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Transportation Demand Module

The NEMS Transportation Demand Module estimates energy consumption across the nine Census Divisions (see Figure 5) and over ten fuel types. Each fuel type is modeled according to fuel-specific 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), freight and passenger aircraft, freight rail, freight shipping, and miscellaneous transport such as mass transit. 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 Model (MTCM) includes 63 fuel saving technologies with data specific to cars and light trucks (Tables 26 and 27) including incremental fuel efficiency improvement, incremental cost, first year of introduction, and fractional horsepower change. These assumed technology characterizations are scaled up or down to approximate the differences in each attribute for 6 Environmental Protection Administration (EPA) size classes of cars and light trucks.

The vehicle sales share module holds the share of vehicle sales by import and domestic manufacturers constant within a vehicle size class at 1999 levels based on National Highway Traffic and Safety Administration data.[1]

EPA size class sales shares are projected as a function of income per capita, fuel prices, and average predicted vehicle prices based on endogenous calculations within the MTCM.[2]

The MTCM utiizes 63 new technologies for each size class and origin of manufacturer (domestic or foreign) 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. The fuel economy module assumes the following:

- All fuel saving technologies have a 3-year payback period.
- The real discount rate remains steady at 15 percent.
- For cars, the fuel economy standards are not attribute based, but apply to both the manufacturer's domestic and imported fleet. For cars, the fuel economy standard increases from 27.5 mpg in 2010 to 41.0 mpg in 2020 in AEO2008. For light trucks, the footprint based average fleet fuel economy standard increases from 24.0 mpg in 2011 to 31.0 mpg in 2020. In AEO2008, the light duty vehicle fuel economy standards are assumed to remain at the 2020 level.
- 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 26. Standard Technology Matrix For Cars[1]

	Fractional Fuel Efficiency Change	Incremental Cost (1990$)	Incremental Cost ($/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse-power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1990	0
Material Substitution III	6.6	0	0.6	0	-10	1998	0
Material Substitution IV	9.9	0	0.9	0	-15	2006	0
Material Substitution V	13.2	0	1.2	0	-20	2014	0
Drag Reduction II	2.3	40	0	0	0	1988	0
Drag Reduction III	4.4	85	0	0	0.2	1992	0
Drag Reduction IV	6.3	145	0	0	0.5	2000	0
Drag Reduction V	8	225	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2004	0
Side Impact Technology	-1.5	100	0	0	2.2	2004	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	0.5	8	0	0	0	2002	0
Aggressive Shift Logic	2	60	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	6.5	435	0	20	0	1995	0
6-Speed Automatic	8	570	0	30	0	2003	0
6-Speed Manual	2	100	0	20	0	1995	0
CVT	10.5	615	0	-25	0	1998	0
Automated Manual Trans	8	100	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	3	80	0	0	0	1980	10
OHC/AdvOHV-6 Cylinder	3	100	0	0	0	1987	10
OHC/AdvOHV-8 Cylinder	3	120	0	0	0	1986	10
4-Valve/4-Cylinder	8	205	0	10	0	1988	17
4-Valve/6-Cylinder	8	280	0	15	0	1992	17
4 Valve/8-Cylinder	8	320	0	20	0	1994	17
5 Valve/6-Cylinder	8	300	0	18	0	1998	20
VVT-4 Cylinder	2.5	45	0	10	0	1994	5
VVT-6 Cylinder	2.5	115	0	20	0	1993	5
VVT-8 Cylinder	2.5	115	0	20	0	1993	5
VVL-4 Cylinder	4	170	0	25	0	1997	10
VVL-6 Cylinder	4	260	0	40	0	2000	10
VVL-8 Cylinder	4	330	0	50	0	2000	10
Camless Valve Actuation-4cyl	7.5	450	0	35	0	2009	13
Camless Valve Actuation-6cyl	7.5	600	0	55	0	2008	13
Camless Valve Actuation-8cyl	7.5	750	0	75	0	2007	13
Cylinder Deactivation	4.5	250	0	10	0	2004	0
Turbocharging/ Supercharging	6	650	0	-100	0	1980	15
Engine Friction Reduction I	2	25	0	0	0	1992	3
Engine Friction Reduction II	3.5	63	0	0	0	2000	5
Engine Friction Reduction III	5	114	0	0	0	2008	7
Engine Friction Reduction IV	6.5	177	0	0	0	2016	9
Stoichiometric GDI/4-Cylinder	7	300	0	20	0	2006	10
Stoichiometric GDI/6-Cylinder	7	450	0	30	0	2006	10
Lean Burn GDI	5	250	0	20	0	2006	0
5W-30 Engine Oil	1	22.5	0	0	0	1998	0
5W-20 Engine Oil	2	37.5	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	2	140	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	50	0	0	0	2007	0
Tires II	2	30	0	-8	0	1995	0
Tires III	4	75	0	-12	0	2005	0
Tires IV	6	135	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-6	1980	0
Four Wheel Drive Improvements	2	100	0	0	-1	2000	0
42V-Launch Assist and Regen	3	600	0	80	0	2005	-5
42V-Engine Off at Idle	4.5	800	0	45	0	2005	0
Tier 2 Emissions Technology	-1	120	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	2.55	2003	0
Variable Compression Ratio	4	450	0	25	0	2015	0

[1] Fractional changes refer to the percentage change from the 1990 values.
Sources: 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).

Table 27. Standard Technology Matrix For Light Trucks[1]

	Fractional Fuel Efficiency Change	Incremental Cost (1990$)	Incremental Cost ($/UnitWt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./UnitWt.)	Introduction Year	Fractional Horse-power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1994	0
Material Substitution III	6.6	0	0.6	0	-10	2002	0
Material Substitution IV	9.9	0	0.9	0	-15	2010	0
Material Substitution V	13.2	0	1.2	0	-20	2018	0
Drag Reduction II	2.3	40	0	0	0	1992	0
Drag Reduction III	4.4	85	0	0	0.2	1998	0
Drag Reduction IV	6.3	145	0	0	0.5	2006	0
Drag Reduction V	8	225	0	0	1	2014	0
Roll-Over Technology	-1.5	100	0	0	2.2	2006	0
Side Impact Technology	-1.5	100	0	0	2.2	2006	0
Adv Low Loss Torque Converter	2	25	0	0	0	2005	0
Early Torque Converter Lockup	0.5	8	0	0	0	2003	0
Aggressive Shift Logic	2	60	0	0	0	2003	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	6.5	435	0	20	0	1999	0
6-Speed Automatic	8	570	0	30	0	2003	0
6-Speed Manual	2	100	0	20	0	2000	0
CVT	10.5	615	0	-25	0	2004	0
Automated Manual Trans	8	100	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	3	80	0	0	0	1980	10
OHC/AdvOHV-6 Cylinder	3	100	0	0	0	1990	10
OHC/AdvOHV-8 Cylinder	3	120	0	0	0	1990	10
4-Valve/4-Cylinder	7	205	0	10	0	1998	17
4-Valve/6-Cylinder	7	280	0	15	0	2000	17
4 Valve/8-Cylinder	7	320	0	20	0	2000	17
5 Valve/6-Cylinder	7	300	0	18	0	2010	20
VVT-4 Cylinder	2.5	45	0	10	0	1998	5
VVT-6 Cylinder	2.5	115	0	20	0	1997	5
VVT-8 Cylinder	2.5	115	0	20	0	1997	5
VVL-4 Cylinder	4	170	0	25	0	2002	10
VVL-6 Cylinder	4	260	0	40	0	2001	10
VVL-8 Cylinder	4	330	0	50	0	2006	10
Camless Valve Actuation-4cyl	7.5	450	0	35	0	2014	13
Camless Valve Actuation-6cyl	7.5	600	0	55	0	2012	13
Camless Valve Actuation-8cyl	7.5	750	0	75	0	2011	13
Cylinder Deactivation	4.5	250	0	10	0	2004	0
Turbocharging/Supercharging	6	650	0	-100	0	1987	15
Engine Friction Reduction I	2	25	0	0	0	1992	3
Engine Friction Reduction II	3.5	63	0	0	0	2000	5
Engine Friction Reduction III	5	114	0	0	0	2010	7
Engine Friction Reduction IV	6.5	177	0	0	0	2016	9
Stoichiometric GDI/4-Cylinder	7	300	0	20	0	2008	10
Stoichiometric GDI/6-Cylinder	7	450	0	30	0	2010	10
Lean Burn GDI	5	250	0	20	0	2010	0
5W-30 Engine Oil	1	22.5	0	0	0	1998	0
5W-20 Engine Oil	2	37.5	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	2	140	0	0	0	2005	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	50	0	0	0	2008	0
Tires II	2	30	0	-8	0	1995	0
Tires III	4	75	0	-12	0	2005	0
Tires IV	6	135	0	-16	0	2015	0
Front Wheel Drive	2	250	0	0	-3	1984	0
Four Wheel Drive Improvements	2	100	0	0	-1	2000	0
42V-Launch Assist and Regen	3	600	0	80	0	2005	-5
42V-Engine Off at Idle	4.5	800	0	45	0	2005	0
Tier 2 Emissions Technology	-1	160	0	20	0	2006	0
Increased Size/Weight	-2.5	0	0	0	3.75	2003	0
Variable Compression Ratio	4	450	0	25	0	2015	0

[1]Fractional changes refer to the percentage change from the 1990 values.

Sources: 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).

Degradation factors (Table 28) used to convert Environmental Protection Agency-rated fuel economy to actual "on the road" fuel economy are based on table values. Baseline degradation factors are tapplication of a logistic curve to the projections of three factors: increases in city/highway driving, increashen adjusted to reflect the percentage of reformulated gasoline consumed.

Table 28. Car and Light Truck Degradation Factors

	2000	2005	2010	2015	2020	2030
Cars	79.1	81.3	81.8	82.3	82.8	83.8
Light Trucks	81.0	80.3	80.8	81.3	81.8	82.8

Source: Energy Information Administration, *Transportation Sector Model of the National Energy Modeling System, Model Documentation 2007*, DOE/EIA-M070(2007), (Washington, DC, 2007).

The vehicle miles traveled (VMT) module forecasts VMT as a function of the cost of driving per mile, and disposable personal income per capita. Coefficients were re-estimated for AEO2008. Based on output from the model, the fuel price elasticity rises to a maximum of -0.13 as fuel prices rise above reference case levels in each year.

Commercial Light Duty Fleet Assumptions

With the current focus of transportation legislation on commercial fleets and their composition, the Transportation Demand Module is designed to divide 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 in fleet use before being sold for use as personal vehicles (Table 29). The average length of time vehicles are kept before being sold for personal use is 4 years for business use, 5 years for government use, and 6 years for utility use. While the total number of vehicles sold to fleets can vary over time, the share of total fleet sales by fleet type is held constant at 2003 levels in the Transportation Demand Module. Of total automobile sales to fleets, 84.8 percent are used in business fleets, 6.5 percent in government fleets, and 8.7 percent in utility fleets. Of total light truck sales to fleets, 58.4 percent are used in business fleets, 7.1 percent in government fleets, and 34.5 percent in utility fleets.[3] Both the automobile and light truck shares by fleet type are held constant from 2004 through 2030. In 2003, 19.1 percent of all automobiles sold and 12.2 percent of all light trucks sold were for fleet use. The share of total automobile and light truck sales to fleet remains constant at these levels over the entire forecast period.

Table 29. 2005 Percent of fleet Alternative Fuel Vehicles by Fleet Type by Size class

	Mini	Subcompact	Compact	Midsize	Large	2-Seater
Car						
Business	0.00	10.52	10.73	42.68	36.07	0.00
Government	0.00	2.80	39.98	2.84	54.39	0.00
Utility	0.00	7.86	34.74	12.32	45.08	0.00
	5 Pk	Pk	5 Van	1 Van	5 Util	1 Util
Light Truck						
Business	7.94	35.14	7.89	26.76	5.46	16.81
Government	6.75	50.81	28.41	4.60	1.62	7.81
Utility	8.22	52.06	5.99	32.69	0.32	0.72

Source: CNEAF Alternatives to Traditional Transportation Fuels 2005 (Part II - User and Fuel Data). http://www.eia.doe.gov/cneaf/alternate/page/aftables/afvtransfuel_II.html #in use

Alternative-fuel shares of fleet sales by fleet type are held constant at year 2005 levels. Size class sales shares of vehicles are held constant at anticipated levels (Table 30).[4] Individual sales shares of alternative-fuel fleet vehicles by technology type are assumed to remain constant for utility, government, and for business fleets[5](Table 31).

Annual 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 30. Commercial Fleet Size Class Shares by Fleet and Vehicle Type
(Percentage)

Fleet Type by Size Class	Automobiles	Light Trucks
Business Fleet		
Mini	3.12	2.46
Subcompact	23.42	8.41
Compact	26.62	23.26
Midsize	36.15	8.12
Large	9.90	14.15
2-seater	0.78	43.60
Government Fleet		
Minl	0.19	6.67
Subcompact	4.58	43.60
Compact	20.55	10.44
Midsize	28.64	17.10
Large	45.99	3.82
2-seater	0.05	18.37
Utility Fleet		
Mini	1.50	7.26
Subcompact	12.47	38.71
Compact	10.01	11.79
Midsize	59.23	18.91
Large	16.42	7.19
2-seater	0.38	16.15

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 Integrated Analysis and Forecasting, (Oak Ridge, TN, January 2003).

Table 31. Purchases of Alternative-Fuel Vehicles by Fleet Type and Technology Type
(Percentage)

Technology	Business	Government	Utility
Ethanol	72.6	54.0	26.8
Methanol	0.0	0.0	0.0
Electric	1.1	3.0	1.1
CNG	4.6	8.5	17.3
LPG	21.7	34.5	54.7

Sources: CNEAF Alternatives to Traditional Transportation Fuels 2005 (part II - User and Fuel Data).
http://www.eia.doe.gov/cneaf/alternate/page/aftables/afvtransfuel_II.html #in use.

The Light Commercial Truck Model

The Light Commercial Truck Module of the NEMS Transportation Model is constructed to represent light trucks that weigh 8,501 to 10,000 pounds gross vehicle weight (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 efficiency, and energy use by vintage. Historic vehicle sales and stock data, which constitute the baseline from which the forecast is made, are taken from a recent Oak Ridge National Laboratory study.[6] The distribution of vehicles by vintage, and vehicle scrappage rates is derived from R.L. Polk company registration data.[7,8] Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle.[9,10]

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

The vehicle sales module compares the legislatively mandated sales to the results from the consumer driven sales shares. If the consumer driven sales shares are less than the legislatively mandated sales The

The growth in light commercial truck VMT is a function of industrial output for agriculture, mining, construction, trade, utilities, and personal travel. These industrial groupings were chosen for their correspondence with output measures being forecast by NEMS. The overall growth in VMT reflects a weighted average based upon the distribution to total light commercial truck VMT by sector. Forecasted fuel efficiencies are assumed to increase at the same annual growth rate as light-duty trucks (<8,500 pounds gross vehicle weight).

Consumer Vehicle Choice Assumptions

The Consumer Vehicle Choice Module (CVCM) 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, bi-fuel and flex-fuel),
- Hybrid (gasoline and diesel),
- Dedicated alternative fuel (CNG, LPG, methanol, and ethanol),
- Fuel cell (gasoline, methanol, and hydrogen), and
- Electric battery powered (lead acid, nickel-metal hydride,lithium polymer)[12]

The vehicle attributes considered in the choice algorithm include: price, maintenance cost, battery replacement cost, range, multi-fuel capability, home refueling capability, fuel economy, acceleration and luggage space. With the exception of maintenance cost, battery replacement cost, and luggage space, vehicle attributes are determined endogenously.[13] 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, CVCM 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 CVCM 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 CVCM vehicle stocks are set according to EIA surveys.[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 of three size classes: light medium (Class 3), heavy medium (Classes 4 -6), and heavy (Classes 7-8). Within the size classes, the stock model structure is designed to cover twenty vehicle vintages and estimate energy use by four fuel types: diesel, gasoline, LPG, and CNG. Fuel consumption estimates are reported regionally (by Census Division) according to the distillate fuel shares from the State Energy Data Report.[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, is shown in Table 32.

Table 32. Standard Technology Matrix for Freight Trucks

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment
Areo dynamic I: Cab top deflector, sloping hood and cab side flares	2002	600.00	0.023	0	750.00	0.023	0	750.00	0.018
Closing/covering of gap between tractor and trailer, aero dynamic bumper, underside air baffles, wheel well covers	N/A	N/A	0.000	2004	800.00	0.036	2005	1500.00	0.023
Trailer leading and trailing edge curvatures	N/A	N/A	0.000	2005	400.00	0.009	2005	500.00	0.012
Aero Dynamics IV: pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2010	2500.00	0.045
Tires I: radials	0	40.00	0.018	0	180.00	0.018	0	300.00	0.014
Tires II: low rolling resistance	2004	180.00	0.023	2005	280.00	0.023	2005	550.00	0.027
Tires III: super singles	N/A	N/A	0.000	N/A	N/A	0.000	2008	700.00	0.018
Tires IV: reduced rolling resistance from pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2015	500.00	0.011
Transmission: lock-up, electronic controls, reduced friction	2005	750.00	0.018	2005	900.00	0.018	2005	1000.00	0.020
Diesel Engine I: turbocharged, direct injection with better thermal management	2003	700.00	0.045	2004	1000.00	0.072	N/A	N/A	0.000
Diesel Engine II: integrated starter/alternator with idle off and limited regenerative breaking	2005	1500.00	0.045	2005	1200.00	0.045	N/A	N/A	0.000
Diesel Engine III: improved engine iwth lower friction, better injectors, and efficient combustion	2012	2000.00	0.090	2008	2000.00	0.072	N/A	300.00	0.000
Diesel Engine IV: hybrid electric powertrain	2010	6000.00	0.360	2010	8000.00	0.360	N/A	N/A	0.000
Diesel Engine V: internal friction reduction - iimproved lubricants and bearings	N/A	N/A	0.000	N/A	N/A	0.000	2005	500.00	0.020
Diesel Engine VI: increased peak cylinder pressure	N/A	NA	0.000	N/A	N/A	0.000	2006	1000.00	0.040
Diesel Engine VII: improved injectors and more efficient combustion	N/A	N/A	0.000	N/A	N/A	0.000	2007	N/A	0.060
Diesel Engine VIII: reduce waste heat improved thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	N/A	0.000

Table 32. Standard Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment
Gasoline Engine I: electronic fuel injection, DOHC, multiple values	2003	700.00	0.045	2003	1000.00	0.045	N/A	N/A	0.000
Gasoline Engine II: integrated starter/alternator with idle off and limited regenerative breaking	2005	1000.00	0.045	2005	1200.00	0.072	N/A	N/A	0.000
Gasoline Engine III: direct injection (GDI)	2008	700.00	0.108	2008	1000.00	0.108	N/A	N/A	0.000
Gasoline Engine IV; hybrid electric powertrain	2010	6000.00	0.405	2010	8000.00	0.405	N/A	N/A	0.000
Weight Reduction I: high strength lightweight materials	2010	1300.00	0.045	2007	2000.00	0.045	2005	2000.00	0.100
Diesel Emission-NO_x I: exhaust recirculation, timing retard, selective catalytic reduction	2002	250.00	-0.040	2003	400.00	-0.040	2003	500.00	-0.040
Diesel Emissions-NO_x II: nitrogen enriched combustion air	2003	500.00	-0.005	2003	700.00	-0.005	2003	750.00	-0.005
Diesel Emissions-NO_x III: non-thermal plasma catalyst	2007	1000.00	-0.015	2006	1200.00	-0.015	2007	1250.00	-0.015
Diesel Emissions-NO_x IV: NO_x absorber system	2007	1500.00	-0.030	2006	2000.00	-0.030	2007	2500.00	-0.030
Diesel Emission-PM I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission-PM II: catalytic particulate filter	2006	1000.00	-0.015	2006	1250.00	-0.025	2006	1500.00	-0.015
Diesel Emission-HC/CO I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesl Emission-HC/CO II: closed crankcase system	2005	50.00	0.000	2005	65.00	0.000	2005	75.00	0.000
Gasoline Emission-PM I: Improved oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000
Gasoline Emission-NO_x I: EGR/spark retard	2002	25.00	-0.015	2002	25.00	-0.015	N/A	N/A	0.000
Gasoline Emission-NO_x II: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-NO_x III: secondary air/closed loop system	2008	50.00	0.000	2008	50.00	0.000	N/A	N/A	0.000

Table 32. Standard Technology Matrix for Freight Trucks (cont.)

	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
Technology Type	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment	Introd-uction Year	Capital Cost	Incr. Fuel Econ. Improve-ment
Gasoline Emission-HC/CO I: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO II: evap. canister w/improved vaccum, materials, and connectors	2003	50.00	0.000	2003	50.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO III: oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000

1. Payback period is same for the three modes.

The freight module uses projections of dollars 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 Industrial 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 various emission control technologies and 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. Emissions control equipment is assumed to enter the market to meet regulated emission standards.

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 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.[21] Vehicle scrappage rates are also estimated using R. L. Polk Co. data.[22]

Freight and Transit Rail Assumptions

The freight rail module uses the industrial output by NAICS code measured in real 1987 dollars and converts these dollars into an adjusted volume equivalent. Coal production from the NEMS Coal Market Module is used to adjust coal rail travel. Freight rail adjustment coefficients (used to convert dollars to volume equivalents) are based on historical data and remain constant.[23,24] Initial freight rail efficiencies are based on the freight model from Argonne National Laboratory.[25] The distribution of rail fuel consumption by fuel type is also based on historical data and remains constant.[26] Regional freight rail consumption estimates are distributed according to the State Energy Data Report.[27]

Domestic and International Shipping Assumptions

As done in the previous sub-module, the domestic freight shipping module uses the industrial output by NAICS code measured in real 1987 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 forecast. [28] Regional domestic shipping consumption estimates are distributed according to the residual oil regional shares in the *State Energy Data Report*. [29]

Air Travel Demand Assumptions

The air travel demand module calculates the domestic and international ticket prices for travel as a function of fuel cost. The ticket price is constrained to be no lower than the current lowest cost per mile provider, adjusted by load factor. Domestic and international revenue passenger miles are based on historic data,[30] per capita income, and ticket price. The revenue ton miles of air freight are based on merchandise exports, gross domestic product, and fuel cost.[31]

Airport capacity constraints based on the *FAA's Airport Capacity Benchmark Report 2004* are incorporated into the air travel demand module using airport capacity measures.[32] 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 is expected to increase over time due to planned infrastructure improvements. If the projected demand in air travel exceeds the capacity constraint, demand is reduced to match the constraint.

Aircraft Stock/Efficiency Assumptions

The aircraft stock and efficiency module consists of a world, US and Non-US, 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 2003, new passenger sales, and the survival rate by vintage (Table 33).[33] New passenger sales are a function of revenue passenger miles and gross domestic product.

Table 33. 2006 USA Passenger and Cargo Aircraft Supply and Survival Rate

	Age of Aircraft (years)					
Aircraft Type	New	1-10	11-20	21-30	>30	Total
Passenger						
Narrow Body	135	1,578	1,405	537	308	3,963
Wide Body	9	303	255	124	36	727
Regional Jets	94	1,863	70	7	12	2,046
Cargo						
Narrow Body	1	21	67	156	329	574
Wide Body	8	127	177	26	196	769
Regional Jets	0	0	4	23	13	40
Survival Curve (fraction)	New	5	10	20	30	
Narrow Body	1.0000	0.9998	0.9992	0.9911	0.9256	
Wide Body	1.0000	0.9980	0.9954	0.9754	0.8892	
Regional Jets	1.0000	0.9967	0.9942	0.9816	0.9447	

Source: Jet Information Services, 2006 World Jet Inventory, data tables (2006).

Older planes, 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, vary over time, with wide bodies remaining constant and narrow bodies increasing.[34] The difference between the seat-miles demanded and the available seat-miles represents potential newly purchased aircraft. If demand is less than supply, then passenger aircraft is either parked or exported, starting with twenty nine year old aircraft, at a pre-defined rate. Aircraft continues to be parked until equilibrium is reached. If supply is less than demand planes are either imported or unparked and brought back into service.

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, at a minimum, a 5-percent improvement over the stock efficiency of surviving airplanes. Maximum growth rates of fuel efficiency for new aircraft are based on a fixed growth rate. Regional shares of all types of aircraft fuel use are assumed to be constant and are consistent with the State Energy Data Report estimate of regional jet fuel shares.

Legislation and Regulations

Energy Independence and Security Act of 2007 (EISA2007)

The EISA2007 legislation requires the development of fuel economy standards for work trucks (8,500 lbs. to less than 10,000 lbs GVWR) and commercial medium- and heavy-duty on-highway vehicles (10,000 lbs or more GVWR). The new fuel economy standards require consideration of vehicle attributes and duty requirements and can prescribe standards for different classes of vehicles, such as buses used in urban operation or semi-trucks used primarily in highway operation. The Act provides a minimum of 4 full model years lead time before the new fuel economy standard is adopted and 3 full model years after the new fuel economy standard has been established before the fuel economy standards for work trucks can be modified. Because these fuel economy standards are pending and NEMS does not currently model fuel economy regulation for work trucks or commercial medium- and heavy- duty vehicles, this aspect of the Act is not included in *AEO2008*.

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 has a switch that allows for sensitivity analysis of CAFE credit banking by manufacturer fleet, but does not model the trading of credits across manufacturers. The *AEO2008* does not consider trading of credits since this would require significant modifications to NEMS and detailed technology cost and efficiency data by manufacturer, which is not readily available.

The CAFE credits specified under the Alternative Motor Fuels Act (AMFA) through 2019 is 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 not model CAFE credits earned from alternative fuel vehicles sales because manufacturer specific data would be required and although some manufacturer detail is represented for light trucks, there is no manufacturer detail currently represented for cars. In addition, an algorithm that counts credits earned from the sale of alternative fueled vehicles would need to be added to NEMS, which would require significant modification to the model structure. *AEO2008* does not consider this section of the Act.

The Energy Policy Act of 2005

The Energy Policy Act of 2005 provides tax credits for the purchase of vehicles that have a lean burn engine or employ a hybrid or fuel cell propulsion system. The amount of the credit received for a vehicle is based the vehicle's inertia weight, improvement in city tested fuel economy relative to an equivalent 2002 base year value, emissions classification, and type of propulsion system. The tax credit is also sales limited by manufacturer for vehicles with lean burn engines or hybrid propulsion systems. After December 31, 2005, the first calendar quarter a manufacturer's sales of lean burn or hybrid vehicles reaches 60,000 units, the phase out period begins. Reduction of credits begins in the second calendar quarter following the initial quarter the sales maximum was reached. For that quarter and the following quarter, the applicable tax credit will be reduced by 50 percent. For the subsequent third and fourth calendar quarters, the applicable tax credit is reduced to 25 percent of the original value. These tax credits are included in the AEO2008.

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 34).

Table 34. 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: EIA, Energy Efficiency and Renewable Energy (Washington, DC, 2005), http://www1.eere.energy.gov/femp/about/fleet-requirements.html, http://www1.eere.energy.gov/vehicles and fuels/epact/state/state-gov.html.

Because the commercial fleet model operates on three fleet type representations (business, government, and utility), the federal and state mandates are weighted by fleet vehicle stocks to create a composite mandate for both. The same combining methodology is used to create a composite mandate for electric utilities and fuel providers based on fleet vehicle stocks.[35]

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. Twelve 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.

vehicle sales module compares the legislatively mandated sales to the results from the consumer driven sales shares. If the consumer driven sales shares are less than the legislatively mandated sales requirements, then the legislative requirements serve as a minimum constraint for the hybrid, electric, and fuel cell vehicle sales.

Transportation Alternative Cases

High Technology Case

In the *high technology case*, the conventional fuel saving technology characteristics came from a study by the American Council for an Energy Efficient Economy.[36] Tables 35 and 36 summarize the High Technology matrix for cars and light trucks. High technology case assumptions for heavy trucks reflect the optimistic values, with respect to efficiency improvement, for advanced engine and emission control technologies as reported by ANL.[37]

Table 35. High Technology Matrix For Cars

	Fractional Fuel Efficiency Change	Incremental Cost (1990$)	Incremental Cost ($/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse-power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1990	0
Material Substitution III	6.6	0	0.5	0	-10	1998	0
Material Substitution IV	9.9	0	0.5	0	-15	2006	0
Material Substitution V	13.2	0	1.1	0	-20	2014	0
Drag Reduction II	1.6	0	0	0	0	1988	0
Drag Reduction III	3.2	0	0	0	0.2	1992	0
Drag Reduction IV	6.3	145	0	0	0.5	2000	0
Drag Reduction V	8	225	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2004	0
Side Impact Technology	-1.5	100	0	0	2.2	2004	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	1	8	0	0	0	2002	0
Aggressive Shift Logic	3.5	65	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	8	410	0	20	0	1995	0
6-Speed Automatic	9.5	495	0	30	0	2003	0
6-Speed Manual	2	80	0	20	0	1995	0
CVT	11.5	365	0	-25	0	1998	0
Automated Manual Trans	8	100	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	3	60	0	0	0	1980	10
OHC/AdvOHV-6 Cylinder	3	80	0	0	0	1987	10
OHC/AdvOHV-8 Cylinder	3	100	0	0	0	1986	10
4-Valve/4-Cylinder	8.8	185	0	10	0	1988	17
4-Valve/6-Cylinder	8.8	260	0	15	0	1992	17
4 Valve/8-Cylinder	8.8	320	0	20	0	1994	17
5 Valve/6-Cylinder	9	300	0	18	0	1998	20
VVT-4 Cylinder	2.5	30	0	10	0	1994	5
VVT-6 Cylinder	2.5	90	0	20	0	1993	5
VVT-8 Cylinder	2.5	90	0	20	0	1993	5
VVL-4 Cylinder	7.5	150	0	25	0	1997	10
VVL-6 Cylinder	7.5	205	0	40	0	2000	10
VVL-8 Cylinder	7.5	290	0	50	0	2000	10
Camless Valve Actuation-4cyl	12	450	0	35	0	2009	13
Camless Valve Actuation-6cyl	12	600	0	55	0	2008	13
Camless Valve Actuation-8cyl	12	750	0	75	0	2007	13
Cylinder Deactivation	9	250	0	10	0	2004	0
Turbocharging/ Supercharging	5	475	0	-100	0	1980	15
Engine Friction Reduction I	2	25	0	0	0	1992	3
Engine Friction Reduction II	3.5	63	0	0	0	2000	5
Engine Friction Reduction III	5	114	0	0	0	2008	7
Engine Friction Reduction IV	6.5	177	0	0	0	2016	9
Stoichiometric GDI/4-Cylinder	7	300	0	20	0	2006	10
Stoichiometric GDI/6-Cylinder	7	450	0	30	0	2006	10
Lean Burn GDI	6	250	0	20	0	2006	0
5W-30 Engine Oil	1	10.5	0	0	0	1998	0
5W-20 Engine Oil	2	20	0	0	0	2003	0
OW-20 Engine Oil	3.1	80	0	0	0	2030	0
Electric Power Steering	2	50	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	50	0	0	0	2007	0
Tires II	1.5	15	0	-8	0	1995	0
Tires III	3	35	0	-12	0	2005	0
Tires IV	6	90	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-6	1980	0
Four Wheel Drive Improvements	2	100	0	0	-1	2000	0
42V-Launch Assist and Regen	5	400	0	80	0	2005	-5
42V-Engine Off at Idle	6	500	0	45	0	2005	0
Tier 2 Emissions Technology	-1	120	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	2.55	2003	0
Variable Compression Ratio	4	350	0	25	0	2015	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).

Table 36. High Technology Matrix For Light Trucks

	Fractional Fuel Efficiency Change	Incremental Cost (1990$)	Incremental Cost ($/Unit Wt.)	Incremenal Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse-power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1994	0
Material Substitution III	6.6	0	0.5	0	-10	2002	0
Material Substitution IV	9.9	0	0.5	0	-15	2010	0
Material Substitution V	13.2	0	1.1	0	-20	2018	0
Drag Reduction II	1.6	0	0	0	0	1992	0
Drag Reduction III	3.2	0	0	0	0.2	1998	0
Drag Reduction IV	6.3	145	0	0	0.5	2006	0
Drag Reduction V	8	225	0	0	1	2014	0
Roll-Over Technology	-1.5	100	0	0	2.2	2006	0
Side Impact Technology	-1.5	100	0	0	2.2	2006	0
Adv Low Loss Torque Converter	2	25	0	0	0	2005	0
Early Torque Converter Lockup	1	8	0	0	0	2003	0
Aggressive Shift Logic	3.5	65	0	0	0	2003	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	8	410	0	20	0	1999	0
6-Speed Automatic	9.5	495	0	30	0	2003	0
6-Speed Manual	2	80	0	20	0	2000	0
CVT	11.5	365	0	-25	0	2004	0
Automated Manual Trans	8	100	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	3	60	0	0	0	1980	10
OHC/AdvOHV-6 Cylinder	3	80	0	0	0	1990	10
OHC/AdvOHV-8 Cylinder	3	100	0	0	0	1990	10
4-Valve/4-Cylinder	8.8	185	0	10	0	1998	17
4-Valve/6-Cylinder	8.8	260	0	15	0	2000	17
4 Valve/8-Cylinder	8.8	320	0	20	0	2000	17
5 Valve/6-Cylinder	9	300	0	18	0	2010	20
VVT-4 Cylinder	2.5	30	0	10	0	1998	5
VVT-6 Cylinder	2.5	90	0	20	0	1997	5
VVT-8 Cylinder	2.5	90	0	20	0	1997	5
VVL-4 Cylinder	7.5	150	0	25	0	2002	10
VVL-6 Cylinder	7.5	205	0	40	0	2001	10
VVL-8 Cylinder	7.5	290	0	50	0	2006	10
Camless Valve Actuation-4cyl	12	450	0	35	0	2014	13
Camless Valve Actuation-6cyl	12	600	0	55	0	2012	13
Camless Valve Actuation-8cyl	12	750	0	75	0	2011	13
Cylinder Deactivation	9	250	0	10	0	2004	0
Turbocharging/Supercharging	5	475	0	-100	0	1987	15
Engine Friction Reduction I	2	25	0	0	0	1992	3
Engine Friction Reduction II	3.5	63	0	0	0	2000	5
Engine Friction Reduction III	5	114	0	0	0	2010	7
Engine Friction Reduction IV	6.5	177	0	0	0	2016	9
Stoichiometric GDI/4-Cylinder	7	300	0	20	0	2008	10
Stoichiometric GDI/6-Cylinder	7	450	0	30	0	2010	10
Lean Burn GDI	6	250	0	20	0	2010	0
5W-30 Engine Oil	1	10.5	0	0	0	1998	0
5W-20 Engine Oil	2	20	0	0	0	2003	0
OW-20 Engine Oil	3.1	80	0	0	0	2030	0
Electric Power Steering	2	50	0	0	0	2005	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	50	0	0	0	2008	0
Tires II	1.5	15	0	-8	0	1995	0
Tires III	3	35	0	-12	0	2005	0
Tires IV	6	90	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-3	1984	0
Four Wheel Drive Improvements	2	100	0	0	-1	2000	0
42V-Launch Assist and Regen	5	400	0	80	0	2005	-5
42V-Engine Off at Idle	6	500	0	45	0	2005	0
Tier 2 EmissionsTechnology	-1	120	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	3.75	2003	0
Variable Compression Ratio	4	350	0	25	0	2015	0

Source: Energy and Enviromental 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).

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