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# Field Operations Program—Overview of Advanced Technology Transportation, Update for CY 2001

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**NOTICE**

# Field Operations Program—Overview of Advanced Technology Transportation, Update for CY 2001

In FY 2000, DOE's Field Operations Program (FOP) produced a document that provided an overview of the transportation market in terms of energy use, vehicle sales, emissions, potential FOP partners, advanced technology vehicle availability, and other important factors. The document was intended to give a "snapshot" of current vehicle technologies and trends. DOE program managers use the document to plan test and evaluation activities that focus resources where they have the greatest impact. This document is an update to the previous publication, which is available on the Internet at www.ott.doe.gov/otu/field_ops/prog_info.html.

The information in this document is based on several sources, which are listed in the appendix. Most of the statistics came from the following sources:

- The Energy Information Administration's (EIA) *Annual Energy Review*, *Monthly Energy Review*, and *Alternatives to Traditional Transportation Fuels*.
- *Transportation Energy Data Book* (edition 20), published by DOE's Oak Ridge National Laboratory.
- The U.S. Environmental Protection Agency's (EPA) *National Air Pollution Emissions Trends Update 1970-1998*.

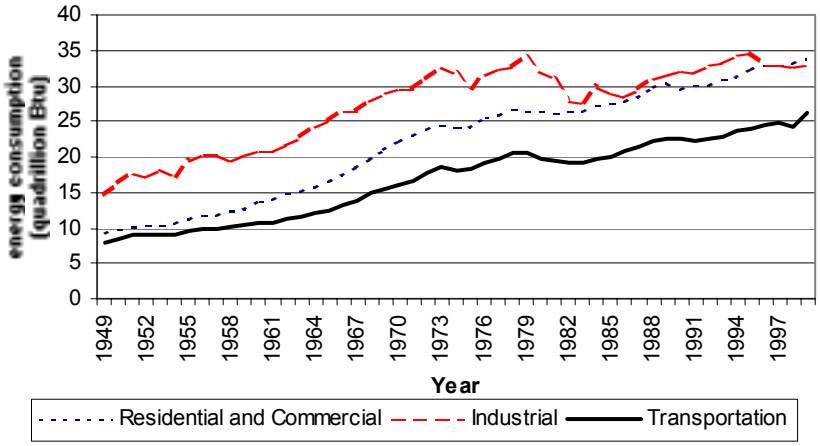
These publications are usually produced annually. We used the most recent volumes available. The information on advanced technology vehicles in development came from various sources, including vehicle manufacturers and news services. Because this information changes daily, we set February 12, 2001 as the cut-off date for inclusion in this document. However, the vehicle tables will be updated on a quarterly basis and posted as separate documents on the Internet at www.ott.doe.gov/otu/field_ops/prog_info.html.

## Transportation Energy Use

The transportation sector in the U.S. is a major consumer of energy. Figure 1 shows the total U.S. energy consumption from 1950 to 1999, categorized by transportation, residential, and industrial consumption. During 1999, transportation accounted for approximately 28% of the total energy consumption of 97 quadrillion Btu/year (source: EIA's *Annual Energy Review*). This is a 3% increase over total energy use for 1998.

**Figure 1. Energy Use by Sector**

(Source: EIA's *Annual* and *Monthly Energy Review*)



While U.S. petroleum consumption has steadily increased, domestic production of petroleum has decreased. Figure 2 shows the dramatic difference between consumption and production. Since 1985 this gap has increased at an average of 4.68% per year. The balance of petroleum consumed by the U.S. is imported. According to EIA's *Monthly Energy Review*, 55.6% of the petroleum consumed in the U.S. during 1999 (19.4 million barrels per day) was imported. In 1999, 45.6% of the total U.S. petroleum imports came from OPEC countries. (Table A in the appendix lists U.S. petroleum imports by country.)

**Figure 2. U.S. Petroleum Consumption vs Production**

(Source: EIA's *Annual Energy Review*)

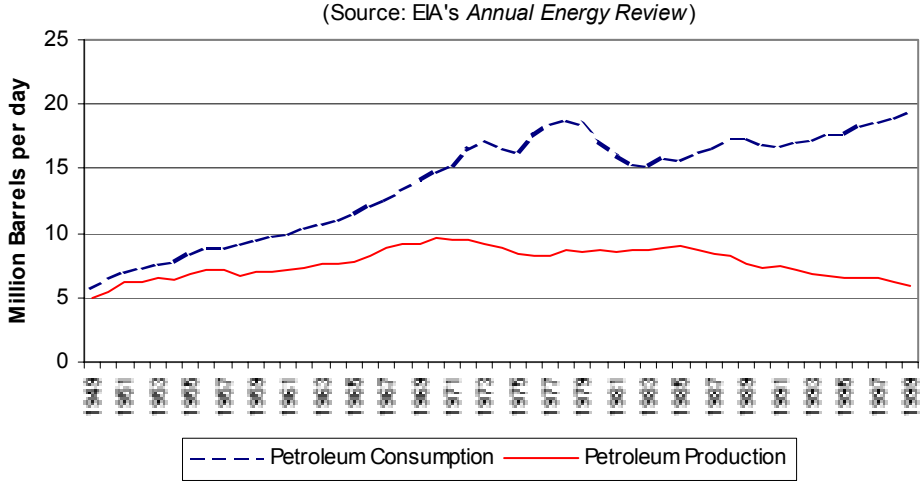
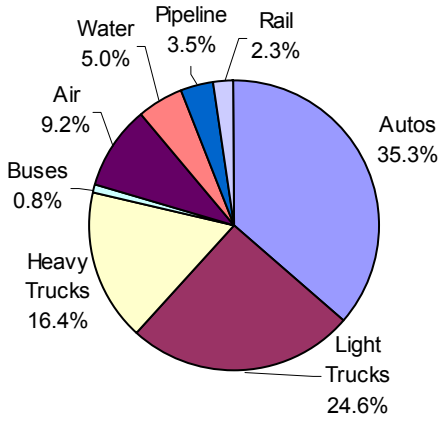


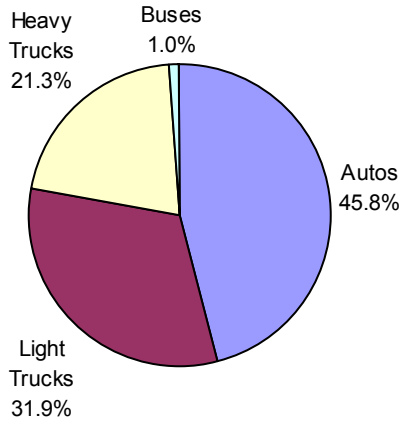

Figure 3 shows that in 1998, highway vehicles (including automobiles, heavy-duty and light-duty trucks, and buses) accounted for more than 77% of total transportation energy use. This is a slight decrease from the previous year. Figure 4 gives the breakdown of highway energy use by mode for 1998. The mix of vehicle types hasn't significantly changed since 1997.

**Figure 3. Transportation Energy Use by Mode** (total = 25.7 trillion Btu - 1998)




(Source: *Transportation Energy Data Book 20-2000* )

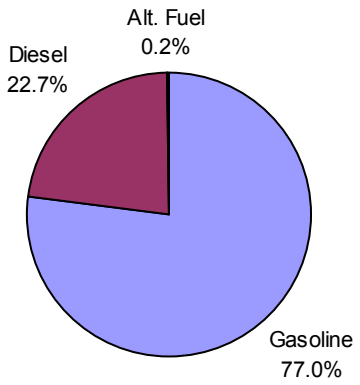
**Figure 4. Highway Energy Use by Mode** (total = 19.8 trillion Btu - 1998)




(Source: *Transportation Energy Data Book 20-2000* )

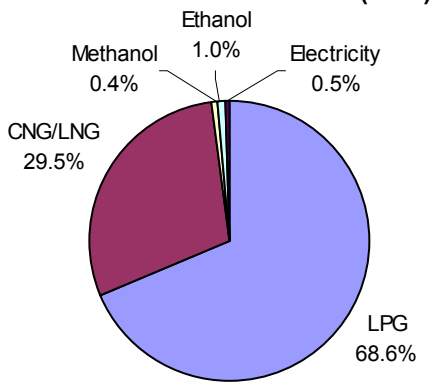
In 2000, more than 163 billion gallons of fuel were consumed in the U. S., which is an increase of 2.5% over the previous year. Figure 5 shows the breakdown of fuel use by fuel type. Gasoline makes up more than 77% of the fuel consumed. This percentage includes oxygenated fuels (methyl tertiary butyl ether [MTBE] and ethanol), which make up about 3% of the gasoline total. Diesel fuel comprises 22.7% of total vehicle fuel consumption during 2000.

**Figure 5. Estimated Consumption of Fuels in the US (2000)**




(Source: EIA's *Alternatives to Traditional Transportation Fuels* )

**Figure 6. Estimated Consumption of Alternative Fuels in the US (2000)**




(Source: EIA's *Alternatives to Traditional Transportation Fuels* )

Figure 6 breaks down alternative fuel use by type of fuel. Although alternative fuel makes up only 0.2% of the total fuel consumed in the U.S., alternative fuel use has increased by about 4% per year during the past three years. Table 1 shows the percent difference in alternative fuel use for the past three years by fuel type. Use of natural gas has increased steadily since 1997. No M85 vehicles have been manufactured since the 1998 model year. The decrease in M85 use can be attributed to the decrease in methanol flexible-fuel vehicles (FFVs) as older vehicles are retired from service.

The nearly 60% increase in E85 use could be due to the large numbers of vehicles that as a standard feature can run on ethanol. The National Ethanol Vehicle Coalition estimates that more than 750,000 vehicles produced for model year 2000 were capable of operating on E85. The number of stations offering ethanol has increased, especially in Minnesota where a public-private partnership was formed to build a fueling network and increase awareness of the environmental and economic benefits of renewable-based E85 fuel. By late 2000, the 50th E85 station opened to the public and more than 50,000 ethanol FFVs were registered in the state. (For more information about this project, visit www.alamn.org/outdoor/e85project.htm#team.)

**Table 1. Percent Difference in Alternative Fuel Use Since 1997**

| Fuel | Percent difference from previous year | | |
|---|---|---|---|
| | 1998 | 1999 | 2000 |
| LPG | 1.35 | 0.23 | 0.23 |
| CNG/LNG | 14.06 | 17.2 | 13.35 |
| Methanol (M85+neat methanol) | -12.62 | -8.49 | -5.72 |
| Ethanol (E85+neat ethanol) | -26.08 | 19.48 | 59.23 |
| Electricity | 19.01 | 19.05 | 27.11 |
| Overall | 3.91 | 4.47 | 4.25 |

(Source: EIA's *Alternatives to Traditional Transportation Fuels*)

## Vehicle Stock and Yearly Sales

The Federal Highway Administration estimated that approximately 211 million vehicles (including automobiles, trucks, and buses) were in use in the U.S. during 1998. The majority of these vehicles were used for personal transportation; only 10% were fleet vehicles.

Figures 7a and b show the annual sales of vehicles for 1998 through 2000. Sales of light-duty automobiles and trucks have increased over the last few years. Sales of automobiles and light trucks in 1999 topped 1998 by 8.7%, breaking the previous record set in 1986. Sales for 2000 were 2.7% higher than 1999,

despite a drop during the last quarter of that year. The year 2000 also marked the first time that light-duty trucks lost market share to automobiles since 1981, when the minivan was first introduced. Sales of heavy-duty trucks declined in 2000 from the record numbers set in 1999.

**Figure 7a. Vehicle Annual Sales - Light- & Medium-Duty**

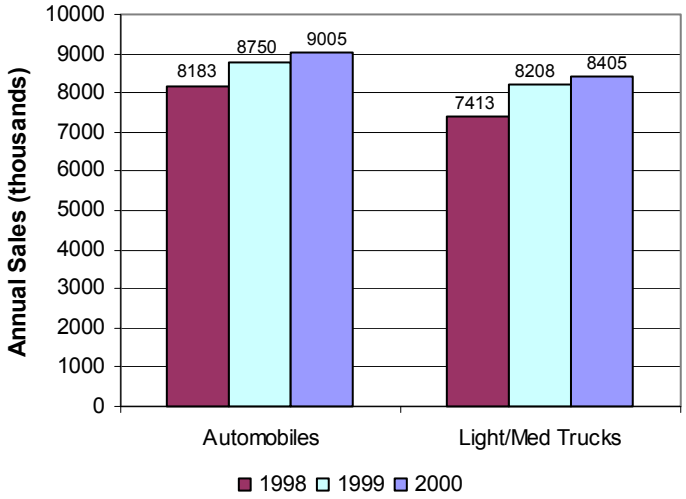
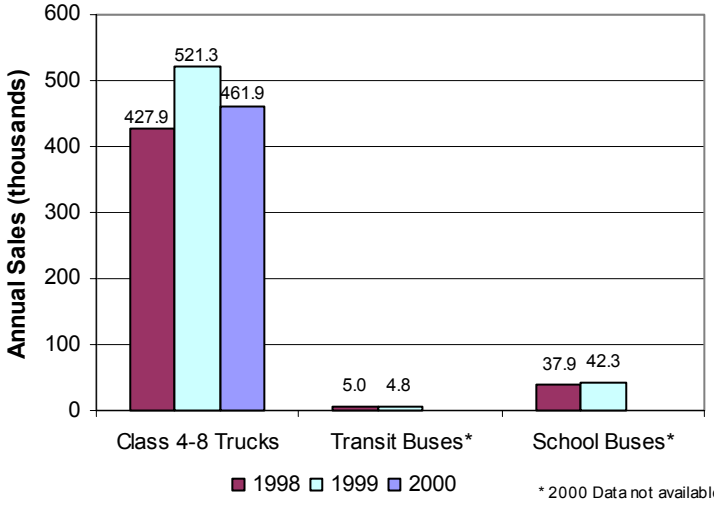



**Figure 7b. Vehicle Annual Sales - Heavy-Duty**




(Sources: *Automotive News Magazine*, American Public Transportation Association, and *School Bus Fleet Magazine*)

## Alternative Fuel Vehicles

In 1992, the U.S. government passed the Energy Policy Act (EPAct) to aid in achieving its goals of reducing dependency on foreign oil and improving air quality. As a part of EPAct, federal, state, and fuel provider fleets are required to purchase increasing numbers of alternative fuel vehicles (AFVs) each year to help achieve a 10% reduction in petroleum use by 2000 and a 30% reduction by 2010. Because of this, we added a section to this document addressing the current status of AFVs.

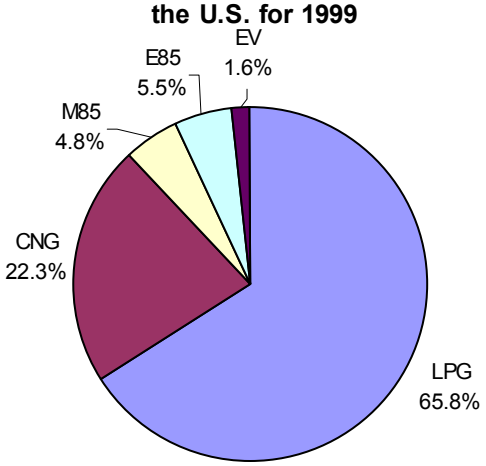
**Table 2. Estimated Number of Alternative Fuel Vehicles in the U.S. by Census Region, 1999**

| Region | LPG | CNG | Methanol | Ethanol | Electric Vehicles | Total by Region |
|---|---|---|---|---|---|---|
| Northeast | 25,907 | 12,867 | 931 | 1,136 | 786 | 41,627 |
| South | 92,757 | 29,110 | 871 | 6,424 | 1,668 | 130,830 |
| Midwest | 80,483 | 13,130 | 1,080 | 11,818 | 625 | 107,136 |
| West | 67,852 | 36,130 | 16,280 | 3,100 | 3,886 | 127,248 |
| **Total by Fuel** | **266,999** | **91,237** | **19,162** | **22,478** | **6,965** | **406,841** |

(Source: EIA's *Alternatives to Traditional Transportation*)

The use of AFVs has seen a slow but steady increase over the last decade. In 1999, an estimated 407,000 AFVs were in use in the U. S., representing an average 7% increase per year since 1992. Table 2 lists the number of AFVs in the U.S. by fuel type and census region for 1999. Figure 8 breaks down the percentages of AFVs in use in 1999 by fuel type. Propane (or LPG) vehicles make up the bulk of AFVs at 65.8%. This includes original equipment manufacturer (OEM) products as well as aftermarket conversions. The second most common fuel used is natural gas (including CNG and LNG), which makes up 22.3% of the total. Alcohol-fueled vehicles that run on methanol and ethanol make up a combined 10.3% of the total AFVs, and electric vehicles (EVs) make up only 1.6%.

**Figure 8. Estimated Percent of AFVs in the U.S. for 1999**




(Source: EIA's *Alternatives to Traditional Transportation Fuels* )

Although the number of AFVs has grown since the previous year, the total number of stations offering alternative fuel has actually decreased. Table 3 shows the number of alternative fueling stations in the U.S. by fuel and census region. According to DOE's Alternative Fuels Data Center (AFDC), 5,214 fueling stations offered alternative fuels as of 2/8/01. This is a 14% decrease compared to 1999. Stations offering E85 and electric charging stations were the only type that saw an increase over the year. The number of stations offering LPG decreased the most. In 2000 the AFDC staff verified the LPG stations listed in the database. Most of the stations dropped from the listing did not fuel vehicles.

**Table 3. Number of Fueling Stations by Census Region and Fuel Type (as of 2/8/01)**

| Region | LPG | CNG | Methanol | Ethanol | EVs | Total |
|---|---|---|---|---|---|---|
| Northeast | 376 | 182 | 0 | 0 | 19 | 577 |
| South | 1,222 | 407 | 0 | 3 | 129 | 1,761 |
| Midwest | 760 | 204 | 0 | 103 | 10 | 1,077 |
| West | 924 | 468 | 3 | 5 | 399 | 1,799 |
| **Total** | **3,282** | **1,261** | **3** | **111** | **557** | **5,214** |

(Source: www.afdc.doe.gov)

Currently, 28 light-duty OEM AFV models are available in the U. S. These models operate on a variety of fuels, including CNG, LPG, electricity, and ethanol. Manufacturers are producing AFVs in all body styles to meet various fleet needs, from small two-seaters to full-size trucks and vans. For a list of AFVs available in the U. S. for model year 2001, see Table B in the appendix.

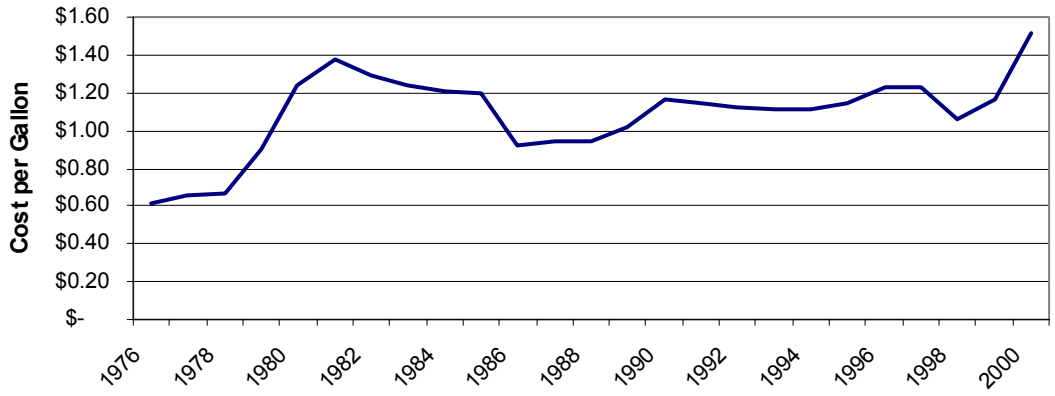
Alternative fuel and advanced technology heavy-duty vehicles are also available. The major engine manufacturers currently offer 19 alternative fuel engines (see Table C in the appendix). This number includes natural gas and LPG fueled engines. Bus and heavy-duty truck manufacturers use these engines in a wide variety of vehicles.

## Gasoline Prices and Fuel Economy

Two important factors to consider when assessing trends within the vehicle market are the price of gasoline and vehicle fuel economy. The fluctuations and increase in gasoline prices during 2000 were a cause of concern for most Americans. Figure 9 shows the average price for regular unleaded gasoline in the U.S.

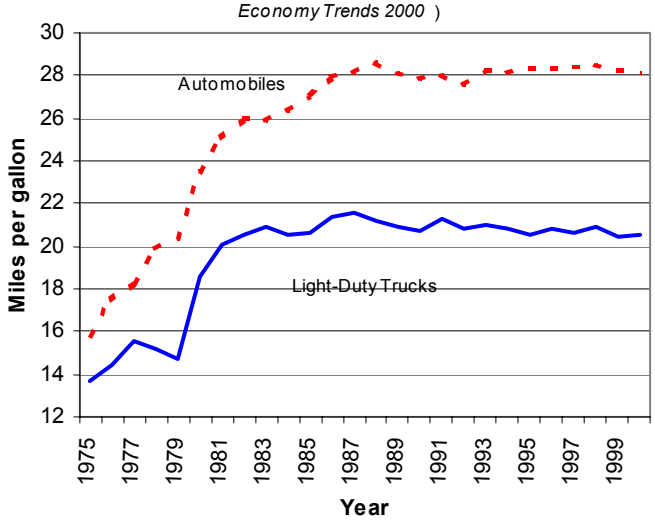
from 1976 through 2000. In comparison to other countries, Americans have experienced extremely low gasoline prices for some time. Prices of gasoline in western Europe are among the highest in the world. According to EIA, the price of gasoline in western Europe in January 2000 averaged $3.79 U.S. dollars per gallon, with a low of $2.72 (Greece), and a high of $5.13 (United Kingdom). The low prices in the U.S. do little to encourage fuel efficiency and the use of alternative fuels.

**Figure 9. Average Yearly Price for Regular Unleaded Gasoline in the U.S.** (Source: EIA's *Monthly Energy Review*)




Environmental groups have begun putting pressure on the government to raise Corporate Average Fuel Economy (CAFE) requirements for light trucks. Several OEMs have pledged to increase the fuel economy of their larger vehicles in the coming year. Figure 10 shows the trend in vehicle fuel economy since 1975. The oil crisis of the early 1970s spurred OEMs to increase the average fuel economy in both cars and trucks, but those numbers leveled off in the late 1980s. The lower fuel economy for light trucks may not have been a factor at that time, but the increase in personal use of trucks over the years is beginning to have an impact on petroleum use.

**Figure 10. Vehicle Fuel Economy Trend**
(Source: EPA's *Light-Duty Automotive Technology and Fuel Economy Trends 2000* )



## Emissions

As shown in Table 4, the transportation sector accounts for a large share of the national emissions of criteria pollutants. Highway vehicle emissions are somewhat less, but still make up a significant portion of the overall contribution. These percentages are similar to the previous year.

**Table 4. Transportation Share of U.S. Emissions in 1998**
(Source: EPA's *National Air Pollutant Emissions Trends 1900-1998*)

| Pollutant | Transport's Share of All Emissions (percent) | Highway's Share of All Emissions (percent) |
|---|---|---|
| CO | 78.6 | 56.3 |
| $NO_x$ | 53.4 | 31.8 |
| VOC | 43.5 | 29.7 |
| PM10 | 2.1 | 0.7 |
| PM2.5 | 7.2 | 2.4 |
| $SO_2$ | 7.2 | 1.7 |
| $NH_3$ | 5.2 | 5.1 |

Figures 11a – 11d show emissions of highway vehicles broken down by class. Light-duty automobiles and trucks account for the majority of CO and VOC emissions and a little over half the $NO_x$ emissions according to EPA's emission inventory. Heavy-duty trucks account for over half the PM emissions.

**Figure 11a. Highway CO Emissions**

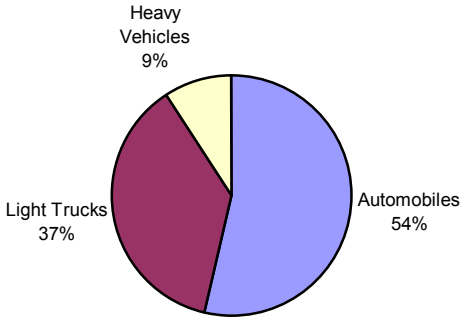



**Figure 11b. Highway VOC Emissions**

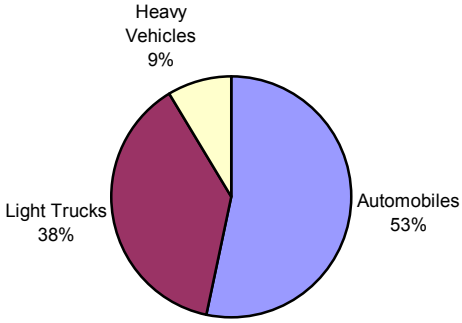



**Figure 11c. Highway NOx Emissions**

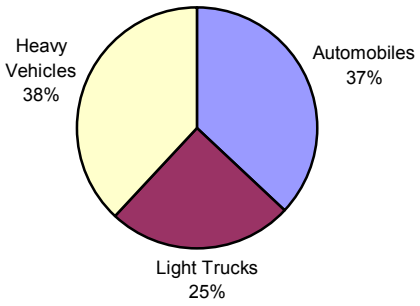
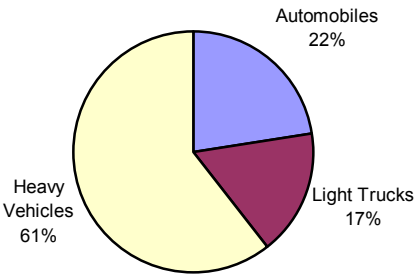



**Figure 11d. Highway PM10 Emissions**




(Source: EPA's *National Emissions Trends Report 1998*)

## Advanced Technology Vehicles

The following sections provide a snapshot of the current market of advanced technology vehicles. The tables contain an update to those provided in the original document and concentrate on the vehicles most likely to be available in the U.S. market. For a more complete listing of ATVs around the world, refer to the companion tables on the Internet at www. ott.doe.gov/otu/field_ops/prog _info.html.

Definitions of the terms used to describe the development stage of a given vehicle vary from manufacturer to manufacturer. For the purpose of this document, the following definitions apply:

- *Research* – In the early stages of development (drawings or models)
- *Concept* – An actual vehicle, usually operational, used by the manufacturer as a display or show vehicle
- *Prototype* – A working vehicle, very close to a production model
- *Demonstration* – Limited production of the vehicle being tested by the manufacturer in a real-world application
- *Production* – Available to the public.

### *Hybrid Electric Technology*

#### Light-Duty Vehicles

Automotive manufacturers continue to work on hybrid technology, especially for the light-duty market. Sales of the two hybrids introduced in the U.S. market last year, the Toyota Prius and the Honda Insight, were higher than expected. Both manufacturers increased planned production to help meet early demand. Sales of the Toyota Prius, launched in the U.S. in July 2000, totaled 5,562 for the year. Sales of the Honda Insight totaled 4,099 units from its introduction in December 1999 through February 2001.

**Table 5. Light-Duty Hybrid Electric Vehicles**

| OEM | Model | Body Style | Power Type | Fuel | Development Stage | Date Introduced/ Announced | Projected Production Date |
|---|---|---|---|---|---|---|---|
| DaimlerChrysler | Durango | SUV | Hybrid | Gasoline | Concept | Oct-00 | 2003 |
| Dodge | Intrepid ESX3 | Sedan | Mild hybrid | Diesel (low sulfur) | Concept | 2000 | Not available |
| Dodge | PowerBox | SUV | Hybrid | CNG | Concept | Jan-01 | Not available |
| Dodge | Ram Pickup Contractor Special | Truck | Hybrid | Gasoline or diesel | Prototype | Nov-00 | 2004 |
| Ford | Escape | SUV | Hybrid | Gasoline | Demonstration | Jan-01 | 2003 |
| Ford | Explorer | SUV | Mild hybrid | Gasoline | Concept | Jan-01 | 2003 |
| Ford | Prodigy | Sedan | LSR (low storage requirement) hybrid | Diesel (low sulfur) | Concept | Dec-99 | 2003 |
| GM | ParadiGM drive system | SUV/ truck | Hybrid | Gasoline | Drive system for multiple body styles | Jan-01 | 2004 |
| GM | Precept | Sedan | Parallel hybrid | Diesel (low sulfur) | Concept | Jan-00 | Not available |
| Honda | Civic | Sedan | IMA[1] hybrid | Gasoline | Concept | Jan-00 | 2002 |
| Honda | Insight | Coupe | IMA[1] hybrid | Gasoline | Production | Dec-99 | 2000 |
| Hyundai | Santa Fe | SUV | Series hybrid | Gasoline | Prototype | | 2003 |
| Toyota | HV-M4 | Minivan | Parallel hybrid | Gasoline | Concept | Oct-99 | No plans |
| Toyota | Prius | Sedan | Parallel/series hybrid | Gasoline | Production | Jun-00 | 2000 |
| Mazda | MX Sport Tourer | Sedan | Parallel hybrid | Gasoline | Concept | Feb-01 | Not available |
| Nissan | Tino | Wagon | Parallel/series hybrid | Gasoline | Limited production | Oct-99 | 2000 (Japan) |

[1] Integrated Motor Assist

Table 5 lists the hybrid vehicles in production as well as the most recent vehicles introduced in the past few years. (For more information on these and other light-duty hybrid vehicles introduced around the world, refer to the companion tables on the Internet.) Several new hybrid vehicles have been developed and introduced in the past year, and manufacturers are beginning to give estimated dates for initial production. Some of the more notable examples are the Ford Escape, Honda Civic, GM ParadiGM platform, and Dodge PowerBox. With the success of the Insight, Honda has announced plans to adapt its IMA technology to the popular Civic. Considering the somewhat limited marketability of a two-seat coupe, a hybrid Civic could prove to be an even bigger success than the Insight. Ford and GM have both announced plans to develop hybrid powertrains for sport utility vehicles (SUVs) and pickups. Ford estimates that their hybrid Escape will achieve 40 mpg; doubling that of the conventional version. GM recently announced the ParadiGM platform for use in full-size pickups and SUVs. They plan to market SUVs with the drive system for the 2004 model year. The Dodge PowerBox is most notable because it's the only new offering powered by CNG. According to a DaimlerChrysler press release, the PowerBox gets 60% better fuel economy with near zero emissions.

## Heavy-Duty Vehicles

While the light-duty market for hybrid vehicles consists of many prototypes and a few models commercially available on a limited basis, the heavy-duty hybrid market is characterized by multiple projects involving small numbers of vehicles in development. For most of these projects, ten or fewer vehicles are placed in normal revenue service alongside conventional vehicles. The manufacturers work closely with the organizations operating the vehicles to optimize them for future market. This is beginning to change.

Table 6 lists some of the more significant projects in the U.S. The most important point to notice is the large number of vehicles on order. More than 400 hybrid vehicles are currently on order for various transit organizations across the country, the largest of which is New York City Transit (NYCT). NYCT has been testing 10 hybrid buses at its Manhattanville Terminal for the past two years. NYCT has placed orders for an additional 325. DOE's Office of Heavy Vehicle Technologies and the Field Operations Program at NREL are conducting an evaluation of NYCT's hybrid buses. The results will be posted on the Internet at www.ott.doe.gov/otu/field_ops/nyc.html.
Other aspects of heavy-duty hybrid projects include:

- The incorporation of turbine technology in many hybrid models. Several bus manufacturers are using turbines in place of internal combustion engines in their hybrid designs. Turbines can operate on many different fuels, including CNG, LPG, and diesel.

- Addition of particulate traps to hybrids operating on diesel. Early tests on hybrid electric buses show lower emissions than conventional buses. In order to cut emissions further, some transit agencies are opting for additional controls. As of September 2000, NYCT is operating all its diesel fleet, including the hybrid buses, on low sulfur diesel with emission control devices.

## Table 6. Heavy-Duty Hybrid Electric Vehicles

| Project | Vehicles Deployed | Hybrid Type | Vehicle Type | Fuel Used | Project Start Date | No. in Project | Status of Project |
|---|---|---|---|---|---|---|---|
| APS/El Dorado EZ Rider 300 | | Series | Bus | Various | | | Active |
| AVS/Arizona | Tempe AZ | Parallel | Shuttle bus | LNG | Feb-01 | 31 | Ordered |
| AVS/Arizona | Tampa, FL | Parallel | Shuttle bus | Diesel | Feb-01 | 10 | Ordered |
| AVS/Capstone | Tampa, FL | Parallel | Bus | CNG/LNG | in devel. | 10 | Ordered |
| AVS/Capstone | Chattanooga Area RTA | Series | Bus | CNG | 8/99 (on order) | 7 | |
| AVS/PEI/UQM | CARTA | | Paratransit | | 2000 | 6 | Ordered |
| AVS/PEI/UQM | CARTA | | Paratransit | | 2000 | 3 | Ordered |
| AVS/PEI/UQM | CARTA | | Shuttle | | 2000 | 1 | Ordered |
| AVS/Solectria | Falls Church, VA | | Shuttle | | 2000 | 4 | Ordered |
| Blue Bird/H-Power | Sacramento Municipal Facility | | Paratransit | | 2000 | 1 | Ordered |
| Blue Bird/Solectria | TBD | | School | | | 1 | Ordered |
| Cedar Rapids Electric Transit Consortium | Cedar Rapids, IA | | Bus | Diesel | Sep-96 | 4 | Active |
| Electric Fuel Corp/NovaBUS | Clark County, Nevada | | Bus | Battery/battery system | Late 98 | 1 | Active |
| Eletricore/GM-Allison/Delphi | Indianapolis Airport & Chattanooga | | Bus | | | | |
| Flexible | Cleveland RTA | Series | Bus | Natural gas | | | Active |
| Gillig/Enova | | | Bus | | Test & eval. by 2001 | | |
| GM Allison/Gillig | | $E^p$ parallel | Bus | Diesel | | | Active |
| GMC | San Francisco, CA MUNI | | Truck | Diesel | in devel. | 2 | |
| ISE Research Military Tractor | | Series | Military tractor | Diesel | May-99 | | |
| ISE Research/El Dorado | Los Angeles DOT | | Paratransit | | 2000 | 4 | Ordered |
| ISE Research/El Dorado RE-29-E | Los Angeles DOT | Series | Bus | Propane | Mar-99 | 5 | Active |
| ISE Research/New Flyer | Omnitrans, San Bernadino, CA | Series | Bus | CNG | Mar-00 | 5 | Ordered |
| ISE Research/Peterbilt | LA | Parallel | Truck (class 8) | CNG/LNG | Jun-99 | 1 | |
| NABI | Concept vehicle | | Bus | CNG | | | |
| NASA Lewis | Cleveland RTA | Series | Bus | CNG | | | |
| Navistar MD Truck | UPS: NY, Atlanta, LA | Series | Truck | Diesel | Jun-98 | | |
| New Flyer/Allison | OCTA | $E^s$ series | Bus | Diesel | Dec-00 | 1 | Active |
| Nova BUS RTS, DUETS Program | NYC MTA, Boston | Series | Bus | CNG | Oct-94 | 1 | Active |
| Nova Bus/BAE | NYCT | | Transit | | 2000 | 5 | Ordered |
| Nova Bus/ISE Research | LA - Foothills Transit | | Transit | | 2001 | 1 | Ordered |
| Orion | San Francisco, CA MUNI | | Bus | Diesel | in devel. | 2 | Active |
| Orion IV Hybrid Bus | NYC MTA, NJ | Series | Bus | Diesel | Sep-98 | 10 | Active |
| Orion VII/BAE | New York | | Bus | Diesel | | 200 | Ordered |
| Orion/BAE | Minneapolis, MN | | Transit | | 2001 | 5 | Ordered |
| Orion/BAE | NYCT | | Transit | | 2001 | 125 | Ordered |
| Orion/Lockheed Martin | Boston, MA | | Bus | Diesel | May-99 | 2 | Active |
| TDM/UQM/Siemens | Warner Robbond AFB, GA | | Shuttle | | 1999 | 8 | Active |
| Transportation Techniques (Transteq) | Denver RTD | Series | Mall shuttle bus | CNG | Oct-98 | 36 | Active |
| Volvo Trucks/U.S. Army | Army's Tank-Automotive & Armaments Command | | Truck (class 8) | Diesel | Dec-00 | 1 | |

## *Fuel Cell Technology*

### Light-Duty Vehicles

We reported in the original market overview that fuel cell technology seemed to be the most widely accepted solution for the future by industry and government. This was based on several factors, including the number of auto manufacturers working on fuel cell vehicles and increased funding for hydrogen projects. This is still the general consensus. Most manufacturers continue to develop prototype vehicles powered by fuel cells. Table 7 lists some of the models introduced in the past few years.

**Table 7. Light-Duty Fuel Cell Vehicles**

| OEM | Model | Body Style | Passengers | Fuel Cell Type | Fuel Type | Development Stage | Date of Introduction | Projected Production Date |
|---|---|---|---|---|---|---|---|---|
| Daihatsu | MOVE FCV | Microvan | 4 | PEM | Methanol | | | |
| DaimlerChrysler | NECAR 4 | Sedan | 5 | PEM | Hydrogen | Prototype | 1999 | 2004 |
| DaimlerChrysler | NECAR 5 | Sedan | 5 | PEM | Methanol | Concept | 2000 | 2004 |
| Ford | FC5 | Sedan | 5 | PEM | Methanol | Concept | Sep-99 | 2004 |
| Ford/Th!nk | Focus | Sedan | 5 | PEM | Methanol | Demonstration | | 2004 |
| Ford/Th!nk | P2000 | Sedan | 5 | PEM | Hydrogen | Prototype | | |
| GM | Precept | Sedan | 5 | PEM | Hydrogen | Concept | Jan-00 | |
| GM/Opel | Zafira | Minivan | | | Methanol | Concept | 1997 | 2004 |
| GM/Opel | Zafira 2nd gen. | Minivan | 5 | | Liquid hydrogen | Concept | 1998 | |
| Honda | FCX-V1 | Sedan | 4 | PEM | Hydrogen | Concept | Nov-99 | 2003 |
| Honda | FCX-V2 | Sedan | 4 | PEM | Methanol | Prototype | Nov-99 | 2003 |
| Honda | FCX-V3 | Sedan | 4 | PEM | Hydrogen | Prototype | Sep-00 | 2003 |
| Hyundai | Santa Fe | SUV | 5 | PEM | Hydrogen | | | |
| Jeep | Commander | SUV | 5 | | Gasoline/other | Concept | 1999 | |
| Jeep | Commander 2 | SUV | 5 | PEM | Methanol | Concept | Oct-00 | |
| Mazda | Demio FCEV | Sedan/wagon | 4 | PEM | Hydrogen | Prototype | Dec-97 | |
| Mazda | Premacy FC-EV | Sedan/wagon | 5 | PEM | Methanol | Prototype | Feb-01 | Testing in Japan 2/15 |
| Mitsubishi | FCV | Sedan | | | Methanol | Concept | | 2003-2005 |
| Nissan | Xterra | SUV | | PEM | Methanol | | | |
| Nissan | Altra based | Wagon | 5 | | Methanol | Concept | | 2003-2005 |
| Nissan | R'nessa | SUV | | | | Concept | | 2003/4 |
| Toyota | FCEV RAV4 | SUV | 4 | | Hydrogen | Concept | | 2003 |
| Toyota | FCEV RAV4 | SUV | 4 | | Methanol | Concept | | 2003 |
| Toyota | FCHV3 | SUV | 5 | PEM | Hydrogen | Prototype | Feb-01 | Test 2001 |
| Volkswagen | Bora HyMotion | Sedan | | | Hydrogen | Demonstration | | |

Many of these vehicles are being demonstrated in real-world conditions as a part of the California Fuel Cell Partnership (CFCP). First announced in April 1999, the CFCP is a collaboration between auto manufacturers, oil companies, fuel cell companies, and state and federal governments. The goal is to demonstrate fuel cell vehicles in real-world conditions, demonstrate the viability of infrastructure technology, explore the path to commercialization, increase public awareness, and enhance opinion about fuel cell technology. The partnership's 28 members include auto manufacturers, fuel cell companies, fuel providers, government agencies, fueling infrastructure companies, and transit agencies. In November 2000, the partnership opened its headquarters facility in Sacramento, CA. The 55,000 square-foot facility houses fuel cell vehicles, a hydrogen fueling station, and a public gallery with educational exhibits.

## Heavy-Duty Vehicles

Fuel cell vehicles continue to be developed for the heavy-duty market. The majority of fuel cell projects to date use transit buses. Table 8 lists projects involving fuel cell heavy vehicles, including a couple of projects underway in Europe.

Xcellsis P4 bus demonstration - SunLine Transit in Thousand Palms, CA is currently testing the latest of the Xcellsis fuel cell buses. This version incorporates design changes made during the initial field tests of the P3 buses in Chicago and Vancouver. SunLine, along with AC Transit, are associate members of the CFCP. AC Transit recently sent out an RFP for fuel cell buses to be tested in several transit agencies in California. SunLine is slated to receive three of the buses; AC Transit expects to operate at least eight. DOE's Field Operations Program plans to evaluate the buses once they go into service. The analysis will focus on performance and operating costs, as well as the transit agencies' experiences integrating advanced technology buses into their fleets.

**Table 8. Heavy-Duty Fuel Cell Vehicles**

| Project Partners | Deployed | Vehicle Type | Fuel | Type | Length | Project Start Date | No. in Project |
|---|---|---|---|---|---|---|---|
| DaimlerChrysler NEBUS | Mexico | Bus | Hydrogen | FC | | | |
| Xcellsis/Newflyer/CTA (P3) | Chicago, IL and Vancouver, BC | Bus | Liquid hydrogen | PEM | 40 ft | Dec-97 (complete) | 6 |
| DOE/FTA/ Georgetown Univ. | Gainesville, FL | Bus | Methanol | PAFC | 30 ft | R&D testing 93 | 3 |
| Georgetown/NovaBUS | Unknown | Bus | Methanol | PEM | 40 ft | | |
| IFC/Thor/ISE Research | Demo only | Bus LF | Hydrogen or powerballs | PEM | 30 ft | Production by 2003 | |
| MAN Bavaria I | Nuernberg & Erlangen | Bus LF | Hydrogen | PEM | 12 m | Prototype 5/00 | 1 |
| Proton Motor/Neoplan Bavaria II | Unknown | Bus LF | Hydrogen | PEM | 10.6 m | Prototype 5/00 | 1 |
| Xcellsis (P4, P5 bus) | SunLine and AC Transit, CA | Bus | Hydrogen | PEM | 40 ft | Prototype | |

## *Additional Projects/Developments*

Several developments in the last year could have an effect on advanced technology and alternative fuel vehicles in the U.S. Of note were:

Environmental Protection Agency (EPA) heavy-duty emissions and sulfur regulations - In December 2000, EPA announced new rules for lowering emissions from heavy-duty vehicles. These regulations will be phased in beginning with the 2007 model year. EPA also announced regulations for the reduction of sulfur in diesel fuel to enable the use of emissions control devices, which are fouled by sulfur in fuel. The fuel provisions go into effect in 2006.

California Air Resources Board (CARB) keeps the zero emission vehicle (ZEV) mandate – CARB announced it would uphold the ZEV mandate, which requires manufacturers to produce a percentage of zero emission vehicles starting in 2003. CARB did, however, make modifications to give automakers additional options to help them meet the requirements. The original ruling required the largest auto manufacturers to offer for sale 10% ZEVs by 2003. Of that percent, 6% could be vehicles qualifying for partial ZEV (PZEV) credits.

To qualify for PZEV status, a vehicle must meet three criteria: 1) "super-ultra-low emission vehicle" emission standard, 2) zero evaporative emissions, and 3) 150,000 mile warranty on emissions control equipment. The most significant modifications to the ruling were:

- Reduced to 2% the number of pure ZEVs required to comply in the early years.
- Allowed a further reduction of up to 50% in the number of ZEVs if a manufacturer produces other types of clean, advanced technology vehicles.
- Reduced the number of vehicles needed in the early years to earn PZEV credits.
- Gradual increase of ZEV requirements from 10% in 2003 to 16% in 2018.

This ruling is significant for several reasons. A growing debate has developed between auto manufacturers and environmental groups about the marketability of battery electric vehicles. Battery technology has not yet evolved to the point of providing inexpensive, long-range options for vehicles. The modifications to the regulations increase the number of credits allowed for early introduction of ZEVs, and include credits for advanced technology PZEVs. The credits a particular manufacturer earns will depend on its strategy for compliance. These credits, however, decrease with time. It is interesting to note that the changes making it easier for OEMs to meet the standard in the short-term ultimately result in a higher number of required ZEVs than the original ruling. To give OEMs further incentive to produce more ZEVs before 2003, CARB set up a program to provide funds to consumers who purchase or lease ZEVs prior to 2003.

New York adopts California automobile emissions rules – In November 2000, New York officials announced the adoption of California's vehicle-emissions standards. This could be significant because about 15% of all vehicles sold in the U.S. are in these two states. Massachusetts, Maine, and Vermont are also considering adopting the California rules.

California Air Resources Board regulation for transit buses – In February 2000, CARB adopted a regulation geared toward reducing emissions from transit buses. The rule requires all California transit agencies to submit a report by January 31, 2001, declaring their chosen paths to comply with the rule. Transit agencies may choose one of two fuel paths--alternative fuel or diesel. As of February 26, 2001, 50 out of 85 agencies reported their chosen paths; 21 chose the alternative fuel path and 29 chose the diesel path. Although all fleets must eventually meet the same regulations, agencies choosing diesel in the short-term will be required to add zero-emission buses sooner than those choosing alternative fuels. To comply with the regulations, transit agencies must meet the following requirements:

*Alternative-Fuel Path*

- From approval of the regulation through 2015, at least 85% of all urban buses purchased or leased must be alternative fuel buses.
- Zero-emission bus purchase requirements begin in the year 2010.

*Diesel Path*

- Transit agencies are required to participate in a zero-emission bus demonstration in 2003-2004.
- Zero-emission bus purchase requirements begin in 2008.

*Regulations Common to Both Paths*

- Beginning October 1, 2002, average $NO_x$ emissions for a fleet must not exceed 4.8 grams per brake horsepower hour (g/bhp-hr) based on engine certification.
- All diesel buses must be retrofitted to control particulate matter and use diesel fuel with a maximum sulfur content of 15 parts per million by weight. (The schedule for adding retrofit devices varies depending on chosen path.)
- Transit agencies may not purchase any buses with 2004-2006 model year engines certified to emissions levels in excess of current regulations.

California has a serious problem with air quality, especially in highly urbanized areas where transit buses typically operate. Particulate emissions from diesel exhaust have been identified as an air toxic. Diesel

buses operating on crowed city streets are of concern to the population because they cause direct exposure to this air toxic. An estimated 8,400 full-size transit buses are in service in the state, more than 1,300 of which are already operating on CNG. Although the regulations do not begin to phase-in until October 2002, the effects could be more immediate. Some of the more pro-active transit agencies are already working toward the goals set forth in the ruling. According to APTA, there were 472 CNG buses on order in 2000, with a potential for at least 1,400 more. An effort is already in the works to demonstrate fuel cell buses in several transit agencies.

Next Generation Natural Gas Vehicle Program - Several government/industry initiatives also have an impact on the continued development of advanced technologies. DOE's Office of Transportation Technologies initiated a program to develop commercially viable medium-duty (class 3-6) and heavy-duty (class 7-8) natural gas vehicles to reduce petroleum imports and help non-attainment areas reduce pollution. These "next-generation natural gas vehicles" (NGNGVs) will use advanced technologies developed with DOE funding. The program's goal is to design, prototype, test, and evaluate two NGNGVs (one medium-duty and one heavy-duty) by the end of FY 2004. The goals of this program are to create vehicles that will:

- Meet the 2007 exhaust emission standard
- Be competitive with diesel vehicles in performance and life-cycle costs
- Be technically and commercially viable
- Help nonattainment areas reduce pollutant emissions from vehicles.

For more information on this initiative, visit www.ctts.nrel.gov/ngngv.

21st Century Truck Initiative - In this project, several heavy- and medium-duty engine manufacturers have joined with the federal government to develop commercially viable propulsion system technologies that will significantly reduce fuel use and emissions, while enhancing safety, performance, and affordability. Specific goals are to produce prototypes that:

- Triple the fuel economy of heavy pickups, large delivery vans, and full-size passenger buses
- Double fuel economy for 18-wheeler long-haul trucks
- Improve safety
- Achieve superior operational performance and lower costs for truckers
- Exceed expected emission requirements for 2010.

## Summary

The focus, direction, and funding of transportation programs and the marketplace for advanced technologies are continually changing and developing. Understanding these trends within the context of today's marketplace is critical to focusing public and private resources where they can have the most impact. Key points from this document include:

- The gap between U.S. consumption and production of petroleum is widening at the rate of 4.68% per year (average from 1985 through 2000).
- Light-duty trucks and automobiles continue to be the major consumer with respect to transportation energy use.
- The 4% increase in alternative fuel use is insignificant compared to the increasing gap between production and consumption of petroleum.
- The 7% increase in AFVs due to flexible-fuel vehicles indicates an increased opportunity for using alternative fuels, provided the infrastructure can be increased.
- There is significantly more development in hybrid electric vehicles and fuel cell electric vehicles for light-, medium-, and heavy-duty vehicle markets.
- Fuel cells and hydrogen appear to be the vision of the future from the auto industry perspective.

# Appendix

**Table A. Average U.S. Petroleum Imports in 1999 by Source (thousand barrels per day)**

| Country | Affiliation | 1999 |
|---|---|---|
| Angola | Non-OPEC | 360.507 |
| Australia | Non-OPEC | 41.882 |
| Bahamas | Non-OPEC | 3.170 |
| Bahrain | Non-OPEC | 25.901 |
| Brazil | Non-OPEC | 1539.400 |
| Canada | Non-OPEC | 21.093 |
| China | Non-OPEC | 468.443 |
| Colombia | Non-OPEC | 117.860 |
| Ecuador | Non-OPEC | 167.800 |
| Gabon | Non-OPEC | 9.808 |
| Italy | Non-OPEC | 34.693 |
| Malaysia | Non-OPEC | 1324.342 |
| Mexico | Non-OPEC | 65.183 |
| Netherlands Antilles | Non-OPEC | 303.545 |
| Netherlands | Non-OPEC | 12.542 |
| Norway | Non-OPEC | 10.323 |
| Puerto Rico | Non-OPEC | 26.603 |
| Russia | Non-OPEC | 89.345 |
| Spain | Non-OPEC | 364.567 |
| Trinidad and Tobago | Non-OPEC | 279.608 |
| United Kingdom | Non-OPEC | 58.041 |
| Virgin Islands | Non-OPEC | 0 |
| Iran | OPEC | 0 |
| Iraq | OPEC | 725.381 |
| Kuwait | OPEC | 248.093 |
| Qatar | OPEC | 9.641 |
| Saudi Arabia | OPEC | 1478.252 |
| United Arab Emirates | OPEC | 2.307 |
| Algeria | Other OPEC | 258.556 |
| Indonesia | Other OPEC | 81.460 |
| Libya | Other OPEC | 0 |
| Nigeria | Other OPEC | 656.556 |
| Venezuela | Other OPEC | 1492.597 |

(Source: EIA's *Monthly Energy Review)*

**Table B. Light-Duty AFVs Available in Model Year 2001 (including EVs)**

| Manufacturer | Model | Fuel | Design | Body |
|---|---|---|---|---|
| Chevrolet | Cavalier | CNG | Bi-fuel | Sedan |
| Chevrolet | Sonoma /S-10 | E85 | FFV | Truck |
| DaimlerChrysler | Voyager/Caravan/ Town & Country | E85 | FFV | Minivan |
| Dodge | Ram van/wagon | CNG | Dedicated | Van |
| Ford | F-series | CNG | Bi-fuel | Truck |
| Ford | Crown Victoria | CNG | Dedicated | Sedan |
| Ford | F-series | CNG | Dedicated | Truck |
| Ford | Econoline | CNG | Dedicated | Van/wagon |
| Ford | Taurus | E85 | FFV | Sedan |
| Ford | Explorer Sport/Sport Track | E85 | FFV | SUV |
| Ford | F-series | LPG | Bi-fuel | Truck |
| Ford | Ranger | EV | Dedicated | Truck |
| Ford | F-series Super Duty | LPG | Bi-fuel | Truck |
| Ford | E-series Cutaway | CNG | Dedicated | Van |
| GM/Chevrolet | Sierra/ CK | CNG | Bi-fuel | Truck |
| GM | EV1 | EV | Dedicated | Coupe |
| GM/Chevrolet | Cavalier | CNG | Bi-fuel | Sedan |
| GM/Chevrolet | Sonoma /S-10 | E85 | FFV | Truck |
| GM/Chevrolet | Savana/Express | CNG | Bi-fuel | Van |
| GM/ Chevrolet | Medium-duty truck | LPG | Dedicated | Truck |
| Honda | Civic GX | CNG | Dedicated | Sedan |
| Nissan | Altra | EV | Dedicated | Sedan |
| Nissan | Hypermini | EV | Dedicated | Mini |
| Solectria | Force | EV | Dedicated | Sedan |
| Solectria | Citivan | EV | Dedicated | Van |
| Solectria | Flash | EV | Dedicated | Truck |
| Toyota | Camry | CNG | Dedicated | Sedan |
| Toyota | Rav4 | EV | Dedicated | SUV |

(Source: www.afdc.nrel.gov/afvehicles.html)

## Table C. Heavy-Duty Alternative Fuel Engines Available

| Manufacturer | Model | Displacement | Fuel | HP @ rpm | Torque @ rpm | Cert. Level |
|---|---|---|---|---|---|---|
| Cummins | B5.9-230G | 5.9 | CNG | 230@2800 | 500@1600 | Ultra low emission vehicle (ULEV) |
| Cummins | B5.9-195G | 5.9 | CNG | 195@2800 | 420@1600 | ULEV |
| Cummins | B5.9-150G | 5.9 | CNG | 150@2500 | 375@1500 | ULEV |
| Cummins | B5.9LPG | 5.9 | LPG | 195@2600 | 420@1600 | |
| Cummins | C8.3-275G | 8.3 | CNG | 275@2400 | 750@1400 | |
| Cummins | C8.3-250G | 8.3 | CNG | 250@2400 | 750@1400 | |
| Cummins | C8.3-250G | 8.3 | CNG | 250@2400 | 660@1400 | |
| John Deere | 6068H | 6.8 | CNG | 225 | 640 | ULEV (optional low $NO_x$) |
| John Deere | 6068H | 6.8 | CNG | 250 | 660 | ULEV (optional low $NO_x$) |
| John Deere | 6081H | 8.1 | CNG | 250 | 800 | ULEV (optional low $NO_x$) |
| John Deere | 6081H | 8.1 | CNG | 280 | 900 | ULEV (optional low $NO_x$) |
| Detroit Diesel | S50G | 8.5 | CNG/LNG | 320@2100 | 1150@2100 | ULEV |
| Detroit Diesel | S60G | 12.7 | CNG | | | |
| Mack | E7G-325 | 12 | CNG/LNG | 325@1950 | 1180@1250 | |
| Mack | E7G-350 | 12 | CNG/LNG | 350@1800 | 1260@1250 | |
| Caterpillar | 3126B | 7.2 | CNG/LNG dual fuel | 190 | | Low emission vehicle |
| Caterpillar | 3126B | 7.2 | CNG/LNG dual fuel | 250 | | |
| Caterpillar | C10 | 10.3 | CNG/LNG | 305 | | |
| Caterpillar | C12 | 12 | CNG/LNG | 410 | | |

## Table D. Heavy-Duty Electric Vehicles Currently Available

| Manufacturer | Model | Class | Battery Type | Development Stage |
|---|---|---|---|---|
| Advanced Vehicle Systems | AVS-20 | Tram | | |
| Advanced Vehicle Systems | AVS-22 | Shuttle bus | | |
| Electric Vehicles International | EV22B | Transit bus | Lead-acid | Production |
| Electric Vehicles International | EV22T | Trolley | Lead-acid/ NiCd | Production |
| Electric Vehicles International | EV4000 | Tram | Lead-acid | Production |
| Electric Transit Inc. | | Trolley | | Prototype being tested in San Francisco |
| Solectria | Citivan | Step van | Sealed, lead-acid | Production |

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## Government/Other Organizations

| | |
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