Transportation Demand

The NEMS Transportation Demand Module estimates transportation energy consumption across the nine Census Divisions (see Figure 5) 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 the sum of energy use in eight transport modes: light-duty vehicles (cars and light trucks), commercial light trucks (8,501-10,000 lbs gross vehicle weight), freight trucks (>10,000 lbs gross vehicle weight), buses, freight and passenger aircraft, freight and passenger rail, 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

Light-duty vehicle assumptions

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, and fractional horsepower change.

The vehicle sales share module holds the share of vehicle sales by manufacturers constant within a vehicle size class at 2008 levels based on National Highway Traffic and Safety Administration (NHTSA) data [1]. 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 [2].

The MTCC utilizes 86 technologies for each size class and manufacturer based on the cost-effectiveness of each technology and an initial availability year. The discounted stream of fuel savings is compared to the marginal cost of each technology to determine cost effectiveness and market penetration. The fuel economy module assumes 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 year2011 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 price 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
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	1150.07	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	7.5	1256.96	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	1383.90	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2096.84	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	1605.80	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	1530.88	0.00	-100	0	2009	3.75

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

	Fuel Efficiency Change %	Incremental Cost $2000	Incremental Cost ($/UnitWt.)	Absolute Incremental Weight (Lbs.)	Per Unit Incremental Weight (Lbs./UnitWt.)	Introduction Year	Horse power Change %
OHV to DOHC TBDS II-I4	26.3	1586.36	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2445.33	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1046.15	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1968.59	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	21.2	1130.47	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	2031.83	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1601.81	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1565.84	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1380.40	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1634.58	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1498.70	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1302.07	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	2902.00	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).
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	Horse power 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	1150.07	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	6.5	1256.96	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
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	1383.90	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	20.2	2096.84	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	1605.80	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	1530.88	0.00	-100	0	2009	3.75

Table 7.2. 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	Horse power Change %
OHV to DOHC TBDS II-I4	26.3	1586.36	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	24.5	2445.33	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	26.3	1046.15	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	24.5	1968.59	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	21.2	1130.47	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	2031.83	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	30.7	1601.81	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	32.6	1565.84	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	30.7	1380.40	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	27.1	1634.58	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	32.6	1498.70	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	30.7	1302.07	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	2902.00	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.

Degradation factors are used to convert new vehicle tested fuel economy values to "on-road" fuel economy values (Table 7.3). 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.

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 Sector Modules of the National Energy Modeling System, Model Documentation 2011, DOE/EIA-M070(2011), (Washington, DC, 2012).

Commercial light duty fleet assumptions

The Transportation Demand Module divides commercial light-duty fleets into three types: business, government, and utility. Based on this classification, 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 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 automobile sales to fleets in 2009, 75.1 percent are used in business fleets, 9.6 percent in government fleets, and 15.3 percent in utility fleets. Of total light truck sales to fleets in 2009, 47.3 percent are used in business fleets, 15.1 percent in government fleets, and 37.6 percent in utility fleets [3]. Both the automobile and light truck shares by fleet type are held constant from 2009 through 2040. In 2009, 18.2 percent of all automobiles sold and 16.9 percent 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.

Table 7.4. 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
	SM Pk	**LG Pk**	**SM Van**	**LG Van**	**SM Util**	**LG Util**
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.doe.gov/cneaf/alternate/page/aftables/afvtransfuel_II.html #in use.

Alternative-fuel shares of fleet vehicle sales by fleet type are held constant at 2005 levels (Table 7.4). Size class sales shares of vehicles are also held constant at 2005 levels (Table 7.5) [4]. Individual sales shares of new vehicles purchased by technology type are assumed to remain relatively constant for utility, government, and for business fleets using the previous 5-year average (Table 7.6) [5].

Annual vehicle miles traveled (VMT) per vehicle by fleet type stays constant over the forecast 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. Commercial fleet size class shares by fleet and vehicle type, 2005

percentage

Fleet Type by Size Class	Automobiles	Light Trucks
Business Fleet		
Mini	3.1	2.5
Subcompact	23.4	8.4
Compact	26.6	23.3
Midsize	36.2	8.1
Large	9.9	14.2
2-seater	0.8	43.6
Government Fleet		
Mini	0.2	6.7
Subcompact	4.6	43.6
Compact	20.6	10.4
Midsize	28.6	17.1
Large	46.0	3.8
2-seater	0.0	18.4
Utility Fleet		
Mini	1.5	7.3
Subcompact	12.5	38.7
Compact	10.0	11.8
Midsize	59.2	18.9
Large	16.4	7.2
2-seater	0.4	16.1

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

Table 7.6. 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

Sources: 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 model

The Light Commercial Truck Module of the NEMS Transportation Model represents light trucks that have a 8,501 to 10,000 pound gross vehicle weight rating (Class 2B vehicles). These vehicles are assumed to be used primarily for commercial purposes. The module 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 [6]. The distribution of vehicles by vintage, and vehicle scrappage rates are derived from R.L. Polk & Co. registration data [7],[8]. Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle [9],[10].

The growth in light commercial truck VMT is a function of industrial output for agriculture, mining, construction, total manufacturing, utilities, and personal travel. These groupings were chosen for their correspondence with output measures being forecast by NEMS. 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 (<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 (i.e., gasoline versus diesel hybrids). The third level choice determines market share among the different technology sets [11]. The technology sets include:

- Conventional fuel capable (gasoline, diesel, compressed natural gas (CNG) and liquefied natural gas (LNG), 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), and
- Electric battery powered (100 mile range and 200 mile range) [12]

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 [13]. 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 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 to vehicle price elasticities. Initial CVCC vehicle stocks are set according to the EIA survey EIA-886 [14]. A fuel switching algorithm based on the relative fuel prices for alternative fuels compared to gasoline is used to determine the percentage of total VMT represented by alternative fuels in bi-fuel and flex-fuel alcohol vehicles.

Freight truck assumptions

The freight truck module 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 7.7). 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 for heavy include parceling the 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 [15]. The technology input data specific to the different types of trucks including the year of introduction, incremental fuel efficiency improvement, and capital cost of introducing the new technologies, are shown in Table 7.8.

Table 7.7. 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.

Table 7.8. 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	0	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, aircompressor	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: aftertreatment 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, low tension piston rings, roller cam followers, piston skirt design, improved crankshaft design and bearings; coating	1-2	2010	116	1.0

Table 7.8. Standard technology matrix for freight trucks (cont.)

Technology Type	Vehicle Category	Introduction Year	Capital Costs (2009$)	Incremental Fuel Economy Improvement (%)
Diesel Engine IV: engine friction reduction, improved bearings to allow lower viscosity oil	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
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; coating	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	750	13.0
Gasoline Engine VII: HCCI	1-4	2030	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

Source: 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 module uses projections of industrial output to estimate growth in freight truck travel. The industrial output is converted to an equivalent measure of volume output using freight adjustment coefficients [16],[17]. These freight adjustment coefficients vary by North American Industry Classification System (NAICS) code with the deviation diminishing gradually over time toward parity. Freight truck load-factors (ton-miles per truck) by NAICS code are constants formulated from historical data [18].

Fuel economy of new freight trucks is dependent on the market penetration of advanced technology components [19]. 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 the U.S. Energy Information Administration using Vehicle Inventory and Use Survey (VIUS) data [20]. Initial freight truck stocks by vintage are obtained from R. L. Polk & Co. and are distributed by fuel type using VIUS data. Vehicle scrappage rates are also estimated by the U.S. Energy Information Administration using R. L. Polk & Co. data.

Freight rail assumptions

The freight rail module uses the industrial output by NAICS code measured in real 2005 dollars and converts these dollars into an adjusted volume equivalent. Coal production from the NEMS Coal Market Module is used to adjust coal-based rail travel. Freight rail adjustment coefficients (used to convert dollars to volume equivalents) are based on historical data and remain constant [21],[22]. Initial freight rail efficiencies are based on historic data taken from the Transportation Energy Data Book [23]. The distribution of rail fuel consumption by fuel type is also based on historical data and remains constant over the projection [24]. Regional freight rail consumption estimates are distributed according to the State Energy Data System [25].

Domestic and international shipping assumptions

Similar to the previous sub-module, the domestic freight shipping module uses the industrial output by NAICS code measured in real 2005 dollars and converts these dollars into an adjusted volume equivalent.

The freight adjustment coefficients (used to convert dollars to volume equivalents) are based on historical data. Domestic shipping efficiencies are based on the model developed by Argonne National Laboratory. The energy consumption in the international shipping module 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 and remains constant throughout the projection [26]. Regional domestic shipping consumption estimates are distributed according to the residual oil regional shares in the State Energy Data System [27].

The air model

The air model is a thirteen region world demand and supply model (Table 7.9). For each region, demand is computed for domestic travel (both takeoff and landing occur in the same region) and international travel (either takeoff or landing is in the region but not both). Once the demand for aircraft is determined, the stock efficiency module moves aircraft between regions to satisfy the demand.

Table 7.9. 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	S. Africa
7	Middle East	Egypt
8	Russia	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, 2009 World Jet Inventory, data tables (2009)

Air travel demand assumptions

The air travel demand module 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 7.10, [28] 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 [29].

Airport capacity constraints based on the Federal Aviation Administration (FAA) Airport Capacity Benchmark Report 2004 are incorporated into the air travel demand module using airport capacity measures [30]. 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 assumptions

The aircraft stock and efficiency module 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 sales, and the survival rate by vintage (Table 7.11) [31]. New passenger sales are a function of revenue passenger miles and gross domestic product.

Wide and narrow body planes over 25 years of age are placed as cargo jets according to a cargo percentage varying from 50 percent of 25-year-old planes to 100 percent 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 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 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. A generic set of new technologies (Table 7.12) 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 State Energy Data System estimate of regional jet fuel shares.

Table 7.10. 2010 Regional population, gdp, per capita gdp, domestic and international rpm and per-capita rpm

Region	Population (million)	GDP (2006$)	GDP_PC
United States	310.8	13,088	42,106.0
Canada	34.1	1,239	36,383.8
Central America	197.3	2,025	10,262.7
South America	393.1	3,993	10,158.3
Europe	607.9	15,367	25,280.1
Africa	931.9	2,636	2,829.1
Middle East	298.7	3,083	10,318.7
Russia	278.6	2,843	10,203.4
China	1,347.3	9,577	7,108.2
Northeast Asia	200.6	5,024	25,045.1
Southeast Asia	627.9	3,752	5,975.7
Southwest Asia	1,629.3	4,971	3,015.2
Oceania	27.9	909	32,641.2

Region	RPM (billion)	RPM_PC (thousand)
Domestic		
United States	564.8	1,816.9
Canada	27.1	795.0
Central America	20.1	101.8
South America	70.7	179.9
Europe	399.4	657.0
Africa	31.0	33.2
Middle East	47.8	159.9
Russia	32.8	117.9
China	208.0	154.4
Northeast Asia	44.5	221.8
Southeast Asia	81.0	129.0
Southwest Asia	30.4	18.7
Oceania	50.0	1,795.2

Table 7.10. 2010 Regional population, gdp, per capita gdp, domestic and international rpm and per-capita rpm (cont.)

Region	RPM (billion)	RPM_PC (thousand)
International		
United States	244.2	785.7
Canada	53.1	1,559.8
Central America	63.7	322.9
South America	49.8	126.7
Europe	378.3	622.4
Africa	59.2	63.5
Middle East	113.5	380.0
Russia	31.0	111.1
China	90.9	67.5
Northeast Asia	93.0	463.5
Southeast Asia	132.9	211.6
Southwest Asia	49.5	30.4
Oceania	44.0	1,579.9

Source: Global Insight 2006 chained weighted dollars, Boeing Current Market Outlook 2009.

Table 7.11. 2010 Regional passenger and cargo aircraft supply

			Age of Aircraft (years)			
Aircraft Type	**New**	**1-10**	**11-20**	**21-30**	**>30**	**Total**
Passenger						
Narrow Body						
United States	98	1456	1397	680	185	3816
Canada	5	144	80	17	13	259
Central America	12	173	46	74	58	363
South America	42	279	138	146	109	714
Europe	204	1630	953	191	20	2998
Africa	22	148	149	162	106	587
Middle East	60	215	160	58	36	529
Russia	14	202	372	283	215	1086
China	168	847	282	11	1	1309
Northeast Asia	22	149	109	7	4	291
Southeast Asia	83	239	201	120	28	671
Southwest Asia	27	224	46	43	7	347
Oceania	14	165	49	2	0	230
Wide Body						
United States	9	201	294	129	18	651
Canada	0	30	32	22	0	84
Central America	0	9	7	8	0	24
South America	3	43	43	6	2	97
Europe	36	345	368	53	9	811
Africa	2	57	43	35	12	149
Middle East	36	236	145	70	11	498
Russia	4	20	83	51	0	158
China	22	132	11 3	4	0	271
Northeast Asia	17	146	158	23	0	344
Southeast Asia	21	204	166	18	7	416
Southwest Asia	3	51	32	23	4	113
Oceania	7	56	55	8	0	126
Regional Jets						
United States	35	1774	487	49	9	2354
Canada	8	132	118	72	25	355
Central America	5	85	61	18	0	169
South America	32	94	11 3	31	3	273
Europe	84	669	638	106	0	1497
Africa	24	106	124	59	13	326
Middle East	15	86	83	10	3	197
Russia	1	73	79	71	3	227

Table 7.11. 2009 Regional passenger and cargo aircraft supply (cont.)

		Age of Aircraft (years)				
Aircraft Type	**New**	**1-10**	**11-20**	**21-30**	**>30**	**Total**
China	18	112	15	1	0	146
Northeast Asia	8	56	5	0	0	69
Southeast Asia	18	78	90	41	7	234
Southwest Asia	7	53	27	5	3	95
Oceania	6	98	91	42	0	237
Cargo						
Narrow Body						
United States	0	0	76	106	218	400
Canada	0	0	4	8	21	33
Central America	0	2	2	5	8	17
South America	0	0	3	17	42	62
Europe	0	0	24	68	10	102
Africa	0	0	4	13	57	74
Middle East	0	0	2	5	6	13
Russia	0	5	2	2	8	17
China	0	2	20	16	1	39
Northeast Asia	0	0	0	0	0	0
Southeast Asia	0	0	0	8	14	23
Southwest Asia	0	0	2	10	5	17
Oceania	0	0	0	10	3	13
Wide Body						
United States	14	86	227	184	102	613
Canada	0	0	0	3	4	7
Central America	0	2	1	3	4	10
South America	0	8	2	7	7	24
Europe	5	32	52	54	8	151
Africa	0	0	2	1	1	4
Middle East	4	10	18	18	5	55
Russia	0	5	9	5	0	19
China	9	35	36	11	0	91
Northeast Asia	0	30	19	4	0	53
Southeast Asia	0	32	18	4	0	54
Southwest Asia	0	0	5	4	1	10
Oceania	0	0	0	0	0	0
Regional Jets						
United States	0	0	22	3	0	25
Canada	0	0	0	7	0	7
Central America	0	0	4	1	0	5
South America	0	0	0	4	0	4
Europe	0	2	55	40	0	97
Africa	0	0	0	5	1	6
Middle East	0	0	0	0	0	0
Russia	0	0	1	0	0	1
China	0	0	0	0	0	0
Northeast Asia	0	0	0	0	0	0
Southeast Asia	0	0	2	3	0	5
Southwest Asia	0	0	1	0	0	1
Oceania	0	0	1	3	0	4
Survival Curve (fraction)	**New**	**5**	**10**	**20**	**40**	
Narrow Body	1.000	0.9998	0.9994	0.9970	0.8000	
Wide Body	1.000	0.9984	0.9961	0.9870	0.7900	
Regional Jets	1.000	0.9971	0.9950	0.9830	0.7800	

Source: Jet Information Services, 2009 World Jet Inventory (2009).

Table 7.12. Standard technology matrix for air travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (1987$/per gallon)
Technology #1	2008	0.03	1.34
Technology #2	2014	0.07	1.34
Technology #3	2020	0.11	1.34
Technology #4	2025	0.15	1.34
Technology #5	2018	0.20	1.34
Technology #6	2018	0.00	1.34

Source: Jet Information Services, 2009 World Jet Inventory, data tables (2009)

Legislation and regulations

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

The *AEO2013* 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, the EPA and NHTSA jointly announced a final rule, called the HD National Program [32], which for the first time establishes greenhouse gas (GHG) emissions and fuel consumption standards for on-road heavy-duty trucks and their engines. The *AEO2013* Reference case incorporates the new 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. *AEO2013* models standard compliance among 13 HDV regulatory classifications that represent the discrete vehicle categories set forth in the rule.

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 will allow 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 begins in 2011, EISA2007 allows manufacturers to apply credits earned to any of the 3 model years prior to the model year the credits are earned, and to any of the 5 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. The *AEO2013* does not consider trading of credits since this would require significant modifications to the 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 vehicles 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 kilowatthours 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 kilowatthours, an additional $417 per kilowatthour 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 phaseout 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 percent of the total value for the first two calendar quarters of the phase-out period and then to 25 percent 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 percent against the cost of a qualified electric vehicle with a battery capacity of at least 4 kilowatthours 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 *AEO2013*.

Energy Policy Act of 1992 (EPACT)

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 Module calculations. Total projected AFV sales are divided into fleets by government, business, and fuel providers (Table 7.13).

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 [33].

Table 7.13. EPACT legislative mandates for AFV purchases by fleet type and year
percent

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

Source: U.S. Energy Information Administraiton, Energy Efficiency and Renewable Energy (Washington, DC, 2005), www1.eere.energy.gov/vehicles and fuels/epact/state/statutes_regulations.,html.

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 (CAAA90), 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 CAAA90. Fourteen states have elected to adopt the California LEVP.

The LEVP is an emissions-based policy, setting sales mandates for 6 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 requires that in 2005, 10 percent of a manufacturer's sales are ZEVs or equivalent ZEV earned credits, increasing to 11 percent in 2009, 12 percent in 2012, 14 percent in 2015, and 16 percent in 2018 where it remains constant thereafter. In August 2004, CARB enacted further amendments to the LEVP that place a greater emphasis on emissions reductions from PZEVs and AT-PZEVs and requires that manufacturers produce a minimum number of fuel cell and electric vehicles. In addition, manufacturers are allowed to adopt alternative compliance requirements for ZEV sales that are based on cumulative fuel cell vehicle sales targets for vehicles sold in all States participating in California's LEVP. Under the alternative compliance requirements, ZEV credits can also be earned by selling battery electric vehicles. Currently, all manufacturers have opted to adhere to the alternative compliance requirements. The mandate still includes phase-in multipliers for pure ZEVs and allows 20 percent of the sales requirement to be met with AT-PZEVs and 60 percent of the requirement to be met with PZEVs. AT-PZEVs and PZEVs are allowed 0.2 credits per vehicle. EIA assumes that credit allowances for PZEVs will be met with conventional vehicle technology, hybrid vehicles will be sold to meet the AT-PZEV allowances, and that hydrogen fuel cell vehicles will be sold to meet the pure ZEV requirements under the alternative compliance path.

Transportation alternative case

Integrated High Technology case

In the Integrated High Technology case for cars and light trucks, the conventional fuel saving technology characteristics are based on NHTSA and EPA values [34]. Tables 7.14 and 7.15, summarize the high technology matrices for cars and light trucks. Table 7.16 reflects the high technology case assumptions for freight trucks. These reflect optimistic values, with respect to efficiency improvement and capital cost, for advanced technologies [35-38]. For the air module, the Integrated High Technology case reflects earlier introduction years for the new aircraft technologies and a greater penetration share, Table 7.17.

Table 7.14. High technology matrix for cars

	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	4.4	89.92	0.00	0	-6	1980	0
Mass Reduction I	1.1	0.00	0.06	0	-1.5	2005	0
Mass Reduction II	2.9	0.00	0.13	0	-3.5	2009	0
Mass Reduction III	5.9	0.00	0.37	0	-10	2011	0
Mass Reduction IV	9.2	0.00	0.56	0	-15	2099	0
Mass Reduction V	12.8	0.00	0.65	0	-20	2099	0
Aerodynamics I	2.6	43.35	0.00	0	0.5	2000	0
Aerodynamics II	5.4	182.96	0.00	0	1	2011	0
6 Speed Manual	2.4	230.03	0.00	20	0	1995	0
Aggressive Shift Logic I	2.8	29.20	0.00	0	0	1999	0
Aggressive Shift Logic II	7.4	24.46	0.00	0	0	2017	0
Early Torque Converter Lockup	0.6	26.54	0.00	0	0	2002	0
High Efficiency Gearbox	1.8	180.56	0.00	0	0	2017	0
5 Speed Automatic	1.5	93.52	0.00	20	0	1995	0
6 Speed Automatic	2.4	243.05	0.00	30	0	2003	0
7 Speed Automatic	5.6	360.93	0.00	40	0	2009	0
8 Speed Automatic	8.8	479.55	0.00	50	0	2010	0
Dual Clutch Automated Manual	6.1	51.08	0.00	-10	0	2004	0
CVT	9.2	225.88	0.00	-25	0	1998	0
Low Friction Lubricants	0.8	2.88	0.00	0	0	2003	0
Engine Friction Reduction I-4 cyl	2.2	42.44	0.00	0	0	2000	1.25
Engine Friction Reduction I-6 cyl	2.9	64.02	0.00	0	0	2000	1.25
Engine Friction Reduction I-8 cyl	3.1	84.89	0.00	0	0	2000	1.25
Engine Friction Reduction II-4 cyl	4.0	90.64	0.00	0	0	2017	2.25
Engine Friction Reduction II-6 cyl	5.2	133.08	0.00	0	0	2017	2.25
Engine Friction Reduction II-8 cyl	5.6	175.53	0.00	0	0	2017	2.25
Cylinder Deactivation-6 cyl	7.2	168.36	0.00	10	0	2004	0
Cylinder Deactivation-8 cyl	7.6	188.97	0.00	10	0	2004	0
VVT I-OHV Intake Cam Phasing-6 cyl	2.9	39.51	0.00	20	0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	3.0	39.51	0.00	30	0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.3	39.51	0.00	10	0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.9	79.88	0.00	20	0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	3.0	79.88	0.00	30	0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.9	39.51	0.00	20	0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	6.4	39.51	0.00	30	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.7	39.51	0.00	10	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.9	79.88	0.00	20	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	6.4	79.88	0.00	30	0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.9	89.33	0.00	25	0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	6.4	89.33	0.00	37.5	0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.7	81.60	0.00	12.5	0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.9	176.09	0.00	25	0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	6.4	176.09	0.00	37.5	0	2009	1.56
VVL I-OHV Discrete-6 cyl	6.1	202.72	0.00	40	0	2000	2.5
VVL I-OHV Discrete-8 cyl	6.5	290.33	0.00	50	0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.7	140.01	0.00	25	0	2000	2.5
VVL I-OHC Discrete-6 cyl	6.1	202.72	0.00	40	0	2000	2.5
VVL I-OHC Discrete-8 cyl	6.5	290.33	0.00	50	0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.7	1035.06	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	8.3	1131.26	0.00	50	0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.9	209.59	0.00	25	0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.7	384.82	0.00	40	0	2011	2.5
VVL II-OHC Continuous-8 cyl	8.3	420.04	0.00	50	0	2011	2.5
Stoichiometric GDI-4 cyl	1.7	237.93	0.00	20	0	2006	2.5
Stoichiometric GDI-6 cyl	1.7	358.19	0.00	30	0	2006	2.5
Stoichiometric GDI-8 cyl	1.7	430.34	0.00	40	0	2006	2.5
OHV to DOHC TBDS-I4	23.8	1245.51	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	22.2	1887.16	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-I4	23.8	744.73	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-V6	22.2	1445.22	0.00	-100	0	2009	3.75
DOHC TBDS I-I3	19.3	823.75	0.00	-100	0	2009	3.75
DOHC TBDS I-I4	23.8	672.57	0.00	-100	0	2009	3.75
DOHC TBDS I-V6	22.2	1377.79	0.00	-100	0	2009	3.75

Table 7.14. High technology matrix for cars (cont.)

	Fuel Efficiency Change %	Incremental Cost $2000	Incremental Cost ($/ UnitWt.)	Absolute Incremental Weight (Lbs.)	Per Unit Incremental Weight (Lbs./ UnitWt.)	Introduction Year	Horsepower Change %
OHV to DOHC TBDS II-I4	28.9	1427.73	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	27.0	2200.80	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	28.9	941.53	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	27.0	1771.73	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	23.3	1017.42	0.00	-100	0	2012	3.75
DOHC TBDS II-I4	28.9	871.48	0.00	-100	0	2012	3.75
DOHC TBDS II-V6	27.0	1706.27	0.00	-100	0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	35.9	1828.65	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	33.8	1441.63	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	35.9	1409.25	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	33.8	1242.36	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	29.8	1471.12	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	35.9	1348.83	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	33.8	1171.86	0.00	-200	0	2017	3.75
Electric Power Steering	1.4	96.44	0.00	0	0	2004	0
Improved Accessories I	0.8	78.74	0.00	0	0	2005	0
12V Micro Hybrid w/EPS and IACC	7.7	576.22	0.00	45	0	2005	0
Improved Accessories II	2.8	115.82	0.00	0	0	2012	0
Mild Hybrid w/EPS and IACC II	12.1	2611.80	0.00	80	0	2012	-2.5
Tires I	2.2	5.04	0.00	-12	0	2005	0
Tires II	4.4	52.51	0.00	-15	0	2017	0
Low Drag Brakes	0.9	53.23	0.00	0	0	2000	0
Secondary Axle Disconnect	1.4	86.70	0.00	0	-1	2012	0

Source: Energy and Environmental 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.

Table 7.15. High technology matrix for light trucks

	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	4.4	90.00	0.00	0	-6	1980	0
Mass Reduction I	1.1	0.00	0.06	0	-1.5	2005	0
Mass Reduction II	2.9	0.00	0.13	0	-7.5	2009	0
Mass Reduction III	5.9	0.00	0.37	0	-10	2011	0
Mass Reduction IV	9.2	0.00	0.56	0	-15	2016	0
Mass Reduction V	12.8	0.00	0.65	0	-20	2020	0
Aerodynamics I	2.6	43.35	0.00	0	0.5	2000	0
Aerodynamics II	5.4	182.96	0.00	0	1	2011	0
6 Speed Manual	2.2	230.03	0.00	20	0	1995	0
Aggressive Shift Logic I	2.5	29.20	0.00	0	0	1999	0
Aggressive Shift Logic II	6.9	24.46	0.00	0	0	2017	0
Early Torque Converter Lockup	0.6	26.54	0.00	0	0	2002	0
High Efficiency Gearbox	1.8	180.56	0.00	0	0	2017	0
5 Speed Automatic	1.5	93.52	0.00	20	0	1995	0
6 Speed Automatic	2.2	243.05	0.00	30	0	2003	0
7 Speed Automatic	5.5	360.93	0.00	40	0	2009	0
8 Speed Automatic	8.8	479.55	0.00	50	0	2014	0
Dual Clutch Automated Manual	5.4	164.02	0.00	-10	0	2004	0
CVT	8.6	225.88	0.00	-25	0	1998	0
Low Friction Lubricants	0.8	2.88	0.00	0	0	2003	0
Engine Friction Reduction I-4 cyl	2.2	42.44	0.00	0	0	2000	1.25
Engine Friction Reduction I-6 cyl	2.9	64.02	0.00	0	0	2000	1.25
Engine Friction Reduction I-8 cyl	2.8	84.89	0.00	0	0	2000	1.25
Engine Friction Reduction II-4 cyl	4.0	90.64	0.00	0	0	2017	2.25
Engine Friction Reduction II-6 cyl	5.2	133.08	0.00	0	0	2017	2.25
Engine Friction Reduction II-8 cyl	4.8	175.53	0.00	0	0	2017	2.25
Cylinder Deactivation-6 cyl	7.0	168.36	0.00	10	0	2004	0
Cylinder Deactivation-8 cyl	6.6	188.97	0.00	10	0	2004	0
VVT I-OHV Intake Cam Phasing-6 cyl	2.9	39.51	0.00	20	0	2051	1.25
VVT I-OHV Intake Cam Phasing-8 cyl	2.8	39.51	0.00	30	0	2051	1.25
VVT I-OHC Intake Cam Phasing-4 cyl	2.3	39.51	0.00	10	0	1993	1.25
VVT I-OHC Intake Cam Phasing-6 cyl	2.9	79.88	0.00	20	0	1993	1.25
VVT I-OHC Intake Cam Phasing-8 cyl	2.8	79.88	0.00	30	0	1993	1.25
VVT II-OHV Coupled Cam Phasing-6 cyl	5.9	39.51	0.00	20	0	2009	1.25
VVT II-OHV Coupled Cam Phasing-8 cyl	5.6	39.51	0.00	30	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-4 cyl	4.7	39.51	0.00	10	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-6 cyl	5.9	79.88	0.00	20	0	2009	1.25
VVT II-OHC Coupled Cam Phasing-8 cyl	5.6	79.88	0.00	30	0	2009	1.25
VVT III-OHV Dual Cam Phasing-6 cyl	5.9	89.33	0.00	25	0	2051	1.56
VVT III-OHV Dual Cam Phasing-8 cyl	5.6	89.33	0.00	37.5	0	2051	1.56
VVT III-OHC Dual Cam Phasing-4 cyl	4.7	81.60	0.00	12.5	0	2009	1.56
VVT III-OHC Dual Cam Phasing-6 cyl	5.9	176.09	0.00	25	0	2009	1.56
VVT III-OHC Dual Cam Phasing-8 cyl	5.6	176.09	0.00	37.5	0	2009	1.56
VVL I-OHV Discrete-6 cyl	6.1	202.72	0.00	40	0	2000	2.5
VVL I-OHV Discrete-8 cyl	5.7	290.33	0.00	50	0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.6	140.01	0.00	25	0	2000	2.5
VVL I-OHC Discrete-6 cyl	6.1	202.72	0.00	40	0	2000	2.5
VVL I-OHC Discrete-8 cyl	5.7	290.33	0.00	50	0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.7	1035.06	0.00	40	0	2011	2.5
VVL II-OHV Continuous-8 cyl	7.2	1131.26	0.00	50	0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.8	209.59	0.00	25	0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.7	384.82	0.00	40	0	2011	2.5
VVL II-OHC Continuous-8 cyl	7.2	420.04	0.00	50	0	2011	2.5
Stoichiometric GDI-4 cyl	1.7	237.93	0.00	20	0	2006	2.5
Stoichiometric GDI-6 cyl	1.7	358.19	0.00	30	0	2006	2.5
Stoichiometric GDI-8 cyl	1.7	430.34	0.00	40	0	2006	2.5
OHV to DOHC TBDS-I4	23.8	1245.51	0.00	-100	0	2009	3.75
OHV to DOHC TBDS I-V6	22.2	1887.16	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-I4	23.8	744.73	0.00	-100	0	2009	3.75
SOHC to DOHC TBDS I-V6	22.2	1445.22	0.00	-100	0	2009	3.75
DOHC TBDS I-I3	19.3	823.75	0.00	-100	0	2009	3.75
DOHC TBDS I-I4	23.8	672.57	0.00	-100	0	2009	3.75
DOHC TBDS I-V6	22.2	1377.79	0.00	-100	0	2009	3.75

Table 7.15. High technology matrix for light trucks (cont.)

	Fuel Efficiency Change %	Incremental Cost $2000	Incremental Cost ($/ UnitWt.)	Absolute Incremental Weight (Lbs.)	Per Unit Incremental Weight (Lbs./ UnitWt.)	Introduction Year	Horsepower Change %
OHV to DOHC TBDS II-I4	28.9	1427.73	0.00	-100	0	2012	3.75
OHV to DOHC TBDS II-V6	27.0	2200.80	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-I4	28.9	941.53	0.00	-100	0	2012	3.75
SOHC to DOHC TBDS II-V6	27.0	1771.73	0.00	-100	0	2012	3.75
DOHC TBDS II-I3	23.3	1017.42	0.00	-100	0	2012	3.75
DOHC TBDS II-I4	28.9	871.48	0.00	-100	0	2012	3.75
DOHC TBDS II-V6	27.0	1706.27	0.00	-100	0	2012	3.75
OHV to DOHC TBDS III-I4 (from V6)	35.9	1828.65	0.00	-100	0	2017	3.75
OHV to DOHC TBDS III-I4 (from V8)	33.8	1441.63	0.00	-200	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V6)	35.9	1409.25	0.00	-100	0	2017	3.75
SOHC to DOHC TBDS III-I4 (from V8)	33.8	1242.36	0.00	-200	0	2017	3.75
DOHC TBDS III-I3 (from I4)	29.8	1471.12	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V6)	35.9	1348.83	0.00	-100	0	2017	3.75
DOHC TBDS III-I4 (from V8)	33.8	1171.86	0.00	-200	0	2017	3.75
Electric Power Steering	1.1	96.44	0.00	0	0	2004	0
Improved Accessories I	0.8	78.74	0.00	0	0	2005	0
12V Micro Hybrid w/EPS and IACC	7.4	628.01	0.00	45	0	2005	0
Improved Accessories II	2.6	115.82	0.00	0	0	2012	0
Mild Hybrid w/EPS and IACC II	11.7	2611.80	0.00	80	0	2012	-2.5
Tires I	2.2	5.04	0.00	-12	0	2005	0
Tires II	4.4	52.51	0.00	-15	0	2017	0
Low Drag Brakes	0.9	53.23	0.00	0	0	2000	0
Secondary Axle Disconnect	1.5	86.70	0.00	0	-1	2012	0

Source: Energy and Environmental 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.

Table 7.16. High technology matrix for freight trucks

Technology Type	Vehicle Category	Capital Costs (2009$)	Incremental Fuel Economy Improvement (%)
Aerodynamics I: streamlined bumper, grill, windshield, roof	1	53	2.0
Aerodynamics I: conventional features; general aerodynamic shape, removal of classic non-aerodynamic features	5, 8, 11	900	4.5
Aerodynamics I	7,10, 13	900	5.1
Aerodynamics II: SmartWay features; streamlined shape, bumper grill, hood, mirrors, side fuel tank and roof fairings, side gap extenders	5, 8	997	2.0
Aerodynamics II	7,10	997	4.0
Aerodynamics II	11	1040	5.0
Aerodynamics II	13	1355	5.0
Aerodynamics III: underbody airflow, down exhaust, lowered ride height	7	1552	5.0
Aerodynamics III	13	1803	7.0
Aerodynamics IV: skirts, boat tails, nose cone, vortex stabilizer, pneumatic blowing	5-13	4950	14.0
Tires I: low rolling resistance	1	6	2.0
Tires I	2,3	110	3.0
Tires I	4	131	2.2
Tires I	5-7	114	2.2
Tires I	8-13	172	2.2
Tires II: super singles	5-13	140	6.2
Tires III: single wide tires on trailer	5-13	720	3.4
Weight Reduction I	1	116	1.8
Weight Reduction I: aluminum dual tires or super singles	5-13	580	1.1
Weight Reduction II: weight reduction 15%	3-13	5580	3.3
Weight Reduction III: weight reduction 20%	3-13	9900	3.9
Accessories I: Electric/electrohydraulic improvements; electric power steering or electrohydraulic power steering	1	105	2.0
Accessories II: Improved accessories; electrified water, oil, fuel injection, power steering pump, aircompressor	1	85	2.0
Accessories III: Auxiliary Power Unit	11-13	4834	6.4
Transmission I: 8-speed Automatic from 6-speed automatic	1	248	1.9
Transmission II: 6-Manual from 4-speed automatic	1	135	1.1
Transmission III: Automated Manual Transmission	2-13	4500	3.9
Diesel Engine I: aftertreatment improvements	1	109	5.0
Diesel Engine I	2	109	4.0
Diesel Engine II: low friction lubricants	1-13	3	1.0
Diesel Engine III: variable valve actuation	2	0	1.1
Diesel Engine III	3-13	270	1.1
Diesel Engine IV: engine friction reduction, low tension piston rings, roller cam followers, piston skirt design, improved crankshaft design and bearings; coating	1-2	111	2.0
Diesel Engine IV: engine friction reduction, improved bearings to allow lower viscosity oil	3-13	225	2.0
Diesel Engine V: improved turbo efficiency	2-13	15	2.0
Diesel Engine VI: improved water, oil, fuel pump; pistons; valve train friction reduction	2	192	2.0
Diesel Engine VI	3, 5-7	167	2.0
Diesel Engine VI: improved water, oil, fuel pump; pistons	4, 8-13	135	2.0
Diesel Engine VII: improved cylinder head, fuel rail and injector, EGR cooler	2	36	7.0
Diesel Engine VII	3-13	26	7.0
Diesel Engine VIII: turbo mechanical compounding	5-13	900	5.0
Diesel Engine IX: low temperature EGR, improved turbochargers	1	166	6.0
Diesel Engine X: sequential downsizing/turbocharging	5-13	1080	2.8
Diesel Engine XI: waste heat recovery, Organic Ranking Cycle (bottoming cycle)	3-13	9000	8.8
Diesel Engine XII: electric turbo compounding	4-13	7200	10.0
Gasoline Engine I: low friction lubricants	1-13	3	0.6
Gasoline Engine II: coupled cam phasing	2-4	43	4.0
Gasoline Engine III: engine friction reduction; low tension piston rings, roller cam followers, piston skirt design, improved crankshaft design and bearings; coating	1	111	3.0
Gasoline III	2	104	3.0
Gasoline III	3-4	86	3.0
Gasoline Engine IV: stoichiometric gasoline direct injection V8	1-2	425	2.0
Gasoline Engine IV	3-4	430	2.0
Gasoline Engine V: turbocharging and downsizing SGDI V8 to V6	1-4	1569	2.2
Gasoline Engine VI: lean burn GDI	1-4	675	14.0
Gasoline Engine VII: HCCI	1-4	617	14.0
Hybrid System I: 42V engine off at idle	1-2	1350	7.7
Hybrid System I	3-4	1350	5.0
Hybrid System II: dual mode hybrid	1-2	10800	27.5
Hybrid System II: electric, ePTO, or hydraulic	3-4	24000	33.0
Hybrid System II: 4 kWh battery, 50 kW motor generator	5-13	24000	6.0

Source: 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).

Table 7.17. High technology matrix for air travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (1987$ per gallon)
Technology #1	2008	0.03	1.34
Technology #2	2014	0.07	1.34
Technology #3	2020	0.11	1.34
Technology #4	2025	0.15	1.34
Technology #5	2018	0.22	1.34
Technology #6	2018	0.10	1.34
Technology #7	2025	0.04	1.00
Technology #8	2020	0.05	1.34

Source: Jet Information Services, 2009 World Jet Inventory, data tables (2009). Energy Information Administration, Transportation Sector Model of the National Energy Modeling System, Model Documentation 2010, DOE/EIA-M070(2010), (Washington, DC, 2010).

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