TSD.pdf, 2004.

[10] CDOT provided a state level VMT estimate for 2020. By using the MPO forecasts, CCS incorporated more detail for the urban areas. The resulting state-level growth rate was similar to that from CDOT (2.1% compared to 2.2%)

proportion of total VMT by vehicle type in each year. Next, these proportions were applied to the estimates for total VMT in the State for each year to yield vehicle-specific VMT estimates and compound annual average growth rates displayed in Tables C2 and C3, respectively.

Table C2. Colorado Vehicle Miles Traveled Estimates (millions)

Vehicle Type	2002	2005	2010	2015	2020
Heavy-Duty Diesel Vehicle	1,188	1,374	1,644	1,924	2,213
Heavy-Duty Gasoline Vehicle	499	555	617	703	792
Light-Duty Diesel Truck	50	60	85	119	167
Light-Duty Diesel Vehicle	21	25	36	50	70
Light-Duty Gasoline Truck	12,333	13,180	14,701	16,266	17,679
Light-Duty Gasoline Vehicle	11,918	12,736	14,206	15,719	17,084
Motorcycle	91	98	109	120	131
Total	26,098	28,027	31,397	34,903	38,135

Table C3. Colorado Vehicle Miles Traveled Compound Annual Growth Rates

Vehicle Type	2002-2005	2005-2010	2010-2015	2015-2020
Heavy-Duty Diesel Vehicle	4.97%	3.65%	3.20%	2.83%
Heavy-Duty Gasoline Vehicle	3.66%	2.13%	2.65%	2.40%
Light-Duty Diesel Truck	6.47%	7.21%	7.06%	6.93%
Light-Duty Diesel Vehicle	6.47%	7.21%	7.06%	6.93%
Light-Duty Gasoline Truck	2.24%	2.21%	2.04%	1.68%
Light-Duty Gasoline Vehicle	2.24%	2.21%	2.04%	1.68%
Motorcycle	2.24%	2.21%	2.04%	1.68%

Onroad gasoline and diesel fuel consumption was forecast 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 EIA's AEO2006. These projections suggest onroad fuel consumption growth rates of 1.2% 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 Colorado were not available. Therefore, ethanol consumption was assumed to remain at the 2002 level (2.5% of total gasoline consumption) in the reference case projections. Biodiesel and other biofuel consumption were not included in this inventory, because historical and projection data were not available for these fuels.

Emissions for aircraft operations for 1990 to 2002 were based on SGIT methods and fuel consumption from EIA SED. The consumption of international bunker fuels is included in jet fuel consumption from EIA. This fuel consumption associated with international air flights should not be included in the state inventory (as much of it is actually consumed out of state); however, data were not available to subtract this consumption from total jet fuel estimates. The 2002 estimates were then projected to 2005 in order to apply post-2005 projection data available

from CDOT (as described below). Jet fuel emissions were projected based on 2002 and 2005 total operations for Denver International Airport, provided by CDOT. Aviation gasoline emissions were projected from 2002 to 2005 using EIA data for 2002-2005 aviation gasoline prime supplier sales volumes in Colorado.[11]

Emissions from aviation were projected from 2005 to 2020 using general aviation and commercial aircraft operations data for 2005 and 2025 as provided by CDOT.[12] General aviation refers to the operation of civilian aircraft for purposes other than commercial passenger transport. Jet fuel emissions were projected based on commercial aircraft operations forecasts, and aviation gasoline emissions were projected using the general aviation forecasts. While military fuel consumption is included in the historical estimates, projections of military aircraft operations were not available. Jet fuel projections 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 overall aviation gasoline consumption were based solely on the projected number of general aviation aircraft operations. These data on aircraft operations project growth rates of 2.2% per year for general aviation and 2.4% per year for commercial operations between 2005 and 2020. The resulting compound annual average growth rates are displayed in Table C4.

Table C4. Colorado Aviation Fuels Use Compound Annual Growth Rates

Fuel	2002-2005	2005-2010	2010-2015	2015-2020
Aviation Gasoline	-5.32%	2.36%	2.36%	2.36%
Jet Fuel	2.94%	1.28%	1.28%	1.28%

For the rail and marine sectors, 1990 – 2004 estimates are based on SGIT methods and fuel consumption from EIA SED. For rail, the historic data show a reduction in fuel consumption in the mid-1990's followed by no growth through 2004. Therefore, no growth was assumed for this sector. The marine sector gasoline consumption data show a growth rate of about 0.7% per year from 1990 to 2004. This historic growth rate was applied to estimate emissions in the forecast years.

Fuel consumption data from EIA includes nonroad gasoline and diesel fuel consumption in the commercial and industrial sectors. Therefore, nonroad emissions are included in the Residential, Commercial, and Industrial (RCI) fuel combustion sector in this inventory (see Appendix B). Table C5 shows how EIA divides gasoline and diesel fuel consumption between the transportation, commercial, and industrial sectors.

[11] Colorado Prime Supplier Sales Volumes of Petroleum Products, Energy Information Administration, http://tonto.eia.doe.gov/dnav/pet/xls/pet_cons_prim_dcu_SCO_a.xls.
[12] Chris Pomeroy, Senior Aviation Planner, Colorado Division of Aeronautics.

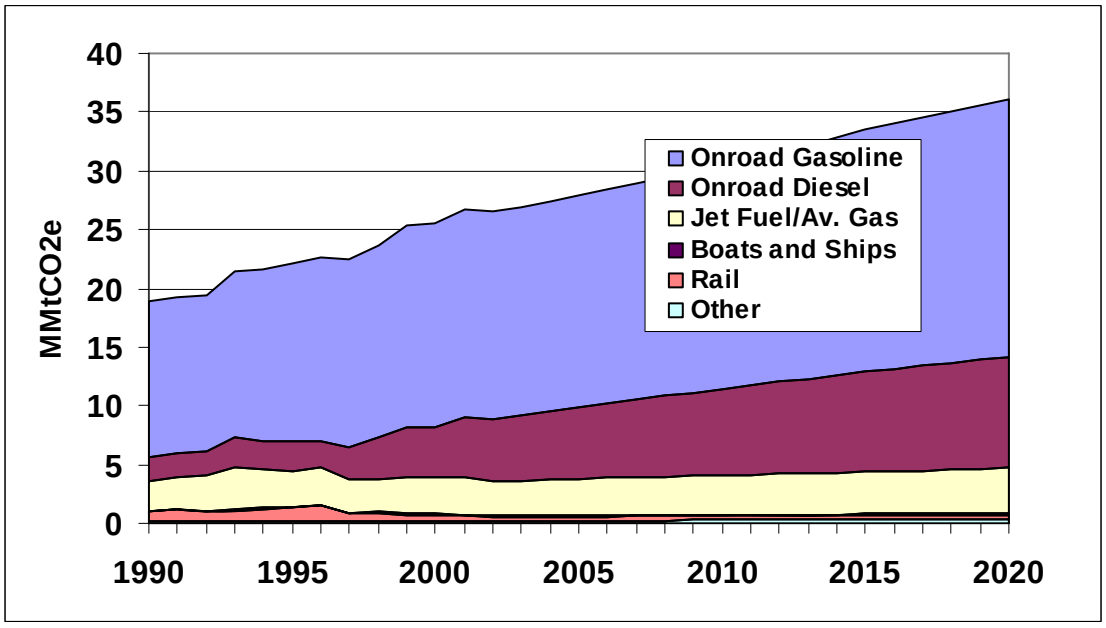
Table C5. EIA Classification of Gasoline and Diesel Consumption

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 32% from 1990-2002, covering almost 66% of total transportation emissions in 2002. GHG emissions from onroad diesel fuel consumption increased by 151% from 1990 to 2002, and by 2002 accounted for 20% of GHG emissions from the transportation sector. Emissions from aviation grew by 16% from 1990-2002, and were 11% of transportation emissions in 2002. Emissions from all other categories combined (boats and ships, locomotives, natural gas and liquid petroleum gas (LPG), and oxidation of lubricants) contributed only 2% of total transportation emissions in 2002.

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



Note: Units = million metric tons (MMt) of carbon dioxide equivalent (CO_2e).

Key Uncertainties

Projections of VMT and Biofuels Consumption

One source of uncertainty in the projections of transportation sector GHG emissions presented above 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 2002 and 2020 was not taken into account (due to a lack of data).

The consumption of international bunker fuels included in jet fuel consumption from EIA is another uncertainty. At least the bulk of this fuel consumption associated with international air flights should not be included in the state inventory (as much of it is actually consumed out of Colorado airspace); data were not, however, available to allow this consumption to be subtracted from total jet fuel use 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. Also, jet fuel consumption includes consumption by military aircraft; projections of military aircraft operations were not available.