Transportation Demand Module

The NEMS Transportation Demand Module (TDM) estimates transportation energy consumption across 9 Census Divisions and over 10 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 (LDV) fuel consumption is further subdivided into personal usage and commercial fleet consumption.

Key assumptions

By submodules and their components, key assumptions for transportation travel demand, efficiency, and energy consumption address LDVs, commercial light trucks, freight transportation, and air travel.

Light-duty vehicle submodule

The LDV vehicle Manufacturers Technology Choice Component (MTCC) includes 86 advanced technology input assumptions specific to cars and light trucks (Tables 1 and 2) that include incremental fuel economy improvement, incremental cost, incremental weight change, first year of introduction or commercial availability, and fractional horsepower change.

The LDV Regional Sales Component holds the share of vehicle sales by manufacturers constant within a vehicle size class at 2016 levels based on U. S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA) data [1]. 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 [2].

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 Corporate Average Fuel Economy (CAFE) program standards compared with consumer willingness to pay for fuel economy improvement beyond those minimum requirements.
- Fuel economy standards for LDVs reflect current law through model year (MY) 2025, according to NHTSA MY 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 MYs 2022 through 2025 will undergo a midterm evaluation by NHTSA and are subject to change. For MYs 2026 through 2050, fuel economy standards are held constant at MY 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 three years and four years prior to the present year. This assumption is founded upon an assumed lead time of three to four years to significantly modify the vehicles offered by a manufacturer.

Table 1. Standard technology matrix for cars[1]

	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 %
Unit Body Construction	4.0	99.91	0.00	0.0	-6.0	1980	0.00
Mass Reduction I	1.0	0.00	0.06	0.0	-1.5	2005	0.00
Mass Reduction II	2.6	0.00	0.14	0.0	-3.5	2009	0.00
Mass Reduction III	5.4	0.00	0.42	0.0	-10.0	2011	0.00
Mass Reduction IV	8.4	0.00	0.62	0.0	-15.0	2015	0.00
Mass Reduction V	11.6	0.00	0.72	0.0	-20.0	2015	0.00
Aerodynamics I	2.4	48.17	0.00	0.0	0.5	2000	0.00
Aerodynamics II	4.9	203.29	0.00	0.0	1.0	2011	0.00
6 Speed Manual	2.2	255.59	0.00	20.0	0.0	1995	0.00
Aggressive Shift Logic I	2.5	32.44	0.00	0.0	0.0	1999	0.00
Aggressive Shift Logic II	6.7	27.18	0.00	0.0	0.0	2017	0.00
Early Torque Converter Lockup	0.5	29.49	0.00	0.0	0.0	2002	0.00
High Efficiency Gearbox	1.6	200.63	0.00	0.0	0.0	2017	0.00
5 Speed Automatic	1.4	103.91	0.00	20.0	0.0	1995	0.00
6 Speed Automatic	2.2	270.05	0.00	30.0	0.0	2003	0.00
7 Speed Automatic	5.1	401.04	0.00	40.0	0.0	2009	0.00
8 Speed Automatic	8.0	532.83	0.00	50.0	0.0	2010	0.00
Dual Clutch Automated Manual	5.5	56.75	0.00	-10.0	0.0	2004	0.00
CVT	8.4	250.98	0.00	-25.0	0.0	1998	0.00
Low Friction Lubricants	0.7	3.20	0.00	0.0	0.0	2003	0.00
Engine Friction Reduction I-4 cyl	2.0	47.16	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction I-6 cyl	2.6	71.14	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction I-8 cyl	2.8	94.32	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction II-4 cyl	3.6	100.71	0.00	0.0	0.0	2017	2.25
Engine Friction Reduction II-6 cyl	4.7	147.87	0.00	0.0	0.0	2017	2.25
Engine Friction Reduction II-8 cyl	5.1	195.03	0.00	0.0	0.0	2017	2.25
Cylinder Deactivation-6 cyl	6.5	187.06	0.00	10.0	0.0	2004	0.00
Cylinder Deactivation-8 cyl	6.9	209.97	0.00	10.0	0.0	2004	0.00
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.90	0.00	20.0	0.0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	2.7	43.90	0.00	30.0	0.0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.90	0.00	10.0	0.0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.76	0.00	20.0	0.0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	2.7	88.76	0.00	30.0	0.0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.90	0.00	20.0	0.0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	5.8	43.90	0.00	30.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.90	0.00	10.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.76	0.00	20.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	5.8	88.76	0.00	30.0	0.0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.26	0.00	25.0	0.0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	5.8	99.26	0.00	37.5	0.0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.67	0.00	12.5	0.0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.65	0.00	25.0	0.0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	5.8	195.65	0.00	37.5	0.0	2009	1.56
VVL I-OHV Discrete-6 cyl	5.5	225.24	0.00	40.0	0.0	2000	2.50

Table 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	0.0	2000	2.50
VVL I-OHC Discrete-4 cyl	4.3	155.57	0.00	25.0	0.0	2000	2.50
VVL I-OHC Discrete-6 cyl	5.5	225.24	0.00	40.0	0.0	2000	2.50
VVL I-OHC Discrete-8 cyl	5.9	322.59	0.00	50.0	0.0	2000	2.50
VVL II-OHV Continuous-6 cyl	7.0	1,150.07	0.00	40.0	0.0	2011	2.50
VVL II-OHV Continuous-8 cyl	7.5	1,256.96	0.00	50.0	0.0	2011	2.50
VVL II-OHC Continuous-4 cyl	5.4	232.88	0.00	25.0	0.0	2011	2.50
VVL II-OHC Continuous-6 cyl	7.0	427.58	0.00	40.0	0.0	2011	2.50
VVL II-OHC Continuous-8 cyl	7.5	466.71	0.00	50.0	0.0	2011	2.50
Stoichiometric GDI-4 cyl	1.5	264.37	0.00	20.0	0.0	2006	2.50
Stoichiometric GDI-6 cyl	1.5	397.99	0.00	30.0	0.0	2006	2.50
Stoichiometric GDI-8 cyl	1.5	478.16	0.00	40.0	0.0	2006	2.50
OHV to DOHC TBDS-I4	21.6	1,383.90	0.00	-100.0	0.0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2,096.84	0.00	-100.0	0.0	2009	3.75
SOHC to DOHC TBDS I-I4	21.6	827.47	0.00	-100.0	0.0	2009	3.75
SOHC to DOHC TBDS I-V6	20.2	1,605.80	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-I3	17.5	915.28	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-I4	21.6	747.30	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-V6	20.2	1,530.88	0.00	-100.0	0.0	2009	3.75
OHV to DOHC TBDS II-I4	26.3	1,586.36	0.00	-100.0	0.0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2,445.33	0.00	-100.0	0.0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1,046.15	0.00	-100.0	0.0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1,968.59	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-I3	21.2	1,130.47	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-I4	26.3	968.31	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-V6	24.5	1895.85	0.00	-100.0	0.0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	32.6	2,031.83	0.00	-100.0	0.0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1,601.81	0.00	-200.0	0.0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1,565.84	0.00	-100.0	0.0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1,380.40	0.00	-200.0	0.0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1,634.58	0.00	-100.0	0.0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1,498.70	0.00	-100.0	0.0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1,302.07	0.00	-200.0	0.0	2017	3.75
Electric Power Steering	1.3	107.15	0.00	0.0	0.0	2004	0.00
Improved Accessories I	0.7	87.49	0.00	0.0	0.0	2005	0.00
12V Micro Hybrid w/EPS and IACC	7.0	640.24	0.00	45.0	0.0	2005	0.00
Improved Accessories II	2.5	128.69	0.00	0.0	0.0	2012	0.00
Mild Hybrid w/EPS and IACC II	11.0	2,902.00	0.00	80.0	0.0	2012	-2.50
Tires I	2.0	5.60	0.00	-12.0	0.0	2005	0.00
Tires II	4.0	58.35	0.00	-15.0	0.0	2017	0.00
Low Drag Brakes	0.8	59.15	0.00	0.0	0.0	2000	0.00
Secondary Axle Disconnect	1.3	96.34	0.00	0.0	-1.0	2012	0.00

[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 2. Standard technology matrix for light trucks[1]

	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 %
Unit Body Construction	4.0	100.00	0.00	0.0	-6.0	1980	0.00
Mass Reduction I	1.0	0.00	0.06	0.0	-1.5	2005	0.00
Mass Reduction II	2.6	0.00	0.14	0.0	-7.5	2009	0.00
Mass Reduction III	5.4	0.00	0.42	0.0	-10.0	2011	0.00
Mass Reduction IV	8.4	0.00	0.62	0.0	-15.0	2016	0.00
Mass Reduction V	11.6	0.00	0.72	0.0	-20.0	2020	0.00
Aerodynamics I	2.4	48.17	0.00	0.0	0.5	2000	0.00
Aerodynamics II	4.9	203.29	0.00	0.0	1.0	2011	0.00
6 Speed Manual	2.0	255.59	0.00	20.0	0.0	1995	0.00
Aggressive Shift Logic I	2.3	32.44	0.00	0.0	0.0	1999	0.00
Aggressive Shift Logic II	6.3	27.18	0.00	0.0	0.0	2017	0.00
Early Torque Converter Lockup	0.5	29.49	0.00	0.0	0.0	2002	0.00
High Efficiency Gearbox	1.6	200.63	0.00	0.0	0.0	2017	0.00
5 Speed Automatic	1.3	103.91	0.00	20.0	0.0	1995	0.00
6 Speed Automatic	2.0	270.05	0.00	30.0	0.0	2003	0.00
7 Speed Automatic	5.0	401.04	0.00	40.0	0.0	2009	0.00
8 Speed Automatic	8.0	532.83	0.00	50.0	0.0	2014	0.00
Dual Clutch Automated Manual	4.9	182.24	0.00	-10.0	0.0	2004	0.00
CVT	7.8	250.98	0.00	-25.0	0.0	1998	0.00
Low Friction Lubricants	0.7	3.20	0.00	0.0	0.0	2003	0.00
Engine Friction Reduction I-4 cyl	2.0	47.16	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction I-6 cyl	2.6	71.14	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction I-8 cyl	2.5	94.32	0.00	0.0	0.0	2000	1.25
Engine Friction Reduction II-4 cyl	3.6	100.71	0.00	0.0	0.0	2017	2.25
Engine Friction Reduction II-6 cyl	4.7	147.87	0.00	0.0	0.0	2017	2.25
Engine Friction Reduction II-8 cyl	4.4	195.03	0.00	0.0	0.0	2017	2.25
Cylinder Deactivation-6 cyl	6.4	187.06	0.00	10.0	0.0	2004	0.00
Cylinder Deactivation-8 cyl	6.0	209.97	0.00	10.0	0.0	2004	0.00
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.90	0.00	20.0	0.0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	2.5	43.90	0.00	30.0	0.0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.90	0.00	10.0	0.0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.76	0.00	20.0	0.0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	2.5	88.76	0.00	30.0	0.0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.90	0.00	20.0	0.0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	5.1	43.90	0.00	30.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.90	0.00	10.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.76	0.00	20.0	0.0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	5.1	88.76	0.00	30.0	0.0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.26	0.00	25.0	0.0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	5.1	99.26	0.00	37.5	0.0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.67	0.00	12.5	0.0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.65	0.00	25.0	0.0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	5.1	195.65	0.00	37.5	0.0	2009	1.56
VVL I-OHV Discrete-6 cyl	5.5	225.24	0.00	40.0	0.0	2000	2.50
VVL I-OHV Discrete-8 cyl	5.2	322.59	0.00	50.0	0.0	2000	2.50
VVL I-OHC Discrete-4 cyl	4.2	155.57	0.00	25.0	0.0	2000	2.50
VVL I-OHC Discrete-6 cyl	5.5	225.24	0.00	40.0	0.0	2000	2.50
VVL I-OHC Discrete-8 cyl	5.2	322.59	0.00	50.0	0.0	2000	2.50
VVL II-OHV Continuous-6 cyl	7.0	1,150.07	0.00	40.0	0.0	2011	2.50
VVL II-OHV Continuous-8 cyl	6.5	1,256.96	0.00	50.0	0.0	2011	2.50
VVL II-OHC Continuous-4 cyl	5.3	232.88	0.00	25.0	0.0	2011	2.50
VVL II-OHC Continuous-6 cyl	7.0	427.58	0.00	40.0	0.0	2011	2.50

Table 2. Standard technology matrix for light trucks[1] (cont.)

	Fuel Efficiency Change %	Incremental Cost 2000$	Incremental Cost ($/UnitWt.)	Absolute Incremental Weight (Lbs.)	Per Unit Incremental Weight (Lbs./ UnitWt.)	Introduction Year	Horsepower Change %
VVL II-OHC Continuous-8 cyl	6.5	466.71	0.00	50.0	0.0	2011	2.50
Stoichiometric GDI-4 cyl	1.5	264.37	0.00	20.0	0.0	2006	2.50
Stoichiometric GDI-6 cyl	1.5	397.99	0.00	30.0	0.0	2006	2.50
Stoichiometric GDI-8 cyl	1.5	478.16	0.00	40.0	0.0	2006	2.50
OHV to DOHC TBDS-I4	21.6	1,383.90	0.00	-100.0	0.0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2,096.84	0.00	-100.0	0.0	2009	3.75
SOHC to DOHC TBDS I-I4	21.6	827.47	0.00	-100.0	0.0	2009	3.75
SOHC to DOHC TBDS I-V6	20.2	1,605.80	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-I3	17.5	915.28	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-I4	21.6	747.30	0.00	-100.0	0.0	2009	3.75
DOHC TBDS I-V6	20.2	1,530.88	0.00	-100.0	0.0	2009	3.75
OHV to DOHC TBDS II-I4	26.3	1,586.36	0.00	-100.0	0.0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2,445.33	0.00	-100.0	0.0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1,046.15	0.00	-100.0	0.0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1,968.59	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-I3	21.2	1,130.47	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-I4	26.3	968.31	0.00	-100.0	0.0	2012	3.75
DOHC TBDS II-V6	24.5	1,895.85	0.00	-100.0	0.0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	32.6	2,031.83	0.00	-100.0	0.0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1,601.81	0.00	-200.0	0.0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1,565.84	0.00	-100.0	0.0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1,380.40	0.00	-200.0	0.0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1,634.58	0.00	-100.0	0.0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1,498.70	0.00	-100.0	0.0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1,302.07	0.00	-200.0	0.0	2017	3.75
Electric Power Steering	1.0	107.15	0.00	0.0	0.0	2004	0.00
Improved Accessories I	0.7	87.49	0.00	0.0	0.0	2005	0.00
12V Micro Hybrid w/EPS and IACC	6.7	697.79	0.00	45.0	0.0	2005	0.00
Improved Accessories II	2.4	128.69	0.00	0.0	0.0	2012	0.00
Mild Hybrid w/EPS and IACC II	10.6	2,902.00	0.00	80.0	0.0	2012	-2.50
Tires I	2.0	5.60	0.00	-12.0	0.0	2005	0.00
Tires II	4.0	58.35	0.00	-15.0	0.0	2017	0.00
Low Drag Brakes	0.8	59.15	0.00	0.0	0.0	2000	0.00
Secondary Axle Disconnect	1.4	96.34	0.00	0.0	-1.0	2012	0.00

[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 light-duty vehicle tested fuel economy values to on-road fuel economy values [3]. 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. The degradation factor is 0.817 for cars and 0.800 for light trucks.

The LDV Vehicle Miles Traveled (VMT) Component uses fuel prices, personal income, and population to generate projections of demand for personal travel. Population distribution assumptions are taken from the U.S. Bureau of the Census and are divided into five age categories, further divided by gender. Licensing rates by these five 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 applied to the historical VMT per licensed driver taken from FHWA, to project the VMT per licensed driver, using the below VMT coefficients (Table 3).

Table 3. 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, AEO2018 National Energy Modeling System run REF2018.121317A.

Commercial light-duty fleet assumptions

The TDM separates commercial light-duty fleets into four types: business, government, utility, and autonomous vehicles in ride hailing and taxi service. 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 three years for business use, six years for government use, and five years for utility use. Vehicles used for hide hailing or taxi service remain in fleet use for the life of the vehicle. Of total passenger car sales to fleets in 2013, 80.5% are used in business fleets, 4.7% in government fleets, and 14.8% in utility fleets. Of total light truck sales to fleets in 2013, 52.4% are used in business fleets, 9.4% in government fleets, and 38.2% in utility fleets [4]. Both the automobile and light truck shares by fleet type are held constant from 2013 through 2050. Autonomous vehicles are assumed to enter fleets in 2020 with cars increasing to 5.3% and light trucks increasing to 3.5% of new fleet vehicle sales in 2050. In 2013, 16.2% of all automobiles sold and 15.3% of all light trucks sold were for fleet use. The share of total automobile and light truck sales returns to historical trends over the forecast period.

Alternative-fuel shares of fleet vehicle sales by fleet type are held constant at 2013 levels (Table 4). Autonomous vehicles are assumed to be gasoline fueled. Size class sales shares of vehicles are also held constant at 2013 levels (Table 5) [5]. Autonomous vehicle size class shares are assumed to be similar to business fleets. Individual sales shares of new vehicles purchased by technology type are assumed to remain relatively constant for utility, government, and business fleets (Table 6) [6].

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. Autonomous vehicles are assumed to travel 65,000 miles per year.

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 4. Percent of fleet alternative fuel vehicles by fleet type by size class, 2013

	Mini	**Subcompact**	**Compact**	**Midsize**	**Large**	**2-Seater**
Car						
Business	0.5	1.0	15.9	45.4	37.2	0.0
Government	0.0	0.2	13.8	23.9	62.0	0.1
Utility	0.1	0.4	15.0	55.0	28.4	1.2
Autonomous	0.0	0.0	0.0	0.0	0.0	0.0
	Small Pickup	**Large Pickup**	**Small Van**	**Large Van**	**Small Utility**	**Large Utility**
Light Truck						
Business	1.0	17.7	29.0	1.3	0.1	50.8
Government	1.0	48.5	12.9	2.0	0.0	35.5
Utility	1.0	62.3	9.6	3.6	0.1	23.4
Autonomous	0.0	0.0	0.0	0.0	0.0	0.0

Source: Bobbit Publishing Company, Fleet Fact Book, various issues; IHS Markit Polk, National Vehicle Population Profile, various years.

Table 5. Commercial fleet size class shares by fleet and vehicle type, 2013

percentage

	Mini	Subcompact	Compact	Midsize	Large	2-Seater
Car						
Business	0.4	4.0	17.6	45.7	32.2	0.1
Government	0.0	0.7	10.0	18.7	70.5	0.0
Utility	0.2	3.2	11.8	38.2	45.9	0.8
Autonomous	0.0	0.0	0.0	0.0	0.0	0.0
	Small Pickup	**Large Pickup**	**Small Van**	**Large Van**	**Small Utility**	**Large Utility**
Light Truck						
Business	1.5	13.7	19.0	2.0	17.1	46.6
Government	1.2	41.1	8.4	2.5	4.8	42.0
Utility	3.6	47.3	7.1	3.4	12.2	26.5
Autonomous	0.0	0.0	0.0	0.0	0.0	0.0

Source: Bobbit Publishing Company, Fleet Fact Book, various issues; IHS Markit Polk, National Vehicle Population Profile, various years.

Table 6. Share of new vehicle purchases by fleet type and technology type, 2013

percentage

Technology	Business	Government	Utility	Autonomous
Cars				
Gasoline	88.33	72.58	88.43	0.00
Diesel	0.74	0.04	0.91	0.00
Ethanol Flex	7.54	18.85	4.14	0.00
Electric	0.11	0.66	0.47	0.00
Plug-in Hybrid Electric	0.00	0.00	0.01	0.00
Hybrid Electric	0.01	0.05	0.04	0.00
CNG/LNG Bi-Fuel	0.01	0.02	0.00	0.00
LPG Bi-Fuel	0.00	0.00	0.00	0.00
CNG/LNG	0.01	0.00	0.00	0.00
LPG	0.00	0.00	0.00	0.00
Light Trucks				
Gasoline	47.93	48.15	62.39	0.00
Diesel	0.10	0.02	0.27	0.00
Ethanol Flex	45.14	47.62	36.50	0.00
Electric	0.00	0.04	0.01	0.00
Plug-in Hybrid Electric	0.00	0.00	0.00	0.00
Hybrid Electric	0.00	0.00	0.00	0.00
CNG/LNG Bi-Fuel	0.01	0.02	0.00	0.00
LPG Bi-Fuel	0.04	0.02	0.00	0.00
CNG/LNG	0.01	0.00	0.00	0.00
LPG	0.01	0.00	0.00	0.00

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 . IHS Markit Polk, National Vehicle Population Profile, various years.

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 (GVWR) (Class 2b vehicles). These vehicles are assumed to be used primarily for commercial purposes. This component implements a 34-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 [7]. 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 [8],[9]. Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle [10],[11]. As defined in NEMS, light commercial trucks are a subset of Class 2 vehicles (vehicles with a 6,001 to 10,000 pounds GVWR) and are often referred to as Class 2b vehicles (8,500 to 10,000 pounds GVWR). Class 2a vehicles (6,001 to 8,500 pounds GVWR) are addressed in the Light-Duty Vehicle Submodule.

The growth in light commercial truck VMT is a function of industrial gross 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. Fuel economy of new Class 2b trucks is dependent on the market penetration of advanced technology components [12]. For the advanced technology components, market penetration is determined as a function of technology type, cost effectiveness, and year of expected introduction. Cost effectiveness is based on fuel price, vehicle travel, fuel economy improvement, and incremental capital cost.

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 [13]. The technology sets include the following:

- 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: methanol and hydrogen
- Electric battery powered: 100-, 200-, and 300-mile range

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 [14]. 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 (mpg). Many fuel efficiency improvements in conventional vehicles are assumed to 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 IHS Markit Polk, National Vehicle Population Profile; fleet data from Bobit Publishing Company; and sales data from EPA Engines and Vehicles Compliance Information System [15]. 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

The Freight transport submodule 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 14 subclasses for fuel economy classification purposes (Table 7). These subclasses include 2 breakouts for light-medium size class, including pickup/van and vocational, 1 breakout for heavy-medium, including vocational, and 10 breakouts for heavy. The 10 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 estimate energy use by 7 fuel types: diesel, gasoline, LPG, natural gas (CNG and LNG), ethanol, electricity, and hydrogen. Fuel consumption estimates are reported regionally (by Census Division) according to the distillate fuel shares from the EIA State Energy Data System [16]. 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 8).

Table 7. Vehicle technology category for technology matrix for freight trucks

Vehicle category	Class	Type	Roof[1]
1	2b-3	Pickup and Van	-
2	2b-5	Vocational	-
3	6-7	Vocational	-
4	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
14	8	Tractor - heavy haul	-

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

Source: Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles- Phase2, U.S. Environmental Protection Agency and U.S. Department of Transportation, Final Rules, Federal Register, Vol. 81, No. 206 (October 2016).

Table 8. Standard technology matrix for freight trucks

	Vehicle Category	Introduction Year	Capital Costs (2015$)	Engine Type	Incremental Fuel Economy Improvement (%)
Lower rolling resistance tires 1	1	2010	10	All	1.1[1]
	2-3,5-7	2010	145	All	0.1-1.7[1]
	4,8-13	2010	241	All	0.2-1.3[1]
Lower rolling resistance tires 2	1	2010	82	All	2.2[1]
	2-3,5-7	2010	145	All	0.7-1.7[1]
	4,8-13	2010	241	All	0.0-1.3[1]
Lower rolling resistance tires 3	2-3,5-7	2018	177	All	1.6-2.7[1]
	4,8-13	2018	295	All	2.3-3.5[1]
Lower rolling resistance tires 4	5-7	2021	191	All	4.3-4.6[1]
	8-13	2021	319	All	5.1-5.9[1]
Tire pressure monitoring system	2-4	2018	342	All	0.9
	5-7	2018	421	All	1.0
	8-14	2018	648	All	1.0
Automated tire inflation system	2-3	2018	713	All	1.1
	4	2018	1019	All	1.1
	5-14	2018	1019	All	1.2
Aerodynamics bin 1	1	2015	53	All	0.8
Aerodynamics bin 2	1	2015	240	All	1.5
	5-6,8-9,11-12	2010	1236	All	0.1[1]
Aerodynamics bin 3	5-6,8-9	2014	2250	All	1.2-1.7[1]
	7,10	2014	1144	All	0.7-0.8[1]
	11-12	2014	2574	All	1.9[1]
Aerodynamics bin 4	5-6,8-9	2014	2198	All	3.3-4.4[1]
	7,10	2014	1746	All	3.9-4.1[1]
	11-12	2014	2514	All	4.5-4.7[1]
Aerodynamics bin 5	7,10	2014	2529	All	6.4-7.1[1]
	13	2014	2937	All	7.1[1]
Aerodynamics bin 6	7,10	2014	3074	All	9.0-10.1[1]
	13	2014	3570	All	10.5[1]
Aerodynamics bin 7	7,10	2014	3619	All	11.6-13.2[1]
	13	2014	4204	All	13.9[1]
Weight reduction (via single wide tires and/or aluminum wheels)	4	2014	2702	All	0.9[1]
Weight reduction via material changes (assuming 10% on a 6500lb vehicle), 5% for 2b-3	1	2016	84	All	1.5
Weight reduction via material changes, 200lb for LH/MH vocational, additional 5% for 2b-3	1	2014	249	All	1.5
	2-3	2014	772	All	0.8-1.4[1]
Low drag brakes	1	2014	114	All	0.4
Electric power steering	1	2015	158	SI,CI	0.9
Driveline friction reduction	1	2015	145	All	0.5
Improved accessories IACC1 (electrification)	1	2015	86	SI,CI	0.9
Improved accessories IACC2 (electrification)	1	2021	138	SI,CI	0.9
Improved accessories (42 volt electrical system, power steering, & electric AC)	2	2018	472	SI,CI	2.0
	3	2018	892	All	2.0
	4	2018	1783	All	1.5
	5-14	2018	312	All	1.0
Air conditioning efficiency	2-3	2018	24	All	1.0
	4	2018	24	All	0.5
	5-14	2018	193	All	0.5
"Right sized" diesel engine	1	2014	10	CI	5.0
	5-13	2014	10	CI	0.3

Table 8. Standard technology matrix for freight trucks (cont.)

	Vehicle Category	Introduction Year	Capital Costs (2015$)	Engine Type	Incremental Fuel Economy Improvement (%)
Aftertreatment improvements 1 (diesel I Phase 1)	1	2010	131	CI	4.0
	2	2010	129	CI	1.0
Aftertreatment improvements 2 (Phase 2)	2-14	2014	17	CI	0.6
Low-Friction Lubrications - (diesel II Phase 1)	1-14	2005	4	CI	0.5
Engine friction reduction (diesel IV Phase 1)	1-2	2010	128	CI	1.0
	3-14	2010	275	CI	1.0
Improved water, oil, & fuel pump, pistons; valve train friction (VTF pickup, LH, MH vocational only) (diesel VI Phase 1)	1-2	2010	234	CI	1.3
	3,5-8	2010	205	CI	1.3
	4,9-13	2010	165	CI	1.3
Parasitic/Friction (Cyl Kits, pumps, FIE), lubrication - phase 2 package	5-13	2021	239	CI	1.4
Valve Actuation (diesel III Phase 1)	2-13	2005	231	CI	1.0
Turbo efficiency improvements 1 (diesel V Phase 1 - except pickups)	1	2021	17	CI	2.5
	2-14	2010	20	CI	1.5
Low temperature EGR, improved turbochargers (diesel IX Phase 1)	1	2010	202	CI	5.0
Sequential downsizing/turbocharging - (diesel X Phase 1)	5-13	2010	1320	CI	2.5
Cylinder head, Fuel rail and injector, EGR Cooler improvements 1 (diesel VII Phase 1)	1-2	2010	46	CI	4.7
	3-14	2010	34	CI	4.7
EGR/Intake & exhaust manifolds/turbo/VVT/ports phase 2 package	5-13	2021	255	CI	1.1
Turbo compounding 1 - mechanical (diesel VIII Phase 1)	5-13	2017	1100	CI	3.9
Turbo compound with clutch - diesel phase 2 package	5-13	2021	1127	CI	1.8
Waste heat recovery (same as diesel engine XI Phase 1)	4-13	2021	11377	CI	8.0
Model based control	2-4	2021	129	CI	2.0
Combustion/FI/Control - phase 2 package	5-13	2021	154	CI	1.1
Downspeed - phase 2 package	5-13	2021	0	SI,CI	0.1
Low friction lubricants (gas I phase 1)	1-14	2010	4	SI	0.5
Engine friction reduction 1 - (gas III Phase 1)	1-2	2010	128	SI	2.0
	3-4		104	SI	2.0
Engine changes to accommodate low friction lubes - required for engine friction reduction 2	1	2014	6	SI	0.5
Engine friction reduction 2	1	2014	266	SI	2.0
Stoichiometric gasoline direct injection (SGDI) (gas IV Phase 1)	1	2006	471	SI	1.5
	2	2010	471	SI	1.5
	3-4	2014	471	SI	1.5
Coupled Cam Phasing - SOHC & OHV only (gas II Phase 1 - except pickups)	1	2015	45	SI	2.0
	2-4	2010	51	SI	2.6
Intake Cam Phasing VVT - DOHC gas	1	2015	91	SI	1.5
Dual Cam Phasing VVT - DOHC gas	1	2015	193	SI	2.0
Discrete Variable Valve Lift (DVVL) - Gasoline	1	2015	310	SI	2.0
Continuously Variable Valve Lift (CVVL) - Gasoline	1	2015	519	SI	5.1
Cylinder deactivation - gas	1	2021	205	SI	3.9
Turbocharge and downsize SGDI V8 to V6 (gas V Phase 1)	1-4	2018	1917	SI	2.1
Cooled EGR - gasoline	1	2010	390	SI	4.0
6x2 axle	8-13	2018	223	All	1.7-2.2[1]
Axle disconnect	4	2014	124	All	1.6[1]
Axle downspeed	5-13	2018	61	All	1.2-3.5[1]
High efficiency axle	2-3	2018	148	All	2.0
	4-14	2018	223	All	2.0

Table 8. Standard technology matrix for freight trucks (cont.)

	Vehicle Category	Introduction Year	Capital Costs (2015$)	Engine Type	Incremental Fuel Economy Improvement (%)
8 speed transmission (= 2 gears+HEG+ASL1 for pickups, not for vocational)	1	2018	478	SI,CI	2.7
	2-4	2018	583	SI,CI	1.2
Automated & Automated manual transmission (AMT)	4-14	2018	5025	SI,CI	2.0
High efficiency gearbox (HEG)	2-4	2021	351	SI,CI	8.2
	5-13	2021	351	SI,CI	1.0
Advanced Shift Strategy (was Driveline integration in Proposal)	2-4	2021	97	SI,CI	4.5
Early torque converter lockup (TORQ)	2-4	2015	34	SI,CI	1.6
Auto transmission, power-shift	5-13	2018	15922	SI,CI	2.0
Dual clutch transmission (DCT)	5-14	2021	17241	SI,CI	2.0
Neutral coast - Requires automatic	5-13	2014	0	SI,CI	1.0
Advanced cruise control - requires automatic	5-13	2018	980	All	2.0
Stop-start (no regeneration for pickups, with enhancements for vocational)	1	2015	563	SI,CI	1.1[1]
	2	2021	965	SI,CI	11.4[1]
	3	2021	1015	SI,CI	9.7[1]
	4	2021	1865	SI,CI	7.9[1]
Neutral idle	2-4	2018	121	SI,CI	4.1-6.0[1]
Tamper-Proof AESS	2-3	2018	33	SI,CI	4.8-5.7[1]
	4	2014	33	SI,CI	4.1[1]
	5-13	2014	33	SI,CI	4.1
Adjustable AESS programmed to 5 min	11-13	2014	33	SI,CI	1.0
Tamper-Proof AESS w/ Diesel APU	11-13	2014	6461	SI,CI	4.1
Adjustable AESS w/ Diesel APU	11-13	2014	6461	SI,CI	3.3
Tamper-Proof AESS w/ Battery APU	11-13	2015	5574	SI,CI	6.4
Adjustable AESS w/ Battery APU	11-13	2014	5574	SI,CI	5.1
Tamper-Proof AESS w/ Auto Stop-Start	11-13	2015	8690	SI,CI	3.3
Adjustable AESS w/ auto stop-start	11-13	2015	8690	SI,CI	2.6
Tamper-proof AESS w/ FOH Cold, Main Engine Warm	11-13	2014	997	SI,CI	2.8
Adjustable AESS w/ FOH Cold, Main engine warm	11-13	2021	997	SI,CI	2.2
Mild hybrid (HEV)	1	2017	2854	SI,CI	3.2
	2	2018	6960	SI,CI	12.0
	3	2018	10939	SI,CI	12.0
	4	2018	18269	SI,CI	12.0
Strong Hybrid (without stop-start for vocational)	1	2021	7087	SI,CI	17.2
	2-4	2021	13044	SI,CI	8.0

[1]Estimated with Greenhouse Gas Emissions Model (GEM)

Sources: Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles- Phase2, U.S. Environmental Protection Agency and U.S. Department of Transportation, Final Rules, Federal Register, Vol. 81, No. 206 (October 2016).

Final Rulemaking to Establish Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles- Phase2, Regulatory Impact Analysis, U.S. Environmental Protection Agency and U.S. Department of Transportation, (August 2016).

Commercial Medium- and Heavy-Duty (MD/HD) Truck Fuel Efficiency Technology Study – Report #1, National Highway Traffic Safety Administration (June 2015, Revised October 2015).

Greenhouse Gas Emissions Model (GEM) for Medium- and Heavy-Duty Vehicle Compliance, U.S. Environmental Protection Agency (July 2016).

The Freight Truck Component uses projections of industrial output—reported in NEMS by North America Industry Classification System (NAICS) codes—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) [17] with geographic information system that is based regionalization between origin/destination points [18]. 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 [19],[20].

Fuel economy of new freight trucks is dependent on the market penetration of advanced technology components [21]. 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 [22]. Initial freight truck stocks by vintage are obtained from analysis of R. L. Polk & Co. and Polk data (a foundation of IHS market automotive solutions) 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 [23]. 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 [24]. Historic freight rail efficiencies are based on historical data taken from the U.S. Department of Transportation [25]. 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 [26].

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 [27],[28].

Domestic shipping efficiencies are taken from the Transportation Energy Data Book [29].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 [30]. Historic regional domestic shipping fuel share estimates are distributed according to regional shares in the State Energy Data System (SEDS) [31].

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

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 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 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 and are 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 [32].

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 9). For each region, demand is computed for domestic route travel (i.e., both takeoff and landing occur in the same region) and international route travel (i.e., 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 9. 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, 2015 World Jet Inventory, data tables (2015).

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 2015 data for population, GDP, and RPM (Table 10) [33], as well as per capita disposable income for the United States, per capita Gross Domestic Product (GDP) at Purchasing Power Parity (PPP) 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, GDP, and fuel cost. For the non-U.S. regions, revenue ton-miles are based on GDP PPP growth in the region [34].

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 MY 2015, new passenger aircraft sales, and the survival rate by vintage (Table 11) [35]. New passenger aircraft sales are a function of revenue passenger miles and gross domestic product.

Table 10. 2015 Regional population, GDP, per capita GDP, domestic and international RPM and per capita RPM

Region	Population (million)	GDP (2010 PPP)	GDP per Capita
United States	321.9	12,240	38,026
Canada	36.0	1,506	41,881
Central America	215.2	2,854	13,264
South America	418.0	6,434	15,393
Europe	613.0	20,499	33,443
Africa	1,147.0	5,106	4,451
Middle East	227.1	5,600	24,662
Russia	289.7	4,528	15,629
China	1,413.6	18,439	13,045
Northeast Asia	176.6	6,189	35,052
Southeast Asia	676.4	6,526	9,648
Southwest Asia	1,746.4	8,605	4,927
Oceania	31.9	1,216	38,082
Region	**RPM (billion)**	**RPM per Capita (thousand)**	
Domestic			
United States	641.5	1,993.2	
Canada	28.2	783.1	
Central America	26.4	122.6	
South America	98.9	236.6	

Table 10. 2015 Regional population, GDP, per capita GDP, domestic and international RPM and per capita RPM (cont.)

Region	RPM (billion)	RPM per Capita (thousand)
Europe	495.1	807.8
Africa	36.8	32.1
Middle East	63.5	279.7
Russia	85.8	296.2
China	350.9	248.2
Northeast Asia	69.9	396.0
Southeast Asia	120.5	178.2
Southwest Asia	49.2	28.2
Oceania	63.9	1,999.8
International		
United States	266.9	829.2
Canada	93.5	2,600.3
Central America	93.1	432.8
South America	70.1	167.6
Europe	447.9	730.8
Africa	71.2	62.1
Middle East	187.1	824.1
Russia	94.4	325.9
China	141.6	100.2
Northeast Asia	144.9	820.7
Southwest Asia	171.3	253.2
Southwest Asia	77.5	44.4
Oceania	59.0	1,846.9

Source: Global Insight 2010 PPP, Boeing Current Market Outlook 2015.

Table 11. 2015 Regional passenger and cargo aircraft supply

Passenger and Cargo Aircraft Type	New	Age of Aircraft (years) 1-10	11-20	21-30	30 or more	Total
Passenger						
Narrow Body						
United States	170	1,062	1,691	824	123	3,870
Canada	19	108	121	52	23	323
Central America	34	193	78	52	38	395
South America	48	385	175	89	120	817
Europe	166	1,575	1,166	303	23	3,233
Africa	12	137	152	145	120	566
Middle East	54	348	135	121	45	703
Russia	18	262	293	206	204	983
China	302	1,535	378	52	3	2,270
Northeast Asia	17	258	110	16	9	410
Southeast Asia	104	725	143	135	63	1,170
Southwest Asia	13	299	47	49	26	434
Oceania	12	156	106	4	-	278
Wide Body						
United States	37	101	306	190	25	659
Canada	6	31	28	31	2	98
Central America	3	17	6	6	3	35
South America	15	70	36	12	2	135
Europe	57	327	395	105	9	893
Africa	15	62	48	28	23	176
Middle East	65	371	166	93	26	721
Russia	4	54	70	34	-	162
China	49	293	82	21	-	445
Northeast Asia	35	174	150	31	-	390
Southeast Asia	61	247	160	33	8	509
Southwest Asia	8	58	22	29	3	120
Oceania	8	65	38	9	-	120
Regional Jets						
United States	115	678	1,633	300	8	2,734
Canada	14	120	128	163	32	457
Central America	9	108	62	70	3	252
South America	25	230	74	107	14	450
Europe	27	605	414	357	9	1,412
Africa	6	140	163	181	18	508

Table 11. 2015 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
Middle East	3	85	44	84	1	217
Russia	14	116	137	104	22	393
China	15	140	62	1	-	218
Northeast Asia	6	47	42	8	-	103
Southeast Asia	33	201	73	76	23	406
Southwest Asia	4	66	26	10	1	107
Oceania	7	107	90	180	8	392
Cargo						
Narrow Body						
United States	-	3	36	168	77	284
Canada	-	-	1	11	18	30
Central America	-	2	3	8	6	19
South America	-	-	2	14	38	54
Europe	-	-	13	86	21	120
Africa	-	-	2	13	35	50
Middle East	-	-	3	2	10	15
Russia	2	10	6	5	1	24
China	-	2	29	49	-	80
Northeast Asia	-	-	-	2	-	2
Southeast Asia	-	-	3	12	19	34
Southwest Asia	-	-	2	7	5	14
Oceania	-	-	-	13	1	14
Wide Body						
United States	19	99	147	209	106	580
Canada	-	-	1	7	6	14
Central America	-	1	1	2	5	9
South America	-	12	4	1	6	23
Europe	6	54	38	46	19	163
Africa	2	4	2	3	3	14

Table 11. 2015 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
Middle East	8	36	11	20	15	90
Russia	3	9	4	10	5	31
China	7	51	21	12	1	92
Northeast Asia	2	25	24	13	-	64
Southeast Asia	-	10	30	6	1	47
Southwest Asia	-	-	-	2	2	4
Oceania	-	1	-	-	-	1
Regional Jets						
United States	-	-	2	44	3	49
Canada	-	-	-	9	-	9
Central America	-	-	1	6	-	7
South America	-	-	-	3	-	3
Europe	-	-	5	99	7	111
Africa	-	-	5	5	1	11
Middle East	-	-	-	2	1	3
Russia	-	-	-	1	1	2
China	-	-	-	-	-	-
Northeast Asia	-	-	-	-	-	-
Southeast Asia	-	-	-	5	-	5
Southwest Asia	-	-	1	2	-	3
Oceania	-	-	-	6	1	7
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, 2015 World Jet Inventory (2015).

Wide- and narrow-body passenger planes more than 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 30-year-old and older aircraft. 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 12) 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 12. Standard technology matrix for air travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (1987$/gallon)
Technology #1	2008	0.025	1.34
Technology #2	2014	0.060	1.34
Technology #3	2020	0.120	1.34
Technology #4	2025	0.140	1.34
Technology #5	2018	0.170	1.34
Technology #6	2018	0.050	1.34

Source: Jet Information Services, 2015 World Jet Inventory, data tables (2015).

Legislation and regulations

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

The AEO2018 Reference case includes the attribute-based CAFE standards for LDVs for MY 2011, and the joint attribute-based CAFE and vehicle Greenhouse Gas (GHG) emissions standards for MYs 2012 through 2016 and for MYs 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 [36], which for the first time establishes GHG emissions and fuel consumption standards for on-road heavy-duty trucks and their engines. The AEO2018 Reference case incorporates the standards for heavy-duty vehicles (HDVs) with 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. AEO2018 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 standards begins for MY 2021 vehicles and is fully implemented (i.e., phased in) by MY 2027. The same vehicle classes and their engines are included, but the second round also adds trailers (begins MY 2018) and heavy-haul tractors, which were previously unregulated under the HD National Program. The standards are held constant in subsequent model years.

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 three years and can only be applied to the fleet (car or light truck) from which the credit was earned. Starting in MY 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.

Although 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 MYs 2011 through 2013, the maximum transfer is 1.0 mpg; for MYs 2014 through 2017, the maximum transfer is 1.5 mpg; and for MYs 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 it does not model the trading of credits across manufacturers. AEO2018 does not consider trading of credits because 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 by EISA2007. Prior to passage of this Act, the CAFE credits under AMFA were scheduled to expire after MY 2010. 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 MY 2020. NEMS does model CAFE credits earned from alternative fuel vehicle sales.

American Recovery and Reinvestment Act of 2009 (ARRA) and Energy Improvement and Extension Act of 2008 (EISA2008)

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 kilowatthours (kWh) of capacity and be propelled to a significant extent by an electric motor that draws electricity from a battery 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. 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 AEO2018.

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 13).

Table 13. EPACT legislative mandates for AFV purchases (percent) by fleet type and year

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

Source: U.S. Department of Energy,Energy Efficiency and Renewable Energy (Washington, DC, 2005), https://www.ecfr.gov/cgi-bin/text-idx?SID=5e97f5d9e11e7f57de987560e311c030&node=10:3.0.1.4.33&rgn=div5#se10.3.490_18.

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 [37].

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 U.S., French, and Canadian waters as Emission Control Areas [38]. 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 nm from coasts of the United States, Canada, and the French territories, but they 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 [39],[40]. In October 2016, IMO members agreed to the 2008 MARPOL amendments that implement a new global limit in 2020 for sulfur emissions from ships. The ships will have to use fuel oil on board with a sulfur content of no more than 0.50% m/m, against the current limit of 3.50%, which has been in effect since January 1, 2012. IMO's interpretation of *fuel oil used on board* includes use in main and auxiliary engines and boilers.

Low-Emission Vehicle Program (LEVP)

The LEVP was originally passed into legislation in 1990 in the State of California. The program began as the implementation of a voluntary opt-in pilot program under the purview of Clean Air Act Amendments of 1990 (CAAA1990), which includes a provision that other states could opt in to the California program to achieve lower emissions levels than would otherwise be achieved through CAAA1990. The California

LEVP has been adopted by 15 states. The program was amended and expanded in 1998 to cover more vehicles, increase stringency, and add zero-emission vehicle (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 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 MY 2018 and later. The ZEV program affects MY 2018 and later vehicles, requiring automakers to earn credits for alternative fuel vehicles based on a percentage of their LDV sales in California. Nine other states (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont) have adopted California's ZEV program. The ZEV sales requirement is administered through credits that are earned for selling specific types of vehicles, including 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, such as the electric driving range of electric vehicles. The total percentage requirement starts at 4.5% for MY 2018 sales and increases to 22% for MY 2025 sales. Manufacturers can carry over excess credits from one year to the next, which allows banking of credits. Banked credits from over-compliance can be used in later years to help meet credit requirements. Full ZEVs are required to make up 16% of the required credits by MY 2025, mandating the sale of vehicles powered by either electricity or hydrogen fuel cells.

California Global Warming Solutions Act of 2006: emissions limit (Assembly Bill 32)

The California Global Warming Solutions Act of 2006 set a statewide reduction of GHG emissions to 1990-equivalent levels by 2020. On September 8, 2016, California enacted an Act to add Section 38566 to the Health and Safety Code, relating to greenhouse gases (Senate Bill 32). Senate Bill 32 codifies a 2030 GHG emissions reduction target of 40% below 1990 levels. Senate Bill 32 and Assembly Bill 32 provisions direct state policies that affect transportation sector model assumptions by targeting a higher adoption of ZEVs and other alternative powertrains, and a decrease in travel.

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