Transportation Demand Module

The NEMS Transportation Demand Module estimates energy consumption across the nine Census Divisions 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, light trucks, sport utility vehicles and vans), commercial light trucks (8501-10,000 lbs gross vehicle weight), freight trucks (>10,000 lbs gross vehicle weight), freight and passenger airplanes, 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

Macroeconomic Sector Inputs

Macroeconomic sector inputs used in the NEMS Transportation Demand Module (Table 28) consist of the following: gross domestic product (GDP), industrial output by Standard Industrial Classification code, personal disposable income, new car and light truck sales, total population, driving age population, total value of imports and exports, and the military budget. The share of total vehicle sales that represent light truck sales is assumed to approach fifty percent by 2020.

Table 28. Macroeconomic Inputs to the Transportation Module
(Millions)

Macroeconomic Input	2000	2005	2010	2015	2020	2025
New Car Sales	9.0	8.2	8.9	9.5	9.4	9.4
New Light Truck Sales	7.8	7.6	8.5	9.3	9.4	9.3
Real Disposable Income (billion 1996 Chain-Weighted Dollars)	6,630	7,402	8,622	10,093	11,720	13,430
Real GDP (billion 1996 Chain-Weighted Dollars)	9,191	10,337	12,244	14,307	16,461	18,914
Driving Age Population	213.1	224.8	236.6	246.7	256.5	266.6
Total Population	275.7	288.1	300.2	312.7	325.3	338.2

Source: Energy Information Administration, *AEO2003* National Energy Modeling System run: aeo2003.d110502c.

Light-Duty Vehicle Assumptions

The light duty vehicle Fuel Economy Module includes 63 fuel saving technologies with data specific to cars and light trucks 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 (Tables 29 and 30).

The vehicle sales share module holds vehicle sales shares by import and domestic manufacturers constant within a vehicle size class at the 1999 level from the National Highway Traffic and Safety Administration data.[29]

EPA size class sales shares are projected as a function of income per capita, fuel prices, and average predicted vehicle prices based on endogeous calculations within the Fuel Economy Module.[30]

The Fuel Economy Module utilizes 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

Table 29. 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	2002	0
Drag Reduction V	8	225	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2005	0
Side Impact Technology	-1.5	100	0	0	2.2	2005	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	410	0	20	0	1995	0
6-Speed Automatic	8	495	0	30	0	2004	0
6-Speed Manual	2	100	0	20	0	1995	0
CVT	10.5	415	0	-25	0	1998	0
Automated Manual Trans	8	100	0	0	0	2006	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	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	5	170	0	25	0	1997	10
VVL-6 Cylinder	5	260	0	40	0	2000	10
VVL-8 Cylinder	5	330	0	50	0	2000	10
Camless Valve Actuation-4cyl	11	450	0	35	0	2009	13
Camless Valve Actuation-6cyl	11	600	0	55	0	2008	13
Camless Valve Actuation-8cyl	11	750	0	75	0	2007	13
Cylinder Deactivation	7.5	250	0	10	0	2004	0
Turbocharging/ Supercharging	7	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	50	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.3	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	2001	0
Variable Compression Ratio	4	350	0	25	0	2015	0

N/A = Non Applicable

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

Source: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002)

Table 30. Standard Technology Matrix For Light Trucks[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	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	2006	0
Aggressive Shift Logic	2	60	0	0	0	2006	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	6.5	410	0	20	0	1999	0
6-Speed Automatic	8	495	0	30	0	2008	0
6-Speed Manual	2	100	0	20	0	2000	0
CVT	10.5	415	0	-25	0	2008	0
Automated Manual Trans	8	100	0	0	0	2010	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	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	5	170	0	25	0	2002	10
VVL-6 Cylinder	5	260	0	40	0	2001	10
VVL-8 Cylinder	5	330	0	50	0	2006	10
Camless Valve Actuation-4cyl	11	450	0	35	0	2014	13
Camless Valve Actuation-6cyl	11	600	0	55	0	2012	13
Camless Valve Actuation-8cyl	11	750	0	75	0	2011	13
Cylinder Deactivation	7.5	250	0	10	0	2004	0
Turbocharging/Supercharging	7	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	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	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	2001	0
Variable Compression Ratio	4	350	0	25	0	2015	0

N/A = Non Applicable

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

Source: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002) 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 30 percent.
- Corporate Average Fuel Efficiency standards remain constant at 1998 levels.
- 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.

Degradation factors (Table 31) used to convert Environmental Protection Agency-rated fuel economy to actual “on the road” fuel economy are based on application of a logistic curve to the projections of three factors: increases in city/highway driving, increasing congestion levels, and rising highway speeds.[31] Degradation factors are also adjusted to reflect the percentage of reformulated gasoline consumed.

Table 31. Car and Light Truck Degradation Factors

	2000	2005	2010	2015	2020	2025
Cars	74.5	76.1	77.7	79.4	81.0	81.0
Light Trucks	81.3	80.9	80.6	80.3	80.0	80.0

Source: Energy Information Administration, *Transportation Sector Model of the National Energy Modeling System, Model Documentation 2002*, DOE/EIA-M070(2002), (Washington, DC, January 2002).

The vehicle miles traveled (VMT) module forecasts VMT as a function of the cost of driving per mile, income per capita, ratio of female to male VMT, and growth in the driving population. Coefficients were re-estimated for *AEO2003.* The ratio of female to male VMT is assumed to asymptotically approach 68 percent by 2020. Total VMT is calibrated to Federal Highway Administration VMT data.[32,33] The fuel price elasticity rises from -0.04 to -0.2 as fuel prices rise above reference case levels in each year.

- The share of light truck sales (Class 1 and Class 2 trucks) is assumed to reach a maximum of 50 percent of total sales by 2020. However, the light truck share will gradually decline to 46 percent if fuel prices rise to approximately $1.55 per gallon. The size class sales shares will also gravitate to 25 percent for subcompacts, 40 percent for compacts, 25 percent for mid size, and 10 percent for luxury if fuel prices exceed reference case levels of approximately $1.55 per/gallon.

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 of fleets: business, government, and utility. Based on this classification, commercial light-duty fleet vehicles vary in survival rates and duration in the fleet, before being combined with the personal vehicle stock (Table 32). Sales shares of fleet vehicles by fleet type vary by time period. Automobile fleets are divided into the following shares with the values in years 2000 and through 2025, as follows: business (91.1 percent), government (6.4 percent), and utilities (2.4 percent). Light truck fleets are divided into the following shares: business (56.8 percent), government (12.3 percent), and utilities (31.0 percent)[34,35]. Both cars and light truck fleet sales vary historically over time as a percent of total car and light truck sales, with year 2000 cars being at 23.7 percent and light trucks being at 17.5 percent. Fleet sales of cars vary through 2008 and remain constant thereafter, while light truck sales remain constant over the entire forecast period.

Alternative-fuel shares of fleet sales by fleet type are initially set according to historical shares (business (0.36 percent), government (2.21 percent), utility (2.64 percent))[36,37] then compared to a minimum constraint level of sales based on legislative initiatives, such as the Energy Policy Act of 1992 and the Low Emission Vehicle Program.[38,39] Size class sales shares of vehicles are held constant at anticipated levels (Table 33).[40] Individual sales shares of alternative-fuel fleet vehicles by technology type are assumed to remain at anticipated levels for utility, government, and for business fleets[41,42] (Table 34).

Annual VMT per vehicle by fleet type stays constant over the forecast period based on the Oak Ridge National Laboratory fleet data.

Table 32. The Average Length of Time Vehicles Are Kept Before they are Sold to Others
(Months)

Vehicle Type	Business	Utility	Government
Cars	35	68	81
Light Trucks	56	60	82
Medium Trucks	83	86	96
Heavy Trucks	103	132	117

Source: Oak Ridge National Laboratory, *Fleet Characteristics and Data Issues*, Stacy Davis and Lorena Truett, unpublished final report prepared for the Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, (Oak Ridge, TN, Draft version, Dec. 10, 2003).

Table 33. Commercial Fleet Size Class Shares by Fleet and Vehicle Type
(Percentage)

Fleet Type by Size Class	Automobiles	Light Trucks
Business Fleet		
Mini	0.04	3.77
Subcompact	25.32	11.91
Compact	23.18	37.87
Midsize	41.93	7.92
Large	9.45	3.58
2-seater	0.08	34.96
Government Fleet		
Minl	0.03	7.76
Subcompact	7.64	42.29
Compact	9.08	9.16
Midsize	29.03	18.86
Large	54.21	0.21
2-seater	0.01	21.72
Utility Fleet		
Mini	0.04	13.50
Subcompact	25.32	42.68
Compact	23.18	5.43
Midsize	41.93	26.14
Large	9.45	1.14
2-seater	0.08	11.11

Source: Oak Ridge National Laboratory, *Fleet Characteristics and Data Issues*, Stacy Davis and Lorena Truett, unpublished final report prepared for the Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, (Oak Ridge, TN, Draft version, Dec. 10, 2003).

Table 34. Anticipated Purchases of Alternative-Fuel Vehicles by Fleet Type and Technology Type
(Percentage)

AFV 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: Energy Information Administration, *Describing Current and Potential Markets for Alternative Fuel Vehicles*, DOE/EIA-0604(96), (Washington, DC, March 1996). Energy Information Administration, *Alternatives to Traditional Transportation Fuels* http://www.eia.doe.gov/cneaf/solar.renewables/alt_trans_fuel98/table14.html.

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.

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.[43] The distribution of vehicles by vintage, and vehicle scrappage rates is derived from R.L. Polk company registration data.[44],[45] Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle.[46],[47]

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 currently 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).

Alternative-Fuel Vehicle Technology Choice Assumptions

The Alternative-Fuel Vehicle (AFV) technology choice module 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.[48] The technology sets include:

- Conventional fuel capable (gasoline, disel, bi-fuel and flex-fuel),
- Hybrid (gasoline and disel),
- 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)[49]

The vehicles 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.[50] 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, AFV fuel efficient technology attributes are calculated relative to conventional gasoline miles per gallon. It is assumed that many fuel efficiency improvements to conventional vehicles will be transferred to alternative-fuel vehicles. Specific individual alternative-fuel technological improvements are also dependent upon the AFV technology type, cost, research and development, and availability over time. Make and model availability estimates are assumed values according to a logistic curve based on the initial technology introduction date and are based on current offerings. Coefficients summarizing consumer valuation of vehicle attributes were derived from assumed economic valuation compared to vehicle price elasticities. Initial AFV vehicle stocks are set according to EIA surveys.[51,52] A fuel switching algorithm based on the relative fuel prices for alternative fuels compared to gasoline is used to determine the percentage of total VMT represented by alternative fuels in bi-fuel and flex-fuel alcohol vehicles.

Freight Truck Assumptions

The freight truck module estimates vehicle stocks, travel, fuel efficiency and energy use for three size classes; light medium (Class 3), heavy medium (Classes 4 through 6), and heavy (Classes 7 and 8). Within size class, the stock model structure is designed to estimate energy use by four fuel types (diesel, gasoline, LPG, and CNG) and twenty vehicle vintages. Fuel consumption estimates are reported regionally (by Census division) according to the State Energy Data Report distilate regional shares.[53] The module uses projections of dollars of industrial output to estimate growth in freight truck travel. Industrial output is converted to an equivalent measure of volume output using freight adjustment coefficients.[54,55] These freight adjustment coefficients vary by NEMS Standard Industrial Classification (SIC) code, gradually diminishing their deviation over time toward parity. Freight truck load factors (ton-miles per truck) by SIC code are constants formulated from historical data.[56]

New freight truck fuel economy is dependent on the market penetration of various emission control technologies and advanced engine components.[57] For the advanced engine components, market penetration is determined as a function of technology 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 are assumed to enter the market to meet regulated emission standards.

Heavy truck freight travel is estimated by size class and fuel type and is based on matching projected freight travel demand (measured by industrial output) to the travel supplied by the current fleet. Travel by vintage by size class is then adjusted so that total travel meets total demand. Initial heavy vehicle travel by vintage and size class was derived using Vehicle Inventory and Use Survey (VIUS) data.[58]

Initial freight truck stocks by vintage are obtained from R.L. Polk Co. and are distributed by fuel type using VIUS data.[59] Vehicle scrappage rates were also estimated using R.L. Polk Co. Data.[60]

Freight and Transit Rail Assumptions

The freight rail module receives industrial output by SIC code measured in real 1987 dollars and converts these dollars into an adjusted volume equivalent. Specific NEMS coal production from the Coal Market Module is also used to adjust coal rail travel. Freight rail adjustment coefficients, which are used to convert dollars into volume equivalents, remain constant and are based on historical data.[61,62] Initial freight rail efficiencies are based on the freight model from Argonne National Laboratory.[63] The distribution of rail fuel consumption by fuel type remains constant and is based on historical data.[64] Regional freight rail consumption estimates are distributed according to the *State Energy Data Report 1999*.[65]

Freight Domestic and International Shipping Assumptions

The freight domestic shipping module also converts industrial output by SIC code measured in dollars, to a volumetric equivalent by SIC code.[66,67] These freight adjustment coefficients are based on analysis of historical data and remain constant throughout the forecast period. Domestic shipping efficiencies are based on the freight model by Argonne National Laboratory. The energy consumption in the freight 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 remains constant throughout the analysis and is based on historical data.[68] Regional domestic and international shipping consumption estimates are distributed according to the *State Energy Data Report* residual oil regional shares.[69]

Air Travel Demand Assumptions

The air travel demand module calculates the ticket price for travel as a function of fuel cost. Similar to the light-duty vehicle module, the air travel fuel price elasticity rises from -0.05 to -0.2 if jet fuel prices exceed reference case levels. A demographic index based on the propensity to fly was introduced into the air travel demand equation.[70] The propensity to fly was made a function of the age and gender distribution over the forecast period[71],[72] The air travel demand module assumes that these relationships between the groups and their propensity to fly remain constant over time. International revenue passenger miles are based on historical data.[73] The revenue ton miles of air freight are based on merchandise exports and gross domestic product.

Airport capacity constraints based on the *FAA's Airport Capacity Benchmark Report 2001* were incorporated into the air travel demand module using airport capacity measures. 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, price feedbacks are utilized to reduce demand and achieve market equilibrium.

Aircraft Stock/Efficiency Assumptions

The aircraft stock and efficiency module consists of a stock model of both wide and narrow body planes by vintage. The shifting of passenger load between narrow and wide body aircraft is assumed to occur at a constant historical annual 1-percent rate.[74] The available seat-miles per plane, which measure the carrying capacity of the airplanes by aircraft type, remain constant and are based on holding the seat-miles and the number of planes constant within an aircraft type.[75] The difference between the seat-miles demanded and the available seat-miles represents newly purchased aircraft. Aircraft purchases in a given year cannot exceed historical annual growth rates, a constraint that sets an upper limit on the application of new aircraft to meet the gap between seat-miles demanded and available seat-miles. With a constraint on new aircraft purchases, it is assumed that when the gap exceeds historical aircraft sales levels, planes that have been temporarily stored or retired will be brought back into service. Technological availability, economic viability, and efficiency characteristics of new aircraft are based on the technologies listed in the Oak Ridge National Laboratory Air Transport Energy Use Model. (Table 35)[76] Fuel efficiency of new aircraft acquisitions represents, at a minimum, a 5-percent improvement over the stock efficiency of surviving airplanes.[77] Maximum growth rates of fuel efficiency for new aircraft are based on a future technology improvement list consisting of an estimate of the introduction year, jet fuel price, and an estimate of the proposed marginal fuel efficiency improvement. Regional shares of all types of aircraft fuel are assumed to be constant and are consistent with the *State Energy Data Report* estimate of regional jet fuel shares.

Table 35. Future New Aircraft Technology Improvement List

Proposed Technology	Introduction Year	Jet Fuel Price Necessary For Cost-Effectiveness (1987 dollars per gallon)	Seat-Miles per Gallon Gain Over 1990 (percent)	
			Narrow Body	Wide Body
Engines				
Ultra-high Bypass	1995	$.69	10	10
Propfan	2000	$1.36	23	0
Thermodynamics	2010	$1.22	20	20
Aerodynamics				
Hybrid Laminar Flow	2020	$1.53	15	15
Advanced Aerodynamics	2000	$1.70	18	18
Other				
Weight Reducing Materials	2000	-	15	15

Source: Greene, D.L., *Energy Efficiency Improvement Potential of Commercial Aircraft to 2010*, ORNL-6622, 6/1990., and from data tables in the Air Transportation Energy Use Model (ATEM), Oak Ridge National Laboratory.

Table 36. EPACT Legislative Mandates for Percentage AFV Purchases by Fleet Type, Year

Year	Municipal & Business	Federal	State	Fuel Providers	Electric Utilities
1996	-	25	-	-	-
1997	-	33	10	30	-
1998	-	50	15	50	30
1999	-	75	25	70	50
2000	-	75	50	90	70
2001	-	75	75	90	90
2002	20	75	75	90	90
2003	40	75	75	90	90
2004	60	75	75	90	90
2005	70	75	75	70	90

Source: EIA, *Alternatives to Traditional Transportation Fuels 1994*, DOE/EIA-0585(94), (Washington, D.C, February 1996).

Legislation

Energy Policy Act of 1992 (EPACT)

Fleet alternative-fuel vehicle sales necessary to meet the EPACT regulations were 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 36). Business fleet EPACT mandates are not included in the projections for AFV sales pending a decision on a proposed rulemaking.

Because the commercial fleet model operates on three fleet type representations (business, government, and utility), the federal and state mandates were weighted by fleet vehicle stocks to create a composite mandate for both. The same combining methodology was used to create a composite mandate for electric utilities and fuel providers based on fleet vehicle stocks.[78],[79] Fleet vehicle stocks by car and light truck were disaggregated to include only fleets of 50 or more (in accordance with EPACT) by using a fleet size distribution function based on The Fleet Factbook and the Truck and Inventory Use Survey.[80],[81] To account for the EPACT regulations which stipulate that "covered" fleets (which refer to fleets bound by the EPACT mandates) include only fleets in the metropolitan statistical areas (MSA's) of 250,000 population or greater, 90 percent of the business and utility fleets were included and 63 percent were included for government fleets.[82] EPACT covered fleets were to only include those fleets that could be centrally fueled, which was assumed to be 50 percent of the fleets for all fleet types, and only fleets of 50 or more that had 20 vehicles or more in those MSA's of 250,000 or greater population; it was assumed that 90 percent of all fleets were within this category except for business fleets, which were assumed to be 75 percent.[83]

Low Emission Vehicle Program (LEVP)

The LEVP, which began in California, was later instituted in New York and Massachusetts, and most recently by Maine and Vermont has now been rolled back to begin in 2005 at the original 10 percent mandate for California, Massachusetts and New York. All of the ULEV sales were assumed to meet the ULEV air standards with reformulated gasoline and a heated catalytic converter.

On November 5, 1998, the California Air Resources Board (CARB) amended the original LEVP to include ZEV credits for advanced technology vehicles. According to CARB these advanced technology vehicles must be capable of achieving extremely low levels of emissions on the order of the power plant emissions that occur from charging battery-powered electric vehicles, and some that demonstrate other ZEV-like characteristics such as inherent durability and partial zero-emission range.[84]

There are three components to calculating the ZEV credit, a baseline ZEV allowance, a zero-emission vehicle-miles traveled (VMT) allowance, and a low fuel-cycle emission allowance. Using these advanced vehicles in place of ZEV's in order to comply with the LEVP mandates requires assessment of each vehicle characteristic relative to the three criteria allowances.

The baseline ZEV allowance potentially can provide up to .2 credits if the advanced technology vehicle meets the: a) Super Ultra Low Emission Vehicle (SULEV) standards contained in the originial LEVP proposal; b) on-board diagnostics requirements (OBD) which illuminates indicators on the dashboard when vehicles are out of emissions compliance levels; c) 150,000 mile emission equipment warranty; and d) evaporative emissions requirements in California which prevent emissions during refueling. SULEV emissions standards approximate the emissions from powerplants associated with recharing electric vehicles.

The second criteria, zero-emission VMT allowance, will allow a maximum .6 credit if the vehicle is capable of some all-electric operation which was fueled by off-vehicle sources (i.e. no on-board fuel reformers), or if the vehicle has ZEV-like equipment on-board such as regenerative braking, advanced batteries, or an advanced electric drivetrain.

An emission allowance was also made for low fuel-cycle vehicle fuels used in the advanced technology vehicles. A maximum of .2 credit is provided for vehicles which use fuel that has less than or equal to .01 nonmethane organic gases (NMOG) grams per mile emissions based on the grams per gallon and the fuel efficiency of the vehicle.

Overall, large volume manufacturers can apply ZEV credits up to a maximum of 60 percent of the original 10 percent ZEV mandate; the original ZEV mandate required that all (100 percent) of the 10 percent of all light-duty vehicle sales must be ZEVs (defined only as dedicated electric vehicles) beginning with the 2003 model year. The remaining 40 percent of the ZEV mandates must still come from electric vehicles, or variants of fuel cell vehicles, which have extremely low emissions such as a hydrogen fuel cell vehicle.

In September of 2000, further modifications were proposed for the ZEV mandate. The proposal was designed to maintain progress towards the 2003 goal while recognizing technology and cost limited ZEV product offerings. The CARB proposal removed ZEV sales requirements prior to 2003, but maintained the 2003 required ZEV sales goal of 10 percent and requires a gradual increase of ZEV sales to 16 percent by year 2018. Additionally, the number of vehicles included in the estimation of required ZEV sales has been increased to include small light duty trucks.

The proposal also provides manufacturers flexibility in meeting the goal through increased vehicle credits and greater allowances for partial ZEVs (PZEVs) and advanced technology ZEVs (AT-PZEVs). Prior to 2006, ZEVs earn 1.25 credits per vehicle and PZEVs get a phase-in multiplier of 4, 2, and 1.3 per vehicle for years 2004 through 2006, respectively. Extra credits will also be allowed for ZEVs with extended range and/or reduced fueling times.

The AFV sales module compares these legislatively mandated sales to the results from the AFV logit market-driven sales shares. The legislatively mandated sales serve as a minimum constraint to AFV sales.

According to the EPA federal register, EPA's Tier II proposed regulations for light-duty vehicles below 6000 pounds must meet a sales weighted average of 0.07 grams/mile nitrogen oxides (NOx) emissions standard by 2004 and approximately a 0.01 to 0.02 grams/mile standard for particulates.[85] The previous Clean Air Act 1990 Tier I emissions standards were set at 0.6 grams per mile for NOx and 0.1 grams per mile for particulates.[86] EPA has estimated the costs to consumers range from $100 per car to $200 per light truck.[87] However, recently the U.S. Circuit Court ruling determined that EPA was not authorized to set new standards without indicating the benefits of the new regulations.

In the National Research Council's (NRC) Fifth Annual Review of Partnership for a New Generation of Vehicles (PNGV)[88], the NRC committee commented,"..the most difficult technical challenge facing the CIDI (compression ignition direct injection diesel) engine program will be meeting the standards for NOx and particulate emissions. In addition, meeting an even more stringent research objective (0.01 grams/mile) for particulate matter instead of the 0.04 grams/mile PNGV target would require additional technological breakthroughs."

The NRC has stated their concern that the Tier II regulations may affect the commercial viability of many advanced vehicles. Meeting the Tier II proposed standards may: require trading-off emissions levels for fuel economy by redesigning engines; add significant cost to a technology due to exhaust catalyst systems and their potential lack of effectiveness; stifle development of diesel technologies as a result of the unknown health effects of particulates; and result in new specifications for diesel fuel or development of advanced low emission fuels.

High Technology and 2003 Technology Cases

In the *high technology case*, the conventional fuel saving technology characteristics came from a study by the American Council for an Energy Efficient Economy.[89] Tables 37 and 38 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.[90]

The *2003 technology case* assumes that new fuel efficiency technologies are held constant at 2002 levels over the forecast. As a result, the energy use in the transportation sector was 5.9 percent higher (2.34 quadrillion Btu) than in the reference case by 2025. Both cases were run with only the transportation demand module rather than as a fully integrated NEMS run. Consequently, no potential macroeconomic feedback on travel demand, or fuel economy was captured.

The air model in the *high technology case* assumed efficiency from new aircraft could improve by 40 percent from the 1992 level based on the conclusion from the Aeronautics and Space Engineering Board of the National Research Council.[91]

Table 37. 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	2002	0
Drag Reduction V	8	225	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2005	0
Side Impact Technology	-1.5	100	0	0	2.2	2005	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	2	8	0	0	0	2002	0
Aggressive Shift Logic	5	65	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	9.5	410	0	20	0	1995	0
6-Speed Automatic	11	495	0	30	0	2004	0
6-Speed Manual	2	60	0	20	0	1995	0
CVT	12.5	315	0	-25	0	1998	0
Automated Manual Trans	8	100	0	0	0	2006	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	3	40	0	0	0	1980	10
OHC/AdvOHV-6 Cylinder	3	60	0	0	0	1987	10
OHC/AdvOHV-8 Cylinder	3	80	0	0	0	1986	10
4-Valve/4-Cylinder	9.6	165	0	10	0	1988	0
4-Valve/6-Cylinder	9.6	240	0	15	0	1992	17
4 Valve/8-Cylinder	9.6	320	0	20	0	1994	0
5 Valve/6-Cylinder	10	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	9.5	130	0	25	0	1997	10
VVL-6 Cylinder	9.5	190	0	40	0	2000	10
VVL-8 Cylinder	9.5	250	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	10	250	0	10	0	2004	0
Turbocharging/ Supercharging	5	300	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	7	250	0	20	0	2006	0
5W-30 Engine Oil	1	1.5	0	0	0	1998	0
5W-20 Engine Oil	2	2.5	0	0	0	2003	0
OW-20 Engine Oil	3.1	10	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	0	0	-8	0	1995	0
Tires III	3	0	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	300	0	80	0	2005	-5
42V-Engine Off at Idle	6	400	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	2001	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).

Table 38. High Technology Matrix For Light Trucks

	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	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	2	8	0	0	0	2006	0
Aggressive Shift Logic	5	65	0	0	0	2006	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	9.5	410	0	20	0	1999	0
6-Speed Automatic	11	495	0	30	0	2008	0
6-Speed Manual	2	60	0	20	0	2000	0
CVT	12.5	315	0	-25	0	2008	0
Automated Manual Trans	8	100	0	0	0	2010	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	3	40	0	0	0	1980	0
OHC/AdvOHV-6 Cylinder	3	60	0	0	0	1990	10
OHC/AdvOHV-8 Cylinder	3	80	0	0	0	1990	10
4-Valve/4-Cylinder	9.6	165	0	10	0	1998	17
4-Valve/6-Cylinder	9.6	240	0	15	0	2000	17
4 Valve/8-Cylinder	9.6	320	0	20	0	2000	17
5 Valve/6-Cylinder	10	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	9.5	130	0	25	0	2002	10
VVL-6 Cylinder	9.5	190	0	40	0	2001	10
VVL-8 Cylinder	9.5	250	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	10	250	0	10	0	2004	0
Turbocharging/Supercharging	5	300	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	7	250	0	20	0	2010	0
5W-30 Engine Oil	1	1.5	0	0	0	1998	0
5W-20 Engine Oil	2	2.5	0	0	0	2003	0
OW-20 Engine Oil	3.1	10	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	0	0	-8	0	1995	0
Tires III	3	0	0	-12	0	2005	0
Tires IV	6	90	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	5	300	0	80	0	2005	-5
42V-Engine Off at Idle	6	400	0	45	0	2005	0
Tier 2 EmissionsTechnology	-1	160	0	20	0	2006	0
Increased Size/Weight	-2.5	0	0	0	3.75	2001	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).

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