

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, light trucks, sport utility vehicles and vans), commercial light trucks (8,501-10,000 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 25) 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 increase to about sixty percent by 2025.

Table 25. Macroeconomic Inputs to the Transportation Module
(Millions)

Macroeconomic Input	2002	2005	2010	2015	2020	2025
New Car Sales	8.2	8.2	8.1	8.1	8.3	8.4
New Light Truck Sales	7.9	8.4	9.0	9.8	11.0	12.0
Real Disposable Income (billion 1996 Chain-Weighted Dollars)	7,032	7,755	8,894	10,330	11,864	13,826
Real GDP (billion 1996 Chain-Weighted Dollars)	9,440	10,402	12,190	14,101	16,188	18,520
Driving Age Population	224.3	231.9	244.1	254.5	264.3	274.3
Total Population	288.9	296.8	309.3	321.9	334.6	347.5

Source: Energy Information Administration, *AEO2004* National Energy Modeling System run: aeo2004.d101703e.

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.³²

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.³³

The MTCM 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 discounted stream

Table 26. Standard Technology Matrix For Cars¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horsepower 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	0.5	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	2001	0
Variable Compression Ratio	4	350	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 Trucks¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/UnitWt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./UnitWt.)	Introduction Year	Fractional Horsepower 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
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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

¹Fractional 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).

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.
- Corporate Average Fuel Efficiency standards remain constant at 27.5 mpg for cars and rise from a level of 20.7 mpg in 2004 to 22.2 mpg in 2007 for light trucks, and then remain constant throughout the forecast period.
- 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 28) 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.³⁴ Degradation factors are also adjusted to reflect the percentage of reformulated gasoline consumed.

Table 28. 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 2004*, DOE/EIA-M070(2004), (Washington, DC, 2004).

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 *AEO2004*. Based on output from the model, the fuel price elasticity rises to a maximum of -0.4 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). 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 in the Transportation Demand Module. Of total automobile sales to fleets, 91.1 percent are used in business fleets, 6.4 percent in government fleets, and 2.4 percent in utility fleets. Of total light truck sales to fleets, 56.8 percent are used in business fleets, 12.3 percent in government fleets, and 31.0 percent in utility fleets.³⁵ Both the automobile and light truck shares by fleet type are held constant from 2002 through 2025. The share of total automobile and light truck sales to fleets varies historically over time. In 2000, 23.7 percent of all automobiles sold and 17.5 percent of all light trucks sold were for fleet use. In the Transportation Demand Module, the share of total automobile sales to fleet varies through 2008, but is held constant thereafter, while the share of total light truck sales remains constant over the entire forecast period.

Alternative-fuel shares of fleet sales by fleet type are held constant at year 2000 levels (business (4.78 percent), government (7.91 percent), utility (0.84 percent)),³⁶ but compared to a minimum level of sales based on legislative initiatives, such as the Energy Policy Act of 1992 and the Low Emission Vehicle Program.³⁷⁻³⁸ Size class sales shares of vehicles are held constant at anticipated levels (Table 30).³⁹ Individual sales shares of alternative-fuel fleet vehicles by technology type are assumed to remain constant at fixed levels for utility, government, and for business fleets⁴⁰ (Table 31).

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

Table 29. 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 30. 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
Midsized	41.93	7.92
Large	9.45	3.58
2-seater	0.08	34.96
Government Fleet		
Mini	0.03	7.76
Subcompact	7.64	42.29
Compact	9.08	9.16
Midsized	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
Midsized	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 31. Anticipated 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: 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.⁴¹ The distribution of vehicles by vintage, and vehicle scrappage rates is derived from R.L. Polk company registration data.^{42,43} Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle.⁴⁴⁻⁴⁵

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.⁴⁶ 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)⁴⁷

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.⁴⁸ 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.⁴⁹ 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 these size classes, 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 distillate regional shares.⁵⁰ 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.^{51,52} 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.⁵³

New freight truck fuel economy is dependent on the market penetration of various emission control technologies and advanced engine components.⁵⁴ 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 is 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 and 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.⁵⁵

Initial freight truck stocks by vintage are obtained from R.L. Polk Co. and are distributed by fuel type using VIUS data.⁵⁶ Vehicle scrappage rates were also estimated using R.L. Polk Co. data.⁵⁷

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. Coal production from the NEMS Coal Market Module is 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.^{58,59} Initial freight rail efficiencies are based on the freight model from Argonne National Laboratory.⁶⁰ The distribution of rail fuel consumption by fuel type remains constant and is based on historical data.⁶¹ Regional freight rail consumption estimates are distributed according to the *State Energy Data Report 1999*.⁶²

Freight Domestic and International Shipping Assumptions

The freight domestic shipping module converts industrial output by SIC code measured in dollars, to a volumetric equivalent by SIC code.^{63,64} 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.⁶⁵ Regional domestic and international shipping consumption estimates are distributed according to residual oil regional shares in the *State Energy Data Report*.⁶⁶

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 lowest cost per mile, adjusted by load factor. Domestic and international revenue passenger miles are based on historic data,⁶⁷ per capita income, and ticket price. The revenue ton miles of air freight are based on merchandise exports, gross domestic product, and fuel cost.⁶⁸

Airport capacity constraints based on the *FAA's Airport Capacity Benchmark Report 2001* are incorporated into the air travel demand module using airport capacity measures.⁶⁹ 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 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 2002, new passenger sales, and the survival rate by vintage (Table 32).⁷⁰ New passenger sales are a function of revenue passenger miles and gross domestic product.

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.⁷¹ The difference between the seat-miles demanded and the available seat-miles represents potential newly purchased planes. If demand is greater than supply, then passenger aircraft is parked, starting with twenty nine year old aircraft, at a pre-defined rate. Aircraft continues to be parked until equilibrium is reached. If supply is greater than demand planes that have been temporarily stored, or parked, are 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 33).⁷² Fuel efficiency of new aircraft acquisitions represents, at a minimum, a 5-percent improvement over the stock efficiency of surviving airplanes.⁷³ 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.⁷⁴

Table 32. 2002 Passenger and Cargo Aircraft Supply and Survival Rate

Aircraft Type	Age of Aircraft (years)					Total
	New	1-10	11-20	21-30	>30	
Passenger						
Narrow Body	157	1651	1560	657	428	4,453
Wide Body	32	372	305	220	20	949
Regional Jets	279	919	71	9	12	1,290
Cargo						
Narrow Body	0	49	45	163	292	549
Wide Body	6	141	119	139	19	424
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, 2002 World Jet Inventory, data tables (2002).

Table 33. Future New Aircraft Technology Improvement List

Proposed Technology	Introduction Year	Jet Fuel Price Necessary For Cost-Effectiveness (2002 dollars per gallon)	Seat-Miles per Gallon Gain Over 1990 (percent)
Engines			
Ultra-high Bypass	2008	\$0.67	10
Propfan	2000	\$1.64	23
Thermodynamics	2010	\$1.47	30
Aerodynamics			
Hybrid Laminar Flow	2020	\$1.84	15
Advanced Aerodynamics	2000	\$2.05	18
Other			
Weight Reducing Materials	2000	-	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),

Legislation

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). Business fleet EPACT mandates are not included in the projections for AFV sales pending a decision on a proposed rulemaking.

Table 34. EPACT Legislative Mandates for AFV Purchases by Fleet Type and Year
(Percent)

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).

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.⁷⁵ Fleet vehicle stocks by car and light truck are 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.^{76,77} 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 are included and 63 percent are included for government fleets.⁷⁸ EPACT covered fleets only include those fleets that can be centrally fueled, which is 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 is assumed that 90 percent of all fleets are within this category except for business fleets, which are assumed to be 75 percent.⁷⁹

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. New York, Massachusetts, Maine, and Vermont 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, 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 December 2001 California Air Resources Board (CARB) amended the LEVP to allow ZEV credits for partial zero emission vehicles (PVEVs), advanced technology partial zero emission vehicles (AT-PZEVs), phase-in credits for pure ZEVs, and additional credits for high fuel economy vehicles. Auto manufactures filed federal suits in both California and

New York in 2002 arguing that the revisions to the ZEV program are pre-empted by the federal fuel economy statute enacted by the Energy Policy and Conservation Act of 1975.

In April 2003, CARB proposed further amendments to the ZEV mandates in response to the suit filed by the auto manufacturers. Due the changes proposed in the amendment (Resolution 03-4), the auto manufacturers agreed to settle litigation with California. The proposed mandate places 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. The mandate still requires the minimum ZEV sales goals, but 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, that hybrid vehicles will be sold to meet the AT-PZEV allowances, and that battery electric and hydrogen fuel cell vehicles will be sold to meet the pure ZEV requirements. Given the auto manufacturers response to the proposed amendments, AEO 2004 incorporates the proposed mandates in the forecast as if they were enacted law.

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 requirements, then the legislative requirements serve as a minimum constraint for the hybrid, electric, and fuel cell vehicle sales.

High Technology and 2004 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.⁸⁰ 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.⁸¹

The *2004 technology case* assumes that new fuel efficiency technologies are held constant at 2004 levels over the forecast. As a result, the energy use in the transportation sector was 5.6 percent higher (2.33 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.

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	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	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	2004	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	2006	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	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). 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.)	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	1	8	0	0	0	2006	0
Aggressive Shift Logic	3.5	65	0	0	0	2006	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	2008	0
6-Speed Manual	2	80	0	20	0	2000	0
CVT	11.5	365	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	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	0.5	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	160	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	3.75	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). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002).

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