Transportation Demand Module

The NEMS Transportation Demand Module (TDM) estimates transportation energy consumption across 9 census divisions and for 10 fuel types. Each fuel type is modeled according to fuel-specific and associated technology attributes by transportation mode. Total transportation energy consumption is reported as the sum of energy use in the following transport modes:

- Light-duty vehicles (cars, light trucks, and two- and three-wheeled vehicles)
- Commercial light trucks (8,501–10,000 pounds gross vehicle weight rating)
- Freight trucks (greater than 10,000 pounds gross vehicle weight)
- Buses
- Freight and passenger aircraft
- Freight and passenger rail
- Maritime freight shipping
- Miscellaneous transport (such as recreational boating)

Light-duty vehicle (LDV) fuel consumption is further subdivided into household 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 Manufacturers Technology Choice Component (MTCC) includes advanced technology input assumptions specific to cars and light trucks (Table 1 and Table 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]. 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 the technologies in Table 1 and Table 2 for each manufacturer and size class to make a market adoption determination 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.

- Future fuel economy standards for LDVs correspond to current law through model year (MY) 2025, reflecting the joint attribute-based final and augural CAFE and final vehicle Greenhouse Gas (GHG) Emissions standards as issued in 2012 [3]. 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 before 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.
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Table 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	99.9	0.0	0.0	-6.0	1980	0.0
Mass Reduction I-1.5% reduction	1.0	0.0	0.1	0.0	-1.5	2005	0.0
Mass Reduction II-3.5% reduction	2.6	0.0	0.1	0.0	-3.5	2009	0.0
Mass Reduction III-10% reduction	5.4	0.0	0.4	0.0	-10.0	2011	0.0
Mass Reduction IV-15% reduction	8.4	0.0	0.6	0.0	-15.0	2015	0.0
Mass Reduction V-20% reduction	11.6	0.0	0.7	0.0	-20.0	2015	0.0
Aero I-10% Cd reduction	2.4	48.2	0.0	0.0	0.5	2000	0.0
Aero II-20% Cd reduction	4.9	203.3	0.0	0.0	1.0	2011	0.0
6 Speed Manual	2.2	255.6	0.0	20.0	0.0	1995	0.0
Aggressive Shift Logic I	2.5	32.4	0.0	0.0	0.0	1999	0.0
Aggressive Shift Logic II	6.7	27.2	0.0	0.0	0.0	2016	0.0
Early Torque Converter Lockup	0.5	29.5	0.0	0.0	0.0	2002	0.0
High Efficiency Gearbox	1.6	200.6	0.0	0.0	0.0	2016	0.0
5-Speed Automatic	1.4	103.9	0.0	20.0	0.0	1995	0.0
6-Speed Automatic	2.2	270.1	0.0	30.0	0.0	2003	0.0
7-Speed Automatic	5.1	401.0	0.0	40.0	0.0	2009	0.0
8-Speed Automatic	8.0	532.8	0.0	50.0	0.0	2010	0.0
Dual Clutch Automated Manual	5.5	56.8	0.0	-10.0	0.0	2004	0.0
CVT	8.4	251.0	0.0	-25.0	0.0	1998	0.0
Low Friction Lubricants	0.7	3.2	0.0	0.0	0.0	2003	0.0
Engine Friction Reduction I-4 cyl	2.0	47.2	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction I-6 cyl	2.6	71.1	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction I-8 cyl	2.8	94.3	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction II-4 cyl	3.6	100.7	0.0	0.0	0.0	2016	2.3
Engine Friction Reduction II-6 cyl	4.7	147.9	0.0	0.0	0.0	2016	2.3
Engine Friction Reduction II-8 cyl	5.1	195.0	0.0	0.0	0.0	2016	2.3
Cylinder Deactivation-6 cyl	6.5	187.1	0.0	10.0	0.0	2004	0.0
Cylinder Deactivation-8 cyl	6.9	210.0	0.0	10.0	0.0	2004	0.0
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.9	0.0	20.0	0.0	2051	1.3
VVT I-OHV Intake Cam Phasing-8 cyl	2.7	43.9	0.0	30.0	0.0	2051	1.3
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.9	0.0	10.0	0.0	1993	1.3
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.8	0.0	20.0	0.0	1993	1.3
VVT I-OHC Intake Cam Phasing-8 cyl	2.7	88.8	0.0	30.0	0.0	1993	1.3
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.9	0.0	20.0	0.0	2009	1.3
VVT II-OHV Coupled Cam Phasing-8 cyl	5.8	43.9	0.0	30.0	0.0	2009	1.3
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.9	0.0	10.0	0.0	2009	1.3
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.8	0.0	20.0	0.0	2009	1.3

Table 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	Horsepower change %
VVT II-OHC Coupled Cam Phasing-8 cyl	5.8	88.8	0.0	30.0	0.0	2009	1.3
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.3	0.0	25.0	0.0	2051	1.6
VVT III-OHV Dual Cam Phasing-8 cyl	5.8	99.3	0.0	37.5	0.0	2051	1.6
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.7	0.0	12.5	0.0	2009	1.6
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.7	0.0	25.0	0.0	2009	1.6
VVT III-OHC Dual Cam Phasing-8 cyl	5.8	195.7	0.0	37.5	0.0	2009	1.6
VVL I-OHV Discrete-6 cyl	5.5	225.2	0.0	40.0	0.0	2000	2.5
VVL I-OHV Discrete-8 cyl	5.9	322.6	0.0	50.0	0.0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.3	155.6	0.0	25.0	0.0	2000	2.5
VVL I-OHC Discrete-6 cyl	5.5	225.2	0.0	40.0	0.0	2000	2.5
VVL I-OHC Discrete-8 cyl	5.9	322.6	0.0	50.0	0.0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.0	1150.1	0.0	40.0	0.0	2011	2.5
VVL II-OHV Continuous-8 cyl	7.5	1257.0	0.0	50.0	0.0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.4	232.9	0.0	25.0	0.0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.0	427.6	0.0	40.0	0.0	2011	2.5
VVL II-OHC Continuous-8 cyl	7.5	466.7	0.0	50.0	0.0	2011	2.5
Stoichiometric GDI-4 cyl	1.5	264.4	0.0	20.0	0.0	2006	2.5
Stoichiometric GDI-6 cyl	1.5	398.0	0.0	30.0	0.0	2006	2.5
Stoichiometric GDI-8 cyl	1.5	478.2	0.0	40.0	0.0	2006	2.5
OHV to DOHC TBDS-I4 (from V6), VVT, VVL, SGDI	21.6	1383.9	0.0	-100.0	0.0	2009	3.8
OHV to DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	2096.8	0.0	-100.0	0.0	2009	3.8
SOHC to DOHC TBDS I-I4 (from V6), VVT, VVL, SGDI	21.6	827.5	0.0	-100.0	0.0	2009	3.8
SOHC to DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	1605.8	0.0	-100.0	0.0	2009	3.8
DOHC TBDS I-I3 (from I4), VVT, VVL, SGDI	17.5	915.3	0.0	-100.0	0.0	2009	3.8
DOHC TBDS I-I4 (from V6), VVT, VVL, SGDI	21.6	747.3	0.0	-100.0	0.0	2009	3.8
DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	1530.9	0.0	-100.0	0.0	2009	3.8
OHV to DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	1586.4	0.0	-100.0	0.0	2012	3.8
OHV to DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	2445.3	0.0	-100.0	0.0	2012	3.8
SOHC to DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	1046.1	0.0	-100.0	0.0	2012	3.8
SOHC to DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	1968.6	0.0	-100.0	0.0	2012	3.8
DOHC TBDS II-I3 (from I4), VVT, VVL, SGDI	21.2	1130.5	0.0	-100.0	0.0	2012	3.8
DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	968.3	0.0	-100.0	0.0	2012	3.8
DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	1895.9	0.0	-100.0	0.0	2012	3.8
OHV to DOHC TBDS III-I4 (from V6), VVT, VVL, SGDI, EGR	32.6	2031.8	0.0	-100.0	0.0	2016	3.8

Table 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	Horsepower change %
OHV to DOHC TBDS III-I4 (from V8), VVT, VVL, SGDI, EGR	30.7	1601.8	0.0	-200.0	0.0	2016	3.8
SOHC to DOHC TBDS III-I4 (from V6), VVT, VVL, SGDI, EGR	32.6	1565.8	0.0	-100.0	0.0	2016	3.8
SOHC to DOHC TBDS III-I4 (from V8), VVT, VVL, SGDI, EGR	30.7	1380.4	0.0	-200.0	0.0	2016	3.8

[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$	Incremental cost ($/UnitWt.)	Absolute incremental weight (lbs.)	Per unit incremental weight (lbs./UnitWt)	Introduction year	Horsepower change %
Unit Body Construction	4.0	100.0	0.0	0.0	-6.0	1980	0.0
Mass Reduction I-1.5% reduction	1.0	0.0	0.1	0.0	-1.5	2005	0.0
Mass Reduction II-7.5% reduction	2.6	0.0	0.1	0.0	-7.5	2009	0.0
Mass Reduction III-10% reduction	5.4	0.0	0.4	0.0	-10.0	2011	0.0
Mass Reduction IV-15% reduction	8.4	0.0	0.6	0.0	-15.0	2016	0.0
Mass Reduction V-20% reduction	11.6	0.0	0.7	0.0	-20.0	2016	0.0
Aero I-10% Cd reduction	2.4	48.2	0.0	0.0	0.5	2000	0.0
Aero II-20% Cd reduction	4.9	203.3	0.0	0.0	1.0	2011	0.0
6 Speed Manual	2.0	255.6	0.0	20.0	0.0	1995	0.0
Aggressive Shift Logic I	2.3	32.4	0.0	0.0	0.0	1999	0.0
Aggressive Shift Logic II	6.3	27.2	0.0	0.0	0.0	2016	0.0
Early Torque Converter Lockup	0.5	29.5	0.0	0.0	0.0	2002	0.0
High Efficiency Gearbox	1.6	200.6	0.0	0.0	0.0	2016	0.0
5-Speed Automatic	1.3	103.9	0.0	20.0	0.0	1995	0.0
6-Speed Automatic	2.0	270.1	0.0	30.0	0.0	2003	0.0
7-Speed Automatic	5.0	401.0	0.0	40.0	0.0	2009	0.0
8-Speed Automatic	8.0	532.8	0.0	50.0	0.0	2014	0.0
Dual Clutch Automated Manual	4.9	182.2	0.0	-10.0	0.0	2004	0.0
CVT	7.8	251.0	0.0	-25.0	0.0	1998	0.0
Low Friction Lubricants	0.7	3.2	0.0	0.0	0.0	2003	0.0
Engine Friction Reduction I-4 cyl	2.0	47.2	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction I-6 cyl	2.6	71.1	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction I-8 cyl	2.5	94.3	0.0	0.0	0.0	2000	1.3
Engine Friction Reduction II-4 cyl	3.6	100.7	0.0	0.0	0.0	2016	2.3
Engine Friction Reduction II-6 cyl	4.7	147.9	0.0	0.0	0.0	2016	2.3
Engine Friction Reduction II-8 cyl	4.4	195.0	0.0	0.0	0.0	2016	2.3
Cylinder Deactivation-6 cyl	6.4	187.1	0.0	10.0	0.0	2004	0.0

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 %
Cylinder Deactivation-8 cyl	6.0	210.0	0.0	10.0	0.0	2004	0.0
VVT I-OHV Intake Cam Phasing-6 cyl	2.6	43.9	0.0	20.0	0.0	2051	1.3
VVT I-OHV Intake Cam Phasing-8 cyl	2.5	43.9	0.0	30.0	0.0	2051	1.3
VVT I-OHC Intake Cam Phasing-4 cyl	2.1	43.9	0.0	10.0	0.0	1993	1.3
VVT I-OHC Intake Cam Phasing-6 cyl	2.6	88.8	0.0	20.0	0.0	1993	1.3
VVT I-OHC Intake Cam Phasing-8 cyl	2.5	88.8	0.0	30.0	0.0	1993	1.3
VVT II-OHV Coupled Cam Phasing-6 cyl	5.4	43.9	0.0	20.0	0.0	2009	1.3
VVT II-OHV Coupled Cam Phasing-8 cyl	5.1	43.9	0.0	30.0	0.0	2009	1.3
VVT II-OHC Coupled Cam Phasing-4 cyl	4.3	43.9	0.0	10.0	0.0	2009	1.3
VVT II-OHC Coupled Cam Phasing-6 cyl	5.4	88.8	0.0	20.0	0.0	2009	1.3
VVT II-OHC Coupled Cam Phasing-8 cyl	5.1	88.8	0.0	30.0	0.0	2009	1.3
VVT III-OHV Dual Cam Phasing-6 cyl	5.4	99.3	0.0	25.0	0.0	2051	1.6
VVT III-OHV Dual Cam Phasing-8 cyl	5.1	99.3	0.0	37.5	0.0	2051	1.6
VVT III-OHC Dual Cam Phasing-4 cyl	4.3	90.7	0.0	12.5	0.0	2009	1.6
VVT III-OHC Dual Cam Phasing-6 cyl	5.4	195.7	0.0	25.0	0.0	2009	1.6
VVT III-OHC Dual Cam Phasing-8 cyl	5.1	195.7	0.0	37.5	0.0	2009	1.6
VVL I-OHV Discrete-6 cyl	5.5	225.2	0.0	40.0	0.0	2000	2.5
VVL I-OHV Discrete-8 cyl	5.2	322.6	0.0	50.0	0.0	2000	2.5
VVL I-OHC Discrete-4 cyl	4.2	155.6	0.0	25.0	0.0	2000	2.5
VVL I-OHC Discrete-6 cyl	5.5	225.2	0.0	40.0	0.0	2000	2.5
VVL I-OHC Discrete-8 cyl	5.2	322.6	0.0	50.0	0.0	2000	2.5
VVL II-OHV Continuous-6 cyl	7.0	1150.1	0.0	40.0	0.0	2011	2.5
VVL II-OHV Continuous-8 cyl	6.5	1257.0	0.0	50.0	0.0	2011	2.5
VVL II-OHC Continuous-4 cyl	5.3	232.9	0.0	25.0	0.0	2011	2.5
VVL II-OHC Continuous-6 cyl	7.0	427.6	0.0	40.0	0.0	2011	2.5
VVL II-OHC Continuous-8 cyl	6.5	466.7	0.0	50.0	0.0	2011	2.5
Stoichiometric GDI-4 cyl	1.5	264.4	0.0	20.0	0.0	2006	2.5
Stoichiometric GDI-6 cyl	1.5	398.0	0.0	30.0	0.0	2006	2.5
Stoichiometric GDI-8 cyl	1.5	478.2	0.0	40.0	0.0	2006	2.5
OHV to DOHC TBDS-I4 (from V6), VVT, VVL, SGDI	21.6	1383.9	0.0	-100.0	0.0	2009.0	3.8
OHV to DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	2096.8	0.0	-100.0	0.0	2009.0	3.8
SOHC to DOHC TBDS I-I4 (from V6), VVT, VVL, SGDI	21.6	827.5	0.0	-100.0	0.0	2009.0	3.8
SOHC to DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	1605.8	0.0	-100.0	0.0	2009.0	3.8
DOHC TBDS I-I3 (from I4), VVT, VVL, SGDI	17.5	915.3	0.0	-100.0	0.0	2009.0	3.8
DOHC TBDS I-I4 (from V6), VVT, VVL, SGDI	21.6	747.3	0.0	-100.0	0.0	2009.0	3.8

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 %
DOHC TBDS I-V6 (from V8), VVT, VVL, SGDI	20.2	1530.9	0.0	-100.0	0.0	2009.0	3.8
OHV to DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	1586.4	0.0	-100.0	0.0	2012.0	3.8
OHV to DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	2445.3	0.0	-100.0	0.0	2012.0	3.8
SOHC to DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	1046.1	0.0	-100.0	0.0	2012.0	3.8
SOHC to DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	1968.6	0.0	-100.0	0.0	2012.0	3.8
DOHC TBDS II-I3 (from I4), VVT, VVL, SGDI	21.2	1130.5	0.0	-100.0	0.0	2012.0	3.8
DOHC TBDS II-I4 (from V6), VVT, VVL, SGDI	26.3	968.3	0.0	-100.0	0.0	2012.0	3.8
DOHC TBDS II-V6 (from V8), VVT, VVL, SGDI	24.5	1895.9	0.0	-100.0	0.0	2012.0	3.8
OHV to DOHC TBDS III-I4 (from V6), VVT, VVL, SGDI, EGR	32.6	2031.8	0.0	-100.0	0.0	2016.0	3.8
OHV to DOHC TBDS III-I4 (from V8), VVT, VVL, SGDI, EGR	30.7	1601.8	0.0	-200.0	0.0	2016.0	3.8
SOHC to DOHC TBDS III-I4 (from V6), VVT, VVL, SGDI, EGR	32.6	1565.8	0.0	-100.0	0.0	2016.0	3.8
SOHC to DOHC TBDS III-I4 (from V8), VVT, VVL, SGDI, EGR	30.7	1380.4	0.0	-200.0	0.0	2016.0	3.8
DOHC TBDS III-I3 (from I4), VVT, VVL, SGDI, EGR	27.1	1634.6	0.0	-100.0	0.0	2016.0	3.8
DOHC TBDS III-I4 (from V6), VVT, VVL, SGDI, EGR	32.6	1498.7	0.0	-100.0	0.0	2016.0	3.8
DOHC TBDS III-I4 (from V8), VVT, VVL, SGDI, EGR	30.7	1302.1	0.0	-200.0	0.0	2016.0	3.8
Electric Power Steering	1.0	107.2	0.0	0.0	0.0	2004.0	0.0
Improved Accessories I	0.7	87.5	0.0	0.0	0.0	2005.0	0.0
12V Micro Hybrid w/EPS and IACC	6.7	697.8	0.0	45.0	0.0	2005.0	0.0
Improved Accessories II	2.4	128.7	0.0	0.0	0.0	2012.0	0.0
Mild Hybrid w/EPS and IACC II	10.6	2902.0	0.0	80.0	0.0	2012.0	-2.5
Tires I-10% Crr reduction	2.0	5.6	0.0	-12.0	0.0	2005.0	0.0
Tires II-20% Crr reduction	4.0	58.3	0.0	-15.0	0.0	2016.0	0.0
Low Drag Brakes	0.8	59.1	0.0	0.0	0.0	2000.0	0.0
Secondary Axle Disconnect	1.4	96.3	0.0	0.0	-1.0	2012.0	0.0
CAV Level 1 (long range radar)	0.0	1000.0	0.0	10.0	0.0	2016.0	0.0
CAV Level 2 (1 long range radar, 2 short range radar, 2 cameras, GPS, system)	0.0	2000.0	0.0	20.0	0.0	2016.0	0.0
CAV Level 3 (1 long range radar, 2 short range radar, 2 cameras, GPS, higher system)	0.0	2500.0	0.0	20.0	0.0	2016.0	0.0
CAV Level 4 low speed (manual hwy capable)	0.0	41191.0	0.0	28.0	0.0	2020.0	0.0
CAV Level 4 high speed tri-mode	0.0	46191.0	0.0	48.0	0.0	2025.0	0.0
CAV Level 5 fully autonomous	0.0	53691.0	0.0	51.0	0.0	2030.0	0.0

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

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

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

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

U.S. Environmental Protection Agency, Interim Report: New Powertrain Technologies and Their Projected Costs (October 2005)
Environmental Protection Agency and Department of Transportation National Highway Traffic Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule," Federal Register Vol. 77, No. 199, October 15, 2012. 40 CFR Parts 85, 86, 600, 49 CFR Parts 523, 531, 533, et al. and 600

Levels of shortfall, expressed as degradation factors, are used to convert new LDV as-tested fuel economy values to on-road fuel economy values [4]. 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 0.815 for light trucks.

The LDV Vehicle Miles Traveled (VMT) Component uses fuel prices, personal income, employment, number of vehicles per licensed driver, and population demographics to generate projections of demand for personal travel. Population demographic distribution assumptions are taken from the U.S. Census Bureau and are divided into five age categories by gender. Licensing rates, taken from the U.S. Department of Transportation's Federal Highway Administration (FHWA), by these five age categories are also used. Licensing rates are then projected for each age category using the population estimates from the U.S. Census Bureau. 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 VMT coefficients (Table 3) below.

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	-0.0386	-0.0353	-0.0392	-0.0460	-0.0274
female	-0.0364	-0.0333	-0.0397	-0.0387	-0.0368
ALPHA					
male	0.7466	0.6850	0.9683	0.6399	0.6213
female	0.5579	0.6992	0.5221	-2.2145	-0.8011
BETAVMT					
male	0.8618	0.8444	0.6916	0.7977	0.7430
female	0.7259	0.8458	0.7399	0.7057	0.8714
BETAINC					
male	-0.0395	-0.0143	0.0000	0.0000	0.0000
female	0.0000	-0.0254	0.0000	0.2686	0.0797
BETAVPLD					
male	0.1366	0.0632	0.3244	0.2835	0.4019
female	0.0218	0.2010	0.5698	0.4143	0.5340
BETAEMP					
male	0.0000	0.0624	0.0393	0.0171	0.0000
female	0.0000	0.0000	-0.2410	-0.1894	-0.4220

Source: U.S. Energy Information Administration, AEO2019 National Energy Modeling System run REF2019.111618A

Commercial light-duty fleet assumptions

The TDM separates commercial light-duty fleets into four types: business (rental), government, commercial and utility, and ride hailing and taxi service. Based on these classifications, commercial light-duty fleet vehicles vary in survival rates and duration of in-fleet use, reflected in vehicle miles traveled, before sale for use as personal vehicles. Fleet vehicles are sold to households for personal use at different rates for passenger cars and light-duty trucks, depending on the fleet type. Vehicles used for ride hailing or taxi service remain in fleet use for the life of the vehicle. Of total passenger car sales to fleets in 2018, 73% are used in business (rental) fleets, 8% in government fleets, 15% in commercial and utility fleets, and 4% in ride hailing or taxi fleets. Of total light truck sales to fleets in 2018, 49% are used in business (rental) fleets, 11% in government fleets, 37% in commercial and utility fleets, and 3% in ride hailing or taxi fleets. Ride hailing or taxi fleets are derived as an assumed 5% of the business fleet (rental) fleet as designated by IHS Markit Polk respectively for cars and light trucks [5]. Both the car and light truck shares by fleet type are held constant from 2019 through 2050. Autonomous vehicles are assumed to enter the ride hailing or taxi fleet in 2020 with adoption determined by a fleet operator monthly return on investment calculation with assumed adoption rate limitations. In 2018, 20% of all passenger cars and 17% of all light trucks sold were for fleet use. After 2018, the share of total passenger car and light-truck sales marginally changes and remains constant after 2019.

The share of fleet vehicles that are alternatively fueled by fleet type are held constant at 2016 levels (Table 4). Throughout the projection period, Shares of new vehicle sales purchased by fuel type change by fleet type and for passenger car and light truck. Autonomous vehicles are assumed to be gasoline fueled. Size class shares of vehicles sales also remain at 2016 levels (Table 5) [6]. Autonomous vehicle size class shares are assumed to be similar to business fleets. Individual sales shares of new vehicles purchased by technology type (Table 6) after 2016 are assumed to change depending on the usage and regulations for each fleet type.

Annual VMT per vehicle by fleet type stays constant during the projection period based on the Oak Ridge National Laboratory fleet data. Autonomous vehicles are assumed to travel 65,000 miles per year, similar to fleet taxi vehicles.

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 eight size classes for cars and light trucks.

Table 4. Percentage of fleet alternative-fuel vehicles by fleet type and size class, 2016

	Fleet type			
Size class	Business	Government	Commercial and utility	Ride hailing and taxi
Car				
Mini	0.0	0.0	0.3	2.0
Subcompact	3.1	0.7	4.7	4.0
Compact	21.1	8.3	17.5	17.0
Midsize	41.2	24.6	44.2	46.0
Large	17.0	59.2	10.2	30.0
2-seater	0.1	0.2	1.2	1.0
Small crossover utility vehicle	12.6	4.6	13.4	0.0
Large crossover utility vehicle	4.7	2.4	8.6	0.0
Light truck				
Small pickup	3.5	4.1	7.3	0.5
Large pickup	13.0	27.8	27.4	0.5
Small van	1.8	2.7	4.8	10.0
Large van	21.3	8.8	10.8	34.0
Small utility	2.6	0.2	2.2	35.0
Large utility	9.2	11.8	8.0	20.0
Small crossover utility vehicle	21.0	4.6	13.6	0.0
Large crossover utility vehicle	27.5	40.0	25.9	0.0

Source: IHS Markit Polk, National Vehicle Population Profile, various years

Table 5. Commercial fleet-size class percentage shares by fleet and vehicle type, 2016

	Fleet type			
Size class	Business	Government	Commercial and utility	Ride hailing and taxi
Car				
Mini	0.0	0.0	0.3	2.0
Subcompact	3.1	0.7	4.7	4.0
Compact	21.1	8.3	17.5	17.0
Midsize	41.2	24.6	44.2	46.0
Large	17.0	59.2	10.2	30.0
2-seater	0.1	0.2	1.2	1.0
Small crossover utility vehicle	12.6	4.6	13.4	0.0
Large crossover utility vehicle	4.7	2.4	8.6	0.0
Light truck				
Small pickup	3.5	4.1	7.3	0.5
Large pickup	13.0	27.8	27.4	0.5
Small van	1.8	2.7	4.8	10.0
Large van	21.3	8.8	10.8	34.0
Small utility	2.6	0.2	2.2	35.0
Large utility	9.2	11.8	8.0	20.0
Small crossover utility vehicle	21.0	4.6	13.6	0.0
Large crossover utility vehicle	27.5	40.0	25.9	0.0

Source: IHS Markit Polk, National Vehicle Population Profile, various years

Table 6. Share of new vehicle purchases by fleet type and technology, 2016

percentage

	Fleet type			
	Business	**Government**	**Commercial and Utility**	**Ride Hailing and Taxi**
Car				
Gasoline	91.2	82.3	89.9	93.1
Diesel	0.0	0.0	0.1	0.0
Ethanol Flex	4.9	5.2	2.3	2.4
Electric	2.3	0.9	1.0	0.0
Plug-in Hybrid Electric	0.0	1.5	1.3	0.0
Hybrid Electric	1.5	7.6	4.4	4.5
CNG/LNG Bi-Fuel	0.0	2.1	0.4	0.0
LPG Bi-Fuel	0.0	0.1	0.3	0.0
CNG/LNG	0.0	0.2	0.1	0.0
LPG	0.0	0.0	0.2	0.0
Light Truck				
Gasoline	76.4	84.8	84.2	86.1
Diesel	0.0	0.1	1.0	0.0
Ethanol Flex	23.6	10.6	13.2	13.4
Electric	0.0	0.0	0.0	0.0
Plug-in Hybrid Electric	0.0	0.0	0.2	0.0
Hybrid Electric	0.0	0.3	0.5	0.5
CNG/LNG Bi-Fuel	0.0	2.1	0.4	0.0
LPG Bi-Fuel	0.0	1.6	0.2	0.0
CNG/LNG	0.0	0.3	0.1	0.0
LPG	0.0	0.1	0.1	0.0

Source: U.S. Energy Information Administration, Archive—Alternative Transportation Fuels (ATF) and Alternative Fueled Vehicles (AFV), 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 pound 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. The distribution of vehicles by vintage and vehicle scrappage rates are derived from analysis of registration data from IHS Markit Polk [7],[8]. Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle [9],[10]. As defined in NEMS, light commercial trucks are a subset of Class 2 vehicles (vehicles with 6,001 pounds to 10,000 pounds GVWR) and are often referred to as Class 2b vehicles (8,500 pounds to 10,000 pounds GVWR). Class 2a vehicles (6,001 pounds 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

[11]. 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) uses 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 [12]. The technology sets include

- Conventional fuel capable: gasoline, diesel, bi-fuel compressed natural gas (CNG) and liquefied natural gas (LNG), bi-fuel liquefied petroleum gas (LPG), and flex-fuel
- Hybrid: gasoline and diesel
- Plug-in hybrid: 10-mile all-electric range and 40-mile all-electric range
- Dedicated alternative fuel: CNG, LNG, and LPG
- Fuel cell: 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. Except for 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 during several technology phase periods. The fuel attributes used in market share estimation include availability and price. Vehicle attributes vary by eight 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 also depend on 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 and sales data from EPA Engines and Vehicles Compliance Information System [14],[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 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 (Table 7). These subclasses include 2 breakouts for the light-medium size class (pickup/van and vocational), 1 breakout for heavy-medium (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 to 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 type 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- Phase 2, 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, and 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, and 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—Phase 2, U.S. Environmental Protection Agency and U.S. Department of Transportation, Final Rules, Federal Register, Vol. 81, No. 206 (October 2016)

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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 data that are used to determine regional distances 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 depends 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 from Vehicle Inventory and Use Survey (VIUS) data [22]. Initial freight truck stocks by vintage are obtained from analysis of IHS Markit Polk data and are distributed by fuel type using VIUS data. EIA also estimates vehicle scrappage rates using IHS Markit Polk data.

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 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 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 2009 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 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 2016 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 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 require existing ships to 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; modeling options are up 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 one 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	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, 2017 World Jet Inventory, data tables (2018)

Air travel demand Component

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, gross domestic product (GDP), and RPM (Table 10) [33], as well as per capita disposable income for the United States, per capita 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].

Table 10. 2016 regional population, GDP, per capita GDP, domestic and international routes RPM and per capita RPM

Region	Population (million)	GDP (billion 2010 PPP)	Domestic route RPM (billion)	International route RPM (billion)	GDP per capita	Domestic RPM per capita	International RPM per capita
United States	324	12,609	687	275	38,956	2,122	851
Canada	36	1,529	26	116	42,219	723	3,200
Central America	216	2,789	31	102	12,906	143	473
South America	420	5,909	100	72	14,061	237	171
Europe	631	21,348	547	480	33,816	866	760
Africa	1,206	5,579	40	74	4,626	33	62
Middle East	236	5,506	74	210	23,330	313	890
Russia	284	4,644	86	92	16,359	302	323
China	1,413	20,294	401	164	14,364	284	116
Northeast Asia	179	6,510	74	156	36,465	416	875
Southeast Asia	707	7,564	135	192	10,700	191	272
Southwest Asia	1,803	9,425	62	84	5,226	34	47
Oceania	32	1,257	67	67	39,100	2,085	2,096

Note: Totals may not equal sum of components because of independent rounding.

Sources: GDP and population: Global Insight, RPM: Boeing Current Market Outlook 2017–2036 and Bureau of Transportation Statistics, Air Carrier Statistics (Form 41 Traffic)

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 2016 (Table 11), new passenger aircraft sales, and the survival rate by vintage (Table 12) [35]. New passenger aircraft sales are a function of revenue passenger miles and gross domestic product.

Table 11. 2016 Regional passenger and cargo aircraft supply

		Age of aircraft in years				
Passenger and cargo aircraft type	New	1 to 10	11 to 20	21 to 30	More than 30	Total
Passenger—Narrowbody						
United States	201	1,115	1,755	760	141	3,972
Canada	6	101	138	53	22	320
Central America	30	209	93	50	47	429
South America	31	382	189	94	123	819
Europe	247	1,550	1,282	298	35	3,412
Africa	12	136	164	134	143	589
Middle East	29	387	151	132	49	748
Russia	32	244	285	200	237	998
China	283	1,741	444	45	2	2,515
Northeast Asia	21	264	121	20	9	435
Southeast Asia	93	791	161	104	65	1,214
Southwest Asia	30	303	80	44	27	484
Oceania	5	150	125	3	—	283
Passenger—Widebody						
United States	22	124	298	179	24	647
Canada	11	36	28	38	2	115
Central America	4	14	9	4	3	34
South America	16	79	32	13	3	143
Europe	76	362	429	104	10	981
Africa	19	65	50	26	26	186
Middle East	88	392	173	86	28	767
Russia	4	57	66	38	4	169
China	53	328	84	28	—	493
Northeast Asia	27	196	151	27	—	401
Southeast Asia	42	279	155	39	5	520
Southwest Asia	1	73	17	28	5	124
Oceania	3	68	38	7	—	116
Passenger—Regional jet						
United States	108	681	1,637	325	22	2,773
Canada	20	116	122	170	17	445
Central America	12	109	82	62	6	271
South America	2	224	56	109	18	409
Europe	46	600	408	360	23	1,437
Africa	6	141	163	187	34	531
Middle East	5	68	59	85	2	219
Russia	13	133	123	100	54	423
China	17	144	62	—	1	224

Table 11. 2016 Regional passenger and cargo aircraft supply (cont.)

		Age of aircraft in years				
Passenger and cargo aircraft type	New	1 to 10	11 to 20	21 to 30	More than 30	Total
Passenger—Regional jet (cont.)						
Northeast Asia	9	46	42	8	—	105
Southeast Asia	31	231	67	77	23	429
Southwest Asia	5	69	27	16	1	118
Oceania	11	89	73	204	16	393
Cargo—Narrowbody						
United States	—	3	30	177	102	312
Canada	—	—	1	12	10	23
Central America	—	1	3	9	9	22
South America	—	—	2	16	43	61
Europe	—	—	19	84	25	128
Africa	—	—	2	18	39	59
Middle East	—	—	3	2	10	15
Russia	—	13	6	5	3	27
China	—	1	29	59	1	90
Northeast Asia	—	—	—	2	—	2
Southeast Asia	—	—	5	9	25	39
Southwest Asia	—	—	1	10	5	16
Oceania	—	—	—	13	2	15
Cargo—Widebody						
United States	13	113	128	235	94	583
Canada	—	—	—	8	3	11
Central America	—	—	1	2	5	8
South America	—	12	4	1	6	23
Europe	5	57	42	47	17	168
Africa	—	6	2	3	3	14
Middle East	6	43	6	13	14	82
Russia	1	11	5	13	9	39
China	1	54	20	19	1	95
Northeast Asia	7	23	22	14	—	66
Southeast Asia	—	5	34	5	2	46
Southwest Asia	—	—	—	2	2	4
Oceania	—	—	1	—	—	1
Cargo—Regional jet						
United States	—	—	—	41	11	52
Canada	—	—	1	12	—	13
Central America	—	—	—	7	—	7
South America	—	—	—	3	—	3
Europe	—	—	5	93	13	111
Africa	—	—	5	6	1	12

Table 11. 2016 Regional passenger and cargo aircraft supply (cont.)

	Age of aircraft in years					
Passenger and cargo aircraft type	**New**	**1 to 10**	**11 to 20**	**21 to 30**	**More than 30**	**Total**
Cargo—Regional jet (cont.)						
Middle East	—	—	—	1	1	2
Russia	—	—	—	1	1	2
China	—	—	—	—	—	—
Northeast Asia	—	—	—	—	—	—
Southeast Asia	—	—	—	5	—	5
Southwest Asia	—	—	—	2	—	2
Oceania	—	—	—	6	3	9

Note: Totals may not equal sum of components because of independent rounding.

Source: Source: Jet Information Services, 2017 World Jet Inventory (2018)

Table 12. Aircraft survival curve fractions

		Age of aircraft in years			
Aircraft type	**New**	**5**	**10**	**20**	**40**
Narrowbody	1.000	1.000	0.999	0.997	0.800
Widebody	1.000	0.998	0.996	0.987	0.790
Regional jet	1.000	0.997	0.995	0.983	0.780

Note: Totals may not equal sum of components because of independent rounding.

Source: Source: Jet Information Services, 2017 World Jet Inventory (2018)

Wide- and narrow-body passenger planes that are more than 25 years old are considered 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 are 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 13) are introduced in different years and with a set of improved efficiencies over the base year (2007). Regional shares of all types of aircraft fuel use are assumed to be constant and are consistent with the SEDS estimate of regional jet fuel shares.

Table 13. 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, 2017 World Jet Inventory, data tables (2017)

Legislation and regulations

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

The AEO2019 Reference case includes the attribute-based CAFE standards for LDVs for MY 2011 and the joint attribute-based CAFE and vehicle 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.

Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles

On September 15, 2011, EPA and NHTSA jointly announced a final rule called the HD National Program [36], which established GHG emissions and fuel consumption standards for the first time for on-road heavy-duty trucks and their engines. The sub-module 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. Standard compliance is modeled 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 [37]. The same vehicle classes and their engines are included, but the second round also adds heavy-haul tractors (increasing the number of regulatory classifications to 14) and trailers (begins MY 2018), 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 them.

Although the credit trading program began in 2011, EISA2007 allows manufacturers to apply credits earned to any of the three model years before 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 credit trading across manufacturers. The projections do not consider credit trading because to do so would require significant modifications to NEMS and detailed technology cost and efficiency data by manufacturer, which are not readily available.

The CAFE credits under the Alternative Motor Fuels Act (AMFA) through 2019 are extended by EISA2007. Before the 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 (EIEA2008)

ARRA Title I, Section 1141, modified the EIEA2008 Title II, Section 205 tax credit for purchasing new, qualified plug-in electric-drive motor vehicles. Under the law, 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 that can be 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 a vehicle manufacturer. The credits are phased out once a manufacturer's cumulative sales of qualified vehicles reach 200,000 vehicles. 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. The credit applies to vehicles with a GVWR 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 the sales projections.

Energy Policy Act of 1992 (EPACT1992)

Fleet alternative-fuel vehicle sales needed to meet the EPACT regulations are based on the current legal requirements and the Commercial Fleet Vehicle Component calculations. Total projected alternatively fueled vehicle (AFV) sales are divided into fleets by government, business, and fuel providers (Table 14).

Table 14. 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)

Because the commercial fleet model operates on multiple fleet types, the federal and state requirements are weighted by fleet vehicle stocks to create a single requirement for both. The same combining methodology is used to create a composite mandate for electric utilities and fuel providers based on fleet vehicle stocks [38].

International Convention for the Prevention of Pollution from Ships (MARPOL)

Around the world, legislation and regulations requiring 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 [39]. 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 [40],[41]. 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% mass by mass (the current limit is 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 California. The program began as a voluntary opt-in pilot program under the 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)
- 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 credits to be banked. Banked credits from over-compliance can be used in later years to help meet credit requirements. Full ZEVs must account for 16% of the MY 2025 credits, requiring 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 added 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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