Chapter 7. Transportation Demand Module

The NEMS Transportation Demand Module (TDM) estimates transportation energy consumption across the nine Census Divisions and over ten fuel types. Each fuel type is modeled according to fuel-specific and associated technology attributes applicable by transportation mode. Total transportation energy consumption is reported as the sum of energy use in eight transport modes: light-duty vehicles (cars and light trucks), commercial light trucks (8,501-10,000 pounds gross vehicle weight), freight trucks (greater than 10,000 pounds gross vehicle weight), buses, freight and passenger aircraft, freight and passenger rail, maritime freight shipping, and miscellaneous transport such as recreational boating. Light-duty vehicle fuel consumption is further subdivided into personal usage and commercial fleet consumption.

Key assumptions

By submodules and their components, key assumptions on transportation demand and energy consumption address light-duty vehicles, commercial light trucks, freight transportation, and air travel.

Light-duty vehicle submodule

The light-duty vehicle Manufacturers Technology Choice Component (MTCC) includes 86 advanced technology input assumptions specific to cars and light trucks (Tables 7.1 and 7.2) that include incremental fuel economy improvement, incremental cost, incremental weight change, first year of introduction or commercial availability, and fractional horsepower change.

The vehicle Regional Sales Component holds the share of vehicle sales by manufacturers constant within a vehicle size class at 2010 levels based on National Highway Traffic Safety Administration (NHTSA) data [40]. U. S. Environmental Protection Agency (EPA) size class sales shares are projected as a function of income per capita, fuel prices, and average predicted vehicle prices based on endogenous calculations within the MTCC [41].

The MTCC uses 86 technologies for each size class and manufacturer to make an economic analysis based on the cost-effectiveness of each technology and an initial year of availability -- i.e., comparing relative costs and outcomes (effects) of different courses of action. A discounted stream of fuel savings (outcomes) is calculated for each technology, which is compared with the marginal cost to determine cost effectiveness and market penetration. The fuel economy calculations assume the following:

- The financial parameters used to determine technology economic effectiveness are evaluated based on the need to improve fuel economy to meet CAFE standards versus consumer willingness to pay for fuel economy improvement beyond those minimum requirements.
- Fuel economy standards for light-duty vehicles reflect current law through model year 2025, according to NHTSA model year 2011 final rulemaking, joint EPA and NHTSA rulemaking for 2012 through 2016, and joint EPA and NHTSA rulemaking for 2017 through 2025. CAFE standards enacted for model years 2022 through 2025 will undergo a midterm evaluation by NHTSA and could be subject to change. For model years 2026 through 2040, fuel economy standards are held constant at model year 2025 levels with fuel economy improvements still possible based on continued improvements in economic effectiveness.

- Expected future fuel prices are calculated based on an extrapolation of the growth rate between a five-year moving average of fuel prices 3 years and 4 years prior to the present year. This assumption is founded upon an assumed lead time of 3 to 4 years to significantly modify the vehicles offered by a manufacturer.

Table 7.1. Standard technology matrix for cars[1]

	Fuel Efficiency Change %	Incremental Cost 2000$	Incremental Cost ($/UnitWt.)	Absolute Incremental Weight (lbs.)	Per Unit Incremental Weight (lbs./UnitWt.)	Introduction Year	Horsepower Change %
Unit Body Construction	4.0	99.91	0.00	0	-6	1980	0
Mass Reduction I	1.0	0.00	0.06	0	-1.5	2005	0
Mass Reduction II	2.6	0.00	0.14	0	-3.5	2009	0
Mass Reduction III	5.4	0.00	0.42	0	-10	2011	0
Mass Reduction IV	8.4	0.00	0.62	0	-15	2099	0
Mass Reduction V	11.6	0.00	0.72	0	-20	2099	0
Aerodynamics I	2.4	48.17	0.00	0	0.5	2000	0
Aerodynamics II	4.9	203.29	0.00	0	1	2011	0
6 Speed Manual	2.2	255.59	0.00	20	0	1995	0
Aggressive Shift Logic I	2.5	32.44	0.00	0	0	1999	0
Aggressive Shift Logic II	6.7	27.18	0.00	0	0	2017	0
Early Torque Converter Lockup	0.5	29.49	0.00	0	0	2002	0
High Efficiency Gearbox	1.6	200.63	0.00	0	0	2017	0
5 Speed Automatic	1.4	103.91	0.00	20	0	1995	0
6 Speed Automatic	2.2	270.05	0.00	30	0	2003	0
7 Speed Automatic	5.1	401.04	0.00	40	0	2009	0
8 Speed Automatic	8.0	532.83	0.00	50	0	2010	0
Dual Clutch Automated Manual	5.5	56.75	0.00	-10	0	2004	0
CVT	8.4	250.98	0.00	-25	0	1998	0
Low Friction Lubricants	0.7	3.20	0.00	0	0	2003	0
Engine Friction Reduction I-4 cyl	2.0	47.16	0.00	0	0	2000	1.25
Engine Friction Reduction I-6 cyl	2.6	71.14	0.00	0	0	2000	1.25
Engine Friction Reduction I-8 cyl	2.8	94.32	0.00	0	0	2000	1.25
Engine Friction Reduction II-4 cyl	3.6	100.71	0.00	0	0	2017	2.25
Engine Friction Reduction II-6 cyl	4.7	147.87	0.00	0	0	2017	2.25
Engine Friction Reduction II-8 cyl	5.1	195.03	0.00	0	0	2017	2.25
Cylinder Deactivation-6 cyl	6.5	187.06	0.00	10	0	2004	0
Cylinder Deactivation-8 cyl	6.9	209.97	0.00	10	0	2004	0
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.90	0.00	20	0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	2.7	43.90	0.00	30	0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.90	0.00	10	0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.76	0.00	20	0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	2.7	88.76	0.00	30	0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.90	0.00	20	0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	5.8	43.90	0.00	30	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.90	0.00	10	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.76	0.00	20	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	5.8	88.76	0.00	30	0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.26	0.00	25	0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	5.8	99.26	0.00	37.5	0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.67	0.00	12.5	0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.65	0.00	25	0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	5.8	195.65	0.00	37.5	0	2009	1.56
VVL I-OHV Discrete-6 cyl	5.5	225.24	0.00	40	0	2000	2.5

Table 7.1. Standard technology matrix for cars[1] (cont.)

	Fuel Efficiency Change %	Incremental Cost 2000$	Incremen-tal Cost ($/UnitWt.)	Absolute Incremen-tal Weight (lbs.)	Per Unit Incremen-tal Weight (lbs./UnitWt.)	Introduc-tion Year	Horsepower Change %
VVL I-OHV Discrete-8 cyl	5.9	322.59	0.00	50	0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.3	155.57	0.00	25	0	2000	2.5
VVL I-OHC Discrete-6 cyl	5.5	225.24	0.00	40	0	2000	2.5
VVL I-OHC Discrete-8 cyl	5.9	322.59	0.00	50	0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.0	1,150.07	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	7.5	1,256.96	0.00	50	0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.4	232.88	0.00	25	0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.0	427.58	0.00	40	0	2011	2.5
VVL II-OHC Continuous-8 cyl	7.5	466.71	0.00	50	0	2011	2.5
Stoichiometric GDI-4 cyl	1.5	264.37	0.00	20	0	2006	2.5
Stoichiometric GDI-6 cyl	1.5	397.99	0.00	30	0	2006	2.5
Stoichiometric GDI-8 cyl	1.5	478.16	0.00	40	0	2006	2.5
OHV to DOHC TBDS-I4	21.6	1,383.90	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2,096.84	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-I4	21.6	827.47	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-V6	20.2	1,605.80	0.00	-100	0	2009	3.75
DOHC TBDS I-I3	17.5	915.28	0.00	-100	0	2009	3.75
DOHC TBDS I-I4	21.6	747.30	0.00	-100	0	2009	3.75
DOHC TBDS I-V6	20.2	1,530.88	0.00	-100	0	2009	3.75
OHV to DOHC TBDS II-I4	26.3	1,586.36	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2,445.33	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1,046.15	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1,968.59	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	21.2	1,130.47	0.00	-100	0	2012	3.75
DOHC TBDS II-I4	26.3	968.31	0.00	-100	0	2012	3.75
DOHC TBDS II-V6	24.5	1895.85	0.00	-100	0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	32.6	2,031.83	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1,601.81	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1,565.84	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1,380.40	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1,634.58	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1,498.70	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1,302.07	0.00	-200	0	2017	3.75
Electric Power Steering	1.3	107.15	0.00	0	0	2004	0
Improved Accessories I	0.7	87.49	0.00	0	0	2005	0
12V Micro Hybrid w/EPS and IACC	7.0	640.24	0.00	45	0	2005	0
Improved Accessories II	2.5	128.69	0.00	0	0	2012	0
Mild Hybrid w/EPS and IACC II	11.0	2,902.00	0.00	80	0	2012	-2.5
Tires I	2.0	5.60	0.00	-12	0	2005	0
Tires II	4.0	58.35	0.00	-15	0	2017	0
Low Drag Brakes	0.8	59.15	0.00	0	0	2000	0
Secondary Axle Disconnect	1.3	96.34	0.00	0	-1	2012	0

[1] Fractional changes refer to the percentage change from the base technology.

Sources: U.S. Energy Information Administration, Energy and Environment Analysis, Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks (September 2002).

National Research Council, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards (Copyright 2002).

National Highway Traffic Safety Administration, Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks (April 2008).

U.S. Environmental Protection Agency, Interim Report: New Powertrain Technologies and Their Projected Costs (October 2005).

U.S. Environmental Protection Agency and Department of Transportation National Highway Traffic Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule," Federal Register Vol. 77, No. 199, October 15, 2012. 40 CFR Parts 85, 86, 600, 49 CFR Parts 523, 531, 533, et al. and 600.

Table 7.2. Standard technology matrix for light trucks[1]

	Fuel Efficiency Change %	Incremental Cost 2000$	Incremental Cost ($/UnitWt.)	Absolute Incremental Weight (lbs.)	Per Unit Incremental Weight (lbs./UnitWt.)	Introduction Year	Horsepower Change %
Unit Body Construction	4.0	100.00	0.00	0	-6	1980	0
Mass Reduction I	1.0	0.00	0.06	0	-1.5	2005	0
Mass Reduction II	2.6	0.00	0.14	0	-7.5	2009	0
Mass Reduction III	5.4	0.00	0.42	0	-10	2011	0
Mass Reduction IV	8.4	0.00	0.62	0	-15	2016	0
Mass Reduction V	11.6	0.00	0.72	0	-20	2020	0
Aerodynamics I	2.4	48.17	0.00	0	0.5	2000	0
Aerodynamics II	4.9	203.29	0.00	0	1	2011	0
6 Speed Manual	2.0	255.59	0.00	20	0	1995	0
Aggressive Shift Logic I	2.3	32.44	0.00	0	0	1999	0
Aggressive Shift Logic II	6.3	27.18	0.00	0	0	2017	0
Early Torque Converter Lockup	0.5	29.49	0.00	0	0	2002	0
High Efficiency Gearbox	1.6	200.63	0.00	0	0	2017	0
5 Speed Automatic	1.3	103.91	0.00	20	0	1995	0
6 Speed Automatic	2.0	270.05	0.00	30	0	2003	0
7 Speed Automatic	5.0	401.04	0.00	40	0	2009	0
8 Speed Automatic	8.0	532.83	0.00	50	0	2014	0
Dual Clutch Automated Manual	4.9	182.24	0.00	-10	0	2004	0
CVT	7.8	250.98	0.00	-25	0	1998	0
Low Friction Lubricants	0.7	3.20	0.00	0	0	2003	0
Engine Friction Reduction I-4 cyl	2.0	47.16	0.00	0	0	2000	1.25
Engine Friction Reduction I-6 cyl	2.6	71.14	0.00	0	0	2000	1.25
Engine Friction Reduction I-8 cyl	2.5	94.32	0.00	0	0	2000	1.25
Engine Friction Reduction II-4 cyl	3.6	100.71	0.00	0	0	2017	2.25
Engine Friction Reduction II-6 cyl	4.7	147.87	0.00	0	0	2017	2.25
Engine Friction Reduction II-8 cyl	4.4	195.03	0.00	0	0	2017	2.25
Cylinder Deactivation-6 cyl	6.4	187.06	0.00	10	0	2004	0
Cylinder Deactivation-8 cyl	6.0	209.97	0.00	10	0	2004	0
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.90	0.00	20	0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	2.5	43.90	0.00	30	0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.90	0.00	10	0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.76	0.00	20	0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	2.5	88.76	0.00	30	0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.90	0.00	20	0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	5.1	43.90	0.00	30	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.90	0.00	10	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.76	0.00	20	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	5.1	88.76	0.00	30	0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.26	0.00	25	0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	5.1	99.26	0.00	37.5	0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.67	0.00	12.5	0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.65	0.00	25	0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	5.1	195.65	0.00	37.5	0	2009	1.56
VVL I-OHV Discrete-6 cyl	5.5	225.24	0.00	40	0	2000	2.5
VVL I-OHV Discrete-8 cyl	5.2	322.59	0.00	50	0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.2	155.57	0.00	25	0	2000	2.5
VVL I-OHC Discrete-6 cyl	5.5	225.24	0.00	40	0	2000	2.5
VVL I-OHC Discrete-8 cyl	5.2	322.59	0.00	50	0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.0	1,150.07	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	6.5	1,256.96	0.00	50	0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.3	232.88	0.00	25	0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.0	427.58	0.00	40	0	2011	2.5
VVL II-OHC Continuous-8 cyl	6.5	466.71	0.00	50	0	2011	2.5
Stoichiometric GDI-4 cyl	1.5	264.37	0.00	20	0	2006	2.5

Table 7.2. Standard technology matrix for light trucks[1] (cont.)

	Fuel Efficiency Change %	Incremental Cost 2000$	Incremen-tal Cost ($/UnitWt.)	Absolute Incremen-tal Weight (Lbs.)	Per Unit Incremen-tal Weight (Lbs./ UnitWt.)	Introduc-tion Year	Horsepower Change %
Stoichiometric GDI-6 cyl	1.5	397.99	0.00	30	0	2006	2.5
Stoichiometric GDI-8 cyl	1.5	478.16	0.00	40	0	2006	2.5
OHV to DOHC TBDS-I4	21.6	1,383.90	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2,096.84	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-I4	21.6	827.47	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-V6	20.2	1,605.80	0.00	-100	0	2009	3.75
DOHC TBDS I-I3	17.5	915.28	0.00	-100	0	2009	3.75
DOHC TBDS I-I4	21.6	747.30	0.00	-100	0	2009	3.75
DOHC TBDS I-V6	20.2	1,530.88	0.00	-100	0	2009	3.75
OHV to DOHC TBDS II-I4	26.3	1,586.36	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2,445.33	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1,046.15	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1,968.59	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	21.2	1,130.47	0.00	-100	0	2012	3.75
DOHC TBDS II-I4	26.3	968.31	0.00	-100	0	2012	3.75
DOHC TBDS II-V6	24.5	1,895.85	0.00	-100	0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	32.6	2,031.83	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1,601.81	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1,565.84	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1,380.40	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1,634.58	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1,498.70	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1,302.07	0.00	-200	0	2017	3.75
Electric Power Steering	1.0	107.15	0.00	0	0	2004	0
Improved Accessories I	0.7	87.49	0.00	0	0	2005	0
12V Micro Hybrid w/EPS and IACC	6.7	697.79	0.00	45	0	2005	0
Improved Accessories II	2.4	128.69	0.00	0	0	2012	0
Mild Hybrid w/EPS and IACC II	10.6	2,902.00	0.00	80	0	2012	-2.5
Tires I	2.0	5.60	0.00	-12	0	2005	0
Tires II	4.0	58.35	0.00	-15	0	2017	0
Low Drag Brakes	0.8	59.15	0.00	0	0	2000	0
Secondary Axle Disconnect	1.4	96.34	0.00	0	-1	2012	0

[1] Fractional changes refer to the percentage change from the base technology.

Sources: U.S. Energy Information Administration, Energy and Environment Analysis, Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks (September 2002).

National Research Council, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards (Copyright 2002).

National Highway Traffic Safety Administration, Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks (April 2008).

U.S. Environmental Protection Agency, Interim Report: New Powertrain Technologies and Their Projected Costs (October 2005).

Environmental Protection Agency and Department of Transportation National Highway Traffic Safety Administration, “2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule,” Federal Register Vol. 77, No. 199, October 15, 2012. 40 CFR Parts 85, 86, 600, 49 CFR Parts 523, 531, 533, et al. and 600.

Levels of shortfall, expressed as degradation factors, are used to convert new vehicle tested fuel economy values to “on-road” fuel economy values (Table 7.3) [42]. The degradation factors represent adjustments made to tested fuel economy values to account for the difference between fuel economy performance realized in the CAFE test procedure and fuel economy realized under normal driving conditions.

Table 7.3. Car and light truck degradation factors

	2005	2010	2015	2020	2030	2040
Cars	79.8	81.7	81.7	81.7	81.7	81.7
Light Trucks	80.6	80.0	80.0	80.0	80.0	80.0

Source: U.S. Energy Information Administration, Transportation Demand Module of the National Energy Modeling System, Model Documentation 2014, DOE/EIA-M070(2014), (Washington, DC, 2012).

The light-duty Vehicle Miles Traveled (VMT) Component uses fuel prices, personal income, and population to generate projections of demand for personal travel (i.e., VMT). Population distribution assumptions are taken from the U.S. Bureau of the Census and are divided into 13 age categories, as well as by gender. Licensing rates by these 13 age categories are also used, taken from the U.S. Department of Transportation's Federal Highway Administration (FHWA). Licensing rates are then projected for each age category using the population estimates from the U.S. Bureau of the Census. These licensing rate projections are then aggregated into five age categories, and applied to the historical VMT per licensed driver taken from FHWA, in order to project the VMT per licensed driver, using the below VMT coefficients (Table 7.4).

Table 7.4. Vehicle miles traveled equation coefficients, by age and gender cohorts

	15-19	20-34	35-54	55-64	65 or more
BETACOST					
Male	-0.0601	-0.0614	-0.0498	-0.0517	-0.0425
Female	-0.0355	-0.0573	-0.0406	-0.0462	-0.0262
ALPHA					
Male	-0.0976	1.2366	1.1304	0.7469	1.3053
Female	1.3265	0.6564	0.4824	-2.1454	-0.8364
BETAVMT					
Male	0.7417	0.6469	0.6429	0.7568	0.7363
Female	0.8551	0.7178	0.7609	0.7464	0.8205
BETAINC					
Male	0.0850	0.0000	0.0000	0.0000	-0.0765
Female	-0.1094	0.0117	0.0003	0.2564	0.0866
BETAVPLD					
Male	-0.2398	0.2522	0.4447	0.3894	0.7451
Female	0.4174	0.4223	0.6079	0.3551	0.5912
BETAEMP					
Male	0.2503	0.2368	0.0445	0.0000	-0.2556
Female	-0.2044	-0.0084	-0.2653	-0.1826	-0.4553

Source: U.S. Energy Information Administration, AEO2016 National Energy Modeling System run REF2016.032416A.

Commercial light-duty fleet assumptions

The Transportation Demand Module separates commercial light-duty fleets into three types: business, government, and utility. Based on these classifications, commercial light-duty fleet vehicles vary in survival rates and duration of in-fleet use before sale for use as personal vehicles. The average length of time fleet passenger cars are kept before being sold for personal use is 3 years for business use, 6 years for government use, and 5 years for utility use. Of total passenger car sales to fleets in 2009, 75.1% are used in business fleets, 9.6% in government fleets, and 15.3% in utility fleets. Of total light truck sales to fleets in 2009, 47.3% are used in business fleets, 15.1% in government fleets, and 37.6% in utility fleets [43]. Both the automobile and light truck shares by fleet type are held constant from 2009 through 2040. In 2009, 18.2% of all automobiles sold and 16.9% of all light trucks sold were for fleet use. The share of total automobile and light truck sales slowly declines over the forecast period based on historic trends.

Alternative-fuel shares of fleet vehicle sales by fleet type are held constant at 2005 levels (Table 7.5). Size class sales shares of vehicles are also held constant at 2005 levels (Table 7.6) [44]. Individual sales shares of new vehicles purchased by technology type are assumed to remain relatively constant for utility, government, and business fleets (Table 7.7) [45].

Annual vehicle miles traveled (VMT) per vehicle by fleet type stays constant over the projection period based on the Oak Ridge National Laboratory fleet data.

Fleet fuel economy for both conventional and alternative-fuel vehicles is assumed to be the same as the personal new vehicle fuel economy and is subdivided into six EPA size classes for cars and light trucks.

Table 7.5. Percent of fleet alternative fuel vehicles by fleet type by size class, 2005

	Mini	Subcompact	Compact	Midsize	Large	2-Seater
Car						
Business	0.0	10.5	10.7	42.7	36.1	0.0
Government	0.0	2.8	40.0	2.8	54.4	0.0
Utility	0.0	7.9	34.7	12.3	45.1	0.0
	Small Pickup	**Large Pickup**	**Small Van**	**Large Van**	**Small Utility**	**Large Utility**
Light Truck						
Business	7.9	35.1	7.9	26.8	5.5	16.8
Government	6.7	50.8	28.4	4.6	1.6	7.8
Utility	8.2	52.1	6.0	32.7	0.3	0.7

Source: U.S. Energy Information Administration, "Archive--Alternative Transportation Fuels (ATF) and Alternative Fueled Vehicles (AFV)," http://www.eia.gov/renewable/afv/archive/

Table 7.6. Commercial fleet size class shares by fleet and vehicle type, 2005

percentage

	Mini	**Subcompact**	**Compact**	**Midsize**	**Large**	**2-Seater**
Car						
Business	3.1	23.4	26.6	36.2	9.9	0.8
Government	0.2	4.6	20.6	28.6	46.0	0.0
Utility	1.5	12.5	10.0	59.2	16.4	0.4
	Small Pickup	**Large Pickup**	**Small Van**	**Large Van**	**Small Utility**	**Large Utility**
Light Truck						
Business	2.5	8.4	23.3	8.1	14.2	43.6
Government	6.7	43.6	10.4	17.1	3.8	18.4
Utility	7.3	38.7	11.8	18.9	7.2	16.1

Source: Oak Ridge National Laboratory, “Fleet Characteristics and Data Issues,” Stacy Davis and Lorena Truett, final report prepared for the U. S. Department of Energy, U. S. Energy Information Administration, Office of Energy Analysis (Oak Ridge, TN, January 2003).

Table 7.7. Share of new vehicle purchases by fleet type and technology type, 2009

percentage

Technology	**Business**	**Government**	**Utility**
Cars			
Gasoline	99.10	72.78	95.52
Ethanol Flex	0.46	26.20	2.11
Electric	0.00	0.02	0.07
CNG/LNG Bi-Fuel	0.14	0.56	1.08
LPG Bi-Fuel	0.16	0.11	0.40
CNG/LNG	0.08	0.33	0.63
LPG	0.08	0.01	0.19
Light Trucks			
Gasoline	71.71	59.46	98.22
Ethanol Flex	16.29	35.09	0.49
Electric	0.04	0.07	0.05
CNG/LNG Bi-Fuel	1.28	2.29	0.51
LPG Bi-Fuel	7.93	2.55	0.31
CNG/LNG	1.54	0.49	0.24
LPG	1.22	0.05	0.18

Source: U.S. Energy Information Administration, Archive - Alternative Transportation Fuels (ATF) and Alternative Fueled Vehicles (AFV), http://www.eia.gov/renewable/afv/archive/index.cfm .

The light commercial truck component

The Light Commercial Truck Component of the NEMS Transportation Demand Module represents light trucks that have an 8,501 to 10,000 pound gross vehicle weight rating (GVW) (Class 2b vehicles). These vehicles are assumed to be used primarily for commercial purposes. The component implements a twenty-year stock model that estimates vehicle stocks, travel, fuel economy, and energy use by vintage. Historic vehicle sales and stock data, which constitute the baseline from which the projection is made, are taken from an Oak Ridge National Laboratory study [46]. The distribution of vehicles by vintage, and vehicle scrappage rates are derived from analysis of registration data from R.L. Polk & Co. and Polk data a foundation of IHS market automotive solutions [47],[48]. Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle [49],[50]. As defined in NEMS, light commercial trucks are a subset of Class 2 vehicles (vehicles weighing 6,001 to 10,000 pounds GVW) and are often referred to as Class 2b vehicles (8,500 to 10,000 pounds GVW). Class 2a vehicles (6,001 to 8,500 pounds GVW) are addressed in the Light-Duty Vehicle Submodule.

The growth in light commercial truck VMT is a function of industrial output for agriculture, mining, construction, total manufacturing, utilities, and personal travel. The overall growth in VMT reflects a weighted average based on the distribution of total light commercial truck VMT by sector. Projected fuel efficiencies are assumed to increase at the same annual growth rate as conventional gasoline light-duty trucks (less than or equal to 8,500 pounds gross vehicle weight).

Consumer vehicle choice assumptions

The Consumer Vehicle Choice Component (CVCC) utilizes a nested multinomial logit (NMNL) model that predicts sales shares based on relevant vehicle and fuel attributes. The nesting structure first predicts the probability of fuel choice for multi-fuel vehicles within a technology set. The second-level nesting predicts penetration among similar technologies within a technology set (e.g., gasoline versus diesel hybrids). The third-level choice determines market share among the different technology sets [51]. The technology sets include:

- Conventional fuel capable (gasoline, diesel, bi-fuel compressed natural gas (CNG) and liquefied natural gas (LNG), bi-fuel liquefied petroleum gas (LPG), and flex-fuel)
- Hybrid (gasoline and diesel)
- Plug-in hybrid (10-mile all-electric range and 40-mile all-electric range)
- Dedicated alternative fuel (CNG, LNG, and LPG)
- Fuel cell (gasoline, methanol, and hydrogen)
- Electric battery powered (100-mile range and 200-mile range) [52]

The vehicle attributes considered in the choice algorithm include: vehicle price, maintenance cost, battery replacement cost, range, multi-fuel capability, home refueling capability, fuel economy, acceleration and luggage space. With the exceptions of maintenance cost, battery replacement cost, and luggage space, vehicle attributes are determined endogenously [53]. Battery costs for plug-in hybrid electric and all-electric vehicles are based on a production-based function over several technology phase periods. The fuel attributes used in market share estimation include availability and price. Vehicle attributes vary by six EPA size classes for cars and light trucks, and fuel availability varies by Census division. The NMNL model coefficients were developed to reflect purchase decisions for size classes, cars, and light trucks separately.

Where applicable, CVCC fuel-efficient technology attributes are calculated relative to conventional gasoline miles per gallon. It is assumed that many fuel efficiency improvements in conventional vehicles will be transferred to alternative-fuel vehicles. Specific individual alternative-fuel technological improvements are also dependent upon the CVCC technology type, cost, research and development, and availability over time. Make and model availability estimates are assumed according to a logistic curve based on the initial technology introduction date and current offerings. Coefficients summarizing consumer valuation of vehicle attributes were derived from assumed economic valuation compared with vehicle price elasticities. Initial CVCC vehicle sales shares are calibrated to data from R.L. Polk & Co. and Polk data a foundation of IHS market automotive solutions fleet data from Bobit Publishing Company, and sales data from Wards Auto [54]. A fuel-switching algorithm based on the relative fuel prices for alternative fuels compared with gasoline is used to determine the percentage of total fuel consumption represented by alternative fuels in bi-fuel and flex-fuel alcohol vehicles.

Freight transport submodule

Freight transport includes Freight Truck, Rail Freight, and Waterborne Freight components.

Freight truck component

The Freight Truck Component estimates vehicle stocks, travel, fuel efficiency, and energy use for three size classes of trucks: light-medium (Class 3), heavy-medium (Classes 4-6), and heavy (Classes 7-8). The three size classes are further broken down into 13 subclasses for fuel economy classification purposes (Table 7.8). These subclasses include two breakouts for light-medium size class, including pickup/van and vocational, one breakout for heavy-medium, including vocational, and ten breakouts for heavy. The ten subclasses parse the heavy size class into class 7 or class 8, day cab or sleeper cab, and low, mid, or high roof. Within the size classes, the stock model structure is designed to cover 34 vehicle vintages and to estimate energy use by four fuel types: diesel, gasoline, LPG, and natural gas (CNG and LNG). Fuel consumption estimates are reported regionally (by Census Division) according to the distillate fuel shares from the State Energy Data System [55]. The technology input data are specific to the different types of trucks and include the year of introduction, incremental fuel efficiency improvement, and capital cost (Table 7.9).

Table 7.8. Vehicle technology category for technology matrix for freight trucks

Vehicle category	Class	Type	Roof[1]
1	3	Pickup and Van	-
2	3	Vocational	-
3	4-6	Vocational	-
4	7-8	Vocational	-
5	7	Tractor - day cab	low
6	7	Tractor - day cab	mid
7	7	Tractor - day cab	high
8	8	Tractor - day cab	low
9	8	Tractor - day cab	mid
10	8	Tractor - day cab	high
11	8	Tractor - sleeper cab	low
12	8	Tractor - sleeper cab	mid
13	8	Tractor - sleeper cab	high

[1] Applies to Class 7 and 8 day and sleeper cabs only.

Source: U.S. Energy Information Administration, Transportation Demand Module of the National Energy Modeling System, Model Documentation 2014, DOE/EIA-M070(2014), (Washington, DC, 2012).

Table 7.9. Standard technology matrix for freight trucks

Technology Type	Vehicle Category	Introduction Year	Capital Costs (2009$)	Incremental Fuel Economy Improvement (%)
Aerodynamics I: streamlined bumper, grill, windshield, roof	1	2010	58	1.5
Aerodynamics I: conventional features; general aerodynamic shape, removal of classic non-aerodynamic features	5,8,11	1995	1000	4.1
Aerodynamics I	7,10,13	1995	1000	4.6
Aerodynamics II: SmartWay features; streamlined shape, bumper grill, hood, mirrors, side fuel tank and roof fairings, side gap extenders	5,8	2004	1126	1.5
Aerodynamics II	7,10	2004	1126	3.1
Aerodynamics II	11	2004	1155	4.2
Aerodynamics II	13	2004	1506	4.2
Aerodynamics III: underbody airflow, down exhaust, lowered ride height	7	2014	2303	4.2
Aerodynamics III	10	2014	2489	5.0
Aerodynamics III	13	2014	2675	5.8
Aerodynamics IV: skirts, boat tails, nose cone, vortex stabilizer, pneumatic blowing	5-13	1995	5500	13.0
Tires I: low rolling resistance	1	2010	7	1.5
Tires I	2,3	2010	162	2.6
Tires I	4, 8-13	2010	194	2.0
Tires I	5-7	2010	130	2.0
Tires II: super singles	5-13	2000	150	5.3
Tires III: single wide tires on trailer	5-13	2000	800	3.1
Weight Reduction I	1	2010	127	1.6
Weight Reduction I: aluminum dual tires or super singles	5-13	2010	650	1.0
Weight Reduction II: weight reduction 15%	3-13	2018	6200	3.0
Weight Reduction III: weight reduction 20%	3-13	2022	11000	3.5
Accessories I: Electric/electrohydraulic improvements; electric power steering or electrohydraulic power steering	1	2010	115	1.5
Accessories II: Improved accessories; electrified water, oil, fuel injection, power steering pump, air compressor	1	2010	93	1.5
Accessories III: Auxiliary Power Unit	11-13	2000	5400	5.8
Transmission I: 8-speed Automatic from 6-speed automatic	1	2000	280	1.7
Transmission II: 6-Manual from 4-speed automatic	1	1995	150	1.0
Transmission III: Automated Manual Transmission	2-13	2000	5000	3.5
Diesel Engine I: after treatment improvements	1	2010	119	4.0
Diesel Engine I	2	2010	117	2.6
Diesel Engine II: low-friction lubricants	1-13	2005	4	0.5
Diesel Engine III: variable valve actuation	2	2010	0	1.0
Diesel Engine III	3-13	2005	300	1.0
Diesel Engine IV: engine friction reduction, improved bearings to allow lower-viscosity oil	1-2	2010	116	1.0
Diesel Engine IV	3-13	2010	250	1.0
Diesel Engine V: improved turbo efficiency	2-13	2010	18	1.5
Diesel Engine VI: improved water, oil, fuel pump; pistons; valve train friction reduction	2	2010	213	1.3
Diesel Engine VI	3, 5-8	2010	186	1.3
Diesel Engine VI: improved water, oil, and fuel pump; pistons	4, 9-13	2010	150	1.3
Diesel Engine VII: improved cylinder head, fuel rail and injector, EGR cooler	2	2010	42	4.7
Diesel Engine VII	3-13	2010	31	4.7
Diesel Engine VIII: turbo mechanical compounding	5-13	2017	1000	3.9
Diesel Engine IX: low temperature EGR, improved turbochargers	1	2010	184	5.0
Diesel Engine X: sequential downsizing/turbocharging	5-13	2010	1200	2.5
Diesel Engine XI: waste heat recovery, Organic Rankine Cycle (bottoming cycle)	3-13	2019	10000	8.0
Diesel Engine XII: electric turbo compounding	4-13	2020	8000	7.6

Table 7.9. Standard technology matrix for freight trucks (cont.)

Technology Type	Vehicle Category	Introduction Year	Capital Costs (2009$)	Incremental Fuel Economy Improvement (%)
Gasoline Engine I: low friction lubricants	1-13	2010	4	0.5
Gasoline Engine II: coupled cam phasing	2-4	2010	46	2.6
Gasoline Engine III: engine friction reduction; low tension piston rings, roller cam followers, piston skirt design, improved crankshaft design, and bearings; costing	1-2	2010	116	2.0
Gasoline III	3-4	2010	95	2.0
Gasoline Engine IV: stoichiometric gasoline direct injection V8	1	2006	481	1.5
Gasoline Engine IV	2	2010	481	1.5
Gasoline Engine IV	3-4	2014	450	1.5
Gasoline Engine V: turbocharging and downsizing SGDI V8 to V6	1-4	2006	1743	2.1
Gasoline Engine VI: lean burn GDI	1-4	2020	450	1.5
Gasoline Engine VII: HCCI	1-4	2035	685	12.0
Hybrid System I: 42V engine off at idle	1-2	2005	1500	7.0
Hybrid System I	3-4	2005	1500	4.5
Hybrid System II: dual mode hybrid	1-2	2008	12000	25.0
Hybrid System II: electric, ePTO, or hydraulic	3-4	2009	26667	30.0
Hybrid System II: 4 kWh battery, 50 kW motor generator	5-13	2012	26000	5.5

Sources: Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, U.S. Environmental Protection Agency and U.S. Department of Transportation, Final Rules, Federal Register, Vol. 76, No. 179 (September 2011).
Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, Regulatory Impact Analysis, U.S. Environmental Protection Agency and U.S. Department of Transportation, (August 2011).
Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions, Final Report, TIAX, LLC. (October 2009).
Update of Technology Information for Forecasting Heavy-Duty On-Road Vehicle Fuel Economy, Final Report, ICF International, Prepared for the U.S. Energy Information Administration (August 2010). Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles, National Research Council of the National Academy of Sciences (2010).

The Freight Truck Component uses projections of industrial output to estimate growth in freight truck travel. Regional heavy-duty freight truck vehicle travel is determined using a ton-mile per dollar of industrial output measure that is converted to freight vehicle miles traveled using shares developed from the Freight Analysis Framework (FAF) [56] with GIS-based regionalization between origin/destination points [587. Freight truck ton-miles, by Census division and industrial commodity, and historical truck vehicle miles traveled are developed using U. S. Department of Transportation and Federal Highway Administration data [58],[59].

Fuel economy of new freight trucks is dependent on the market penetration of advanced technology components [60]. For the advanced technology components, market penetration is determined as a function of technology type, cost effectiveness, and introduction year. Cost effectiveness is calculated as a function of fuel price, vehicle travel, fuel economy improvement, and incremental capital cost.

Heavy truck freight travel is estimated by class size and fuel type based on matching projected freight travel demand (measured by industrial output) to the travel supplied by the current fleet. Travel by vintage and size class is then adjusted so that total travel meets total demand.

Initial heavy vehicle travel, by vintage and size class, is derived by EIA using Vehicle Inventory and Use Survey (VIUS) data [61]. Initial freight truck stocks by vintage are obtained from analysis of R. L. Polk & Co. and Polk data and are distributed by fuel type using VIUS data. Vehicle scrappage rates are also estimated by EIA using R. L. Polk & Co. and Polk data a foundation of IHS market automotive solutions.

Freight rail

The Rail Freight Component uses the industrial output by NAICS code measured in real 2009 dollars and a ton-mile per dollar output measure to project rail ton-miles by Census division and commodity developed from the FAF [62]. Coal production from the NEMS Coal Market Module is used to adjust coal-based rail travel. Freight rail historical ton-miles are developed from U.S. Department of Transportation data [63]. Historic freight rail efficiencies are based on historical data taken from the U.S. Department of Transportation [64]. The distribution of rail fuel consumption by fuel type is based on the cost-effectiveness of LNG as compared with diesel considering fuel costs and incremental locomotive costs [65].

Domestic and international waterborne freight

Similar to the previous component, the domestic freight shipping within the Waterborne Freight Component uses the industrial output by NAICS code measured in real 2005 dollars and a ton-mile per dollar output measure to project domestic marine ton-miles by Census division and industrial commodity to develop domestic marine travel [66, 67].

Domestic shipping efficiencies are taken from the Transportation Energy Data Book [68]. The energy consumption in the international shipping within the Waterborne Freight Component is a function of the total level of imports and exports. The distribution of domestic and international shipping fuel consumption by fuel type is based on historical data through 2013 and allows for LNG as a marine fuel starting in 2013 based on fuel economics [69]. Historic regional domestic shipping fuel share estimates are distributed according to regional shares in the State Energy Data System (SEDS) [70].

Marine fuel choice for ocean-going vessels within Emission Control Areas (ECA)

The North American ECAs generally extend 200 nautical miles (nm) from the U.S. and Canadian ports (50 nm for the U.S. Caribbean ECA), and their requirements went into effect on January 1, 2015. The new requirements mandate that existing ships either burn fuel containing a maximum of 0.1% sulfur or to use scrubbers to remove the sulfur emissions. New ships will be built with engines and controls to handle alternative fuels and meet the ECA limits.

Compliance options, modeled as a logit choice function based on marine fuel prices, associated with travel in the ECAs for new vessels include using exhaust controls (e.g., scrubbers and selective catalytic reduction), changing fuels to marine gas oil (MGO) or liquefied natural gas (LNG), or installing engine-based controls (e.g., exhaust gas recirculation). Other technologies (e.g., biofuels and water injection) are also under development by industry but have not yet reached wide-scale adoption; hence they are modeling options for consideration in future NEMS programs, not in the current program.

Ship efficiency improvements, shipping demand changes, and fuel price fluctuations will also drive future fuel consumption predictions within the North American and U.S. Caribbean ECAs. Details on assumptions for baseline fuel estimates and technology choice options were outlined in a report released by EIA, as well methodology and assumptions for projecting fuel demand within North American ECAs [71].

Air travel submodule

The Air Travel Submodule is a 13-region world demand and supply model for passenger and freight (i.e., cargo) transport (Table 7.10). For each region, demand is computed for domestic route travel (both takeoff and landing occur in the same region) and international route travel (either takeoff or landing is in the region but not both). Once the demand for aircraft is projected, the Aircraft Fleet Efficiency Component shifts parked aircraft between regions to satisfy the projected demand for air travel.

Table 7.10. Thirteen regions for the world model

Region Number	Region	Major Countries in Region
1	United States	United States
2	Canada	Canada
3	Central America	Mexico
4	South America	Brazil
5	Europe	France, Germany
6	Africa	South Africa
7	Middle East	Egypt
8	CIS	Russia
9	China	China
10	Northeast Asia	Japan, Korea
11	Southeast Asia	Vietnam
12	Southwest Asia	India
13	Oceania	Australia, New Zealand

Source: Jet Information Services, 2013 World Jet Inventory, data tables (2013).

Air travel demand

The Air Travel Demand Component calculates the domestic and international per capita revenue passenger miles (RPM-PC) for each region. Domestic and international revenue passenger miles are based on the historical data in Table 7.11 [72], per capita income for the United States, per capita GDP for the non-U.S. regions, and ticket prices. The revenue ton miles of air freight for the United States are based on merchandise exports, gross domestic product, and fuel cost. For the non-U.S. regions, revenue ton-miles are based on GDP growth in the region [73].

Airport capacity constraints based on the Federal Aviation Administration (FAA) Airport Capacity Benchmark Report 2004 are incorporated into the Air Travel Demand Component using airport capacity measures [74]. Airport capacity is defined by the maximum number of flights per hour airports can routinely handle, the amount of time airports operate at optimal capacity, and passenger load factors. Capacity expansion is expected to be delayed due to the economic environment and fuel costs.

Aircraft stock efficiency

The Aircraft Fleet Efficiency Component consists of a world regional stock model of wide body, narrow body, and regional jets by vintage. Total aircraft supply for a given year is based on the initial supply of aircraft for model year 2009, new passenger aircraft sales, and the survival rate by vintage (Table 7.12) [75]. New passenger aircraft sales are a function of revenue passenger miles and gross domestic product.

Table 7.11. 2013 Regional population, GDP, per capita GDP, domestic and international RPM and per capita RPM

Region	Population (million)	GDP (2005$)	GDP per Capita
United States	317.0	11,651	36,752.78
Canada	35.3	1,274	36,115.40
Central America	166.0	2,181	13,136.93
South America	443.2	5,033	11,355.94
Europe	649.7	16,041	24,689.83
Africa	1076.3	4,374	4,063.54
Middle East	220.9	2,562	11,597.03
Russia	252.5	3,752	14,856.79
China	1,463.9	12,124	8,282.08
Northeast Asia	176.1	5,508	31,277.72
Southeast Asia	778.6	4,350	5,587.67
Southwest Asia	1,502.7	5,580	3,713.48
Oceania	29.6	866	29,300.60
Region	**RPM (billion)**	**RPM per Capita (thousand)**	
Domestic			
United States	602.5	1,900.7	
Canada	31.4	890.6	
Central America	23.2	139.6	
South America	93.6	211.2	
Europe	453.4	697.8	
Africa	34.1	31.7	
Middle East	54.8	248.1	
Russia	75.1	297.5	
China	292.6	199.9	
Northeast Asia	66.0	374.6	
Southeast Asia	105.8	135.9	
Southwest Asia	43.2	28.8	
Oceania	62.9	2,126.4	
International			
United States	263.6	832.1	
Canada	62.5	1,770.6	
Central America	79.0	476.0	
South America	66.7	150.5	

Table 7.11. 2013 Regional population, GDP, per capita GDP, domestic and international RPM and per capita RPM (cont.)

Region	RPM (billion)	RPM per Capita (thousand)
Europe	411.6	633.5
Africa	65.9	61.2
Middle East	154.0	696.9
Russia	100.3	397.0
China	115.8	79.1
Northeast Asia	131.6	747.4
Southwest Asia	150.9	193.8
Southwest Asia	70.0	46.6
Oceania	54.5	1,845.0

Source: Global Insight 2005 chain-weighted dollars, Boeing Current Market Outlook 2013.

Table 7.12. 2013 Regional passenger and cargo aircraft supply

		Age of Aircraft (years)				
Passenger and Cargo Aircraft Type	New	1-10	11-20	21-30	30 or more	Total
Passenger						
Narrow Body						
United States	154	1019	1588	886	42	3756
Canada	6	127	94	49	4	297
Central America	21	190	60	64	19	374
South America	49	329	159	109	53	778
Europe	139	1705	890	307	9	3,059
Africa	11	149	150	136	36	559
Middle East	30	319	119	85	11	600
Russia	33	265	333	242	44	1,081
China	235	1250	274	36	0	1,795
Northeast Asia	49	205	106	10	2	374
Southeast Asia	135	533	167	123	10	1007
Southwest Asia	40	254	44	31	0	394
Oceania	21	197	51	10	0	279
Wide Body						
United States	20	88	323	171	3	618
Canada	4	23	28	25	0	81
Central America	3	9	9	5	0	28
South America	9	60	42	6	2	120

Table 7.12. 2013 Regional passenger and cargo aircraft supply (cont.)

Passenger and Cargo Aircraft Type	New	Age of Aircraft (years) 1-10	11-20	21-30	30 or more	Total
Europe	38	327	366	89	0	831
Africa	9	60	39	34	6	154
Middle East	46	310	157	72	0	608
Russia	9	41	89	35	0	178
China	57	195	109	4	0	365
Northeast Asia	23	177	137	20	0	357
Southeast Asia	50	227	158	31	0	473
Southwest Asia	7	53	36	14	0	114
Oceania	8	65	33	25	0	131
Regional Jets						
United States	49	1,222	1,024	177	3	2,476
Canada	14	152	96	146	16	433
Central America	13	80	68	57	0	218
South America	38	190	98	63	3	392
Europe	38	635	531	249	0	1,453
Africa	7	152	145	98	3	415
Middle East	1	98	76	38	0	216
Russia	18	98	122	98	1	352
China	15	137	46	1	0	199
Northeast Asia	7	59	26	3	0	95
Southeast Asia	35	121	103	67	2	338
Southwest Asia	3	52	32	0	0	88
Oceania	10	108	132	107	0	357
Cargo						
Narrow Body						
United States	0	3	68	108	109	288
Canada	0	0	5	2	26	33
Central America	0	1	3	6	9	19
South America	0	0	2	6	46	54
Europe	0	0	18	87	5	110
Africa	0	0	4	16	45	65
Middle East	0	0	1	6	9	16
Russia	1	8	6	3	4	22
China	0	2	36	23	0	61
Northeast Asia	0	0	0	1	0	1
Southeast Asia	0	0	1	13	19	33

Table 7.12. 2013 Regional passenger and cargo aircraft supply (cont.)

		Age of Aircraft (years)				
Passenger and Cargo Aircraft Type	**New**	**1-10**	**11-20**	**21-30**	**30 or more**	**Total**
Southwest Asia	0	0	1	5	6	12
Oceania	0	0	0	11	3	14
Wide Body						
United States	15	101	194	200	89	599
Canada	0	0	0	3	4	7
Central America	0	2	1	3	3	9
South America	3	8	7	4	5	27
Europe	10	48	54	40	19	171
Africa	0	2	2	1	2	7
Middle East	12	17	11	18	13	71
Russia	2	7	8	7	4	28
China	8	47	20	15	2	92
Northeast Asia	6	25	17	10	0	58
Southeast Asia	0	22	29	5	0	56
Southwest Asia	0	0	0	2	3	5
Oceania	0	1	0	0	0	1
Regional Jets						
United States	0	0	5	37	0	42
Canada	0	0	2	8	0	10
Central America	0	0	4	2	0	6
South America	0	0	0	3	0	3
Europe	0	0	18	93	0	111
Africa	0	0	3	6	1	10
Middle East	0	0	0	2	0	2
Russia	0	0	0	2	0	2
China	0	0	0	0	0	0
Northeast Asia	0	0	0	0	0	0
Southeast Asia	0	0	0	5	0	5
Southwest Asia	0	0	3	0	0	3
Oceania	0	0	0	8	0	8
Survival Curve (fraction)	**New**	**5**	**10**	**20**	**40**	
Narrow Body	1.000	0.9998	0.9994	0.9970	0.8000	
Wide Body	1.000	0.9983	0.9961	0.9870	0.7900	
Regional Jets	1.000	0.9971	0.9950	0.9830	0.7800	

Source: Jet Information Services, 2013 World Jet Inventory (2013).

Wide- and narrow-body passenger planes over 25 years of age are placed as cargo jets according to a cargo percentage varying from 50% of 25-year-old planes to 100% of those aircraft 30 years and older. The available seat-miles per plane, which measure the carrying capacity of the airplanes by aircraft type, increase gradually over time. Domestic and international travel routes are combined into a single regional demand for seat-miles and passed to the Aircraft Fleet Efficiency Component, which adjusts the initial aircraft stock to meet that demand. For each region, starting with the United States, the initial stock is adjusted by moving aircraft between regions.

Technological availability, economic viability, and efficiency characteristics of new jet aircraft are assumed to grow at a fixed rate. Fuel-efficiency of new aircraft acquisitions represents an improvement over the stock efficiency of surviving airplanes. Generic sets of new technologies (Table 7.13) are introduced in different years and with a set of improved efficiencies over the base year (2007). Regional shares of all types of aircraft fuel use are assumed to be constant and are consistent with the SEDS estimate of regional jet fuel shares.

Table 7.13. Standard technology matrix for air travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (1987$/gallon)
Technology #1	2008	0.03	1.34
Technology #2	2014	0.05	1.34
Technology #3	2020	0.09	1.34
Technology #4	2025	0.13	1.34
Technology #5	2018	0.17	1.34
Technology #6	2018	0.00	1.34

Source: Jet Information Services, 2013 World Jet Inventory, data tables (2013).

Legislation and regulations

Light-Duty Vehicle Combined Corporate Average Fuel Economy (CAFE) Standards

The AEO2016 Reference case includes the attribute-based CAFE standards for LDVs for model year (MY) 2011, the joint attribute-based CAFE and vehicle GHG emissions standards for MY 2012 through MY 2016 and for MY 2017 through 2025. CAFE standards are then held constant in subsequent model years, although the fuel economy of new LDVs continues to rise modestly over time.

Heavy-Duty Vehicle Combined Corporate Average Fuel Economy Standards

On September 15, 2011, EPA and NHTSA jointly announced a final rule, called the HD National Program [76], which for the first time establishes greenhouse gas (GHG) emissions and fuel consumption standards for on-road heavy-duty trucks and their engines. The AEO2016 Reference case incorporates the standards for heavy-duty vehicles (HDVs) with gross vehicle weight rating (GVWR) above 8,500 pounds (Classes 2b through 8). The HD National Program standards begin for MY 2014 vehicles and engines and are fully phased in by MY 2018. AEO2016 models standard compliance among 13 HDV regulatory classifications that represent the discrete vehicle categories set forth in the rule. On August 16, 2016, EPA and NHTSA jointly adopted a second round of standards for medium- and heavy-duty vehicles. This second round of vehicle standards is not included in AEO2016 Reference case, instead it is included as an AEO2016 side case.

Energy Independence and Security Act of 2007 (EISA2007)

A fuel economy credit trading program is established based on EISA2007. Currently, CAFE credits earned by manufacturers can be banked for up to 3 years and can only be applied to the fleet (car or light truck) from which the credit was earned. Starting in model year 2011, the credit trading program allows manufacturers whose automobiles exceed the minimum fuel economy standards to earn credits that can be sold to other manufacturers whose automobiles fail to achieve the prescribed standards. The credit trading program is designed to ensure that the total oil savings associated with manufacturers that exceed the prescribed standards are preserved when credits are sold to manufacturers that fail to achieve the prescribed standards.

While the credit trading program began in 2011, EISA2007 allows manufacturers to apply credits earned to any of the three model years prior to the model year the credits are earned, and to any of the five model years after the credits are earned. The transfer of credits within a manufacturer's fleet is limited to specific maximums. For model years 2011 through 2013, the maximum transfer is 1.0 mpg; for model years 2014 through 2017, the maximum transfer is 1.5 mpg; and for model years 2018 and later, the maximum credit transfer is 2.0 mpg. NEMS currently allows for sensitivity analysis of CAFE credit banking by manufacturer fleet, but does not model the trading of credits across manufacturers. AEO2016 does not consider trading of credits since this would require significant modifications to NEMS and detailed technology cost and efficiency data by manufacturer, which are not readily available.

The CAFE credits specified under the Alternative Motor Fuels Act (AMFA) through 2019 are extended. Prior to passage of this Act, the CAFE credits under AMFA were scheduled to expire after model year 2010. Currently, 1.2 mpg is the maximum CAFE credit that can be earned from selling alternative fueled vehicles. EISA2007 extends the 1.2 mpg credit maximum through 2014 and reduces the maximum by 0.2 mpg for each following year until it is phased out by model year 2020. NEMS does model CAFE credits earned from alternative fuel vehicle sales.

American Recovery and Reinvestment Act of 2009 and Energy Improvement and Extension Act of 2008

ARRA Title I, Section 1141, modified the EIEA2008 Title II, Section 205, tax credit for the purchase of new, qualified plug-in electric drive motor vehicles. According to the legislation, a qualified plug-in electric drive motor vehicle must draw propulsion from a traction battery with at least 4 kWh of capacity and be propelled to a significant extent by an electric motor which draws electricity from a battery that is capable of being recharged from an external source of electricity.

The tax credit for the purchase of a plug-in electric vehicle is $2,500, plus, starting at a battery capacity of 5 kWh, an additional $417 per kWh battery credit up to a maximum of $7,500 per vehicle. The tax credit eligibility and phase-out are specific to an individual vehicle manufacturer. The credits are phased out once a manufacturer's cumulative sales of qualified vehicles reach 200,000. The phase-out period begins two calendar quarters after the first date in which a manufacturer's sales reach the cumulative sales maximum after December 31, 2009 [i]. The credit is reduced to 50% of the total value for the first two calendar quarters of the phase-out period and then to 25% for the third and fourth calendar quarters before being phased out entirely thereafter. The credit applies to vehicles with a gross vehicle weight rating of less than 14,000 pounds.

ARRA also allows a tax credit of 10% against the cost of a qualified electric vehicle with a battery capacity of at least 4 kWh subject to the same phase-out rules as above. The tax credits for qualified plug-in electric drive motor vehicles and electric vehicles are included in AEO2016.

Energy Policy Act of 1992 (EPACT1992)

Fleet alternative-fuel vehicle sales necessary to meet the EPACT regulations are derived based on the mandates as they currently stand and the Commercial Fleet Vehicle Component calculations. Total projected AFV sales are divided into fleets by government, business, and fuel providers (Table 7.14).

Table 7.14. EPACT legislative mandates for AFV purchases by fleet type and year

Year	Federal	State	Fuel Providers	Electric Utilities
2005	75	75	70	90

Source: U.S. Energy Information Administration, Energy Efficiency and Renewable Energy (Washington, DC, 2005), http://www1.eere.energy.gov/vehiclesandfuels/epact/statutes_regulations.html.

Because the commercial fleet model operates on three fleet type representations (business, government, and utility), the federal and state mandates are weighted by fleet vehicle stocks to create a composite mandate for both. The same combining methodology is used to create a composite mandate for electric utilities and fuel providers based on fleet vehicle stocks [77].

Emission Control Areas in North America and U.S. Caribbean Sea waters under the International Convention for the Prevention of Pollution from Ships (MARPOL)

Around the world, legislation and regulations mandating decreased emissions and lower levels of airborne pollutants have been put into place. In March 2010, the International Maritime Organization (IMO) amended the International Convention for the Prevention of Pollution from Ships (MARPOL) to designate specific portions of the United States, Canada, and French waters as Emission Control Areas (ECAs) [78]. The area of the North American ECA includes waters adjacent to the Pacific coast, the Atlantic coast, and the Gulf coast, and the eight main Hawaiian Islands. The ECAs extend up to 200 nautical miles from coasts of the United States, Canada, and the French territories, but do not extend into marine areas subject to the sovereignty or jurisdiction of other countries. Compliance with the North American ECA became enforceable in August 2012 [79].

Low-Emission Vehicle Program (LEVP)

The LEVP was originally passed into legislation in 1990 in the State of California. It began as the implementation of a voluntary opt-in pilot program under the purview of Clean Air Act Amendments of 1990 (CAAA1990), which included a provision that other states could opt in to the California program to achieve lower emissions levels than would otherwise be achieved through CAAA1990. Fourteen states have elected to adopt the California LEVP. The program was amended in 1998 to expand to cover more vehicles, increase stringency, and add ZEV credits.

The LEVP is a fleet-averaged, emissions-based policy for smog-forming pollutants, setting sales mandates for six categories of low-emission vehicles: low-emission vehicles (LEVs), ultra-low-emission vehicles (ULEVs), super-ultra-low-emission vehicles (SULEVs), partial zero-emission vehicles (PZEVs), advanced technology partial zero-emission vehicles (AT-PZEVs), and zero-emission vehicles (ZEVs). The LEVP was amended multiple times, most recently in 2014, to cover more vehicles, increase stringency, and add ZEV credits.

California Zero-Emission Vehicle regulations for model years 2018 and beyond

On July 10, 2014, the California Air Resource Board (CARB) issued a new rule for its Zero Emission Vehicle (ZEV) program for model year (MY) 2018 and later [80]. The ZEV program affects model year 2018 and later vehicles, requiring automakers to earn credits for alternative fuel vehicles based on a percentage of their sales in California. Nine other states (Connecticut, Maine, Massachusetts, Rhode Island, Vermont, New Jersey, New York, Maryland, and Oregon) have adopted California's ZEV program. The ZEV sales requirement is administered through credits that are earned for selling specific types of vehicles, such as but not limited to battery electric and plug-in hybrid electric vehicles. The value of the credits for vehicles sold within each category depends on certain vehicle characteristics including, for example, the electric driving range of electric vehicles. The total percentage requirement starts at 4.5% for model year 2018 sales and increases to 22% for model year 2025 sales. Full ZEVs are required to make up 16% of the required credits by model year 2025, mandating the sale of vehicles powered by electricity or hydrogen fuel cells.

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