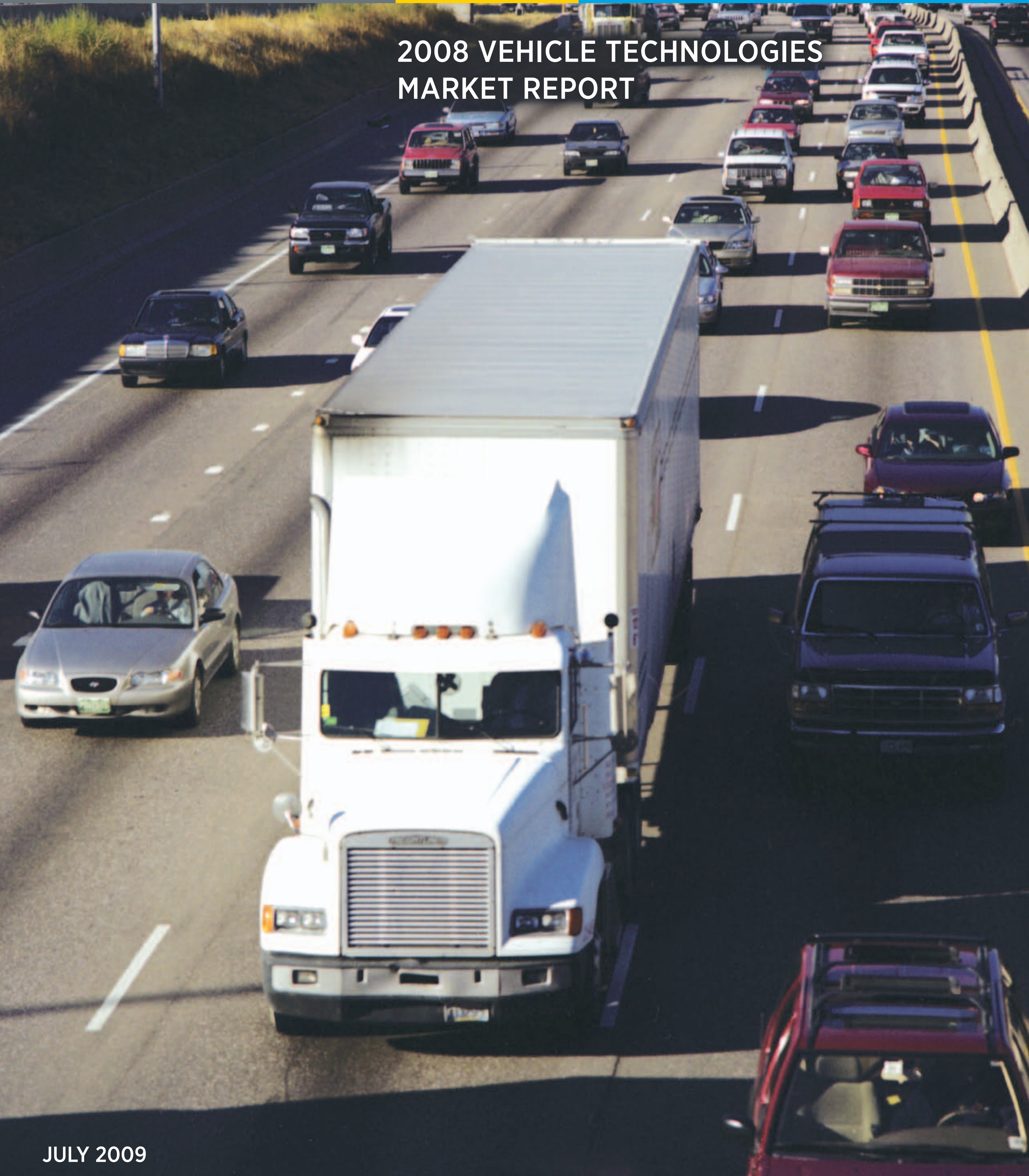
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

2008 VEHICLE TECHNOLOGIES MARKET REPORT



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2008 Vehicle Technologies Market Report

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About the Report

In the past five years, vehicle technologies have advanced on a number of fronts: power-train systems have become more energy efficient, materials have become more lightweight, fuels are burned more cleanly, and new hybrid electric systems reduce the need for traditional petroleum-fueled propulsion. This report documents the trends in market drivers, new vehicles, and component suppliers.

This report is supported by the Department of Energy's (DOE's) Vehicle Technologies Program, which develops energy-efficient and environmentally friendly highway transportation technologies that will reduce use of petroleum in the United States. The long-term aim is to develop "leap frog" technologies that will provide Americans with greater freedom of mobility and energy security, while lowering costs and reducing impacts on the environment.

Acronyms

AMFA	Alternative Motor Fuels Act
CAFE	Corporate Average Fuel Economy
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CVT	Continuously Variable Transmission
DCC/CHR	DaimlerChrysler
DISI	Direct Injection Spark Ignition
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EEA	Energy & Environmental Analysis
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FFV	Flex-Fuel Vehicles
FHWA	Federal Highway Administration
FMC	Ford Motor Company
GDi	Gasoline Direct Injection
GDP	Gross Domestic Product
GGE	Gasoline Gallon Equivalent
GMC	General Motors Corporation
GVWR	Gross Vehicle Weight Rating
HCCI	Homogeneous Charge Compression Ignition
HEV	Hybrid Electric Vehicle
HON	Honda
HVAC	Heating, Ventilation, and Air Conditioning
LCF	Long Carbon Fiber
LCV	Longer Combination Vehicles
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LSD	Low Sulfur Diesel
MPG	Miles Per Gallon
MY	Model Year
NHTSA	National Highway Traffic Safety Administration
NIMH	Nickel-Metal Hydride Battery
NIS	Nissan
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PM	Particulate Matter
R&D	Research and Development
SCR	Selective Catalytic Reduction
SUV	Sport Utility Vehicle
TOY	Toyota
ULSD	Ultralow Sulfur Diesel
VEETC	Volumetric Ethanol Excise Tax Credit
VMT	Vehicle Miles Traveled
Δ	Change

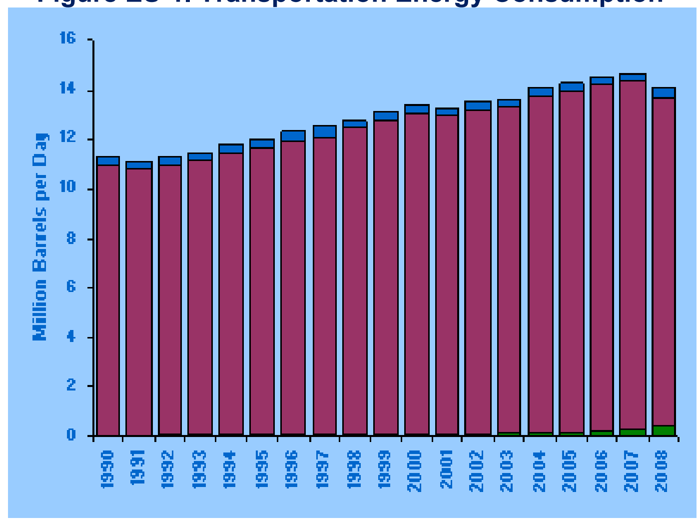
Executive Summary

The American automotive industry experienced sudden, unanticipated change in 2008. The economic downturn, combined with unpredictable oil prices, pushed consumers away from new vehicles, causing purchases of light, medium, and heavy vehicles to decline sharply from past levels. Energy consumed by the transportation sector decreased, and the number of miles traveled by Americans in 2008 declined from the previous year for the first time in 28 years.

The contractions in the automotive industry and transportation energy consumption in 2008 are a temporary aberration from the broader trend: The transportation sector is growing. The demand for mobility and readily available commodities are expected to continue to grow. Energy Information Administration (EIA) projections show increases in the number of vehicles, number of passenger-miles traveled and amount of goods shipped.

Despite a decrease in energy consumption in 2008, transportation-sector energy consumption has generally increased during the past two decades (Figure ES-1). This increase is primarily driven by increasing vehicle miles traveled—more people are traveling more miles, and more goods are being shipped. The increase in energy consumption is less than the increase in mobility, due to an increase in the efficiency of the movement of goods. The stock of light vehicles on the road is also more efficient than five years ago. And mobility is cleaner: Light-, medium-, and heavy-vehicle emissions have decreased significantly during the past five years, thanks to new emissions regulations and the technologies to achieve them.

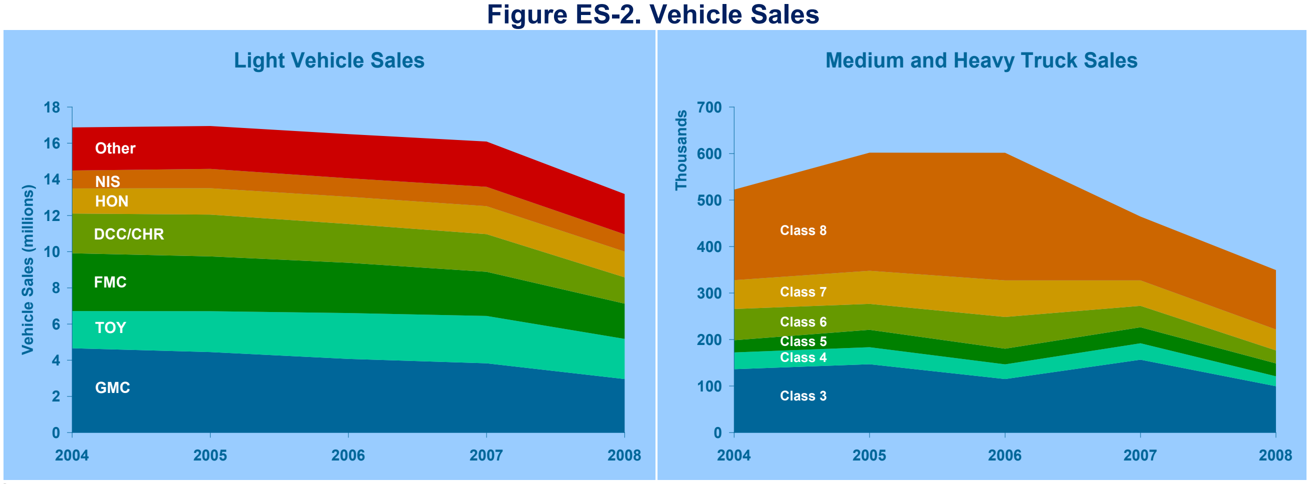
Figure ES-1. Transportation Energy Consumption



Source: EIA, Monthly Energy Review

Vehicle sales figures have decreased significantly in the past two years for both the light vehicles that most Americans used for daily driving, and the medium and heavy trucks used for commercial purposes as well as shipping (Figure ES-2). This steep decline in vehicle purchases comes at a time when the entire country is facing an economic downturn. The transportation industry was hit especially hard in 2008, when economic problems were compounded by an oil shock. Petroleum fuel prices spiked in late summer/early fall, then immediately plummeted to the lowest levels seen in several years. Uncertainty regarding future fuel prices likely contributed to consumer hesitance toward new vehicle purchases.

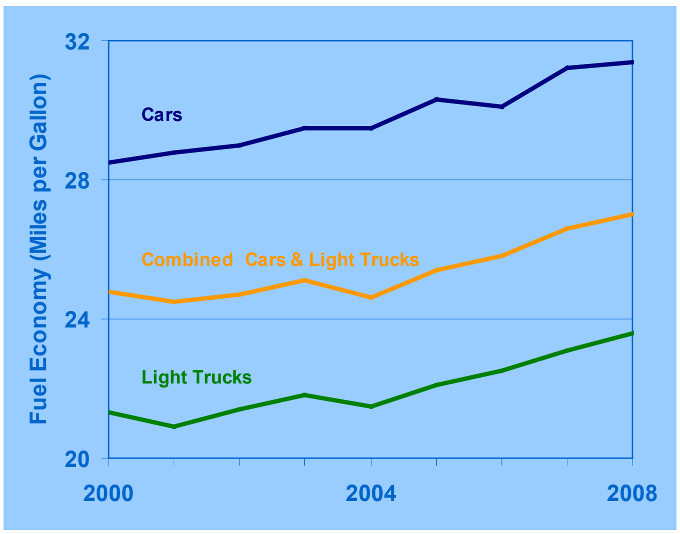
Figure ES-2. Vehicle Sales



Source: Wards

New cars and light trucks today are increasingly more energy efficient than cars and light trucks were five years ago. However, because consumers have preferred light trucks over cars in recent years, the combined Corporate Average Fuel Economy for the entire U.S. fleet of both cars and light trucks has improved little in that time (Figure ES-3). Light trucks are, on average, less fuel efficient than cars. So, even though both cars and light trucks have become more fuel efficient, consumers still seem to prefer buying sport utility vehicles (SUVs), which are less fuel efficient.

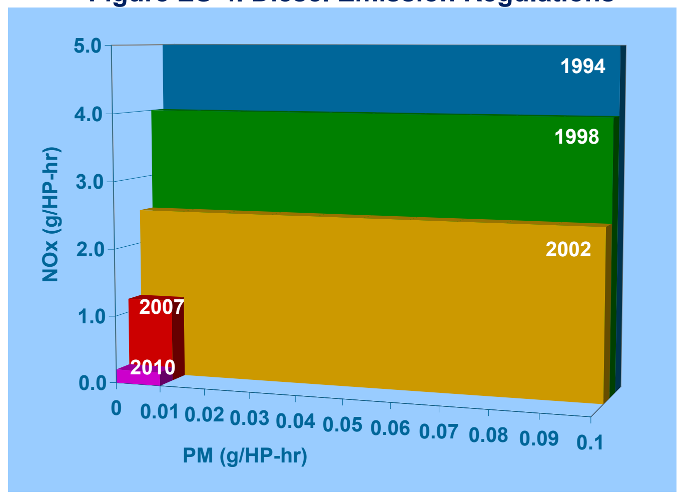
Figure ES-3. Corporate Average Fuel Economy



Source: NHTSA, Summary of Fuel Economy Performance

The reduction in emissions for medium and heavy vehicles is an important trend. Since 2002, the Environmental Protection Agency (EPA) has required that diesel vehicles reduce nitrogen oxide (NOx) emissions by more than 50% (from 2.5 to 1.2 g/HP-hr) and particulate matter (PM) emissions by 90% (from 0.1 g/HP-hr to 0.01 g/HP-hr) (Figure ES-4). Medium- and heavy-truck manufacturers have consistently met these requirements on time, and without significantly sacrificing vehicles' performance characteristics.

Figure ES-4. Diesel Emission Regulations



Source: EPA

The next several years promise to bring increased fuel efficiency to all on-highway vehicles. Light-vehicle fuel economy will increase by 40% by 2030 due to more stringent fuel economy standards required by the Energy Independence and Security Act of 2007. The National Highway Transportation Safety Administration is considering fuel economy standards for medium and heavy vehicles, and the National Academy of Sciences is also providing guidance.

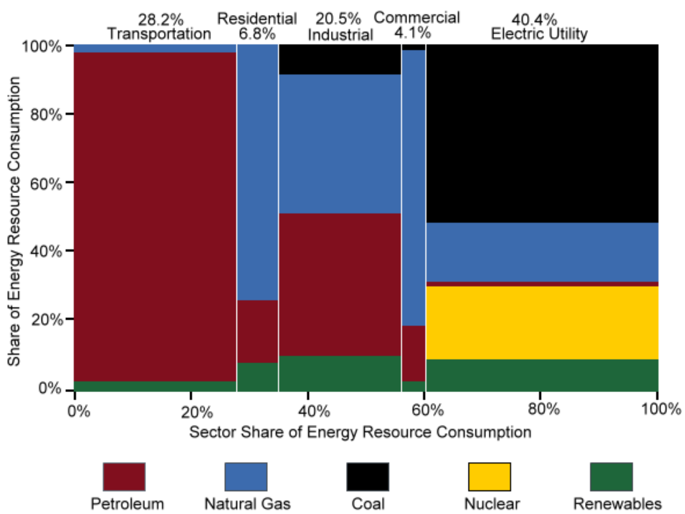
This report details the major trends in transportation energy mentioned here, as well as the underlying trends that caused them. The report opens with a summary of the economic sector, including sector-wide energy consumption trends. The second section includes a discussion on light vehicles, and the third section discusses heavy vehicles. The fourth section discusses the policies that shape the transportation sector, and the fifth section makes projections about what will happen in the transportation sector in the next five years.

Transportation Energy Trends

Transportation accounts for 28% of total U.S. energy consumption

In 2008, the transportation sector used 28 quads of energy, which is 28% of total U.S. energy use (Figure 1). Nearly all of the energy consumed in this sector is petroleum (95%), with small amounts of renewable fuels (3%) and natural gas (2%). With the future use of plug-in hybrids and electric vehicles, transportation will begin to use electric utility resources. The electric-utility sector draws on the widest range of sources and uses only a small amount of petroleum. The energy sources have not changed much during the past five years, although renewable fuel use has grown slightly in each sector.

Figure 1. U.S. Energy Sector and Energy Source, 2008

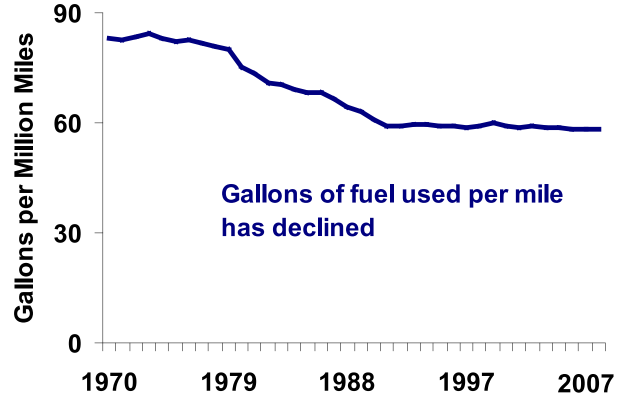


Source: EIA, Monthly Energy Review

Transportation is more efficient

The number of miles driven on our nation's highways has generally been growing during the past three decades, and energy use has grown with it. However, due to advanced engines, materials, and other vehicle technologies, the amount of fuel used per mile has declined from 1970 (Figure 2). The gallons per mile held steady from the early 1990s to 2007, showing that the fuel economy for new vehicles was stagnant during this period.

Figure 2. Fuel Use per Mile

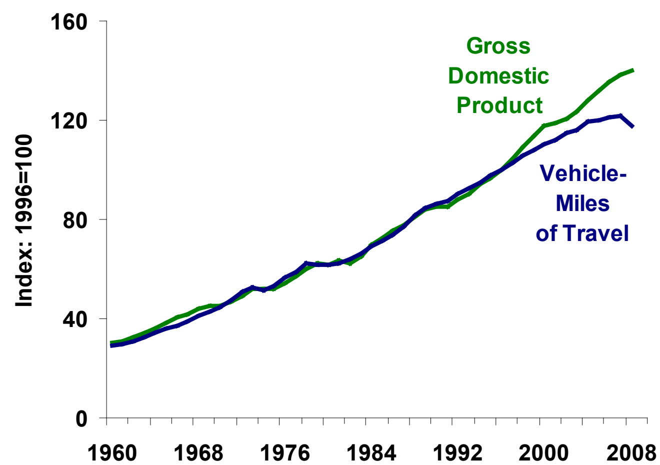


Source: FHWA, Highway Statistics

Vehicle miles are increasingly disconnected from the economy

From 1960 to 1998, the growth in vehicle miles of travel (VMT) closely followed the growth in the U.S. Gross Domestic Product (GDP) (Figure 3). Since 1998, however, the growth in VMT has slowed and has not kept up with the growth in GDP. Like the transportation sector's energy use, VMT declined from 2007 to 2008.

Figure 3. Relationship of VMT and GDP



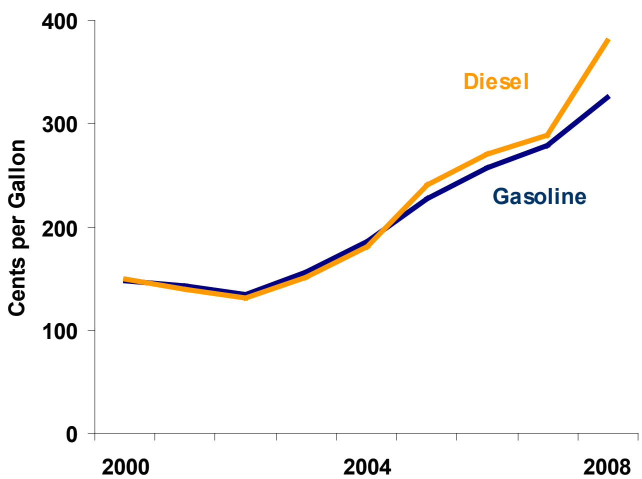
Source: BEA, Survey of Current Business and FHWA, Highway Statistics

Energy prices affect the transportation sector

The prices of gasoline and diesel fuel affect the transportation sector in many ways. For example, price can impact the number of miles driven in a year, and affect the choices consumers make when purchasing vehicles. The price of gasoline rose dramatically during the past five years, from an annual average of $1.48 in 2004 to $3.25 in 2008 (Figure 4). Diesel fuel prices increased 155% during that same time period. The effects of the increase in fuel prices are seen throughout this report in the areas of energy use, VMT, and vehicle sales.

Historically, the price of diesel fuel has been lower than the price of gasoline. In 2005, however, that trend changed and diesel fuel became the more expensive of the two.

Figure 4. Annual Average Price of Gasoline and Diesel Fuel

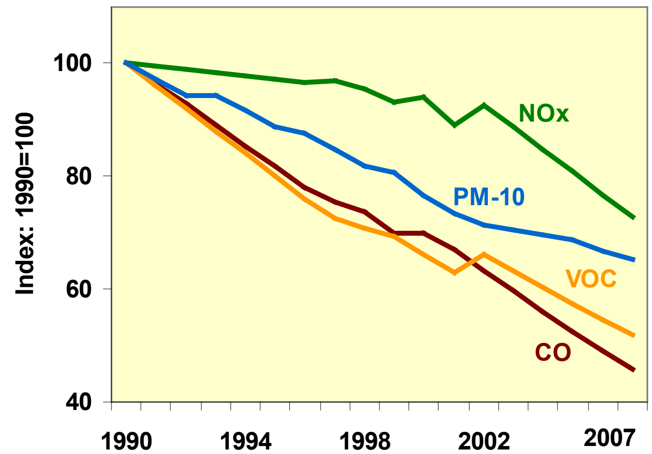


Source: EIA, Petroleum Navigator

Transportation energy consumption is cleaner

Growth in VMT not only equates to higher energy use, but typically means higher emissions coming from the transportation sector. However, due to improvements in vehicle emission technology, the total amount of pollutants emitted has declined (Figure 5). From 1990 to 2007, the emission totals for the transportation sector declined for each of the criteria air pollutants tracked by the EPA – carbon monoxide emissions dropped by 43%. Carbon dioxide (CO_2), the most prevalent greenhouse gas, is another transportation emission. From 1990 to 2007, CO_2 emissions per vehicle mile improved by 10% (Table 1). In the future, the EPA may regulate greenhouse gas emissions, much like they do the criteria air pollutants now.

Figure 5. Transportation Pollutant Emissions



Source: EPA, National Emission Inventory

Table 1. Metric Tons of CO2 per Vehicle Mile

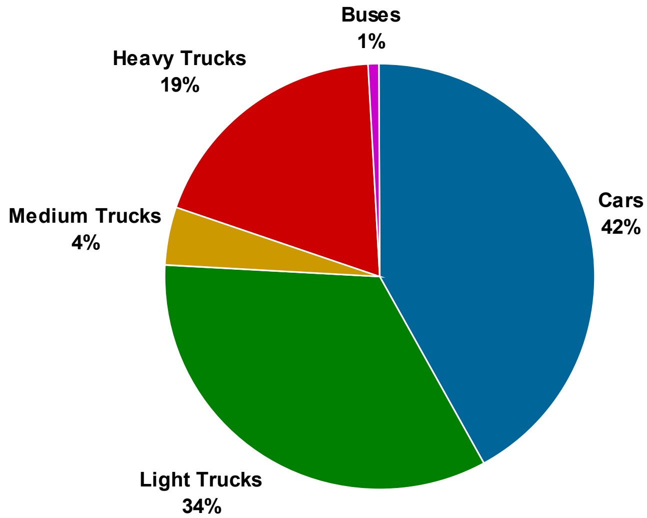
	1990	2007	5-yr Δ
Carbon Dioxide	0.74	0.66	-10%

Sources: EIA, Emissions of Greenhouse Gases in the United States, 2007, and FHWA Highway Statistics 2007

Light vehicles comprise the majority of transportation energy consumption

Light vehicles consume 76% of the energy used by the transportation sector on-road (excluding farm equipment, air, water, and rail transportation) (Figure 6). Heavy trucks comprise the majority of the remaining quarter, with medium trucks and buses consuming a relatively small fraction. The proportion of energy consumption shown in Figure 6 has been fairly constant for the past five years, although light trucks comprise a slightly greater share of fuel consumption (~2 percentage points) now than they did five years ago. This is due to a recent shift in consumer preference for SUVs (fuel consumption is included in the light trucks category) instead of cars. Cars' share of fuel consumption has decreased accordingly.

Figure 6. Breakdown of Transportation Energy Use by Mode, 2006



Source: ORNL, Transportation Energy Data Book

Class 8 trucks, though moderate in number, use the greatest amount of fuel

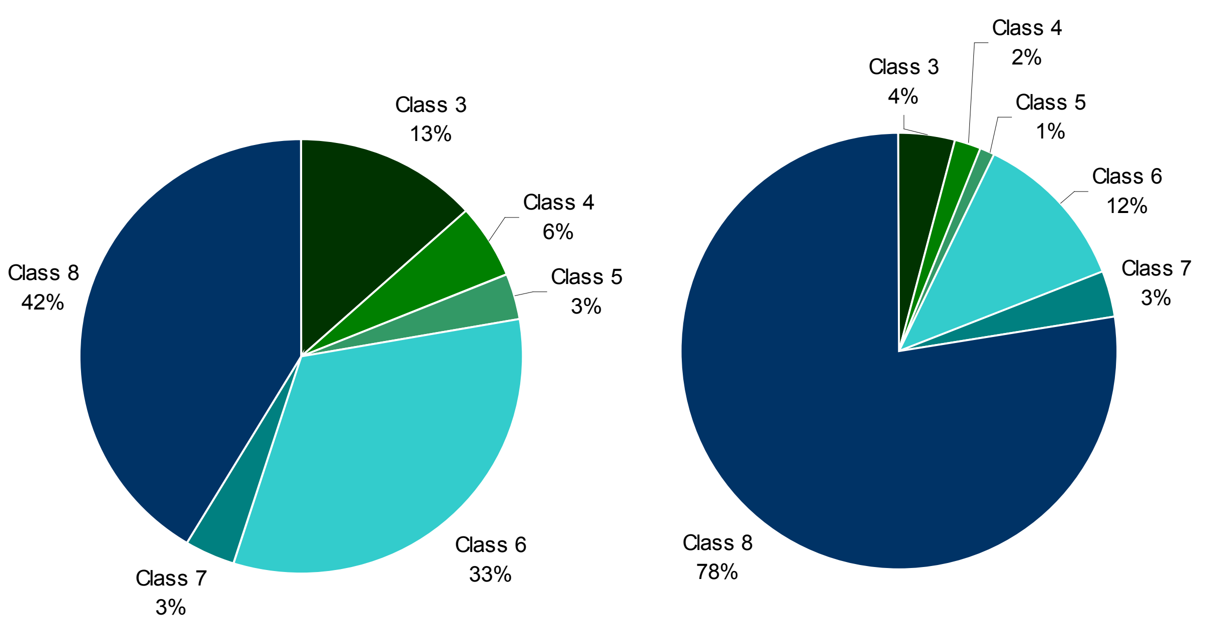
Class 8 trucks comprise only 42% of the heavy- and medium-truck fleet, but they account for 78% of the fuel consumed by medium and heavy trucks (Figure 7). Class 8 trucks carry the largest loads, which require the greatest energy expenditure per mile. Additionally, class 8 trucks, on average, tend to travel the longest distance: nearly 100,000 miles annually.

Leading engine suppliers are stable in the U.S., but their businesses are growing faster abroad

Of the top 100 global suppliers, the top four specializing in engines in 2003 are also the top suppliers in 2007 (Table 2). Though ranks remain unchanged, sales volumes to original equipment manufacturers (OEMs) have increased for all of these suppliers. It is worth noting that despite these increases in U.S. sales, the portion of sales in the United States has decreased, suggesting that growth for these suppliers abroad is outpacing U.S. growth.

Of the top 100 global suppliers, six of the top seven suppliers of engine components in 2003 are among the top eight in 2007. Sales volumes to OEMs shifted for many suppliers, and ranks shifted accordingly. As in the case of engine suppliers, it is worth noting that the portion of sales in the United States has decreased in most cases, again suggesting that growth for these suppliers abroad is outpacing U.S. growth.

Figure 7. Medium and Heavy Truck Fleet Composition (left) and Energy Usage (right)



Source: ORNL, Transportation Energy Data Book

Table 2. Leading Suppliers in Engines and Engine Components

Engines					
2003			2007		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Magna International Inc.	10434.6	(68 %)	Magna International Inc.	13591.9	(53%)
Navistar International	1760.4	(90 %)	Navistar International	2544.9	(77%)
Cummins Engine Co.	1590.3	(61 %)	Cummins Inc.	2104.2	(58%)
Metaldyne Corp.	1186.1	(84 %)	Metaldyne Corp.	1341.4	(72%)
			Draexlmaier Group	284.6	(12%)

Engine Components					
2003			2007		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
TRW Automotive Inc.	4633.0	(41 %)	TRW Automotive Inc.	4066.5	(30%)
DuPont	2755.0	(50 %)	Aisin Seiki Co.	3689.9	(17%)
Aisin Seiki Co.	1624.1	(12 %)	BorgWarner Inc.	1971.7	(37%)
BorgWarner Inc.	1562.4	(57 %)	DuPont	1743.0	(35%)
Metaldyne Corp.	1186.1	(84 %)	Nemak SA	1651.3	(57%)
Nemak SA	827.1	(98 %)	Metaldyne Corp.	1341.4	(72%)
Magneti Marelli	202.0	(7 %)	Eaton Corp.	1120.0	(70%)
			Kolbenschmidt Pierburg AG	370.8	(12%)
			Magneti Marelli	249.8	(5%)

Source: "Top 100 Global Suppliers 2007" and "Top 100 Global Suppliers 2003", both by Automotive News. Note: figures include both light and heavy vehicles

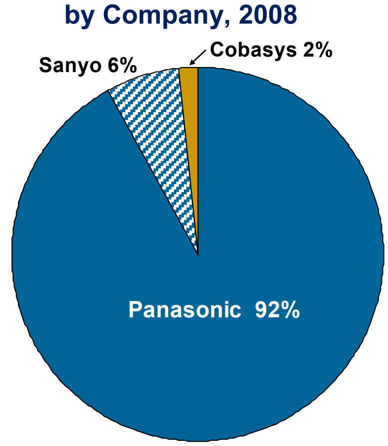
Panasonic dominates the American vehicle battery market

In December 2008, Panasonic (the top battery manufacturer in terms of sales volumes for automotive hybrid use) acquired Sanyo, the second-ranked manufacturer. At the time, media reported that the companies broadly agreed that Panasonic would make Sanyo Electric a subsidiary, and the Sanyo brand would be maintained.

The Cobasys batteries in the Saturn Vue are the only batteries assembled in the United States that have been used in mass-produced vehicles (Figure 8). Even though the Ford Escape Hybrid and Saturn Vue Hybrid are assembled at U.S. facilities, many of their parts—including batteries for the Escape and motors for both—come from Asia (Tables 3 and 4).

From a technical standpoint, the characteristics of batteries and electric-drive systems have improved between 2004 and 2008. Performance has improved as battery internal resistance lowers, and power electronics and motors achieve slight efficiency gains. Batteries are either decreasing in size or producing more power or energy for the same weight. Reliability has not been an issue so far, because both batteries and electric drive systems have shown the durability required to perform in an automotive environment.

Figure 8. Share of Batteries Supplied by Company, 2008



Source: Estimated from HEV sales

Table 3. Batteries Supplied by Manufacturer

Calendar Year	2004	2005	2006	2007	2008	Battery Supplier
Honda	27,215	43,356	37,571	35,980	31,493	Panasonic, Sanyo
Toyota	53,991	146,560	191,742	286,011	249,891	Panasonic
Ford	2,993	19,795	23,323	25,108	19,502	Panasonic
GMC	0	0	0	5,175	11,454	Cobasys, Panasonic
Chrysler	0	0	0	0	46	Panasonic
Total	84,199	209,711	252,636	352,274	312,386	Panasonic

Source: Estimated from HEV sales

Table 4. Batteries Supplied by HEV Model

Calendar Year	2004	2005	2006	2007	2008	Battery Supplier
Prius	53,991	107,897	106,971	181,221	158,574	Panasonic
Camry			31,341	54,477	46,272	Panasonic
Highlander		17,989	31,485	22,052	19,441	Panasonic
RX400h		20,674	20,161	17,291	15,200	Panasonic
Altima				8,388	8,819	Panasonic
LS600hL				937	907	Panasonic
GS 450h			1,784	1,645	678	Panasonic
Civic	25,571	25,864	31,251	32,575	31,297	Panasonic
Accord	1,061	16,826	5,598	3,405	196	Sanyo*
Insight	583	666	722	0	0	Panasonic
Escape	2,993	18,797	20,149	21,386	17,173	Sanyo*
Mariner		998	3,174	3,722	2,329	Sanyo*
Tahoe					3,745	Panasonic
Vue				4,403	2,920	Cobasys
Malibu					2,093	Cobasys
Yukon					1,610	Panasonic
Escalade					801	Panasonic
Aura				772	285	Cobasys
Aspen					46	Panasonic
Total	84,199	209,711	252,636	351,502	312,386	

* Panasonic purchased Sanyo in December 2008.

Source: Estimated from HEV sales

Only two of the top 100 global suppliers (Johnson Controls and Panasonic) have manufactured batteries in the past five years (Table 5). Johnson Controls manufactures lead-acid batteries, which are not relevant for HEV-specific applications; Panasonic has manufactured NiMH batteries for application in many hybrid electric vehicles (HEVs). Similarly, none of the top 100 global suppliers produced electric power trains in 2003, and only two (Hitachi and Valeo) produce electric power trains in 2007.

The leading suppliers may change in the near future with other companies being recognized as the leading performers of R&D in battery and hybrid electric systems in the United States. A123 and Enerdel perform battery R&D; and Delphi, Remy, General Motors (GM), Ford, and General Electric (GE) perform hybrid electric system R&D. The Department of Energy has supported A123, Enerdel, Delphi, GM, Ford, and GE. Worldwide, Johnson Controls and Hitachi can be expected to maintain their top ranks, and they are recognized as the top performers of R&D in batteries and hybrid electric systems, respectively. Other recognized leaders in battery R&D abroad include Sanyo, NEC, and LG Chemical. Hitachi, Denso, Toyota, and Aisin are recognized as leaders in R&D for hybrid electric systems.

Table 5. Battery and Electric Powertrain Suppliers

Leading Suppliers in Batteries					
2003			2007		
Company	2007 Total U.S. Sales (Mil$)	US % of Global Sales	Company	2003 Total U.S. Sales (Mil$)	US % of Global Sales
Johnson Controls Inc.	8,051.8	(53 %)	Johnson Controls Inc.	7,585.0	(41%)
Panasonic Automotive	992.0	(31 %)	Panasonic Automotive Systems Co.	1,320.2	(28%)

Leading Suppliers in Electric Powertrains					
2003			2007		
Company	2007 Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	2003 Total U.S. Sales (Mil$)	U.S. % of Global Sales
			Hitachi Ltd.	2,280.0	(30%)
			Valeo SA	1,860.6	(14%)
Source: "Top 100 Global Suppliers 2007" and "Top 100 Global Suppliers 2003", both by Automotive News. Note: figures include both light and heavy vehicles					

Market Trends: Light Vehicles

OEM production facilities are concentrated by manufacturer and by state

All three domestic manufacturers are physically concentrated in Michigan, where they have more production facilities than anywhere else (Table 6). Toyota (TOY), Honda (HON), and Nissan (NIS) have fewer than five facilities each, which are spread across the United States. Several plants have opened in the past five years. Toyota's Tundra plant in San Antonio, Texas, began production in 2006, the same year as General Motors began production at a new plant in Lansing, Michigan. Honda opened a plant in Greensburg, Indiana, in 2008.

Sales volumes have decreased significantly and market shares have shifted among top OEMs

Due to myriad economic woes in the United States, sales of cars and light trucks in 2008 were dismal. During a five-year period (2004 to 2008), sales of light trucks declined by more than 30%, while sales of cars declined nearly 10%. According to Ward's AutoInfoBank data, light-truck sales had declined slightly each year from 2004 to 2007, but the 2.1 million drop in vehicle sales from 2007 to 2008 was sudden. Car sales declined by 0.8 million from 2007 to 2008 (Table 7).

In 2004, domestic manufacturers—General Motors (GMC), Ford (FMC), and DaimlerChrysler (DCC/CHR) — comprised 44.6% of car sales and 71.8% of light-truck sales. By 2008, the domestic share of car sales dropped sharply to 35% and light truck sales to about 62%. The change in light-truck sales is even more dramatic when considered by company: in 2008, General Motors and Ford both sold less than two-thirds the number of light trucks they sold in 2004.

Not only have market shares shifted, but two of the companies have shifted themselves: DaimlerChrysler agreed in May 2007 to a costly deal with Cerberus Capital Management to undo Daimler's merger with Chrysler, ending a 10-year partnership. Thus, data in the table labeled DCC/CHR is for DaimlerChrysler through 2007 and for Chrysler alone in 2008.

The domestic automakers represented a 60% share of all light-vehicle sales in 2004 (Figure 9). By 2008, the domestic automaker's share of light-vehicle sales dropped to less than half (48%). Conversely, the import manufacturers all gained market share during the same period. Toyota led the imports with nearly 17% of all light-vehicle sales in 2008.

Table 6. Light-Vehicle Production Facilities by State and Manufacturer

State	GMC	CHR	FMC	TOY	HON	NIS	State Total
Alabama	0	0	0	0	1	0	1
California	1	0	0	1	0	0	1*
Delaware	1	1	0	0	0	0	2
Georgia	1	0	0	0	0	0	1
Illinois	0	1	1	0	0	0	2
Indiana	2	0	0	1	1	0	4
Kansas	1	0	0	0	0	0	1
Kentucky	1	0	0	1	0	0	2
Louisiana	1	0	0	0	0	0	1
Michigan	8	3	5	0	0	0	16
Minnesota	0	0	1	0	0	0	1
Missouri	1	2	2	0	0	0	5
Mississippi	0	0	0	0	0	1	1
Ohio	2	2	1	0	2	0	7
Tennessee	1	0	0	0	0	1	2
Texas	1	0	0	1	0	0	2
Wisconsin	1	0	0	0	0	0	1
OEM Total	22	9	10	4	4	2	

* The joint venture of GM and Toyota (New United Motor Manufacturing, Inc) is listed for each manufacturer, but is only counted once in the total.

Notes: State total includes only those manufacturers shown on this table.

Data highlighted in yellow indicate that the manufacturer has opened one new assembly plant in the state since 2004.

Source: Ward's AutoInfobank

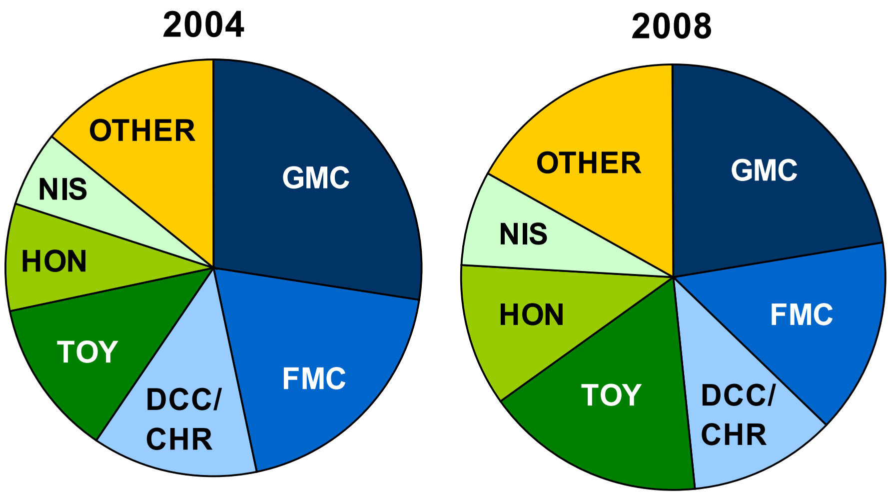
Table 7. New Vehicle Sales and Market Shares by Manufacturer

Car Sales Volumes (Millions of Vehicles)							Car Market Share	
Calendar Year	2004	2005	2006	2007	2008	5-yr Δ	2004	2008
GMC	1.88	1.74	1.62	1.49	1.26	-33.0%	24.9%	18.5%
FMC	0.97	1.01	1.07	0.82	0.72	-25.8%	12.9%	10.5%
DCC/CHR	0.51	0.58	0.55	0.57	0.41	-19.6%	6.8%	6.0%
TOY	1.10	1.29	1.46	1.51	1.36	23.6%	14.6%	19.9%
HON	0.84	0.84	0.84	0.88	0.88	4.8%	11.2%	12.9%
NIS	0.54	0.57	0.55	0.64	0.59	9.3%	7.1%	8.7%
OTHER	1.71	1.69	1.73	1.71	1.59	-7.0%	22.5%	23.5%
ALL	7.55	7.72	7.82	7.62	6.81	-9.8%	100.0%	100.0%

Light Truck Sales Volumes (Millions of Vehicles)							LT Market Share	
Calendar Year	2004	2005	2006	2007	2008	5-yr Δ	2004	2008
GMC	2.78	2.71	2.45	2.34	1.70	-38.9%	29.8%	26.6%
FMC	2.22	2.02	1.71	1.62	1.23	-44.6%	23.8%	19.2%
DCC/CHR	1.69	1.73	1.59	1.51	1.04	-38.5%	18.2%	16.3%
TOY	0.96	0.97	1.08	1.11	0.86	-10.4%	10.3%	13.5%
HON	0.55	0.62	0.67	0.67	0.55	0.0%	5.9%	8.6%
NIS	0.45	0.50	0.47	0.43	0.36	-20.0%	4.8%	5.6%
OTHER	0.67	0.68	0.71	0.79	0.64	-4.5%	7.2%	10.2%
ALL	9.32	9.23	8.68	8.47	6.38	-31.6%	100.0%	100.0%

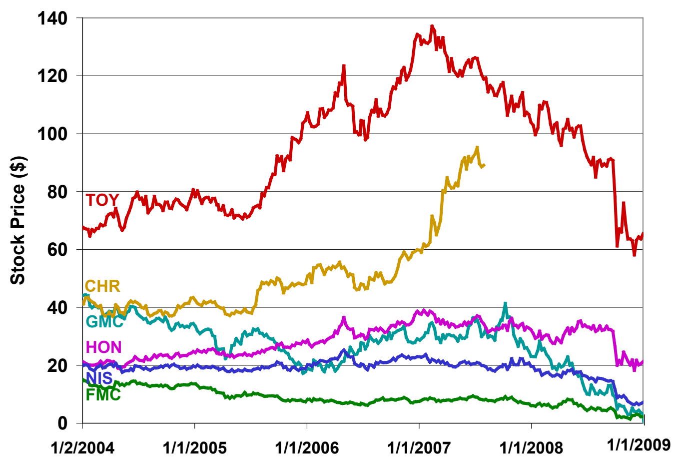
Source: Ward's AutoInfoBank

Figure 9. New Vehicle Shares by Manufacturer



Source: Ward's AutoInfoBank

Figure 10. Stock Prices for Major Vehicle Manufacturers



Source: Yahoo Finance

Major manufacturers have been hard hit by the general economic recession

While the general economic recession was clearly visible in late 2008, it could be seen in the auto industry about 12 months earlier. The stock prices of the six largest auto manufacturers peaked in late 2007 (Figure 10). At the end of 2008, stock prices for Toyota and Honda had declined to 2004 levels. General Motors, Nissan, and Ford have seen a decline in stock prices to levels far below their 2004 levels. General Motors stock has dropped more than 90% from its 2004 peak; Ford has dropped about 75%.

The stock trend for Daimler Chrysler ends on August 3, 2007, at which time Daimler AG sold Chrysler LLC to Cerberus Capital Management, a private equity firm that specializes in restructuring troubled companies. Cerberus runs Chrysler as a private company, and, as such, there has been neither publicly traded stock nor stock pricing data since the date of sale.

Real average vehicle costs are decreasing slightly

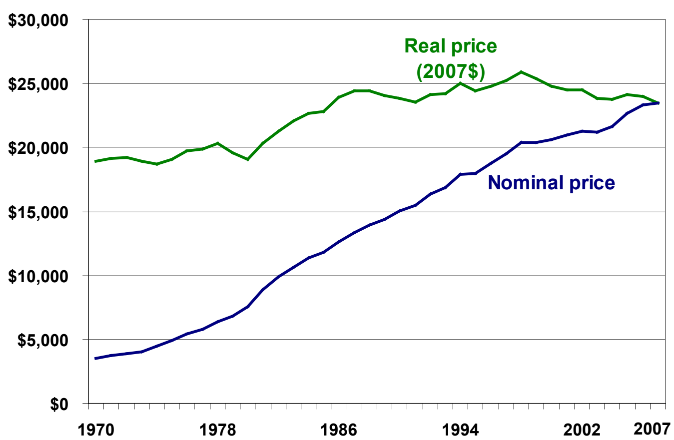
Average vehicle costs have fluctuated during the past five years, but the overall trend is a slight decline in average price (Table 8). These prices agree with a longer term trend: Real average vehicle cost has been near $24,000 since 1986 (Figure 11). In addition, recent stability in regulatory policy—the Corporate Average Fuel Economy Standards (CAFE) did not change significantly until 2008—has caused few perturbations to OEM planning, which has facilitated cost-effective technological improvements and a gradual decrease in prices from a peak of just above $25,000 in 1998.

Table 8. Average Vehicle Cost

Calendar Year	Real price (2007$)
2003	$23,854
2004	$23,749
2005	$24,100
2006	$23,996
2007	$23,482
5-yr change	-1.6%

Source: Bureau of Economic Analysis, National Income and Product Accounts

Figure 11. Average Price of a New Car



Source: Bureau of Economic Analysis, National Income and Product Accounts

Light trucks make up 48 percent of new vehicle sales

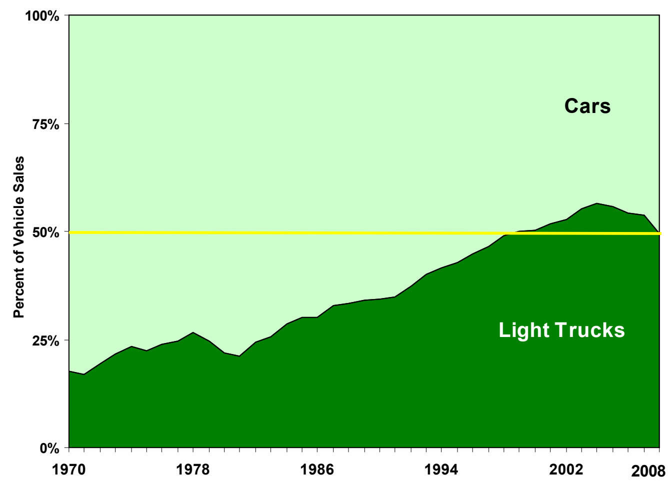
The light-truck share of new vehicle sales during the past five years reached a peak in 2004-2005 (Table 9 and Figure 12). Until that point, light-truck sales' share had increased steadily, from around 20% in the 1980s to just above 50% in more recent years. Light-truck sales declined relative to car sales in 2006 as a result of (1) increasing oil prices, which discouraged buying vehicles with poor fuel economy, and (2) the introduction of the crossover—a vehicle derived from a car platform but borrowing features from an SUV. Depending on their characteristics, some crossovers are classified as cars. Thus, consumers still interested in SUV-like vehicles are buying a vehicle actually classified as a car. It appears that the shift in purchasing patterns is not simply a slowing of what seemed to be an ever-increasing increase of light-truck sales share, but a marked reversal in purchasing behavior. The decrease in light-truck sales' shares between 2005 and 2008 signifies that consumers shifted toward cars.

Table 9. Light Truck Share of Total Light Vehicle Sales

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
GMC	16.48%	15.99%	14.85%	14.54%	12.89%	-21.8%
FMC	13.16%	11.92%	10.36%	10.07%	9.33%	-29.1%
DCC/CHR	10.02%	10.21%	9.64%	9.38%	7.88%	-21.4%
TOY	5.69%	5.72%	6.55%	6.90%	6.52%	14.6%
HON	3.26%	3.66%	4.06%	4.16%	4.17%	27.9%
NIS	2.67%	2.95%	2.85%	2.67%	2.73%	2.3%
OTHER	3.97%	4.01%	4.30%	4.91%	4.85%	22.2%
ALL	55.25%	54.45%	52.61%	52.64%	48.37%	-12.5%

Source: Ward's AutoInfoBank

Figure 12. Share of New Vehicle Sales by Vehicle Type

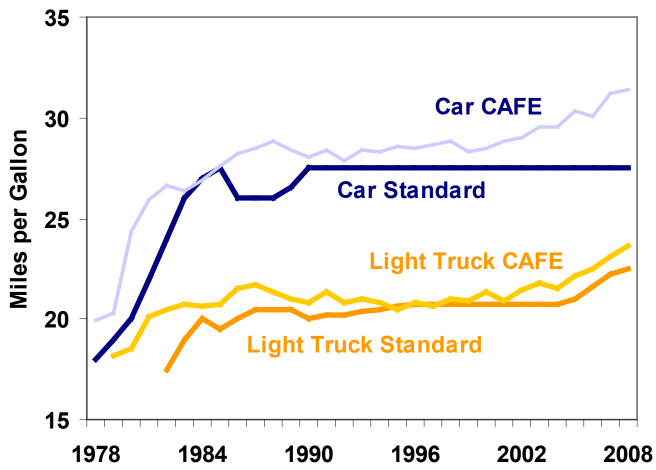


Source: Ward's AutoInfoBank

CAFE has increased for cars and light trucks

Corporate Average Fuel Economy (CAFE)—the sales-weighted harmonic mean fuel economy of a manufacturer's fleet of current model year cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 pounds or less—has increased slightly during the past five years. The requirement for cars has been held constant at 27.5 miles per gallon (mpg) during this period, while the requirement for light trucks has increased from 20.7 mpg in model year (MY) 2004 to 22.2 in MY 2008 (an increase of 7.2%). The actual fuel economy improvement for cars during the past five years was 1.8 mpg (an increase of 6.2%), while the actual fuel economy increase for light trucks was also 1.8 mpg (an increase of 8.8%) (Figure 13).

Figure 13. CAFE and CAFE Standards by Vehicle Type



Source: NHTSA, Summary of Fuel Economy Performance

CAFE compliance is measured by vehicle fleet: "domestic passenger cars," "import passenger cars," and "light trucks." There is a statutory two-fleet rule for passenger cars. Manufacturers' domestic and import fleets must separately meet the 27.5 mpg CAFE standard. For passenger cars, a vehicle (irrespective of who makes it) is considered part of the "domestic fleet" if 75% or more of the cost of the content originates in the United States, Canada, or Mexico. If not, it is considered an import. Light trucks were administratively subjected to a similar two-fleet rule in the past, but the National Highway Traffic Safety Administration (NHTSA) eliminated the two-fleet rule for light trucks beginning with MY 1996. Therefore, there are no fleet distinctions, and trucks are simply counted and CAFE calculated as one distinct fleet of a given manufacturer.

According to the CAFE data, Honda sold the most fuel-efficient fleet of domestic passenger cars, the most fuel-efficient fleet of import passenger cars, and the most fuel-efficient fleet of light trucks (Table 10). DaimlerChrysler manufactured the least fuel-efficient car fleet—both domestic and import—and Ford manufactured the least fuel-efficient light truck fleet. Nissan and Toyota achieved significant improvements in domestic passenger car fuel economy in the past five years. General Motors, Honda, and Toyota achieved similar gains in import passenger car fuel economy. DaimlerChrysler's CAFE figures for passenger and import passenger cars actually declined. CAFE figures are a function not only of the vehicles manufactured, but also of the sales mix: Manufacturers that sell a greater number of more fuel-efficient vehicles will have higher CAFE numbers.

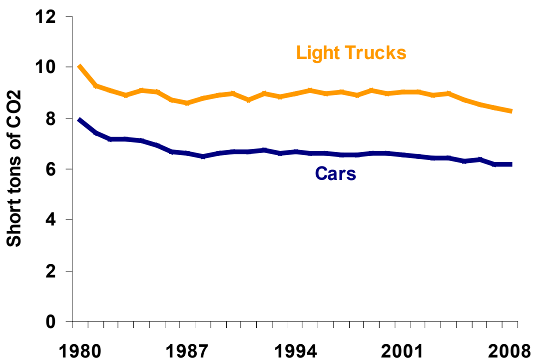
Table 10. CAFE by Manufacturer

Corporate Average Fuel Economy (miles per gallon)						
Domestic Passenger Cars						
	2004	**2005**	**2006**	**2007**	**2008**	**5-yr ∆**
DCC/CHR	29.6	28.8	26	28.5	29.5	-0.34%
FMC	26.7	28.6	28.2	29	29.8	11.61%
GMC	29.3	29.3	29.9	30	29.6	1.02%
HON	33.1	33.2	33.8	33.5	35.3	6.65%
NIS	27.9	30.7	31.1	33.4	33.7	20.79%
TOY	33.2	34.4	34.6	31.3	33.9	2.11%
Import Passenger Cars						
	2004	**2005**	**2006**	**2007**	**2008**	**5-yr ∆**
DCC/CHR	26.9	25.9	24.7	24.7	27.4	1.86%
FMC	27.7	28.4	29.8	30	30.6	10.47%
GMC	30.3	30.5	29	32.3	31.4	3.63%
HON	32.7	33.1	34.5	39.3	33.2	1.53%
NIS	28.9	24.8	24.3	29.6	29.4	1.73%
TOY	32.4	36.6	35	38.3	38.5	18.83%
Light Trucks						
	2004	**2005**	**2006**	**2007**	**2008**	**5-yr ∆**
DCC/CHR	20.5	21.4	21.7	22.9	23.6	15.12%
FMC	21	21.6	21.1	22.3	23.6	12.38%
GMC	21.4	21.8	22.8	22.4	22.8	6.54%
HON	24.6	24.9	24.7	25.1	25.5	3.66%
NIS	21.1	21.7	21.9	22.9	24.0	13.74%
TOY	22.7	23.1	23.7	23.7	23.7	4.41%

Source: NHTSA, Summary of Fuel Economy Performance

Because greenhouse gas emissions are tied to the amount of fuel burned, the fuel economy of vehicles affects the amount of carbon dioxide released into the atmosphere. EPA calculates vehicles' carbon footprint using average car and light-truck fuel economy and assuming 15,000 miles per year. Figure 14 shows that the average carbon footprint for cars and light trucks has not changed a lot during the past 20 years. Table 11 shows the carbon footprint for a Ford Taurus over time.

Figure 14. Average Annual Carbon Footprint for New Vehicles Sold by Model Year



Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008, and Fueleconomy.Gov

Table 11. Carbon Footprint for a Ford Taurus

Model Year	Annual Tons of CO2 per year
1986	9.2
1996	9.2
2006	9.2
2009	8.7

Source: DOE/EPA, Fueleconomy.Gov

Most light vehicles gained weight

During the past five years, new cars gained an average of 79 pounds (2.3%) and light trucks gained an average of 32 pounds (1.6%) (Table 12). Two of the domestic manufacturers—DaimlerChrysler and General Motors—increased the average weight of their vehicles by more than 6% in that time period. New cars made by Nissan were actually lighter in 2008 than in 2004. For light trucks, Toyota and Nissan increased the average weight of their vehicles by more than 6%, mainly due to the size increase for the Toyota Tundra and the debut of the Nissan Titan in 2004. Ford was the only light-truck manufacturer to decrease the weight of light trucks (by 3.8%) during this period.

Consumers are purchasing more powerful engines

From 1980 to 2008, there have been significant gains made in automotive technology, but those advancements have been applied toward improved performance and safety rather than fuel economy. Horsepower has more than doubled, top speed has climbed from 107 miles per hour to 139 miles per hour, and "0-to-60" times have dropped from 14.3 seconds to 9.6 seconds (Figure 15). Average vehicle weight has increased nearly 30% during the same period, primarily due to increased vehicle size as well as reinforced structures and added equipment such as airbags that improve crashworthiness. During this same period, fuel economy has remained relatively unchanged, with only a 1.5% increase in average light-vehicle fuel economy between 1981 and 2008.

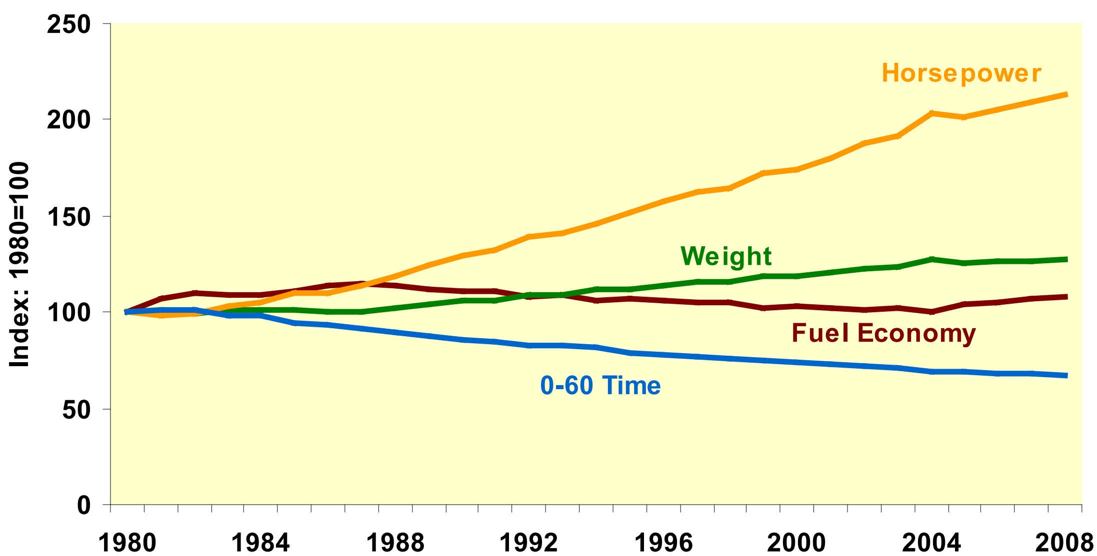
Engine displacement and horsepower are often closely related. Figure 16 shows an obvious spike in horsepower for DaimlerChrysler cars in 2006. This increase in horsepower from 2004 corresponds to the rising popularity of the larger V8 "HEMI" engines made available on many Dodge and Chrysler cars. The price of gasoline began to increase sharply after 2006, depressing demand for the larger engines. Similarly, Figure 16 shows a clear two-stepped increase for Nissan light trucks, which corresponds with the 2004 introduction of the V8 Nissan Titan and its subsequent upgrade in 2007.

Table 12. Average New Vehicle Weight by Manufacturer

Model Year	2004	2005	2006	2007	2008	5 yr ∆
Cars						
GMC	3,415	3,462	3,562	3,566	3,627	6.2%
FOR	3,660	3,599	3,602	3,529	3,671	0.3%
DCC/CHR	3,623	3,756	3,949	3,883	3,883	7.2%
TOY	3,295	3,223	3,236	3,362	3,342	1.4%
HON	3,295	3,308	3,335	3,289	3,346	1.5%
NIS	3,528	3,521	3,525	3,483	3,455	-2.1%
ALL	3,462	3,463	3,534	3,510	3,541	2.3%
Light Trucks						
GMC	5,002	4,926	4,795	5,222	5,112	2.2%
FOR	4,932	4,833	5,009	4,868	4,743	-3.8%
DCC/CHR	4,576	4,561	4,645	4,519	4,581	0.1%
TOY	4,383	4,413	4,459	4,531	4,668	6.5%
HON	4,148	4,179	4,227	4,242	4,215	1.6%
NIS	4,567	4,752	4,746	4,667	4,910	7.5%
ALL	4,710	4,668	4,665	4,741	4,742	0.7%

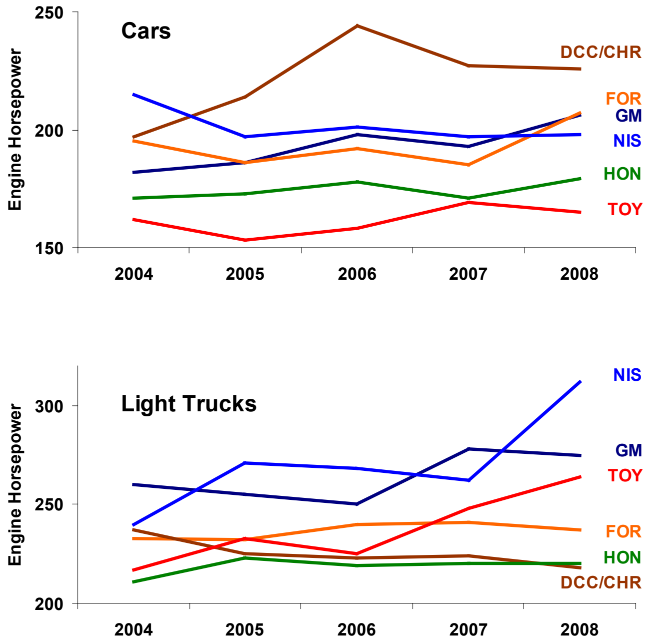
Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008

Figure 15. Characteristics of New Light Vehicles Sold, MY 1980-2008



Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008

Figure 16. Car and Light Truck Horsepower by Manufacturer



Note: Cars include wagons.

Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008

Although bigger engines typically provide greater horsepower, they also lead to increased weight, which hinders fuel economy and performance. Advancements in engine design and overall engine technology can increase horsepower without increasing engine size. Ford cars experienced an overall decrease in engine displacement of 2.1%, while increasing horsepower 6.2% from 2004 to 2008 (Table 13). Honda and Toyota also managed to increase the horsepower of their cars without increasing engine displacement. For trucks, Ford, GM, and Honda all reduced their overall engine displacement while increasing horsepower.

Table 13. Cubic Inch Displacement for Cars and Light Trucks

Model Year	2004	2008	5-yr Δ
Cars			
GM	189	193	2.1%
FOR	194	190	-2.1%
DCC/CHR	165	194	17.6%
TOY	143	143	0.0%
HON	139	139	0.0%
NIS	177	162	-8.5%
ALL	168	168	0.0%
Light Trucks			
GM	284	277	-2.5%
FOR	264	236	-10.6%
DCC/CHR	266	236	-11.3%
TOY	216	236	9.3%
HON	186	183	-1.6%
NIS	242	254	5.0%
ALL	252	240	-4.8%

Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008

Manufacturers are using more efficient transmissions

During the past five years, transmissions have evolved along two dimensions to become more efficient: The control system has shifted away from an electric to a lockup or semi-automatic lockup control system, and the number of speeds has shifted away from a four-speed transmission toward a six-speed or variable transmission (Table 14). With two more gears, the six-speed transmission allows the engine to operate at its optimum efficiency, for a greater period of time, further boosting fuel economy.

Several advanced technology transmissions have increased market shares in the past five years: semi-automatic transmission, the lockup clutch, and continuously variable transmission. A semi-automatic transmission (e.g., "Tiptronic") is a clutchless system that uses electronic sensors, processors, and actuators to shift gears at the command of the driver. Many semi-automatic transmissions can operate similarly to a conventional type of automatic transmission by allowing the transmission's computer to automatically change gear, if, for example the driver was redlining the engine. Early automatic transmissions suffer power losses in the torque converter; however, the use of a lockup clutch that physically links the pump and turbine eliminates slippage and power loss. Continuously variable transmission (CVT), which can smoothly alter its gear ratio by varying the diameter of a pair of belt or chain-linked pulleys, wheels, or cones, is an automatic transmission that is usually as fuel efficient as manual transmissions in city driving.

Table 14. New Light Vehicle Transmission Characteristics

Model Year	2004	2005	2006	2007	2008
Control System					
Manual	6.8%	6.0%	5.2%	5.8%	6.7%
Automatic	0.3%	0.1%	0.0%	0.0%	0.0%
Lockup	91.8%	91.6%	91.9%	87.5%	85.5%
CVT	1.2%	2.3%	2.9%	6.7%	7.8%
Speeds					
4	63.9%	56.1%	48.4%	40.9%	36.7%
5	31.8%	37.2%	38.4%	36.3%	35.2%
6	3.0%	4.1%	8.9%	14.7%	18.6%
7	0.2%	0.2%	1.4%	1.4%	1.6%
Variable	1.2%	2.3%	2.9%	6.7%	7.8%

Source: EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008

The companies that started this particular shift toward efficiency are the transmission suppliers, several of which have been in business since 2003 or earlier (Magna, Valeo, and ZF Friedrichshafen) and others of which are newcomers (Dana Corp. and ZSK Ltd.) (Table 15).

attributable to aluminum and 0.2 points to plastics/composites). The overall advanced materials share—defined here as aluminum, magnesium, plastics/composites, and advanced steels—has increased from 29.6% to 31.4%.

Table 16. Average Materials Content of North American Light Vehicles

Model Year	2003	2004	2005	2006	2007
Regular Steel	41.4%	41.0%	40.7%	40.1%	40.3%
High Strength Steel	11.5%	11.9%	12.2%	12.4%	12.7%
Stainless Steel	1.7%	1.7%	1.8%	1.8%	1.8%
Other Steel	0.8%	0.8%	0.9%	0.9%	0.8%
Aluminum	7.5%	7.7%	7.9%	8.0%	7.7%
Magnesium Castings	0.2%	0.2%	0.2%	0.2%	0.2%
Plastics and Plastic Composites	7.9%	8.1%	8.3%	8.4%	8.1%
Other Material	29.0%	28.5%	28.1%	28.3%	28.2%
All Advanced Materials	29.6%	30.4%	31.2%	31.6%	31.4%

Source: 2008 Ward's Motor Vehicle Facts and Figures

Table 15. Leading Suppliers of Transmissions

Transmissions					
2003			2007		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Magna International Inc.	10434.6	(68%)	Magna International Inc.	13591.9	(53%)
Valeo SA	1687.0	(19%)	Dana Corp.	4796.6	(55%)
ZF Friedrichshafen AG	1640.0	(20%)	Valeo SA	1860.6	(14%)
New Venture Gear Inc.	1332.2	(92%)	ZF Friedrichshafen AG.	1661.0	(11%)
			NSK Ltd.	600.5	(15%)

Source: "Top 100 Global Suppliers 2007" and "Top 100 Global Suppliers 2003", both by Automotive News. Note: figures include both light and heavy vehicles

Vehicles are comprised of more advanced materials

Despite the increase in average vehicle weight, manufacturers are using greater proportions of advanced materials in their vehicles (Table 16). From 2003 to 2007, the percentage of regular steel in an average light vehicle has decreased from 41.4% to 40.3%; while the portion of the car comprised of advanced materials such as aluminum, magnesium, and plastics/composites has increased by 0.4 percentage points (0.2 points are

Several companies have shown exceptional investment in advanced materials. Audi's A8 Space Frame, weighing only 113 pounds (nearly 90 pounds less than a steel body shell of the same type), set new standards in its market segment. The Jaguar XJ11 also features an all-aluminum chassis. Corvettes feature aluminum frames, magnesium engine cradles, a magnesium roof, and carbon-fiber bumpers. The Mercedes 300 SLR features magnesium-alloy bodywork, and the A-Series features advanced composite-fiber materials.

Materials suppliers are numerous among the top 100 global suppliers; six of the top 100 have a specialty in plastics and polymers (Table 17). Between 2003 and 2007, one steel company and two aluminum companies disappeared from the list of the top 100 suppliers; the figures for total sales to OEMs in 2003 and 2007 increased for steel and decreased slightly for aluminum. These shifts hint at volatility in these markets.

Raw-materials manufacturers are one further step removed from OEMs than the suppliers. The manufacturers of advanced steel recognized as world leaders include Arcelor-Mital, Nucor, U.S. Steel, POSCO, and ThyssenKrupp; recognized leading aluminum manufacturers include ALCOA, Novelis, Kaiser, Corus (non-U.S.); recognized leaders in composites include Meridian, MSG, Bayer, and Lincoln Composites (non-U.S.); and leaders in magnesium manufacture include Meridian, NEMAK, and Luoyang (non-U.S.).

The Department of Energy is recognized as a leading supporter of research for all of the aforementioned advanced automotive materials. Arcelor-Mittal, U.S. Steel, GM, Toyota, and Ford conduct R&D in advanced steel; ALCOA, Novelis, and Audi conduct R&D in aluminum; AF Materials Lab, Boeing, Oak Ridge National Laboratory (ORNL), the University of Delaware, and Mercedes-Benz conduct R&D in composites; and Magnesium Elektron, Ford, and GM conduct R&D in magnesium. Government funding also has supported R&D in composites and magnesium.

Table 17. Leading Suppliers of Advanced Materials

Leading Suppliers in Automotive Steel			
2003		2007	
Company	Million Metric Tons of Crude Steel Output	Company	Million Metric Tons of Crude Steel Output
Arcelor	42.80	ArcelorMittal	116.40
Mittal Steel	35.30	Nippon Steel	35.70
Nippon Steel	31.30	JFE	34.00
JFE	30.20	POSCO	31.10
POSCO	28.90	Baosteel	28.60

Leading Suppliers in Plastics, Polymers, and Components Comprised Thereof					
2003			2007		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
DuPont	2755.00	(50 %)	BASF Group	2488.50	(21%)
Flex-N-Gate Corp.	1215.00	(90 %)	Flex-N-Gate Corp.	2393.60	(88%)
Honeywell International	1035.00	(45 %)	DuPont	1743.00	(35%)
Toyoda Gosei Co.	853.74	(27 %)	Toyoda Gosei Co.	1160.46	(21%)
BASF AG	576.00	(24 %)	Dow Automotive	589.90	(34%)
Dow Automotive	563.50	(50 %)	Bayer MaterialScience	561.20	(28%)

Leading Suppliers in Aluminum Components					
2003			2007		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Nemak SA	827.12	(98 %)	Nemak Libramiento Arco Vial Km.	1651.29	(57%)
Superior Industries	714.00	(85 %)			
Alcan Inc.	650.00	(52 %)			

Source: "Top 100 Global Suppliers 2007" and "Top 100 Global Suppliers 2003", both by Automotive News. Note: figures include both light and heavy vehicles

Demonstrations in mass-produced vehicles within the past five years include advanced steel in front ends and door-intrusion beams, aluminum in liftgates, composites in truck beds, and magnesium in instrument panels.

More vehicles feature gasoline direct injection (GDi)

The major advantages of a gasoline direct injection (GDi) engine are increased fuel efficiency and high power output. In addition, the cooling effect of the injected fuel and the more evenly dispersed mixtures allow for more aggressive ignition timing curves. In 2004, Isuzu Motors produced the first GDi engines sold in mainstream American vehicles: GDi came standard on the 2004 Axiom and optional on the 2004 Rodeo. General Motors introduced a 155 hp (116 kW) version of the 2.2 L Ecotec used in the Opel Vectra and Signum in 2004; a 2.0 L Ecotec with Variable Valve Timing technology for the new Opel GT, Pontiac Solstice GXP, and the Saturn Sky Red Line in 2005; and expanded the use of that engine to the Super Sport versions of the Chevrolet Cobalt and the Chevrolet HHR in 2007. Also in 2007, an engine featuring direct injection became available in the second-generation Cadillac CTS.

Mazda uses its own version of direct-injection—referred to as Direct Injection Spark Ignition (DISI)—in the Mazdaspeed 6 / Mazda 6 MPS, the CX-7 sport-utility, and the Mazdaspeed 3. Additional models using GDi technology include the Audi TT, A4, A6; second-generation Mini Cooper S; and the Volkswagen GT, Jetta, and Passat (with 2.0L engines).

Volkswagen is the only volume seller of light diesels in the U.S.

Since 2003, Volkswagen (VW) has been the only volume seller of diesel engines; the company offered a 1.9L engine in the Golf, Jetta, and Beetle subcompact vehicles. Sales were in the 15,000 to 30,000 range annually, but the diesel engine option was suspended in 2006 with the end of the Bin 9/10 certification options (see Table 36 for information on light-vehicle emission standards). Mercedes offered one model, the E320, but this was sold in small volumes (~5,000/yr) and also discontinued after 2006. Energy and Environmental Analysis (EEA) reports that Jeep also offered one model in 2006.

According to EEA, VW sells its 2009 diesel at about a $2,000 increment over gasoline models, which, when a $1,300 tax credit is applied, implies a net cost to the consumer of about $700 (see Table 38 for information on diesel tax credits). Mercedes prices its diesels at only $1,500 over the gasoline model. When this incremental price is considered in conjunction with a $900 subsidy for the M class, $1,550 for the R class, and $1,800 for the G series, the consumer sees a very low—even negative—net incremental cost. The diesel engine's performance is comparable to similar engine-size gasoline models.

Chrysler sold the 45-state Bin 8-certified diesel Jeep Grand Cherokee, which is equipped with Mercedes 3L V6 and the Bluetec after-treatment in model years 2007 and 2008, but stopped selling this product after it was spun off from Daimler. Cummins' new 4.2L V6 will be used for Chrysler's light-truck products, starting with the Dodge Ram.

More diesel light vehicles are becoming available. BMW and Audi join VW and Mercedes-Benz in the list of manufacturers with diesel vehicles available in MY 2009 (Table 18).

Table 18. MY 2009 Diesel Vehicles

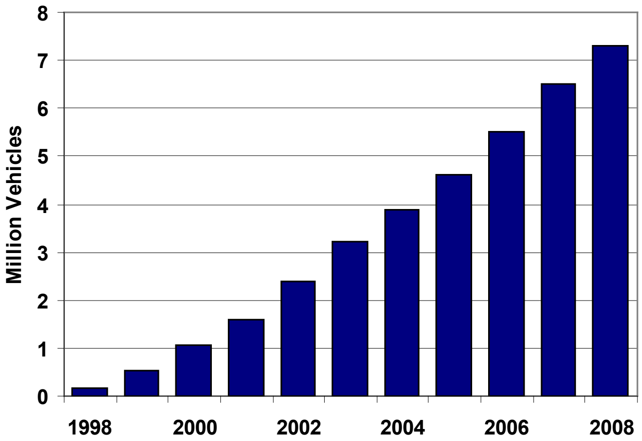
VW Jetta Sedan VW Jetta Sportwagon
Mercedes-Benz E320 Bluetec Mercedes-Benz R320 Bluetec Mercedes-Benz ML320 Bluetec Mercedes-Benz GL320 Bluetec
Audi Q7
BMW 335d Sedan BMW X5 xDrive35d Sports Activity Vehicle

Source: DOE/EPA, Fueleconomy.Gov

Flex-fuel vehicles make their way into the population

There are more than 7 million flex-fuel vehicles (FFVs) in operation. These vehicles can be fueled by gasoline, E85 (a fuel made from 85% ethanol and 15% gasoline), or any combination of the two (Figure 17). Manufacturers first started making flex-fuel vehicles in the late 1990s; however, by 2004, there were only eight different flex-fuel vehicle models on the market (Table 19). In 2008, however, there are 28 different flex-fuel vehicle models available, most of them from GM, Chrysler, and Ford. In summer 2007, the three U.S. OEMs pledged to President Bush that they would make half of their vehicles FFVs by 2012. Although Nissan and Mercedes-Benz are the only foreign manufacturers to produce FFVs in 2008, Toyota and Mitsubishi will also produce flex-fuel pickup trucks in 2009

Figure 17. Number of Flex-fuel Vehicles in Operation.



Source: Source: Alternative Fuels and Advanced Vehicles Data Center

Table 19. Flex-fuel Vehicle Models

Model Year	2004	2008
GMC		11
TOY		0
FMC	5	4
DCC/CHR	3	10
HON		0
NIS		2
OTHER		1
ALL	8	28

Source: Alternative Fuels and Advanced Vehicles Data Center

Toyota sells the most hybrid electric vehicles

The number of HEVs sold has increased 271% from its 2004 level (Table 20 and Figure 18). Although HEV sales have grown during the five-year period, HEVs were not immune to the new car market decline in 2008. In 2008, sales of every model but the Nissan Altima decreased from 2007. The number of models available increased from five in 2004 to 18 in 2008. New HEV models that arrived in 2008 include the Chevy Tahoe and Malibu, GMC Yukon, Cadillac Escalade, and Chrysler Aspen. Despite the increase in make and model availability, domestic manufacturer production is still limited: most HEVs are not produced by the Big 3 (General Motors, Ford, or Chrysler). Of the 312,000 HEVs sold in 2008, only 31,000 (10% of total HEV sales) were manufactured by the Big 3. The Toyota Prius sales have consistently comprised about half of the total sales of HEVs.

Table 20. Hybrid Electric Vehicle Sales

Calendar Year	2004	2005	2006	2007	2008
Honda Insight	583	666	722	0	0
Toyota Prius	53,991	107,897	106,971	181,221	158,574
Honda Civic	25,571	25,864	31,251	32,575	31,297
Ford Escape	2,993	18,797	20,149	21,386	17,173
Honda Accord	1,061	16,826	5,598	3,405	196
Lexus RX400h		20,674	20,161	17,291	15,200
Toyota Highlander		17,989	31,485	22,052	19,441
Mercury Mariner		998	3,174	3,722	2,329
Lexus GS 450h			1,784	1,645	678
Toyota Camry			31,341	54,477	46,272
Nissan Altima				8,388	8,819
Saturn Vue				4,403	2,920
Lexus LS600hL				937	907
Saturn Aura				772	285
Chevy Tahoe					3,745
GMC Yukon					1,610
Chevy Malibu					2,093
Cadillac Escalade					801
Chrysler Aspen					46
Total	84,199	209,711	252,636	352,274	312,386

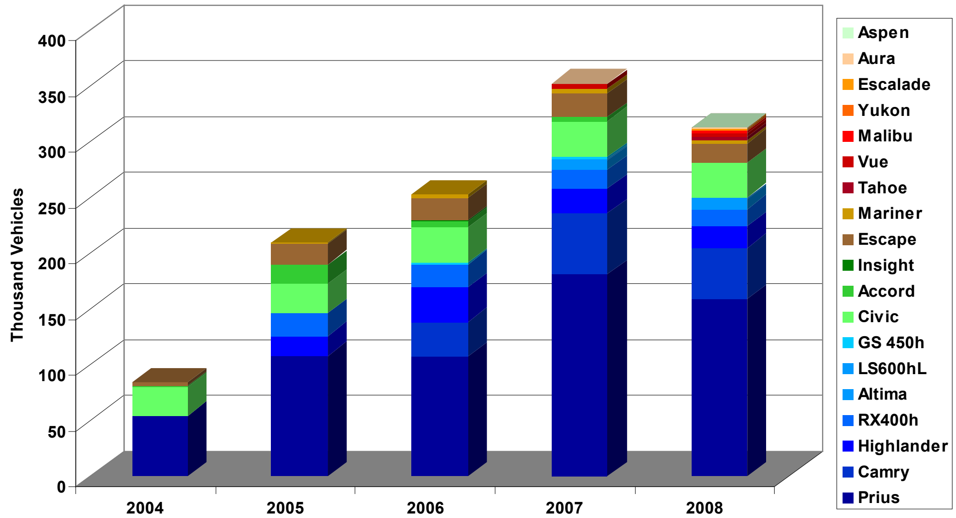
Source: Alternative Fuels and Advanced Vehicles Data Center

HEV incremental price has changed but has not decreased definitively

The average price of a hybrid vehicle has increased during the past five years, largely due to the introduction of a wider array of luxury hybrids (Table 21). But the average incremental price—the additional price of a hybrid over its non-hybrid counterpart—decreased from 2006 to 2008. In general, an HEV incremental price depends on the sophistication level of the hybrid system. This price generally is reflected in an increased price to the consumer of about $5,000 to $8,000 relative to a non-hybrid base model. Generally, incremental price (which declined from 2006 to 2008) will decrease as the technology matures and is less costly to manufacture. The increase in the average incremental price for 2009 is caused by the large increase in the available hybrid models.

Table 22 shows incremental prices for all hybrid models for which a comparison could be made against a non-hybrid. The incremental price for some models appears to increase in some years. This change could be the result of a change in the number of luxury options available, which could increase the total vehicle price and obscure the price change attributable to only the hybrid system.

Figure 18. Hybrid Electric Vehicle Sales



Source: Alternative Fuels and Advanced Vehicles Data Center

Table 21. New Hybrid Vehicle Price

Model Year	2005	2006	2007	2008	2009
Cadillac Escalade	--	--	--	--	80,285
Chevrolet Malibu	--	--	--	--	25,555
Chevrolet Silverado	--	--	--	--	42,663
Chevrolet Tahoe	--	--	--	--	51,858
Chrysler Aspen	--	--	--	--	45,270
Dodge Durango	--	--	--	--	45,040
Ford Escape	28,455	28,525	27,260	29,215	31,685
GMC Sierra	--	--	--	--	43,033
GMC Yukon	--	--	--	--	52,325
Honda Accord	31,140	31,990	32,090	--	--
Honda Civic	20,500	22,900	23,475	23,475	25,250
Honda Insight	20,430	20,430	--	--	--
Lexus GS 450h	--	--	54,900	55,800	56,550
Lexus LS 600h	--	--	--	104,900	106,035
Lexus RX400h	--	45,360	41,880	42,680	--
Mazda Tribute					31,310
Mercury Mariner	28,455	28,525	27,260	29,215	30,965
Nissan Altima	--	--	--	25,480	26,650
Saturn Aura	--	--	--	--	26,325
Saturn Vue	--	--	--	26,330	28,160
Toyota Camry	--	--	26,200	25,200	26,150
Toyota Highlander	--	36,160	34,520	37,325	37,860
Toyota Prius	21,275	21,725	22,623	22,635	--

Note: Figures adjusted for inflation using CPI for year in which model year debuted.

Source: AOL Autos

Table 22. Incremental Price of New Hybrid Vehicles

HEV Incremental Price (2008 $)					
Model Year	**2005**	**2006**	**2007**	**2008**	**2009**
Cadillac Escalade	--	--	--	--	10,930
Chevrolet Malibu	--	--	--	2,378	3,950
Chevrolet Silverado	--	--	--	--	8,965
Chevrolet Tahoe	--	--	--	--	13,490
Chrysler Aspen	--	--	--	--	10,540
Dodge Durango	--	--	--	--	16,910
Ford Escape	--	6,250	6,766	8,626	9,210
GMC Sierra	--	--	--	--	9,335
GMC Yukon	--	--	--	--	13,215
Honda Accord	--	--	--	--	--
Honda Civic	--	8,367	8,319	8,091	8,145
Lexus GS 450h	--	--	--	--	11,550
Lexus LS 600h	--	--	--	--	42,210
Lexus RX400h	--	--	--	--	--
Mazda Tribute	--	--	--	--	9,445
Mercury Mariner	--	--	--	6,273	7,440
Nissan Altima	--	8,648	7,273	6,865	6,750
Saturn Aura	--	--	7,518	7,125	3,670
Saturn VUE	--	--	1,816	3,630	4,880
Toyota Camry	--	--		2,456	7,005
Toyota Highlander	--	--	8,255	6,886	8,995
Average		**7,755**	**6,658**	**5,814**	**10,876**

Note: Figures adjusted for inflation using CPI for year in which model year debuted.

Source: AOL Autos

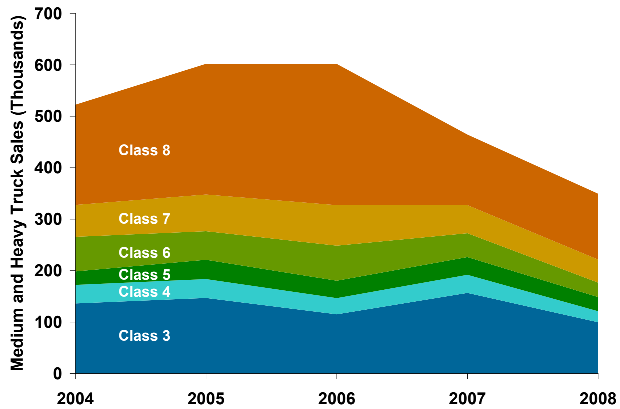
Market Trends: Heavy Vehicles

Heavy- and medium-truck sales have declined significantly

The sales of heavy and medium trucks have gone through two distinct phases during the past five years: moderate growth through 2006, followed by dramatic decline (Figure 19). Although the total-sale composition changed somewhat by class, the total sales of heavy and medium trucks increased slightly or changed little from 2004 through 2006. In 2007, heavy-truck sales had a sharp reduction. By 2008, 33% fewer heavy and medium vehicles were sold than five years earlier (Table 23).

Sales of heavy trucks have been the hardest hit. Beginning in 2007, heavy-truck sales plummeted: Total sales of class 8 heavy trucks in 2007 were less than half that of the previous year. Class 7 heavy trucks experienced a less-drastic, but still sharp, decline. Sales of heavy trucks continued to decline in 2008. Unlike sales of heavy trucks, medium-truck sales continued to increase slightly in 2007 from their 2006 volumes, but declined drastically beginning in 2008. Class 5 trucks appear to be an exception, but 2008 sales are still notably low compared to the prior three years. The sales volume in 2004—the year against which the five-year comparison is made—is unusually low, making the five-year change appear optimistic.

Figure 19. Medium and Heavy Truck Sales



Source: Ward's Motor Vehicle Facts and Figures

Table 23. Medium and Heavy Vehicle Sales

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
Class 3	136,229	146,809	115,140	156,610	99,692	-27%
Class 4	36,203	36,812	31,471	35,293	21,420	-41%
Class 5	26,058	37,359	33,757	34,478	27,558	6%
Class 6	67,252	55,666	68,069	46,158	27,977	-58%
Class 7	61,918	71,305	78,754	54,761	44,943	-27%
Class 8	194,827	253,840	274,480	137,016	127,880	-34%
TOTAL	**522,487**	**601,791**	**601,671**	**464,316**	**349,470**	**-33%**

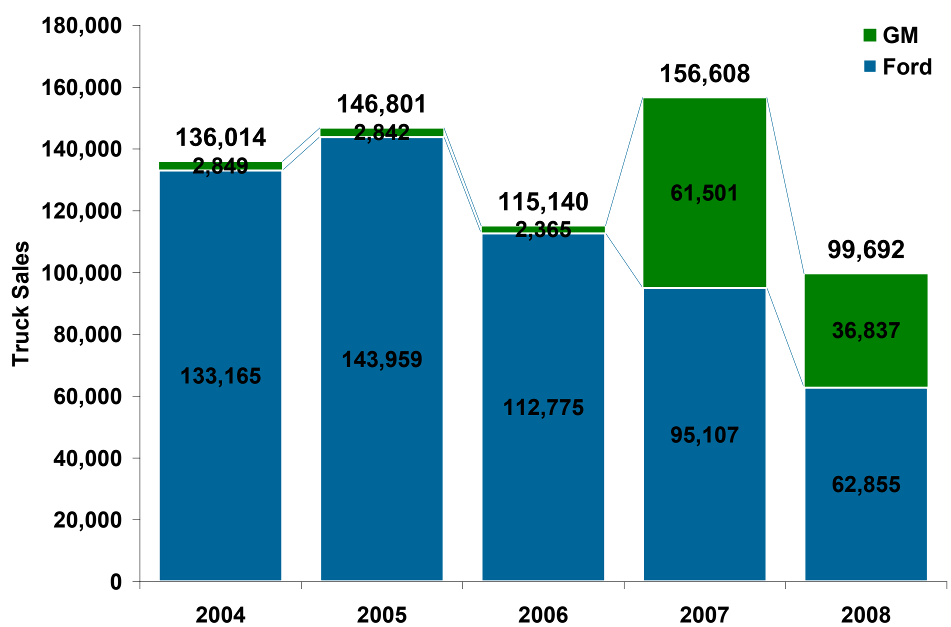
Source: Ward's Motor Vehicle Facts and Figures

GM has significantly increased its class 3 truck market penetration

Class 3 trucks include large pickups often used in ranching and farming, hauling horses, towing motor homes, and recreation. The primary manufacturers of these trucks are Ford and GM. The market share between these two makers shifted considerably during the past five years (Figure 20 and Table 24). GM has increased its medium-truck market share from 2% in 2004 to 37% in 2008. Ford is still the largest in terms of volume, but its share has been reduced from 69% to 57%.

The recent downturn in the economy heavily affected 2008 sales. Strong sales in 2007 decreased nearly 40% in 2008.

Figure 20. Class 3 Truck Sales by Manufacturer



Source: Ward's Motor Vehicle Facts and Figures

Table 24. Class 3 Truck Sales, by Manufacturer

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
Ford	133,165	143,959	112,775	95,107	62,855	-53%
GM	2,849	2,842	2,365	61,501	36,837	1193%
Total	**136014**	**146801**	**115140**	**156608**	**99692**	**-27%**

Source: Ward's Motor Vehicle Facts and Figures

Class 4-7 truck sales have declined steadily since 2007

Class 4-7 trucks are dedicated commercial work trucks, such as parcel-post delivery trucks and large pickups or utility trucks with large bodies for equipment. The major manufacturers of these trucks have not changed significantly during the past five years; however, Hino is relatively new. For these four classes combined, Ford and GM increased their market shares (from 30% to 37% and 20% to 26%, respectively); while, International and Freightliner's market shares declined (from 27% to 18% and 21% to 16%, respectively) (Figure 21 and Table 25).

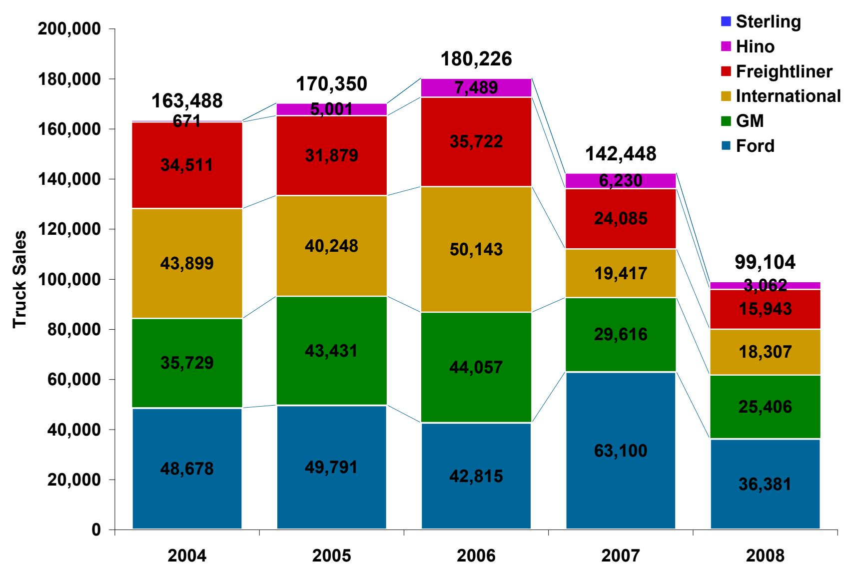
Sales volumes decreased notably in 2007 from their 2006 levels, probably because of new, more stringent diesel emission technologies—and a corresponding price increase and uncertainty—in response to the introduction of more stringent standards. General economic unknowns are probably to blame for the low sales volumes in 2008—strong sales in 2006 decreased by nearly 50% in 2008.

Table 25. Class 4-7 Truck Sales, by Manufacturer

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
Ford	48,678	49,791	42,815	63,100	36,381	-25%
GM	35,729	43,431	44,057	29,616	25,406	-29%
International	43,899	40,248	50,143	19,417	18,307	-58%
Freightliner	34,511	31,879	35,722	24,085	15,943	-54%
Hino	671	5,001	7,489	6,230	3,062	356%
Sterling	0	0	0	0	5	
Total	**163488**	**170350**	**180226**	**142448**	**99104**	**-39%**

Source: Ward's Motor Vehicle Facts and Figures

Figure 21. Class 4-7 Truck Sales by Manufacturer



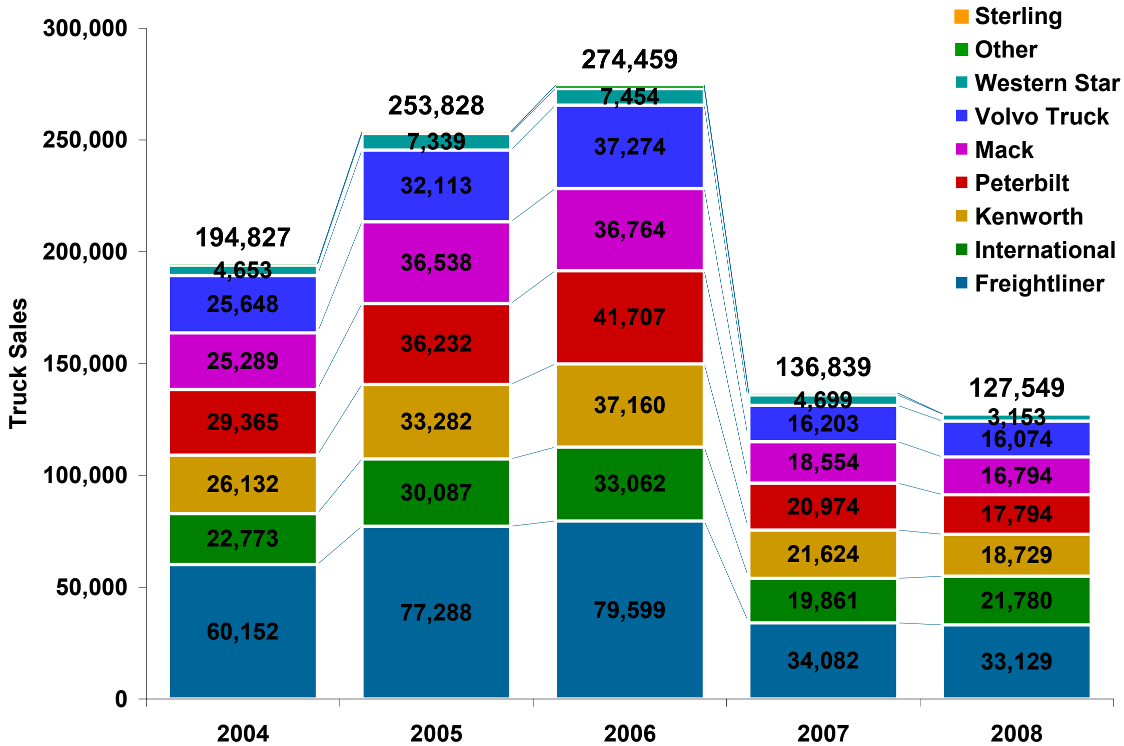
Source: Ward's Motor Vehicle Facts and Figures

Class 8 truck sales dropped 50% in 2007 and have not recovered

Class 8 trucks are the largest trucks (GVW > 33,000 lbs). This class includes single-unit and tractor-trailer equipment typically used for long-haul freight transportation. The major manufacturers of these trucks have been consistent for the past five years. Sales shares have not changed significantly among most manufacturers with one exception: Freightliner's market share declined five percentage points since 2004; International's increased the same amount (Figure 22 and Table 26).

Sales volumes decreased by about 50% in 2007 from their 2006 levels due to the introduction of more advanced diesel emission-control technologies. Nearly 100% of class 8 trucks operate on diesel, so nearly all class 8 trucks incorporated emissions-control devices that raised the vehicle price in 2007. Sales did not recover in 2008 due to the economic recession, which affected all sectors of the economy. The downturn in sales adversely affected most manufacturers similarly: As Table 26 shows, most companies saw declines between 30% and 40% from 2004, with one exception—International's 2008 sales volume is only 4% less than that of 2004.

Figure 22. Class 8 Truck Sales by Manufacturers



Source: Ward's Motor Vehicle Facts and Figures

Table 26. Class Truck Sales, by Manufacturer

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
Freightliner	60,152	77,288	79,599	34,082	33,129	-45%
International	22,773	30,087	33,062	19,861	21,780	-4%
Kenworth	26,132	33,282	37,160	21,624	18,729	-28%
Peterbilt	29,365	36,232	41,707	20,974	17,794	-39%
Mack	25,289	36,538	36,764	18,554	16,794	-34%
Volvo Truck	25,648	32,113	37,274	16,203	16,074	-37%
Western Star	4,653	7,339	7,454	4,699	3,153	-32%
Other	790	623	1,379	842	87	-89%
Sterling	25	326	60	0	9	-64%
Total	**194827**	**253828**	**274459**	**136839**	**127549**	**-35%**

Source: Ward's Motor Vehicle Facts and Figures

Engine sales have decreased significantly

Table 27 shows that the number of engines manufactured for heavy and medium trucks declined from 764,000 thousand in 2004 to 557,000 in 2008.

Most medium- and heavy-truck engines now use exhaust-heat recovery, either through turbocharging or turbocompounding. Turbocharging is the first stage of exhaust heat recovery, whereby exhaust energy is used to boost fresh intake-air charge. Caterpillar, Cummins, Detroit Diesel, Navistar, Mack/Volvo have employed such a process for the past five years. Detroit Diesel began using turbocompounding on approximately 15% of its engines in 2008. Turbocompounding is a second, additional stage of exhaust heat recovery, in which exhaust gas is converted to mechanical energy that goes directly to the crankshaft.

Table 27. Engines Manufactured by Truck Type

Engines Manufactured for Heavy Trucks					
	2004	2005	2006	2007	2008
Cummins	64,630	79,100	91,317	65,228	75,307
Detroit Diesel	48,060	61,074	63,809	29,506	35,174
Caterpillar	74,224	86,806	97,544	33,232	20,099
Mack	25,158	36,221	36,198	18,544	16,794
Mercedes Benz	17,178	24,414	24,584	17,048	10,925
Volvo	12,567	19,298	23,455	9,850	8,822
Navistar	0	0	0	4	927
PACCAR	0	0	0	52	20
Grand Total	241,817	306,913	336,907	173,464	168,068

Engines Manufactured for Medium Trucks					
	2004	2005	2006	2007	2008
Navistar	373,842	382,143	357,470	335,046	264,317
GM	74,328	77,056	83,355	87,749	72,729
Cummins	14,900	15,162	16,400	20,615	27,664
Mercedes Benz	16,075	20,038	27,155	19,330	9,066
Caterpillar	42,535	42,350	45,069	14,693	6,269
PACCAR	0	0	0	9,020	5,694
Hino	671	5,001	7,489	6,230	3,062
Detroit Diesel	0	958	8	0	0
Grand Total	522,351	542,708	536,946	492,683	388,801

Engines Manufactured for Medium and Heavy Trucks					
	2004	2005	2006	2007	2008
Navistar	373,842	382,143	357,470	335,050	265,244
Cummins	79,530	94,262	107,717	85,843	102,971
GM	74,328	77,056	83,355	87,749	72,729
Detroit Diesel	48,060	62,032	63,817	29,506	35,174
Caterpillar	116,759	129,156	142,613	47,925	26,368
Mercedes Benz	33,253	44,452	51,739	36,378	19,991
PACCAR	0	0	0	9,072	5,714
Hino	671	5,001	7,489	6,230	3,062
Grand Total	764,168	849,621	873,853	666,147	556,869

Source: Ward's Motor Vehicle Facts and Figures

Energy intensity is affected by different players during manufacturing and operation

The fuel consumption of medium and heavy trucks is affected by a variety of players during the manufacturing process and operation. As the preceding sections indicated, heavy- and medium-truck vehicle manufacturers are not always the same as the engine manufacturers for those vehicles. Rather, the established process by which medium and heavy trucks are manufactured involves multiple companies, each with their own manufacturing techniques. Table 28 follows the flow of the manufacturing process, from engine design and manufacturing through body and trailer design, to operation. The factors affecting fuel economy and the companies (or vehicle operator) that control the relevant design parameters are listed under each stage.

Table 28. Factors Affecting Fuel Economy

	Engine Manufacturer	Chassis Manufacturer	Body Manufacturer	Trailer Manufacturer	Owner/Operator
Single Unit Trucks	• Engine design	• Drive train design • Vehicle accessories • Cab aerodynamics • Chassis rolling resistance	• Body aerodynamics • Vocational loads		• Vehicle speed • Driver behavior
Combination Trucks	• Engine design	• Drive train design • Vehicle accessories • Cab aerodynamics • Chassis rolling resistance		• Trailer aerodynamics • Trailer rolling resistance	• Truck-trailer pairing • Vehicle speed • Driver behavior
Manufacturers	Navistar Cummins GM Detroit Diesel Caterpillar Mercedez-Benz Mack Volvo PACCAR	Daimler Trucks North America (Freightliner, Wester Star) International Peterbilt Kenworth Ford Volvo Truck Mack GM Hino		Wabash National Great Dane Utility Trailer Hyundai Translead Stoughton Trailers Vanguard National Trailer MANAC Trailmobile Canada Heil Trailer International Strick (many others)	

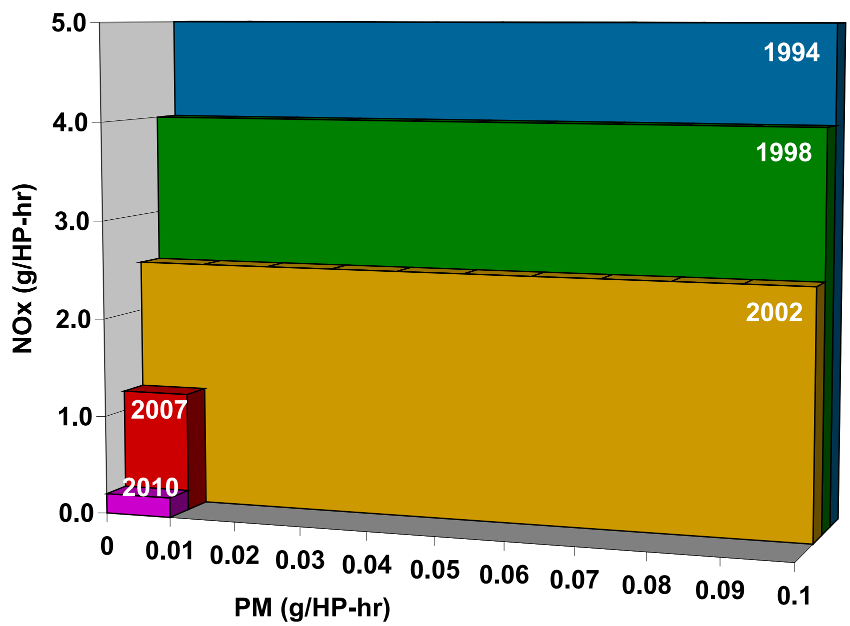
Source: DieselNet

Heavy-truck emissions have been reduced drastically in recent years

Medium- and heavy-truck emissions have declined significantly to meet new standards imposed by the EPA. Manufacturers hold information on nitrogen oxide and particulate matter emissions proprietary and confidential. However, because no manufacturer has failed to meet the requirements during the past five years, it is apparent that all trucks have at least met—and potentially exceeded—these regulations. In 2002, PM was regulated at 0.1 grams per horsepower-hour (g/HP-hr, a unit that describes the grams of the pollutant as a result of the use of the energy equivalent of 1 horsepower for one hour); NOx was regulated at 2.5 g/HP-hr. In 2007, these regulations were made much more stringent: NOx emissions were cut in half (to 1.2 g/HP-hr) and PM emissions were cut by 90% (to 0.01 g/HP-hr) (Figure 23). In response, the emissions by medium and heavy trucks were successfully cut accordingly.

When the 2002 regulations were enacted, engine and truck manufacturers responded by implementing exhaust gas recirculation (several companies) or advanced combustion emissions reduction technology (CAT). The 2007 regulations required the addition of a diesel particulate filter for all companies. Table 29 shows the timeline of these technologies; Table 30 shows their means of operation and efficacies.

Figure 23. Diesel Emission Regulations



Source: EPA

Table 29. Emission Control Technologies

	2008	2007	2006	2005	2004
Caterpillar	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & clean gas induction	advanced combustion emissions reduction technology	advanced combustion emissions reduction technology	advanced combustion emissions reduction technology
Cummins	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation
Detroit Diesel	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation
Navistar	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation
Mack/Volvo	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation

Source: 21st Century Truck Partnership Interviews and DieselNet

Table 30. Emission Control Technologies Explained

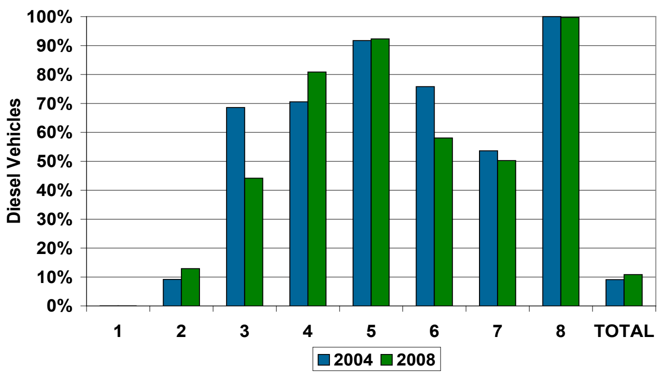
Emission Control Technologies				
Emission Control Device	**Description**	**Expected NOx Efficiency**	**Expected PM Efficiency**	**Status**
Exhaust Gas Recirculation	Recycles the exhaust gas back to the engine intake system	50% - 60%	n/a	In commercial use; still concerns about condensation, packaging and engine integration constraints such as fuel and air management system upgrades.
Advanced Combustion Emissions Reduction Technology	Controls ratio of air and fuel to minimize emissions.			In commercial use.
Diesel Particulate Filter	Collects particles in diesel exhaust	n/a	80% - 90%	Commercially used in light duty; in development for heavy-duty applications.
Clean Gas Induction	Draws clean inert gas from downstream of the particulate filter and inserts into the intake air system.			In commercial use.
SCR	Converts NOx to nitrogen and oxygen in the presence of urea	70% - 90%	20% - 30%	Used in marine and stationary engines; first commercial application in heavy duty engines underway.

Source: 21st Century Truck Partnership Interviews and DieselNet

Medium and heavy trucks are more likely to be diesel vehicles

Most class 3–8 trucks operate on diesel fuel. Traditionally, diesel has been a less expensive fuel, so the vehicle's lifetime cost of ownership was less than that of a comparable gasoline vehicle. Recently, however, diesel prices have increased and been consistently higher than gasoline prices. This change in the balance of fuel price has caused a minor shift away from diesel heavy trucks—fewer heavy-diesel vehicles were sold in 2008 than in 2004 (Figure 24 and Table 31).

Figure 24. Diesel Truck Sales Shares by Class



Source: Ward's Motor Vehicle Facts and Figures

Table 31. Diesel Truck Sales as % Total Truck Sales

Class	2004	2005	2006	2007	2008
1	0.1%	0.1%	0.0%	0.0%	0.0%
2	9.2%	9.5%	10.1%	10.4%	12.9%
3	68.6%	68.6%	68.6%	42.5%	44.1%
4	70.6%	73.8%	75.7%	78.3%	80.9%
5	91.7%	92.2%	91.6%	91.8%	92.3%
6	75.8%	73.4%	75.3%	52.4%	58.0%
7	53.6%	55.8%	58.5%	50.4%	50.3%
8	100.0%	100.0%	100.0%	99.9%	99.7%
TOTAL	9.1%	10.3%	11.6%	9.3%	10.8%

Source: Ward's Motor Vehicle Facts and Figures

This shift has been relatively small, potentially because diesel fuel prices are expected to return to their historical level below gasoline prices. Another explanation for the continued reliance on vehicles powered by diesel engines is the efficiency and performance of diesel engines: They offer higher low-end torque and they can be considered more durable and longer-lasting.

Truck stop electrification reduces idle fuel consumption

The U.S. Department of Transportation (DOT) mandates that truckers rest for 10 hours after driving for 11 hours, during which time, truck operators often park at truck stops for several hours. Often they idle their engines during this rest time to provide their sleeper compartments with air conditioning or heating, or to run electrical appliances such as refrigerators or televisions. Electrification at truck stops allows truckers to "plug in" vehicles to operate necessary systems without idling the engine. Truck stop electrification can reduce diesel emissions and save trucking companies the cost of fuel that would be used while idling. The U.S. Environmental Protection Agency estimates that fuel savings can be as high as $3,240 per parking space. Additionally, truck stop electrification can allow truckers to accommodate local idling regulations and reduce noise.

In "single system electrification," a system owned and operated by a truck stop provides heating, ventilation, and air conditioning (HVAC) systems from a power module contained in a structure above the parking spaces. A hose from the HVAC system is connected to the truck window, and a computer touch screen enables payment. These stand-alone systems are owned and maintained by private companies that charge an hourly fee. To accommodate the HVAC hose, a window template must be installed in the truck. IdleAire Inc. operates a series of 8,000 single-system electrified parking spaces at 133 sites (~3% of the 5,000 parking spaces nationwide) spread over 33 states, half of which are concentrated in six states (Table 30). In a 2008 news release, IdleAire reported serving 49,000 customers with 483,000 hours of service in a week, which the company calculated saved 500,000 gallons of fuel. Despite such success, IdleAire filed for Chapter 11 bankruptcy in 2008 and is currently undergoing restructuring.

"Shore power systems" provide electrical outlets that trucks can plug into. To use these systems, the truck must be equipped with an inverter to convert 120-volt power, an electrical HVAC system, and the hardware to plug into the electrical outlet. Truck stop outlets are owned by private companies that regulate use and fees; onboard equipment is owned and maintained by the trucking company. Industry experts estimate that there are 60,000 class 8 trucks with sleepers that are shore power capable, and 50% of all new class 8 trucks have 120VAC connections for block heaters, oil pan heaters, fuel-water separators, and battery chargers. Shorepower Technologies is the largest provider of these systems; they operate six locations in Oregon and Washington.

More than 130 truck stops nationwide are equipped with idle reduction facilities, half of which are concentrated in six states (Table 32).

Because truck stop electrification infrastructure is still expanding, the codes and standards that ensure uniformity and interoperability for trucks are critical. Recently, the Society of Automotive Engineers Committee, in conjunction with the Electric Power Research Institute (EPRI), established the J2698 standard for the 120V AC electrification of trucks. Since then, the Technology & Maintenance Council Task Force on the establishment of Recommended Practice (RP) 437 has published "Guidelines for Truck Stop Electrification Interface."

Table 32. Electrified Truck Parking Spaces

State	2006	2007	2008
TX	12	19	22
CA	10	13	13
OH	–	10	11
PA	3	9	11
IL	–	7	7
AR	2	6	6
Other	19	66	66
Total	**46**	**130**	**136**

Source: Alternative Fuels and Advanced Vehicles Data Center

Hybrid electric medium trucks have been commercialized

The first diesel electric hybrid was produced in 2007. To date, there have been approximately 1,000 units sold around the world. According to data books, the incremental price for a diesel-electric hybrid medium truck ranged from $45,000 to $60,000 in 2008.

Hybrid electric medium trucks achieve a fuel economy of 35%–40% greater than a non-hybrid medium truck according to a study conducted by Navistar in 2008 (the hybrid achieved 6.8 mpg while the conventional drive truck achieved only 4.8 mpg). Hybrid electric medium trucks offer the on-road fuel economy increase that light vehicles offer, and, in some cases, they also provide a means for performing relevant work—such as power tools on a utility truck—without using the engine.

Heavy-duty hydraulic hybrids are still in the development phase and are not yet commercially available.

Heavy trucks are increasingly comprised of advanced materials

Aluminum and high-strength steel vs. conventional steel; super-wide tires vs. conventional (dual) tires; and extensive use of "plastics" are common throughout American trucking (Table 33). In general, advanced materials penetrate the market as a function of the price: Only those materials that are satisfactory for both buyer and seller succeed.

Table 33. Heavy Truck Materials

Conventional Material	Advanced Material
• conventional steel	• high-strength steel • aluminum • plastics
• conventional dual tires	• super-wide tires

Source: 21st Century Truck Partnership Interviews

American heavy-truck hoods are made from lightweight and cost-effective plastic. More advanced materials have been less successful in penetrating the market. For example, long carbon fiber (LCF) hoods are not widely used due to the overwhelming costs to compete with widely used sheet molded compound. LCF and similar truck cab and hood "plastic" materials were proven cost-prohibitive by DOE. Interestingly, one of the LCF cost factors presented during that study was the prices paid for huge wind turbine blades, comprised of LCF, that convert wind power into electricity. At present, LCF was and remains beyond the bounds of private industry to justify.

Energy performance was relatively steady despite improvements in emissions

The average fuel economy for medium- and heavy-duty trucks decreased slightly from 2003 to 2007 due to significant increases in the number of on-board technologies required to satisfy new emissions regulations. However, these fuel economy figures are only rough estimates. Medium- and heavy-truck companies consider fuel economy data confidential and proprietary, so the average fuel economies presented here are derived from related data in the Federal Highway Administration's *Highway Statistics*. More accurate truck fuel economy data were estimated in the past as part of the Vehicle Inventory and Use Survey (VIUS), which was conducted every five years by the Bureau of the Census—the survey was discontinued in 2002.

Fuel economies for combination units (separate tractor and trailer) are less than those of single-units (tractor and trailer on a single chassis) because combination units tend to be box-like trailers, which are designed to maximize freight capacity over aerodynamics (Table 34).

Table 34. Medium and Heavy Truck Fuel Economy (mpg)

Calendar Year	2003	2004	2005	2006	2007	5-yr Δ
Single-Unit	8.8	8.8	8.3	8.2	8.2	-7%
Combination	5.9	5.9	5.2	5.1	5.1	-14%
Single-Unit & Combination	6.7	6.7	6.0	5.9	5.9	-12%

Source: FHWA, Highway Statistics

Given the energy requirements of new emission-control technologies, the reduction in fuel economy observed during the past five years was significantly less than was expected. Vehicle manufacturers and Tier 1 suppliers are working in conjunction with DOE to conduct research and development of new engine technologies and other means for energy efficiency gains. This R&D will help minimize the negative impact of implementing emission-control devices on fuel economy.

Fuel consumption keeps heavy truck owners mindful of fuel efficiency

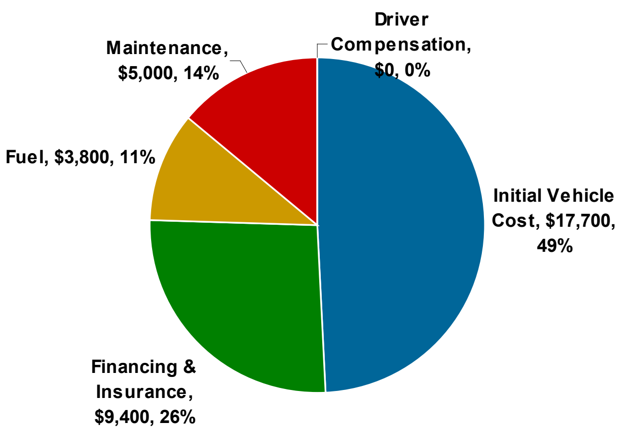
Heavy trucks travel farther and carry heavier loads than light trucks and cars—therefore, they consume significantly more fuel during the lifetime of the vehicle. The most important cost consideration for a prospective light-truck owner is, by far, the initial vehicle cost. But, in the case of heavy trucks, the initial vehicle cost is about as important as the fuel efficiency, because the lifetime fuel cost is expected to be about equal to the initial vehicle cost, on average (Figure 25). This calculus suggests that prospective owners of heavy trucks are more likely willing to spend more at the time of purchase to save on fuel over the lifetime of the vehicle than prospective owners of light trucks.

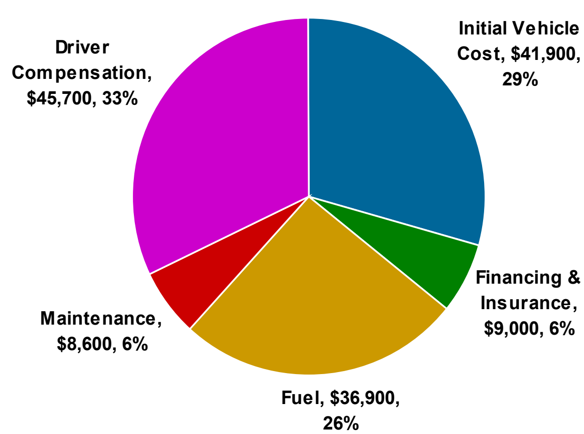
Measuring medium and heavy truck energy intensity requires a freight-based metric

In a comparison of three "average" vehicles' fuel economies, a half-ton pickup can achieve 22 mpg, a medium truck achieves only 6.5 mpg, and a tractor hauling a triple trailer—a heavy truck—achieves only 3.5 mpg. A freight-based metric more appropriately reflects the energy intensity of the medium and heavy trucks. The medium truck, with a potential cargo volume of 4,000 cubic feet, could achieve a volume-based energy intensity (ft^3-mi/gal) of eight times that of the light truck; and the heavy truck, with a cargo volume of 11,000 cubic ft, could achieve 24 times that of the light truck. Similarly, the medium truck, with a gross vehicle weight of 30 tons, could achieve a volume-based energy intensity (ft^3-mi/gal) of eight times that of the light truck; and the heavy truck, with a cargo volume of 11,000 cubic ft, could achieve 12 times that of the light truck (Figure 26).

The National Academy of Sciences is reviewing the appropriate metric to use for regulating truck fuel economy. The metric could be a fuel economy metric, like those shown in Figure 26; or a fuel consumption metric, such as gallons per mile, gallons per ton-mile, and gallons per ft^3-mile. Some experts prefer fuel consumption metrics to fuel economy metrics because they express fuel consumption linearly—fuel economy metrics do not. For example, a 5-mpg increase in fuel economy from 10 mpg to 15 mpg saves more fuel than a 5-mpg increase from 15 mpg to 20 mpg.

Figure 25. Lifetime Vehicle Costs for a Light Truck (left) and Heavy Truck (right)





Source: ORNL, Automotive Systems Cost Model

Figure 26. Truck Statistics by Class

Source: 21st Century Truck Partnership Interviews

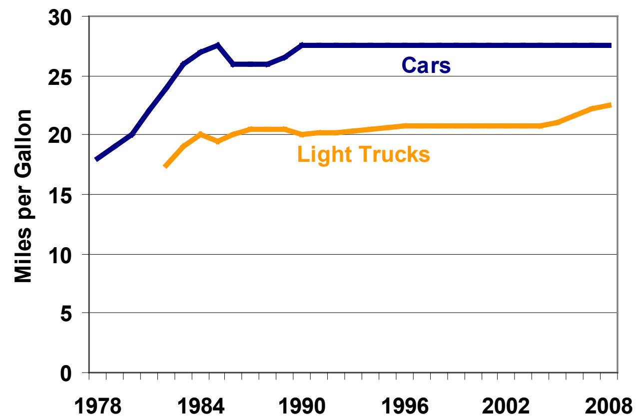
Policies Drive the Markets

Corporate average fuel economy rules require more fuel-efficient vehicles

Corporate average fuel economy (CAFE) rules—the sales-weighted harmonic mean fuel economy of a manufacturer's fleet of current model year cars or light trucks with a GVWR of 8,500 pounds or less—has increased slightly during the past five years. The requirement for cars has been constant at 27.5 mpg during this period, while the requirement for light trucks has increased from 20.7 mpg in 2003 to 22.5 in 2008 (an increase of 8.7%) (Figure 27). For MY 2008, manufacturers have an additional choice of CAFE standards. Light trucks can be held to a reformed standard of 22.7 mpg, which accounts for the size of the vehicle. The calculation uses the vehicle footprint (the distance between the wheels multiplied by the distance between the axles), and each manufacturer can choose to use this reformed standard or the unreformed standard for MY 2008.

The actual fuel economy improvement for cars was 1.9 mpg (an increase of 6.4%), while the actual fuel economy increase for light trucks was also 1.8 mpg (an increase of 8.3%), as previously discussed in Figure 13.

Figure 27. CAFE Standards for Cars and Light Trucks



Source: NHTSA, Summary of Fuel Economy Performance

The Alternative Motor Fuels Act eases CAFE requirements for flex-fuel fleets

The Alternative Motor Fuels Act (AMFA) of 1988 enabled OEMs to increase their calculated CAFE by producing flex-fuel vehicles. The act, extended by the Automotive Fuel Economy Manufacturing Incentives for Alternative Fueled Vehicles Rule of 2004, encourages the production of motor vehicles capable of operating on alternative fuels. It gives a credit of up to 1.2 mpg toward an automobile manufacturer's CAFE, which helps it avoid penalties of the CAFE standards.

Ford and General Motors have taken nearly full advantage of the credit for the past five years: Their credits for light truck CAFE have been at or near the 1.2 mpg limit allowed by law (Table 35). Credits for cars have historically tended to be less for all manufacturers—until recently, when General Motors received the maximum credit.

Table 35. AMFA Flex Fuel CAFE Credits

	2003	2004	2005	2006	2007
Light Trucks					
DCC	1.0	0.0	0.1	0.1	0.1
FMC	1.4	1.5	1.1	0.8	1.0
GMC	1.4	1.2	1.0	1.1	1.1
NIS	0.0	0.0	0.8	0.9	0.9
Domestic Cars					
DCC	0.6	0.6	0.3	0.2	0.1
FMC	0.9	0.6	1.0	1.0	0.8
GMC	0.0	0.0	0.0	1.6	1.4
Import Cars					
DCC	0.3	0.5	0.6	0.0	0.0

Note: The maximum credit is 1.2 mpg; where the calculated credit exceeds the maximum credit, the maximum credit applies.

Source: NHTSA 2003-2006 summary and 2007 annual reports

Light-vehicle emissions standards require clean diesels

Light-vehicle diesel engines and gasoline engines must meet the same emissions regulations. The EPA allows certification at eight alternative levels (or "bins"), as long as a manufacturer's sales-weighted average is lower than or equal to Bin 5 levels. Table 36 shows the eight alternative bins, as well as the two that were used prior to 2006. Until 2006, EPA had allowed certification to Bin 9 and Bin 10, which were specially designed to allow diesels into the marketplace, because they allowed PM emission levels of 0.08/0.06 g/mi, respectively; and NOx emission levels of 0.60/0.30, respectively. These bins were phased out at the end of 2006, and all other bins required PM emission standards of 0.02 g/mi or lower. These essentially mandate the use of PM traps and low-sulfur diesel fuel.

California has more restrictive emission standards offering a choice of levels approximately equal to bins 1, 2 and 5 of the federal levels. Even stricter standards may be required for 2015.

Suppliers of emission-control equipment have increased their sales to U.S. OEMs significantly in the past five years (Table 37). For example, Faurecia, the 2007 top-ranked emission supplier, more than doubled its 2003 sales figure in 2007. For most suppliers, the portion of sales comprised by U.S. OEMs has increased since 2003, implying that the U.S. market for emission-control systems is growing.

Table 36. Diesel Emission Standards

Emission Standards (g/mi)				
BIN	NOx	NMOG	CO	PM
10	0.60	0.156	4.2	0.08
9	0.30	0.090	4.2	0.06
8	0.20	0.125	4.2	0.02
7	0.15	0.090	4.2	0.02
6	0.10	0.090	4.2	0.01
5	0.07	0.090	4.2	0.01
4	0.04	0.070	2.1	0.01
3	0.03	0.055	2.1	0.01
2	0.02	0.010	2.1	0.01
1	0.00	0.000	0.0	0.00

Source: EEA[1]

[1] References to EEA refer to a 2008 Light-Duty Diesel Report by Energy and Environmental Analysis (EEA), an ICF International Company, funded by DOE.

Ultralow sulfur diesel (ULSD) requirements sparked the re-emergence of light diesel vehicles

The ultralow sulfur diesel (ULSD) standard has increased the availability of diesel-fueled cars in the United States. Without ULSD fuel, new diesel vehicles would not be able to meet the strict EPA emission standards. Sulfur levels in ULSD are comparable to European grades, so European engines no longer need to be redesigned to cope with higher sulfur content and may now use advanced emissions-control systems that would otherwise be damaged by sulfur.

The EPA proposed ULSD fuel as a new standard for the sulfur content in on-road diesel fuel sold in the United States, which has been in effect since October 15, 2006. The EPA mandated the use of ULSD fuel in model year 2007 as well as the newer highway diesel fuel engines equipped with advanced emission-control systems that require that fuel. The allowable sulfur content for ULSD (15 ppm) is much lower than the previous U.S. on-highway standard for low-sulfur diesel (LSD, 500 ppm), which allows use of advanced emission-control systems that would otherwise be poisoned by sulfur.

California has required ULSD since September 1, 2006, and rural Alaska will transition all diesel fuel to ULSD in 2010. By December 1, 2010, all U.S. highway diesel fuel will be ULSD; currently, more than 97%of the stations in the United States are dispensing ULSD.

Table 37. Leading Suppliers in Emissions Control

Leading Suppliers in Emissions Control					
2003			2007		
Company	Total U.S. Sales (Mil$)	US % of Global Sales	Company	Total U.S. Sales (Mil$)	US % of Global Sales
Tenneco Automotive Inc.	1,418.5	(50 %)	Faurecia	2,610.0	(15%)
CalsonicKansei Corp.	1,413.4	(26 %)	Tenneco Inc.	2,336.8	(46%)
Faurecia	1,270.0	(10 %)	CalsonicKansei Corp.	1,785.3	(25%)
Benteler Automobiltechnik GmbH	714.0	(21 %)	Benteler Automobiltechnik GmbH	1,773.4	(27%)
Magneti Marelli S.	202.0	(7 %)	Eaton Corp.	1,120.0	(70%)
J. Eberspaecher GmbH & Co.	52.0	(4 %)	J. Eberspaecher GmbH & Co. KG	425.6	(16%)
			Magneti Marelli Holding S.	249.8	(5%)

Source: "Top 100 Global Suppliers 2007" and "Top 100 Global Suppliers 2003", both by Automotive News. Note: figures include both light and heavy vehicles

High fuel economy diesel vehicles are subsidized

The Federal Alternative Fuel Vehicle Tax Credit provision of the Energy Policy Act of 2005 (EPAct 2005) includes a tax credit for lean-burn diesel vehicles. The credit, sometimes referred to as the Clean Diesel Tax Credit, became effective January 1, 2006. Light-diesel vehicles receive a subsidy in the form of a tax credit proportional to the fuel economy increase over a comparable MY 2002 vehicle. The tax credit can be as large as $2,400 for a vehicle whose fuel economy is at least 2.5 times higher than the reference 2002 vehicle fuel economy.

Diesel vehicles up to 6,000 pounds gross vehicle weight rating (GVWR) that meet EPA Tier II Bin 5 emissions requirements will be eligible for the credit. Diesel vehicles of 6,001 to 8,500 lGVWR must meet Tier II Bin 8 requirements. No 2006, 2007, or 2008 diesel vehicles met the emissions requirements for credit; however, eight vehicles in MY 2009 are eligible (Table 38).

Diesels enjoy economies of scale in Europe

According to EEA, high diesel sales enable economies of scale, because every ten-fold increase in production cuts the cost by approximately 30% to 35%. Typical production levels for U.S. manufacturers planning to enter the diesel market are likely to be at 100,000

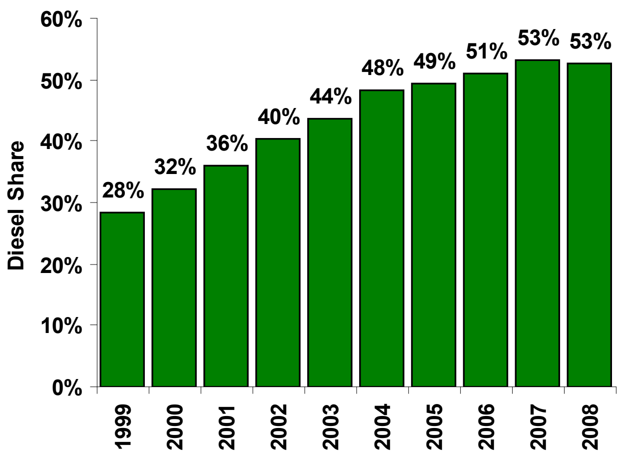
Table 38. Federal Diesel Vehicle Credits

Vehicle Make & Model	Full Credit	Phase Out		No Credit
		50%	25%	
Audi	Jan. 1, 2006	TBD	TBD	TBD
2009 Audi Q7 3.0L TDI	$1,150	--	--	--
BMW	Jan. 1, 2006	TBD	TBD	TBD
2009 BMW 335d Sedan	$900	--	--	--
2009 BMW X5 xDrive35d Sports Activity Vehicle	$1,800	--	--	--
Mercedes-Benz	Jan. 1, 2006	TBD	TBD	TBD
2009 Mercedes-Benz GL 320 BlueTEC	$1,800	--	--	--
2009 Mercedes-Benz ML 320 BlueTEC	$900	--	--	--
2009 Mercedes-Benz R 320 BlueTEC	$1,550	--	--	--
Volkswagen	Jan. 1, 2006	TBD	TBD	TBD
2009 Volkswagen Jetta TDI Sedan	$1,300	--	--	--
2009 Volkswagen Jetta TDI SportWagon	$1,300	--	--	--

Source: DOE/EPA, Fueleconomy.Gov

vehicles per year per engine model while European producers typically produce at four to eight times that level. Since 2006, more than 50% of new cars sold in Europe have been diesels (Figure 28).

Figure 28. Diesel Share of New Car Sales in Europe.



Source: AID Newsletters

Special tax credits incentivize the purchase of HEVs

Hybrids bought or placed into service after December 31, 2005, may be eligible for a federal income tax credit of up to $3,400 (Table 39). The Internal Revenue Service must first acknowledge the manufacturers' certifications of qualified vehicles and credit amounts, which are based on improved fuel economy and lifetime fuel-savings potential.

Credit amounts begin to phase out for a given manufacturer once it has sold more than 60,000 eligible vehicles. The subsidy decreases by half at the second calendar quarter after the manufacturers' sales reach that mark,. The subsidy is halved again at the beginning of the fourth quarter after the sales reach the 60,000-vehicle mark. The credit ends at the beginning of the sixth calendar quarter. In addition to the phase-out rules, any vehicle bought after December 31, 2010, will not be eligible for the credit.

Six states also have tax credits, and two more states and the District of Columbia have tax exemptions that give consumers a financial incentive to purchase HEVs (Table 40). Other states give incentives such as allowing HEVs in high-occupancy vehicle lanes, designating special parking spaces, exempting HEVs from emission inspections, and discounting insurance or registration fees. Several states also give tax credits, tax exemptions, or grants to businesses that manufacture or develop hybrid parts and technology.

Federal subsidies discount alternative fuels

An excise tax credit is available for certain alternative fuels that are sold for use or used as a fuel to operate a motor vehicle. The credit is $0.50 per gasoline gallon equivalent of compressed natural gas (CNG) and $0.50 per liquid gallon of liquefied petroleum gas (LPG), liquefied natural gas (LNG), and liquefied hydrogen. The entity eligible for the credit is the one liable for reporting and paying the federal excise tax on the fuel. Eligible entities must be registered with the Internal Revenue Service.

Biodiesel users that deliver pure, unblended biodiesel (B100) into the tank of a vehicle or use B100 as an on-road fuel in their trade or business may be eligible for a nonrefundable income tax credit in the amount of $1 per gallon of agri-biodiesel, such as biodiesel made from soybean oil. If the biodiesel was sold at retail, only the person that sold the fuel and placed it into the tank of the vehicle is eligible for the tax credit. The volumetric excise tax does not apply to the sale or use of B100.

For ethanol, blenders registered with the Internal Revenue Service are eligible for the Volumetric Ethanol Excise Tax Credit (VEETC), an excise tax credit in the amount of $0.45 per gallon of pure ethanol (minimum 190 proof) blended with gasoline. Only entities that have produced and sold or used the qualified ethanol mixture as a fuel in their trade or business are eligible for the credit. This tax credit expires on December 31, 2010. There is also a blender credit for biodiesel, separate from the user credit. An entity that blends B100 with diesel to produce a mixture containing at least 0.1% diesel fuel may be eligible for a nonrefundable income tax credit in the amount of $1 per gallon of agri-biodiesel (e.g., biodiesel made from soybean oil), or pure biodiesel made from other sources (e.g., waste grease). Only blenders that have produced, sold, or used the qualified biodiesel mixture as a fuel in their trade or business are eligible for the tax credit.

Biofuels are the only advanced fuels not derived from a fossil fuel. However, unlike the petroleum industry, the biofuels industry is not dominated by just a few players. There are many companies at a similar technical level, and DOE has worked with a number of them, in addition to the biofuels industry associations (the National Biodiesel Board and Renewable Fuels Association).

One of the most noteworthy advancements in the alternative fuels market was the production of high-quality Fischer-Tropsch-like fuel from animal fat by Conoco-Phillips in partnership with Tyson

Table 39. Federal HEV Credits

Vehicle Make & Model		Full Credit	Phase Out		No Credit
			25%	50%	
Ford Motor Company		**Jan. 1, 2006**	**Apr. 1 – Sep. 30, 2009**	**Oct. 1, 2009 – Mar. 31, 2010**	**Apr. 1, 2010**
2009 Ford Escape Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$1,950	$975	$487.50	$0
2008 Ford Escape Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,200	$1,100	$550	$0
2005-07 Ford Escape Hybrid	2WD	$2,600	$1,300	$650	$0
	4WD	$1,950	$975	$487.50	$0
2010 Ford Fusion Hybrid		$3,400	$1,700	$850	$0
2009 Mazda Tribute Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$1,950	$975	$487.50	$0
2008 Mazda Tribute Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,200	$1,100	$550	$0
2009 Mercury Mariner Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$1,950	$975	$487.50	$0
2008 Mercury Mariner Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,200	$1,100	$550	$0
2006-07 Mercury Mariner Hybrid	4WD	$1,950	$975	$487.50	$0
2010 Mercury MilanHybrid		$3,400	$1,700	$850	$0
General Motors		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2009 Cadillac Escalade Hybrid	2WD	$2,200	--	--	--
	AWD	$1,800	--	--	--
2008 Chevrolet Malibu Hybrid		$1,300	--	--	--
2009 Chevrolet Malibu Hybrid		$1,550	--	--	--
2006-07 Chevrolet Silverado Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
2009 Chevrolet Silverado Hybrid (2WD & 4WD)		$2,200	--	--	--
2008-09 Chevrolet Tahoe Hybrid (2WD & 4WD)		$2,200	--	--	--
2006-07 GMC Sierra Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
2009 GMC Sierra Hybrid (2WD & 4WD)		$2,200	--	--	--
2008-09 GMC Yukon 1500 Hybrid (2WD & 4WD)		$2,200	--	--	--
2007-08 Saturn Aura Hybrid		$1,300	--	--	--
2009 Saturn Aura Hybrid		$1,550	--	--	--
2007 Saturn Vue Hybrid		$650	--	--	--
2008-09 Saturn Vue Hybrid		$1,550	--	--	--
Honda		**Jan. 1, 2006 – Dec. 31, 2007**	**Jan. 1 – Jun. 30, 2008**	**July 1 – Dec. 31, 2008**	**Jan. 1, 2009**
2005-06 Insight CVT		$1,450	$725	$362.50	$0
2005 Accord Hybrid AT & Navi AT		$650	$325	$162.50	$0
2006 Accord Hybrid AT & Navi AT (w/o updated control calibration)		$650	$325	$162.50	$0
2006-07 Accord Hybrid AT & Navi AT (w/ updated control calibration)		$1,300	$650	$325	$0
2005 Civic Hybrid (SULEV) MT & CVT		$1,700	$850	$425	$0
2006-09 Civic Hybrid CVT		$2,100	$1,050	$525	$0

Continued on next page.

Table 39. Federal HEV Credits (continued)

Nissan	Jan. 1, 2006	TBD	TBD	TBD
2007-09 Altima Hybrid	$2,350	--	--	--

Toyota	Jan. 1 – Sep. 30, 2006	Oct. 1, 2006 – Mar. 31, 2007	Apr. 1 – Sep. 30, 2007	Oct. 1, 2007
2005-08 Prius	$3,150	$1,575	$787.50	$0
2006-08 Highlander Hybrid (2WD & 4WD)	$2,600	$1,300	$650	$0
2006-08 Lexus RX400h (2WD & 4WD)	$2,200	$1,100	$550	$0
2007-08 Camry Hybrid	$2,600	$1,300	$650	$0
2007 Lexus GS 450h	$1,550	$775	$387.50	$0
2008 Lexus LS 600h	--	--	$450	$0

Source: DOE/EPA, Fueleconomy.Gov

Table 40. State HEV Tax Credits and Exemptions

HEV Tax Credit	
Colorado	Income tax credits vary by HEV model, ranging from $1,947 to $13,779 in MY2008.
Louisiana	Income tax credit of 20% of incremental purchase cost.
Maryland	Tax credit not to exceed $1,000 against the excise tax for HEV purchase
Oklahoma	Tax credit of 50% of the incremental purchase cost
Oregon	Residential tax credit of up to $1,500; Business tax credit of up to 35% of incremental purchase cost.
South Carolina	Income tax credit of 20% of the Federal tax credit
HEV Tax Exemption	
DC	Vehicle excise tax exemption
New Mexico	Vehicle excise tax exemption
Washington	State sales and use tax exemption

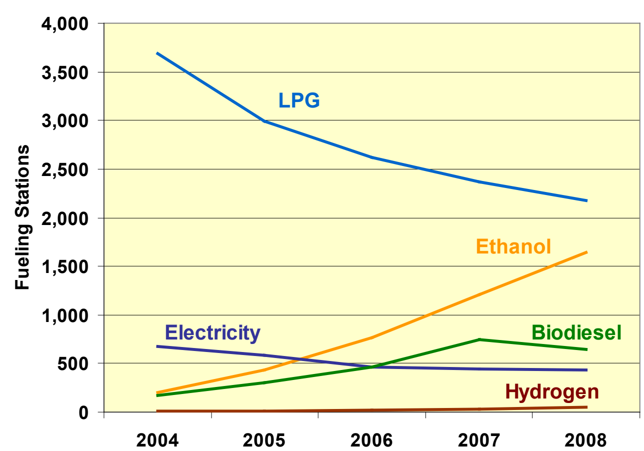
Source: Alternative Fuels and Advanced Vehicles Data Center

Foods. This product demonstrated that renewable feedstocks could be used in an existing refinery process (with little capital improvement) to generate high-value fuels. In the future, these fuels could be used to offset negative aspects of fuels derived from heavy crude. However, the economic viability of this process is tied to tax credits for renewable fuels, and recent decisions have not favored this efficient means of using existing infrastructure.

Consumers still face limited alternative fuel availability

From 2004 to 2008, the total number of alternative fuel stations changed little—from 5,720 in 2004 to 5,756 in 2008—but the type of fuel offered changed (Figure 29 and Table 41). In particular, the number of stations offering E85 and biodiesel has increased significantly. There were 1,644 E85 stations in 2008; only five years earlier, there were only 200. Similarly, the number of biodiesel stations had grown to 645 in 2008 from only 176 in 2004. Despite significant growth in the number of stations, biofuel availability pales in comparison to conventional gasoline. According to the *U.S. National Petroleum News*, as of 2007, there were 164,292 retail gasoline outlets in the United States, thus, about 1% of stations offering gasoline also offer E85.

Figure 29. Number of Alternative Fuel Stations



Source: Alternative Fuels and Advanced Vehicles Data Center

Table 41. Number of Alternative Fuel Stations by State and Share of U.S. Total within State

	2004		2005		2006		2007		2008	
E85 Stations										
Minnesota	87	(46%)	154	(35%)	296	(27%)	334	(24%)	357	(21%)
Illinois	13	(7%)	64	(15%)	142	(13%)	175	(12%)	181	(10%)
Indiana	0	(0%)	4	(1%)	73	(7%)	98	(7%)	114	(7%)
Wisconsin	10	(5%)	12	(3%)	59	(5%)	93	(7%)	114	(7%)
Iowa	11	(6%)	25	(6%)	65	(6%)	88	(6%)	107	(6%)
Other	67	(36%)	177	(41%)	450	(41%)	625	(44%)	857	(50%)
Total	188		436		1,085		1,413		1,730	
Biodiesel Stations										
South Carolina	2	(1%)	22	(7%)	64	(10%)	72	(11%)	75	(11%)
North Carolina	22	(15%)	32	(11%)	48	(7%)	69	(11%)	69	(10%)
Texas	1	(1%)	6	(2%)	41	(6%)	55	(8%)	54	(8%)
California	17	(12%)	17	(6%)	32	(5%)	35	(5%)	47	(7%)
Washington	14	(10%)	16	(5%)	26	(4%)	34	(5%)	42	(6%)
Other	86	(61%)	211	(69%)	444	(68%)	386	(59%)	400	(58%)
Total	142		304		655		651		687	
Electricity Charging Stations										
California	514	(62%)	490	(83%)	379	(85%)	370	(85%)	404	(87%)
Oregon	4	(0%)	0	(0%)	9	(2%)	8	(2%)	14	(3%)
Massachusetts	41	(5%)	29	(5%)	18	(4%)	18	(4%)	12	(3%)
New Hampshire	12	(1%)	7	(1%)	10	(2%)	9	(2%)	8	(2%)
Arizona	54	(7%)	18	(3%)	11	(2%)	12	(3%)	5	(1%)
Other	205	(25%)	44	(7%)	18	(4%)	18	(4%)	23	(5%)
Total	830		588		445		435		466	
Hydrogen Stations										
California	5	(71%)	9	(64%)	23	(72%)	23	(70%)	28	(48%)
Michigan	0	(0%)	2	(14%)	3	(9%)	0	(0%)	7	(12%)
New York	0	(0%)	0	(0%)	0	(0%)	0	(0%)	4	(7%)
Nevada	1	(14%)	1	(7%)	1	(3%)	1	(3%)	2	(3%)
Pennsylvania	0	(0%)	0	(0%)	1	(3%)	1	(3%)	2	(3%)
Other	1	(14%)	2	(14%)	4	(13%)	8	(24%)	15	(26%)
Total	7		14		32		33		58	

Source: Alternative Fuels and Advanced Vehicles Data Center

In contrast, the numbers of LPG stations have decreased significantly: There were 2,175 in 2008, which is about half the number of stations offering the fuel at its peak in 1998 (5,318). Similarly, the number of electric-charging stations in 2008 are down from 2004, but the rate of facility closure has slowed in recent years.

Alternative fuel stations tend to be regionally clustered. E85 stations are concentrated in the Midwest, where more than one-third of the nation's E85 stations have been located since 2003. However, in recent years, new E85 developments outside the Midwest have reduced the strong regional bias. Biodiesel stations are rather heavily concentrated in the Carolinas, which consistently have about one-fifth of the nation's total number of biodiesel stations. The apparent decline in the number of stations from 2007 to 2008 is the result of a change in collection methodology: The station counts from 2004–2007 include stations offering low-level blends of biodiesel (usually B5); whereas, the 2008 number only includes stations selling B20 and higher blends. Both electric and hydrogen stations are heavily concentrated in California.

Despite the fact that alternative fuels are not as available as conventional fuels, the amount of energy consumed through alternative fuels increased from 2002 to 2006 (Table 42). LNG and E85 saw the greatest increases in consumption, while LPG and electricity saw decreases. In both 2005 and 2006, the total consumption of alternative fuels decreased relative to consumption in the year before, primarily due to a significant decrease in the amount of LPG consumed. Despite this decrease in total alternative-fuel consumption, the consumption of ethanol, electricity, and hydrogen combined has increased steadily, climbing to nearly twice its 2002 level by 2006. These fuels comprise a greater portion of alternative fuels consumed each year.

SmartWay encourages efficient heavy truck purchases

The Environmental Protection Agency certifies tractors and trailers that incorporate long-haul truck components with significantly lower emissions and fuel consumption. When manufacturers equip long-haul tractors and trailers with these specifications, they are designated and labeled as "U.S. EPA Certified SmartWay." The U.S. EPA Certified SmartWay label may be used at point-of-sale and applied to the interior of the tractors and trailers by the equipment manufacturers.

An EPA-certified SmartWay tractor is characterized by a model year 2007 or later engine; integrated sleeper-cab high roof fairing; tractor-mounted side fairing gap reducers; tractor fuel-tank side fairings; aerodynamic bumper and mirrors; options for reducing periods of extended engine idling (auxiliary power units, generator sets, direct-fired heaters, battery-powered HVAC system, and automatic engine start/stop system); and options for low-rolling resistance tires (single wide or dual) mounted on aluminum wheels. An EPA-certified SmartWay trailer is characterized by side skirts; weight-saving technologies; gap reducer on the front or trailer tails (either extenders or boat tails); and options for low-rolling resistance tires (single wide or dual) mounted on aluminum wheels.

Manufacturers who produce tractors, trailers, or tires that have earned SmartWay certification are shown in Table 43.

Table 42. Alternative Fuel Consumption

Year	2002	2003	2004	2005	2006	5-yr %Δ
Liquefied Petroleum Gases (LPG)	223,600	224,697	211,883	188,171	173,130	-22.6%
Compressed Natural Gas (CNG)	123,081	133,222	158,903	166,878	172,011	39.8%
Liquefied Natural Gas (LNG)	9,593	13,503	20,888	22,409	23,474	144.7%
85% Ethanol (E85)	18,250	26,376	31,581	38,074	44,041	141.3%
Electricity	7,274	5,141	5,269	5,219	5,104	-29.8%
Hydrogen	0	2	8	25	41	
Total Renewables	25,524	31,519	36,858	43,318	49,186	92.7%
Renewables % of Total	6.7%	7.8%	8.6%	10.3%	11.8%	
Total	382,152	402,941	428,532	420,776	417,801	9.3%

Source: DOE Clean Cities Program

Table 43. SmartWay Certified Manufacturers

Tractors	Trailers	Tires
Daimler	Great Dane Trailers	Bridgestone
Kenworth	Hyundai Translead	Continental
Mack	Manac Inc.	Goodyear
Navistar International	Stoughton Trailers LLC	Hancock
Peterbilt	Trailmobile Canada Limited	Michelin
Volvo	Utility Trailer Manufacturing Company	Yokohama
	Vanguard National Trailer Corporation	
	Wabash National Corporation	

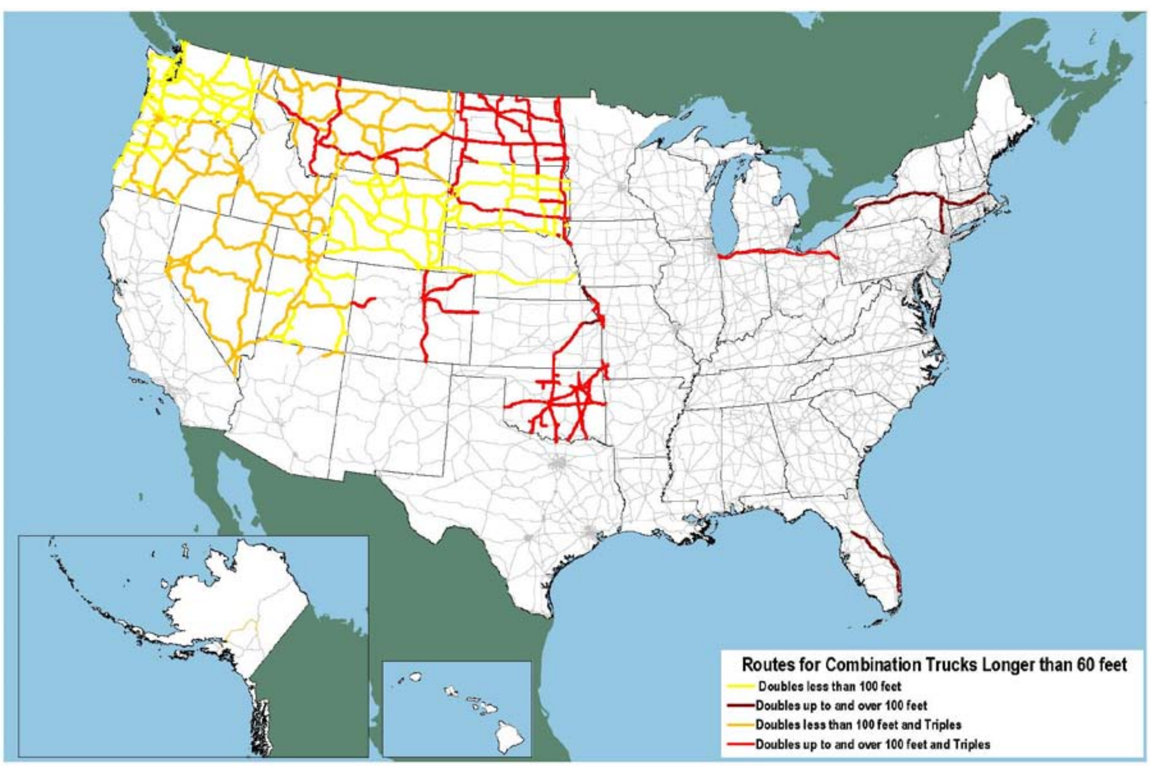
Source: EPA

Inconsistent policies among states send truck manufacturers mixed signals

Although all states allow conventional combinations consisting of a 28-foot semitrailer and a 28-foot trailer, only 14 states and six state turnpike authorities allow longer combination vehicles (LCVs) on at least some parts of their road networks. LCVs are tractors pulling a semitrailer longer than 28 feet and a trailer longer than 28 feet; a semitrailer longer than 28 feet and a trailer no more than 28 feet long; or a 28-foot semitrailer and two 28-foot trailers. The routes along which these LCVs can travel are shown in Figure 30. Allowable routes for LCVs have been frozen since 1991.

The maximum truck speed limit is inconsistent among states (Figure 31). It ranges from 55 mph in four states (California, Illinois, Ohio, and Oregon) to 75 mph in 10 states (Arizona, Colorado, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Utah, and Wyoming). This 20-mph span means that there is not one common highway speed at which trucks travel. This multitude of speeds precludes truck manufacturers from

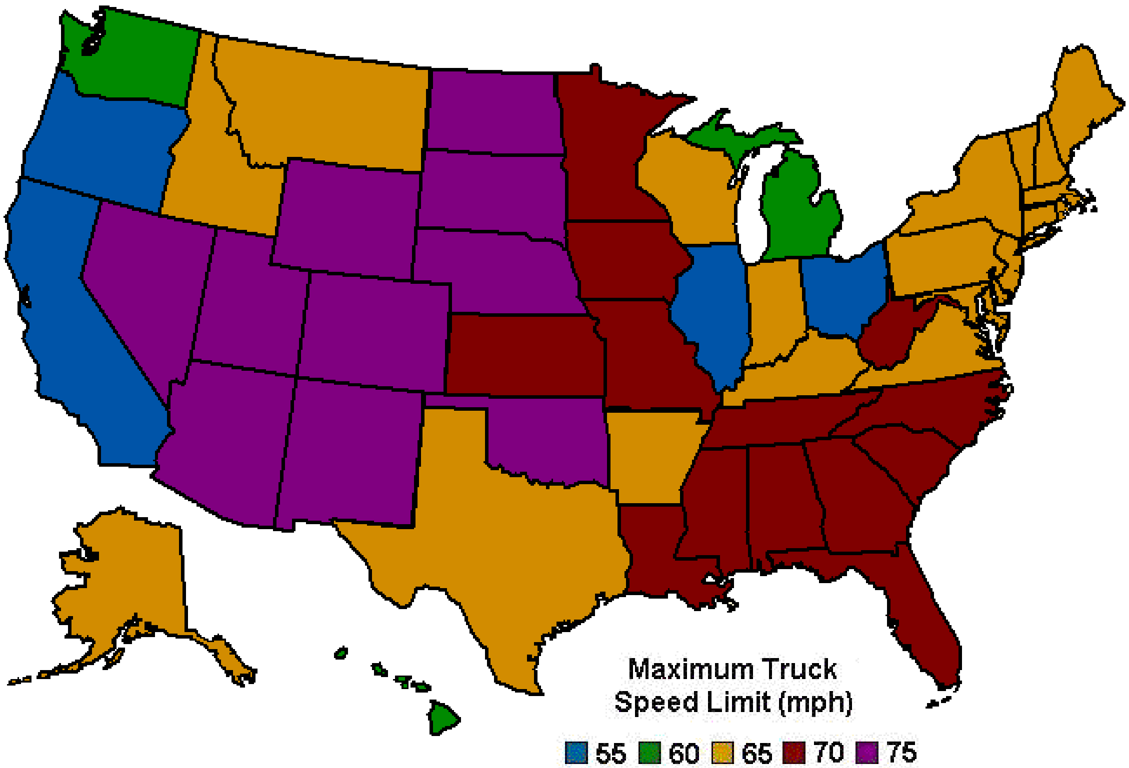
Figure 30. Routes Permitting Longer Combination Vehicles



Note: Empty trucks are allowed on I-80 in Nebraska.

Source: FHWA, Office of Freight Management and Operations

Figure 31. Truck Speed Limits



Source: FHWA, Freight Facts and Figures 2008

engineering truck engines that peak in efficiency after reaching the speed at which the vehicles most commonly travel. Instead, manufacturers design the vehicle to perform well over the entire range. Experts have estimated that a common nationwide speed limit would enable manufacturers to fine-tune engine efficiency to increase fuel economy by 5% to 10%.

The nation's largest commercial fleets include advanced technology vehicles

With close to 9 million vehicles, commercial fleets—comprised of both light and heavy vehicles—account for about 4% of the vehicles in the United States today. The prevalence of alternative fuel vehicles within some fleets can be much higher than the national average. Commercial entities buy alternative fuel vehicles to demonstrate their environmental and energy consciousness to their clients and the general public.

Schwan's Home Service Inc., a ready-made meal- and grocery-delivery company, has the largest alternative fuel vehicle fleet, which is comprised entirely of propane or propane bi-fuel vehicles. Bristol-Myers Squibb, a pharmaceutical company, has the largest flexible fuel-capable fleet, and has the second-largest alternative fleet overall (Table 44). UPS drives the fleet with the most natural gas-powered vehicles, and Novartis Pharmaceuticals drives the most hybrid-electric or all-electric vehicles. Nearly half of Delta airlines fleet are hybrid-electric or all-electric vehicles.

Table 44. Commercial Fleet Alternative Fuel Use

	Company	Total Alt-Fuel	CNG*	Propane*	Flex-Fuel	Hybrid / Electric*	Biodiesel	Total Vehicles	Percent Alt Fuel	Percent Hybrid
1	Schwan's Home Service, Inc.	6,094		6,094				6,094	100%	0%
2	Bristol-Myers Squibb Co.	3,562			3,550	12		5,134	69%	0%
3	Ferrellgas	3,530		3,530				3,733	95%	0%
4	State Farm Mutual Auto Insurance Co.	3,166			3,068	97	1	14,292	22%	1%
5	GE Healthcare	2,514			2,514			5,753	44%	0%
6	Honeywell International, Inc.	2,000			2,000			4,187	48%	0%
7	Johnson & Johnson Services, Inc.	1,703			912	791		10,683	16%	7%
8	United Parcel Service (UPS)	1,448	725	720		3		69,455	2%	0%
9	Eli Lilly & Co.	1,331	27	1	1,129		174	5,260	25%	0%
10	DSWaters of America	1,236		1,131		105		1,573	79%	7%
11	PepsiCo, Inc.	1,101			531	570		20,280	5%	3%
12	Delta Airlines	861	4	124		733		1,546	56%	47%
12	Monsanto Co.	861			860	1		3,040	28%	0%
14	Ecolab, Inc.	809			809			7,310	11%	0%
15	Alliant Energy	804			4		800	1,837	44%	0%
16	Novartis Pharmaceuticals	797				797		8,002	10%	10%
17	Federal Express Corp.	786	90	696				36,701	2%	0%
18	BMC West	738		418	315	5		875	84%	1%
19	Comcast Corp.	673			615	58		39,689	2%	0%
20	Land O' Lakes, Inc.	601			600	1		1,078	56%	0%
21	JEA Fleet Services	502			55	9	438	774	65%	1%
22	PPG Industries	500			500			2,577	19%	0%
23	Consolidated Coca-Cola Bottling	402				402		2,527	16%	16%
24	Archer Daniels Midland	325			200		125	1,230	26%	0%
25	Roche	242				242		1,900	13%	13%
26	Yellow Cab of Greater Orange County	156	156					227	69%	0%
27	Anixter, Inc.	150			150			525	29%	0%
28	Walgreen Co.	138			138			2,943	5%	0%
29	Panda Restaurant Group, Inc.	108				108		125	86%	86%
30	Apple, Inc.	100				100		502	20%	20%

Source: "Top 50 Green Commercial Fleets," AUTOMOTIVE FLEET 500 / 2008

Coming up in 2009 – 2013…

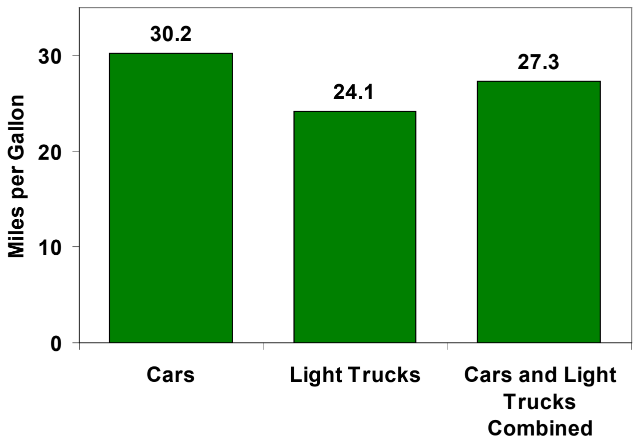
Despite recent technological advances in batteries, hybrid electric systems, diesels, and fuels, the gloomy outlook for the U.S. economy is expected to make the next few years difficult for the automotive industry. And despite this hardship, the recently passed Energy Independence and Security Act (EISA) of 2007 requires auto manufacturers to increase fuel economy significantly in the coming years. Thus, although uncertainty surrounds the technologies, fuel economy improvement is—at present—a legal certainty. The following sections show in what vehicles and by what dates commercialization of emerging technologies is expected to occur in combustion, alternative fuels, and hybrid electric vehicles during the next five years.

Light-vehicle CAFE standards will become more stringent

EISA 2007 sets an ambitious goal for the national fuel economy standard of 35 mpg by 2020, an increase of 40%. This increase marks the first instance that CAFE standards have increased above the levels established when they were created in 1975.

On March 30, 2009, NHTSA published the final rule for MY 2011 by raising CAFE standards for both cars and light trucks. In this rule, the fuel economy targets are based on the size of the vehicle as measured by the vehicle footprint [the distance between the wheels (width) multiplied by the distance between the axles (length)]. NHTSA estimates that the new standards will save 887 million gallons of fuel over the lifetime of the MY 2011 cars and light trucks and reduce CO_2 emissions by 8.3 million metric tons during that time. The average standards are shown in Figure 32. Each manufacturer will have a slightly different standard to meet based on how its average footprint varies from the total average footprint. NHTSA is researching proposed standards for future model years.

Figure 32. Average CAFE Standards for MY 2011



Source: Federal Register, Vol. 74, No. 59, March 30, 2009

New heavy-truck technologies will be deployed in response to tighter emissions regulations

Emissions regulations will become more stringent in 2010. Manufacturers have announced two technologies under consideration for meeting EPA2010 regulations. Urea/diesel exhaust fluid selective catalytic reduction (SCR) in tandem with exhaust gas recirculation (Cummins, Detroit Diesel, Paccar, Volvo). Volvo has announced publicly that this technology will increase the retail price of its class 8 trucks by $9,600. Navistar will employ a heavy exhaust gas recirculation (EGR) method under the marketing name "Advanced EGR." No viable alternatives to these technologies announced for 2010 are currently known.

The development of more advanced future technologies is hindered by uncertainty of regulatory environment due to simultaneous discussions about which governmental entities will regulate in the future: Will EPA or the California Air Resources Board (CARB) regulate carbon dioxide emissions, or will the Department of Transportation expand its role as fuel efficiency regulator to medium and heavy trucks?

Homogeneous charge compression ignition (HCCI) will be mass-produced

Homogeneous charge compression ignition (HCCI) combines the positive characteristics of gasoline and diesel engines: the low emission output of a gasoline spark ignition engine with three-way catalyst emission control (NOx, HC, CO) and the high efficiency of diesel engines. HCCI engines have been shown to achieve extremely low levels of NOx emissions without an after-treatment catalytic converter; however, unburned hydrocarbon and carbon monoxide emissions are still high due to lower peak temperatures, as in gasoline engines, and must still be treated to meet automotive emission regulations.

Research has been conducted to determine whether advanced combustion methods like HCCI or low-temperature diesel combustion will require a special fuel. So far, advanced combustion has considerable tolerance toward traditional gasoline and diesel, yet some optimization of fuel properties and engine technology can be projected. Researchers are also trying to understand the effects of the specific chemistry of oil-sands and biodiesel fuels on low-temperature diesel combustion.

Table 45 shows the expected timeline of vehicles with HCCI.

Table 45. HCCI Release Timeline

Make	Model	Demo	Target Release
GMC	Opel Vectra		
GMC	Saturn Aura	2007	
GMC	Vauxhall Vectra	2008	2012
MBZ	F 700	2007	
VWA	Touran	2015	2015
HON			

Source: Autobloggreen.com

Diesel offerings will expand

Diesel engines are a major part of the slate of technologies available to meet future CAFE regulations. EEA reports that the three domestic manufacturers and all major Japanese and European manufacturers selling vehicles in the United States are planning to introduce diesel engines by 2011.

Table 46 shows EEA's 2012 diesel market share forecast (derived from DOE's CAFE compliance model) for the seven biggest OEMs. The forecast excludes the heavy pickups and the Mercedes and BMW fleet. Other forecasts are included for comparison; they also show rapid diesel market growth (forecasts include heavy pickups). All forecasters agree that, in the near term, the diesels will be primarily concentrated in light trucks.

Table 46. Diesel Light Truck Market Forecast for 2012

OEM	Car Diesel Share [%]	Light Truck Diesel Share [%]
GM	0.0%	5.5%
Chrysler	0.0%	3.5%
Ford	0.0%	5.8%
Toyota	0.0%	5.1%
Honda	2.2%	6.0%
Hyundai	0.0%	2.9%
VW/Audi	16.1%	18.2%

Other Diesel Vehicle Market Share Forecasts	
Ricardo	9% by 2013
J.D. Power	10 to 15% by 2015.
Bosch	6% by 2010 and 15% by 2015
Martec	10 to 12% by 2013 (NAFTA)

Source: EEA

Light diesels will be offered again in MY 2009 by VW in the Jetta, BMW in the 3-series, and Mercedes-Benz in the R-class wagon and M and GL class SUV models. These were all new for model year 2009. The VW sedan gets a tax credit of $1,300. The tax credits for the R, M, and GL models are $1,550, $1,800 and $900, respectively. Data on light-diesel sales are not available, but Mercedes targets for all diesel models are about 10,000 units. BMW is also expected to sell about 10,000 units in MY 2009. VW had an original target of about 25,000 Jetta diesels for MY 2009. However, *Automotive News* reports that VW has experienced a higher-than-expected demand for the diesel car. VW originally expected that about 20% of Jetta sales would be diesel; however, in 2009, about 50% of the Jetta wagon sales and 30% of the Jetta sedan sales are diesels. Still, current market share is very small (less than 0.1% of total light-vehicle sales). The impending financial downturn and fiscal constraints on domestic manufacturers may result in delays or outright cancellation of new diesel engines planned for model year 2010 introduction. Table 47 shows makes and models anticipated for release in the near future (<2012).

The diesel hybrid application is a relatively new development but appears to be moving from conceptual stage to commercialization quite rapidly. However, the cost differential will still be large, so the full diesel hybrids will be adopted among large and heavy vehicles, such as cars and SUVs with a high profit margin.

Electric drive offerings will diversify and expand significantly

The number of electric drive vehicles will increase significantly in the near future with planned increases in hybrid electric vehicle production and the expected introduction of plug-in hybrid electric vehicles around 2010. Electric drive concept and production vehicles that have been announced for possible release within the next five years (<2013) and the characteristics of each, where known, are summarized in Table 48.

Table 47. Upcoming Diesel Light Truck Models and Technologies

Upcoming Light Diesels					
Manufacturer	**Engine**	**Cylinder Pressure Sensor**	**Extended PCCI HCCI?**	**NOx After-Treatment**	**Other known specs.**
Mercedes	3L V6	No	No	Future Urea – SCR	BluetecII
	2.2L I4	Possible	No?	Urea – SCR?	2,000bar CR, dual turbo
BMW	3L I6	No	No	Urea – SCR	Dual turbo and EGR
VW/Audi	2L I4	Yes	Yes	Adsorber	1,800bar CR
	3L V6	Yes	Yes	Urea - SCR	2,000bar CR
GM	2.9L V6	Yes	Yes	Adsorber (Bin 8)	
	4.5L V8	Yes	Yes?	Urea – SCR	2,000bar CR
Honda	2.4L I4	Yes	Yes	Adsorber	2,000bar CR
	3.3L? V6	Yes	Yes	Adsorber?	
Ford	4.4L V8	No	No	Urea – SCR	1,700bar CR?
Chrysler (Cummins)	4.2L V6 5.6L V8	No	No	Urea – SCR	Developed with US DOE
Toyota	4.5L V8	No	No	Urea SCR	1,800 bar CR?
	3L V6 (Isuzu)			Urea SCR	
Hyundai	3L V6				1,600bar CR
Mitsubishi	2.2L I4			Adsorber	
Subaru	2L H4			Adsorber	

Source: EEA

Table 48. (P)HEV Demonstration and Upcoming Models

Upcoming Electric Drive Vehicles								
Organization(s)	**Specific Product(s) Planned**	**US Release**	**MPG**	**AER**	**Engine**	**Battery**	**Motor**	**Additional**
Audi	Audi Metroproject		50	60	1.4L		30 kW	
Audi	Audi A1 Sportback Hybrid		72.4	60	1.4L		20 kW	Both a turbo and supercharger; 7.9s 0-60
BYD	BYD F6-DM	2010		60				
Chrysler LLC	Chrysler ecoVoyager							
Chrysler LLC	Jeep Renegade PHEV Concept		110	40	115 hp 1.5L 3-cyl diesel		2x 268 hp	
Chrysler LLC	Jeep Wrangler Range Extended Range EV			40		27 kWh		
Chrysler LLC	Chrysler Town & Country Extended Range EV		50	40		22 kWh		
Daimler (with EPRI)	Sprinter PHEV van			20	2.7L gas or 2.3L diesel	14 kWh Li-ion	90 kW	
Daimler	Smart Micro-Hybrid							Hybrid versions of existing Smart compact vehicle.
Ford (with DOE)	AirStream Concept, HySeries Drive Concept	2007	41	25		Li-ion		Ballard fuel cell
Ford	Ford Escape PHEV30			30				
Ford (with EPRI, Southern California Edison and Argonne National Laboratory)	PHEV Escape	2009			2.3L 4-cyl	Li-ion		
General Motors (Saturn, with Idaho National Laboratory and Argonne National Laboratory)	Saturn VUE Green-line and 2-mode	2009						Cobasys batteries
General Motors (Cadillac)	Cadillac Provoq			20		9 kWh Li-ion	70 kW fron axle + 2x 40 kW rear wheels	
General Motors (Chevrolet)	Chevrolet Volt (E-Flex hybrid system)		150	40	1.4L gas	16 kWh	53 kW (120 kW peak)	A123 systems or Compact Power, Inc. batteries
General Motors (Saturn)	Saturn VUE 2-Mode PHEV	2010		10	3.6L V6			
Fisker Automotive, Inc.	Fisker Quantum Karma Plug-in Hybrid	2009		50	"small"			

(Continued on next page)

Table 48. (P)HEV Demonstration and Upcoming Models (Continued)

Honda	Insight	2009						
Nissan	"Range extender" PHEV	2010						
PML Flightlink	Plug-in Hybrid Ford F150 Pickup EV	2009	100			40 kWh		
Subaru	G4e EV			124		Li-ion	65 kW	
Toyota	Prius 3rd Generation	2009						Panasonic batteries
Toyota	Prius PHEV	2010		7		Li-ion		Panasonic batteries
Volkswagen	VW Space up! Blue					Li-ion		Fuel cell
Volkswagen	VW Golf Twin Drive	2010		30	2.0L turbodiesel	Li-ion	82 hp electric + 122 hp	
Volvo (Ford)	ReCharge Concept	2012		62	Diesel			Fast charge of 1 hour allows 30 mile range; DOE supported

Source: ORNL, "PHEV Activities Summary"

The National Academy of Sciences is considering heavy-truck fuel economy regulation

The Department of Transportation's National Highway Traffic and Safety Administration has commissioned a report evaluating medium-duty and heavy-duty truck fuel economy standards with the National Academy of Sciences under the direction of the Energy Independence and Security Act of 2007, Section 108. The organizations have established a committee to develop guidance on regulating medium- and heavy-truck fuel economy.

The committee is considering approaches to measuring fuel economy for medium- and heavy-duty, by vehicle class, if appropriate. The committee will also consider what might be an appropriate metric for a fuel economy standard (e.g., miles per gallon or ton-miles per gallon or other measures) or a fuel consumption standard (e.g., gallons per mile or gallons per ton-mile); how might an appropriate baseline be defined for estimating improvements; what kinds of test cycles would be appropriate; and what kinds of testing facilities exist, or would be needed, to evaluate fuel economy.

In addition to considering fuel economy regulation, the committee will consider current and potential medium- and heavy-truck technologies and the corresponding fuel economy improvements that might be achieved. A report documenting the committee's conclusions and recommendations will be a foundation that NHTSA can use to construct fuel economy regulations.

Medium- and heavy-truck sales will suffer through the recession but will recover with the economy

The economic recession of 2008 severely affected the trucking industry: New Class 8 truck sales projections for 2009 have been as low as 80,000 units (down nearly 40% from 128,000 in 2008). The American Trucking Association forecast a 15% increase in the freight tonnage shipped by truck between 2006 and 2012; however, this estimation was made before the economic recession began in 2008, so it is probably overly optimistic. The six-year volume increase was based on an assumption of average annual growth rate of 2.2%, primarily due to an assumed average annual increase in GDP of 2.6%. Given more recent estimations of annual GDP growth, trucking should not be expected to increase until more favorable levels of GDP growth return.

The hard times anticipated for medium and heavy trucking are underscored by the difficulties that the freight-drivers are experiencing. Limited output in domestic manufacturing, construction, agricultural commodities, mining, and non-oil merchandise imports will constrain demand for freight transport, and, therefore, for new medium and heavy trucks.

Once the economy turns around, however, sales should pick up significantly. Engine production volumes are at historical lows moving into the third year in a row (2007, 2008, and 2009). Therefore, once industries that drive freight transportation recover, fleets are expected to increase buying engine and vehicles to make up for the lag during the recession.

Heavy-truck use of advanced fuels will expand, but slowly

No significant changes to current diesel fuels are anticipated; although the availability of B5, which is accepted by all diesel engine manufacturers, is expected to expand over time. Furthermore, some states are considering proposals that may lead to higher biodiesel blends. Manufacturers are quick to point out that the durability of engines when using such blends is not known. Testing and characterization of engines using higher biodiesel blends would likely delay the implementation of any legislation designed to increase the amount of biofuel included in diesel fuel blends at the pump.

Penetration of natural gas engines is growing for urban bus markets. This trend is expected to continue.

Several possibilities exist to reduce heavy-truck engine idling

Idle reduction is a worthy goal for all heavy-truck operators and fleet managers: It reduces fuel consumption and increases savings. The medium by which idle reduction is achieved is ultimately the decision of the operator or fleet manager. Some fleets may opt to pursue auxiliary power=-unit technology, which consists of a small auxiliary engine used to provide climate control and electrical power for the sleeper cab and engine block heater when the vehicle is parked. Other may pursue other solutions, such as those promoted by IdleAire or Shorepower Technologies, both of which were discussed in more detail earlier.

An integrated electric hybrid solution probably holds the most promise for idle reduction in the long term. The speed at which heavy trucks progress toward that solution will be most directly affected by fuel prices and government regulations.

References

AID Newsletter Nos. 0102, 0302, 0501, 0602, 0702, 0714, and 0904. http://www.eagleaid.com/.

Alternative Fuels and Advanced Vehicles Data Center. "U.S. Alternative Fueling Stations by Fuel Type." http://www.afdc.energy.gov/afdc/data/docs/alt_fueling_stations_fuel.xls.

Alternative Fuels and Advanced Vehicles Data Center. "Light-Duty E85 FFVs in Use in US." http://www.afdc.energy.gov/afdc/data/docs/ffvs_in_use.xls.

AOL Autos. http://autos.aol.com. Data compiled by looking up hybrid and non-hybrid models.

Autoblog Green. http://www.autobloggreen.com/. Several articles on HCCI were summarized.

Automotive Fleet. "2008 Top 50 Green Commercial Fleets." http://www.fleet-central.com/TopFleets/pdf/top50green_08.pdf.

Automotive News. *Top 100 Global Suppliers 2007* and *Top 100 Global Suppliers 2003*, http://www.autonews.com/ .

Automotive News. *April 13, 2009 "While other brands sputter, VW boosts U.S. diesel sales forecast,"* http://www.autonews.com/ .

Bureau of Economic Analysis. National Income and Product Accounts, Current Dollar and Real GNP, http://www.bea.gov/national/xls/gdplev.xls

DieselNet. http://www.dieselnet.com/.

DOE. 21st Century Truck Partnership, http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/21centurytruck/ Members of the Executive Committee of the 21st Century Truck Partnership contributed their expert opinions to this report.

DOE. "Clean Cities Fact Sheet," April 2009. http://www1.eere.energy.gov/cleancities/pdfs/44929.pdf.

DOE/EPA. "New Energy Tax Credits for Diesels." http://www.fueleconomy.gov/feg/taxLeanBurn.shtml .

DOE/EPA. "New Energy Tax Credits for Hybrids." http://www.fueleconomy.gov/feg/tax_hybrid.shtml.

DOT, FHWA. *Highway Statistics 2007*.Table VM-1 in this and historical versions of the Highway Statistics report. http://www.fhwa.dot.gov/policyinformation/statistics/2007/ .

DOT, FHWA, Office of Freight Movement and Operations. "Permitted Longer Combination Vehicles on the National Highway System: 2008 Map" http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/nhslongcombveh2008.htm.

DOT, FHWA, *Freight Facts and Figures 2008*, Table 3-8, http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/08factsfigures/table3_8.htm

EEA. "2008 Light-Duty Diesel Report" submitted to DOE. http://www.eea-inc.com/ .

EIA. *Emissions of Greenhouse Gases Report*, Table 6. http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html.

EIA. Monthly Energy Review, Table 2.5. http://www.eia.doe.gov/mer/pdf/pages/sec2_11.pdf

EIA. Petroleum Navigator, "U.S. Regular All Formulations Retail Gasoline Prices." http://tonto.eia.doe.gov/dnav/pet/hist/mg_rt_usA.htm.

EIA. Petroleum Navigator, "U.S. No 2 Diesel Retail Sales by All Sellers." http://tonto.eia.doe.gov/dnav/pet/hist/ddr001A.htm

EPA. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008*, Appendices D, I, L, and P. http://www.epa.gov/otaq/fetrends.htm

EPA. National Emission Inventory, 1970 - 2007 Average annual emissions, all criteria pollutants. http://www.epa.gov/ttn/chief/trends/trends06/nationaltier1upto2007basedon2005v1.xls
EPA. Emission Standards Reference Guide for Heavy-Duty and Nonroad Engines, http://www.epa.gov/otaq/cert/hd-cert/stds-eng.pdf
Federal Register. Vol. 74, No. 59, March 30, 2009. http://www.gpoaccess.gov/fr/
NHTSA. Flexible Fuel Credits 2003-2006 summary, http://www.nhtsa.dot.gov/portal/nhtsa_static_file_downloader.jsp?file=/staticfiles/DOT/NHTSA/Rulemaking/Articles/Associated%20Files/Flexible%20fuel%20credits_2008_01.pdf .The 2007 data were calculated using a NHTSA database.
NHTSA. Summary of Fuel Economy Performance, http://www.nhtsa.dot.gov/portal/nhtsa_static_file_downloader.jsp?file=/staticfiles/DOT/NHTSA/Rulemaking/Articles/Associated%20Files/Nov2008_CAFE_Performance.pdf
ORNL. Automotive Systems Cost Model, http://cta.ornl.gov/cta/One_Pagers/Auto_System_Cost_Modeling.pdf
ORNL, "PHEV Activities Summary." Electric drive vehicle information.
ORNL.*Transportation Energy Data Book: Ediiton 27*, Table 2.6, http://cta.ornl.gov/data/tedb27/Spreadsheets/Table2_06.xls
Ward's. Autoinfobank. http://wardsauto.com/.
Ward's. *Motor Vehicle Facts and Figures 2008*, "Average Materials Content of North American Light Vehicles." http://wardsauto.com/about/ff/.
Ward's. *Motor Vehicle Facts and Figures 2008*, "Factory Sales of Trucks by Gross Vehicle Weight Rating." http://wardsauto.com/about/ff/.
Ward's. *Motor Vehicle Facts and Figures 2008*, "U.S. Factory Sales of Diesel Trucks by Gross Vehicle Weight Rating." http://wardsauto.com/about/ff/.
World Steel Association. "Top Steel Producers 2007" http://www.worldsteel.org/?action=storypages&id=284.
Yahoo Finance. http://finance.yahoo.com/.

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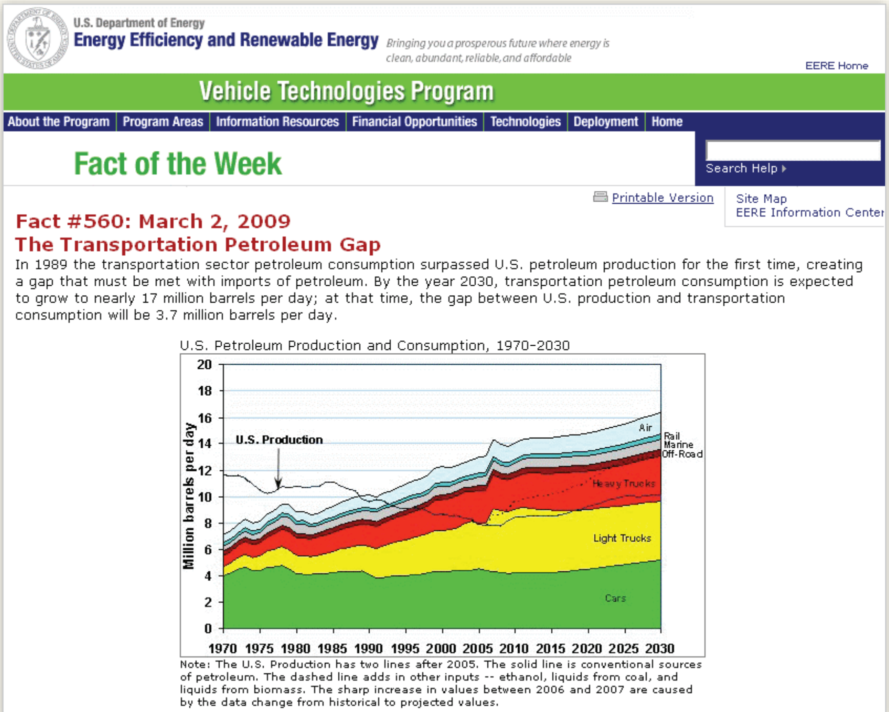
Vehicle Technologies Web Sites

U.S. Department of Energy Vehicle Technologies Program
www.eere.energy.gov/vehiclesandfuels/

Fact of the Week
www.eere.energy.gov/vehiclesandfuels/facts/



Clean Cities Program
www.eere.energy.gov/cleancities/

Fuel Economy.gov
fueleconomy.gov/

Alternative Fuels and Advanced Vehicles Data Center
www.afdc.energy.gov/afdc/

Freedomcar And Fuel Partnership
www.uscar.org/

21st Century Truck Partnership
www.eere.energy.gov/vehiclesandfuels/about/partnerships/21centurytruck/index.html

Transportation Energy Data Book
cta.ornl.gov/data/

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On the Cover

Vehicles travel on a U.S. highway during rush hour. Transportation accounts for 70% of U.S. oil use and 28% of U.S. energy use.
Warren Gretz/PIX 10640

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