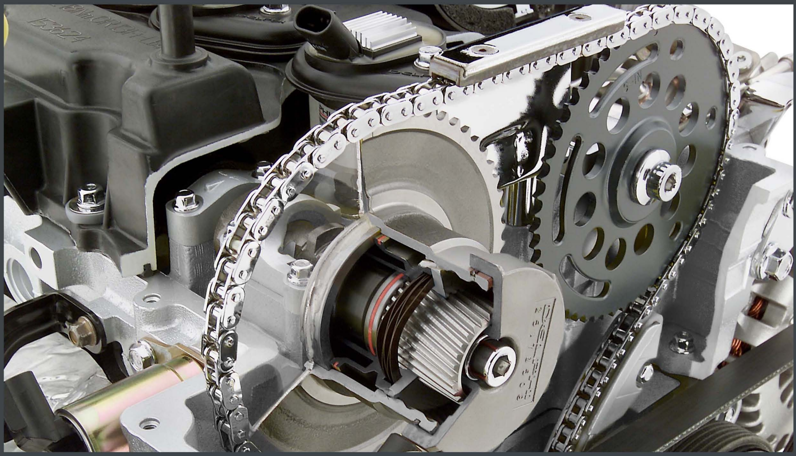
2010 VEHICLE TECHNOLOGIES MARKET REPORT


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

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2010 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 U.S. 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
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CVT	Continuously Variable Transmission
CHR	Chrysler
DCC	DaimlerChrysler
DISI	Direct Injection Spark Ignition
DOE	U.S. Department of Energy
EEA	Energy and Environmental Analysis
EPA	Environmental Protection Agency
FFV	Flex-Fuel Vehicles
FHWA	Federal Highway Administration
FMC	Ford Motor Company
GDi	Gasoline Direct Injection
GDP	Gross Domestic Product
GE	General Electric
GM	General Motors
GMC	General Motors Corporation
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
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
MPG	Miles Per Gallon
MY	Model Year
NHTSA	National Highway Traffic Safety Administration
NIMH	Nickel-Metal Hydride Battery
NIS	Nissan
NO_X	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
U.S.	United States
VMT	Vehicle Miles Traveled
VW	Volkswagen
Δ	Change

Executive Summary

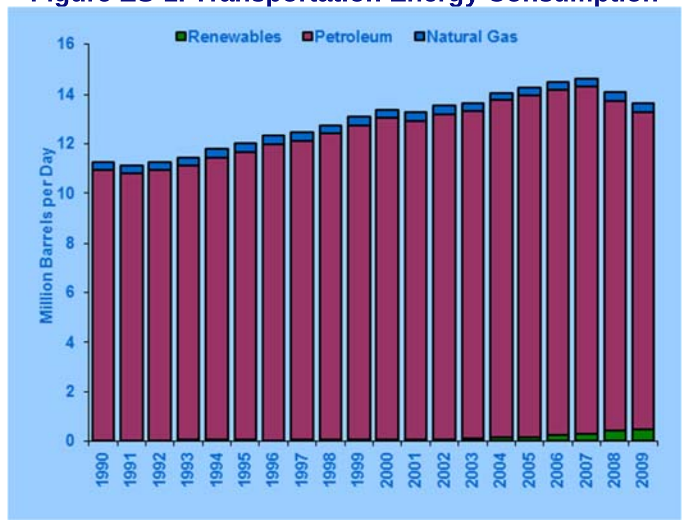
The bankruptcy of two American manufacturers rocked the automotive world in 2009. Chrysler filed for bankruptcy in April, with General Motors following in June of that year. Both manufacturers emerged quickly from bankruptcy, with help from the Federal government. Chrysler (CHR) merged with Fiat (Fabbrica Italiana Automobili Torino) SpA and General Motors cancelled or spun-off several brands, including Pontiac, Hummer, Saturn, and Saab.

The economic downturn that began in 2008 continued into 2009, with consumers continuing to forgo purchases of new light, medium, and heavy vehicles. This caused even further declines in vehicle sales, despite a Federal government effort that created a surge of light vehicle purchases in the summer of 2009. Energy consumed by the transportation sector decreased for the second year in a row as vehicle miles of travel fell just below the 2008 level.

Despite the contraction in the industry in 2008 and 2009, the automotive industry is predicted to grow as the U.S. economy slowly expands in 2010. As manufacturers increase production, the movement of commodities will grow as well as demand for passenger mobility. Energy Information Administration projections show increases in the number of vehicles, number of passenger-miles traveled and amount of goods shipped.

With the exception of 2008 and 2009, the transportation sector's 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



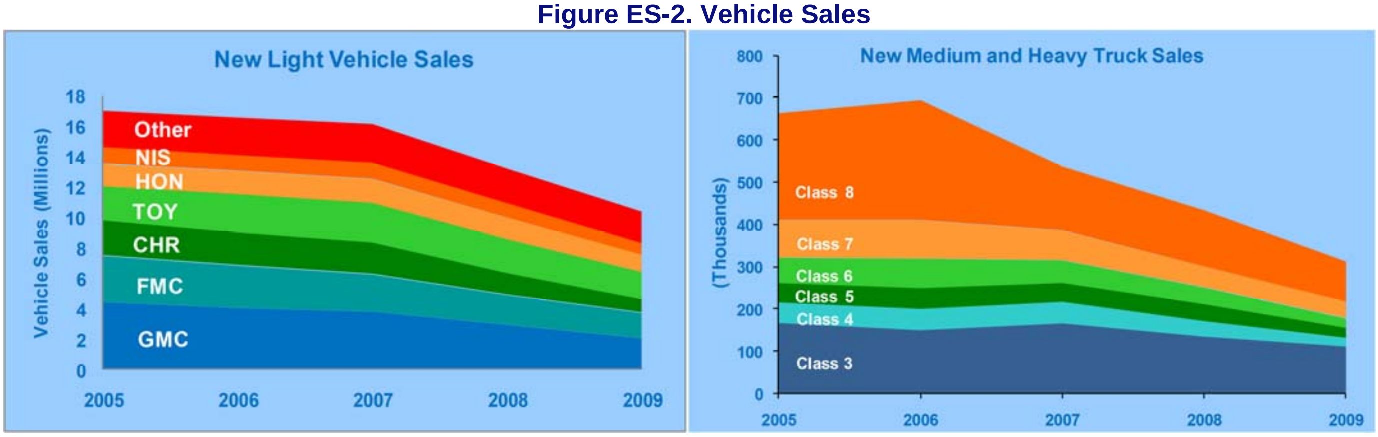
Source: *EIA, Monthly Energy Review*

Vehicle sales figures have decreased significantly in the past three 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 experiencing an economic downturn. The transportation industry was hit especially hard in 2008, when economic problems were compounded by an oil shock.

Petroleum fuel prices recovered in 2009 from the late 2008 price plunge, and the price of a gallon of gasoline stayed near $2.00 per gallon in the first half of the year and near $2.60/gallon in the last half of 2009.

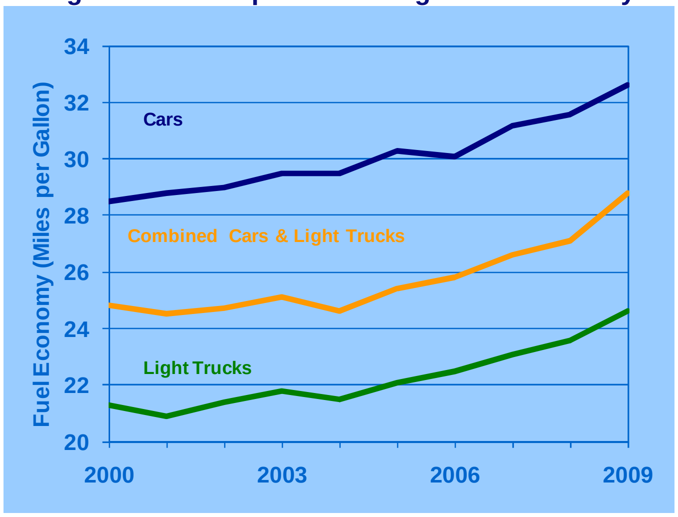
New cars and light trucks today are increasingly more energy efficient than cars and light trucks were five years

Figure ES-2. Vehicle Sales



ago. However, because consumers have preferred light trucks over cars in recent years, the combined Corporate Average Fuel Economy (CAFE) for the entire U.S. fleet of both cars and light trucks was not improving much until recently (Figure ES-3). From 2005 to 2009, the CAFE for cars rose 7.6%, and for light trucks rose 11.3%. Light trucks are, on average, less fuel efficient than cars.

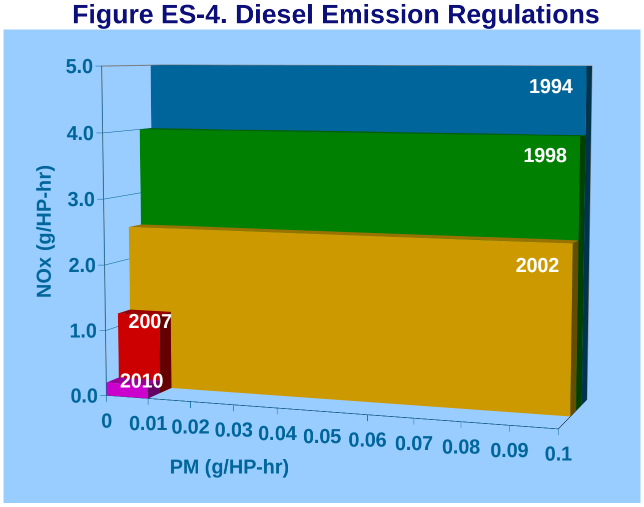
Figure ES-3. Corporate Average Fuel Economy



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 (NO_X) 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

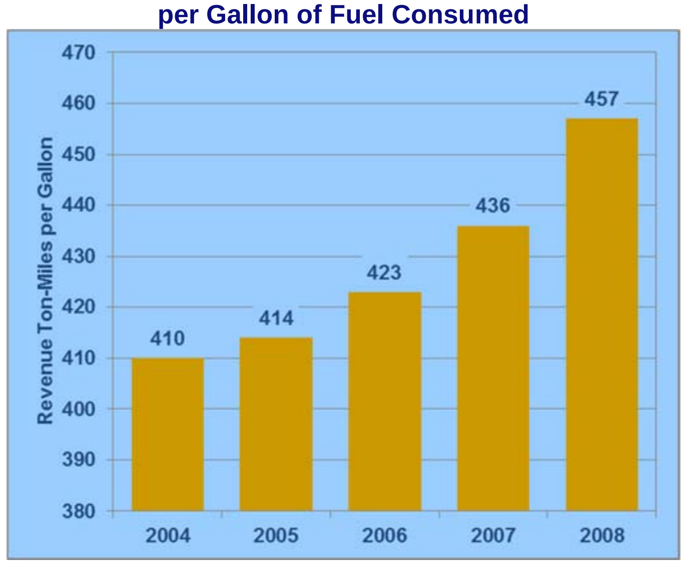


Source: *EPA*

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 and EPA have jointly proposed fuel economy standards and emission standards for medium and heavy vehicles.

In addition to the highway vehicles already mentioned, this year's Market Report includes facts about freight rail. The seven Class I railroads move freight over a network of more than 94.000 road-miles, not including parallel tracks at sidings and yards. Average railcar capacity has grown to 100 tons and productivity for the railroads, measured as revenue ton-miles per employee-hour, has increased 10% from 2004 to 2008. The freight railroads are gaining in fuel efficiency; the revenue ton-miles per gallon has increased by 11.5% (see Figure ES-5). The new hybrid diesel-electric locomotives in development, along with start/stop technologies to reduce engine idle time, will help the rail industry to continue fuel efficiency improvement.

Figure ES-5. Class I Railroads Revenue Ton-Miles per Gallon of Fuel Consumed



Source: *AAR*

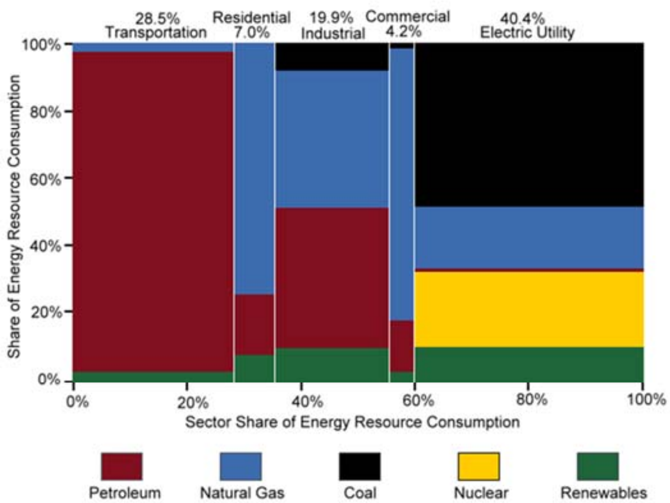
This report details the major trends in transportation energy mentioned here, as well as the underlying trends that caused them. The report opens with a summary of the economic sector, including sector-wide energy consumption trends. The second section includes a discussion on light vehicles, and the 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 highway sector in the next five years. A section on the freight rail industry completes the report.

Transportation Energy Trends

Transportation accounts for 28.5% of total U.S. energy consumption

In 2009, the transportation sector used 27 quads of energy, which is 28.5% of total U.S. energy use (Figure 1). Nearly all of the energy consumed in this sector is petroleum (94%), with small amounts of renewable fuels (3%) and natural gas (3%). 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

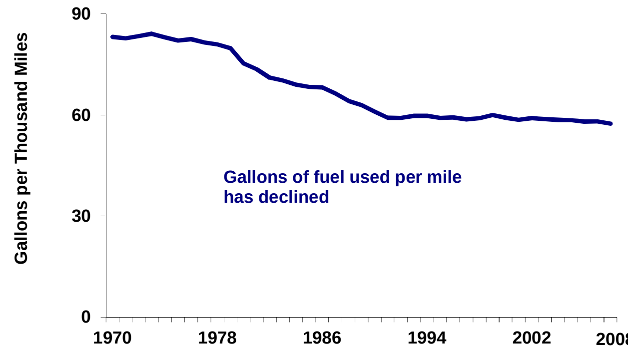


Source: *EIA, Monthly Energy Review*

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 2008, showing that the fuel economy for new vehicles was stagnant during this period.

Figure 2. Fuel Use per Mile

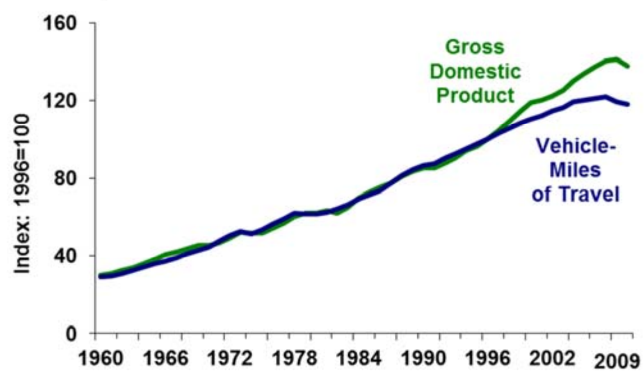


Source: *FHWA, Highway Statistics 2008, Table VM-1 and previous editions of the report.*

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 2009.

Figure 3. Relationship of VMT and GDP

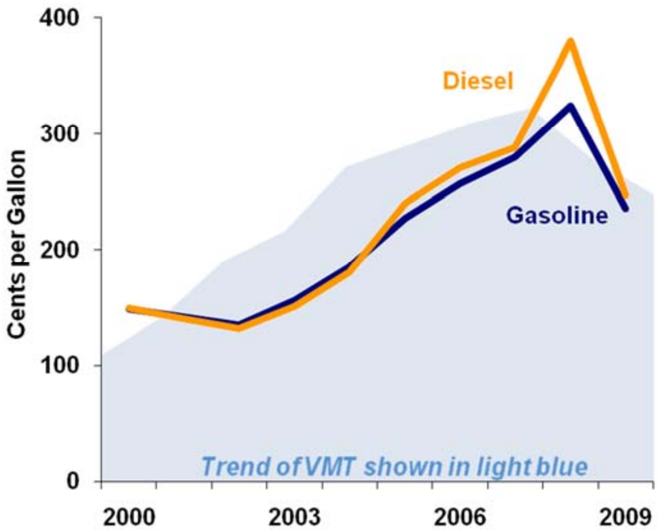


Source: *BEA, Survey of Current Business and FHWA, Highway Statistics*

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 from 2005 to 2008, then fell to near 2005-levels again in 2009; from an annual average of $2.27 per gallon in 2005 to $3.25 in 2008, and back to $2.35 in 2009 (Figure 4). Diesel fuel prices rose even higher than gasoline in 2008 ($3.80 per gallon), but fell to $2.47 per gallon in 2009. The effects of these sharp changes in fuel prices are seen throughout this report in the areas of energy use, VMT, and vehicle sales.

Figure 4. Annual Average Price of Gasoline and Diesel Fuel



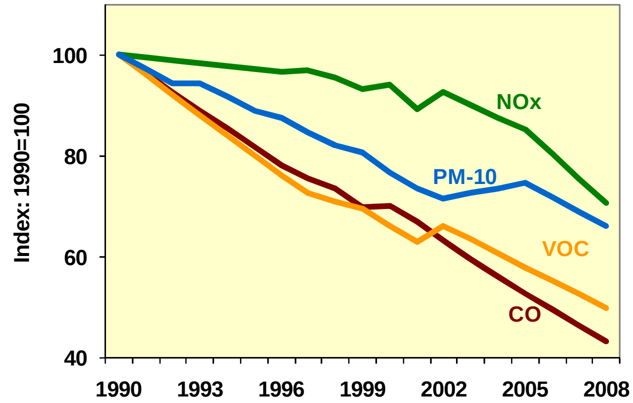
Source: *EIA, Petroleum Navigator*

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. In 2009, the difference between them was 11 cents per gallon.

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 2008, the emission totals for the transportation sector declined for each of the criteria air pollutants tracked by the EPA – carbon monoxide (CO) emissions dropped by 57%.

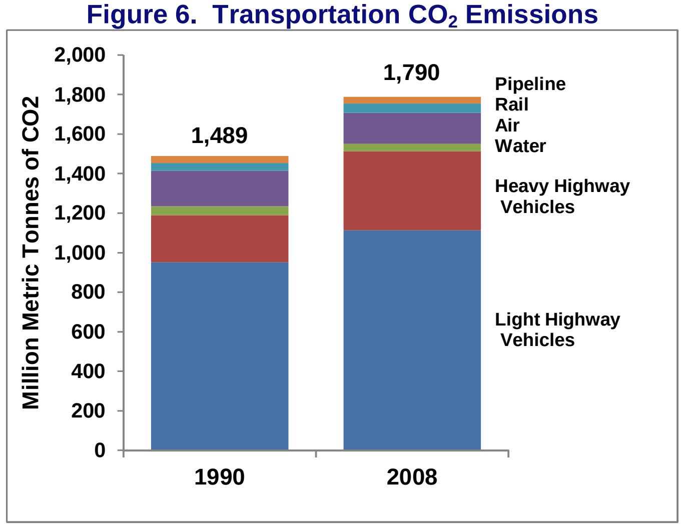
Figure 5. Transportation Pollutant Emissions



Source: *EPA, National Emission Inventory*

Carbon dioxide (CO_2) emissions in the transportation sector have grown from 1,489 million metric tons (MMT) in 1990 to 1,709 in 2008 – a 20% increase (Figure 6). Much of the increase was due to increases in the amount of CO_2 emissions from highway vehicles. However, the CO_2 emissions per highway vehicle mile improved by 12% (Table 1).

Figure 6. Transportation CO_2 Emissions



Source: *EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008, Table 3-12, April 2010.*

Table 1. Metric Tons of CO_2 per Highway Vehicle Mile

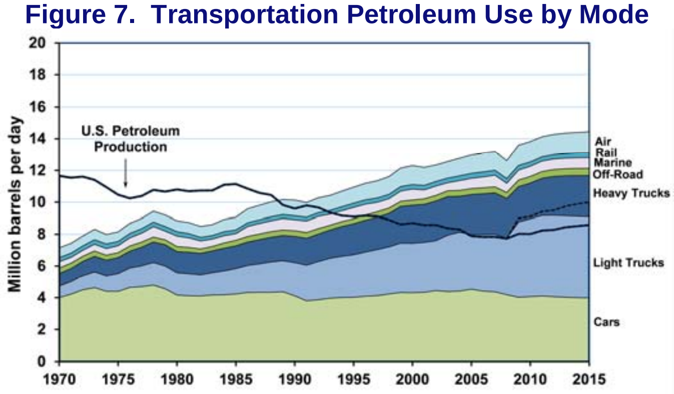
	1990	2008	18-yr Δ
Carbon Dioxide	0.74	0.65	-12%

Sources: *EIA, Emissions of Greenhouse Gases in the United States, 2008, and FHWA Highway Statistics 2008*

Light vehicles comprise the majority of transportation energy consumption

Light vehicles consume the majority of the energy used by the transportation sector and are predicted to continue that trend, according to the EIA Annual Energy Outlook (Figure 7). The proportion of energy consumption shown in Figure 6 has been fairly constant for the past five years, but the growth of light truck petroleum use is evident when looking at the series history. Beginning in 2005, the United States produced only enough petroleum to meet the energy needs of cars and light trucks. With conventional sources of petroleum (solid black line), the petroleum used by cars and light trucks is expected to outgrow U.S. production.

Figure 7. Transportation Petroleum Use by Mode



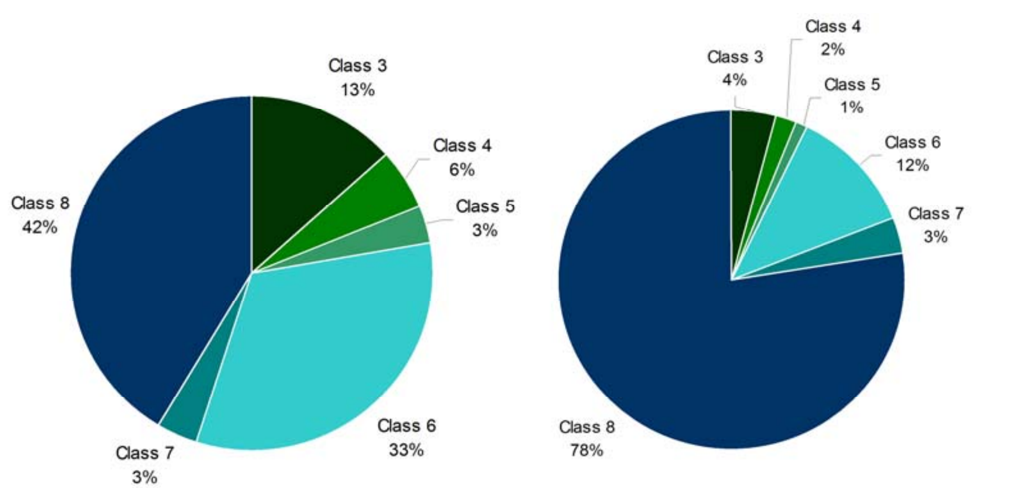
Note: *The U.S. Production has two lines after 2005. The solid line is conventional sources of petroleum, including crude oil, natural gas plant liquids, and refinery gains. The dashed line adds in other non-petroleum sources, including ethanol, biomass, liquids from coal, other blending components, other hydrocarbons, and ethers. The sharp increase in values between 2007 and 2008 are the result of the data change from historical to projected values.*

Source: *Historical - ORNL, Transportation Energy Data Book: Edition 29. Projections- EIA Annual Energy Outlook 2010.*

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 8). 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.

Figure 8. Medium and Heavy Truck Fleet Composition (left) and Energy Usage (right)



Source: *ORNL, Transportation Energy Data Book*

Leading engine suppliers are stable in the United States, but their businesses are growing faster abroad

Of the top 100 global suppliers, the two of the top three specializing in engines in 2005 are also the top suppliers in 2009 (Table 2). Magna International discontinued the production of engines in 2007. Hyundai-WIA Corp. (a Hyundai subsidiary) joined the engine suppliers in 2009. Total company sales increased slightly for Cummins from 2005 to 2009, but declined for Navistar International. It is worth noting that the portion of sales in the United States has decreased, suggesting that growth for these suppliers abroad is outpacing U.S. growth. Light vehicle engine manufacturers are not included in this list, as their production is tabulated as an Original Equipment Manufacturer (OEM), the metric for which is vehicles manufactured, rather than an engine supplier.

Of the top 100 global engine component suppliers, seven companies from 2005 are among the top in 2009. Total company sales 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 all cases, again suggesting that growth for these suppliers abroad is outpacing U.S. growth.

Panasonic dominates the American hybrid 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 (Figure 9, Tables 3 and 4). Sanyo Electric, however, has been maintained as a subsidiary, thus the

Table 2. Leading Suppliers in Engines and Engine Components, Excluding OEMs

Engines					
2005			2009		
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.	12,768.0	(56%)	Cummins Inc.	2,513.3	(51%)
Cummins Engine Co.	2,363.8	(63%)	Navistar International	1,883.0	(70%)
Navistar International	2,776.1	(85%)	Hyundai-WIA Corp.	19.1	(1%)

Engine Components					
2005			2009		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Delphi Corp.	16,037.4	(71%)	Delphi Corp.	3,761.6	(32%)
Magna International Inc.	12,768.0	(56%)	TRW Automotive Inc.	3,016.0	(26%)
Dana Corp.	5,424.9	(63%)	Magna International, Inc.	2,952.4	(32%)
TRW Automotive Inc.	4,455.9	(38%)	Aisin Seiki Co.	2,470.2	(12%)
Aisin Seiki Co.	3,223.6	(18%)	Benteler Automobiltechnik GmbH	1,902.4	(29%)
BorgWarner Inc.	1,884.7	(43%)	Hitachi Automotive Systems Ltd.	1,312.8	(20%)
Hitachi Ltd. Automotive Systems	1,484.2	(29%)	BorgWarner Inc.	1,109.4	(28%)
CalsonicKansei Corp.	1,419.9	(22%)	CalsonicKansei Corp.	1,055.7	(17%)
Benteler Automobiltechnik GmbH	1,269.0	(27%)	Nemak	1,052.5	(54%)
Timken Co.	1,196.6	(72%)	Eaton Corp.	860.3	(70%)
Behr GmbH & Co.	874.0	(23%)	Behr GmbH	756.0	(20%)
Mitsubishi Electric Corp.	681.6	(20%)	Schaeffler Group	684.0	(18%)
Kolbenschmidt Pierburg AG	360.0	(15%)	Mitsubishi Electric Corp.	414.5	(15%)
Magneti Marelli Holding S.p.A.	270.0	(6%)	CIE Automotive S.A.	289.6	(18%)
			LG Chem Ltd.	130.8	(1%)

Source: "Top 100 Global Suppliers 2009" and "Top 100 Global Suppliers 2005", both by Automotive News. Note: data include both light and heavy vehicles. Shares listed do not represent the actual share of engines/engine components, but of all North American sales.

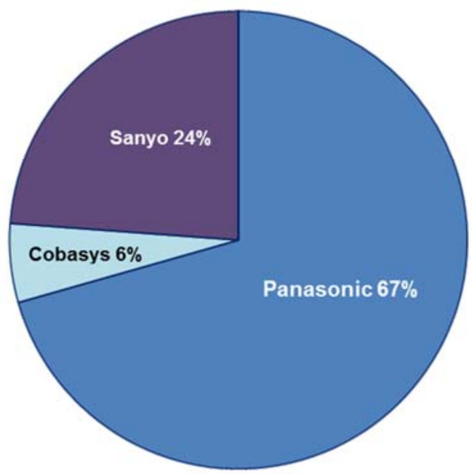
Sanyo brand name has continued. Cobasys, which produced batteries for General Motors, was sold in 2009 to SB Li Motive, LLC – a battery joint venture formed by Bosch and Samsung. For the all-electric Leaf which is coming in MY 2011, Nissan plans to use a lithium-ion battery made by NEC.

From a technical standpoint, the characteristics of batteries and electric-drive systems have improved between 2005 and 2009. 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.

Only two of the top 100 global suppliers (Johnson Controls and Panasonic) have manufactured batteries over 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). Hitachi Automotive Systems has produced electric powertrains for several years, and Valeo has recently begun producing electric powertrains.

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. DOE has supported A123, Enerdel, Delphi, GM, Ford, and GE. Worldwide, Johnson Controls can be expected to maintain the top rank. 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.

Figure 9. Share of Batteries Supplied by Company, 2009



Source: *Estimated from HEV sales*

Table 3. Batteries Supplied by Manufacturer

Calendar Year	2005	2006	2007	2008	2009	Battery Supplier
Chrysler	0	0	0	46	42	Panasonic
GMC	0	0	5,175	11,454	16,134	Cobasys, Panasonic
Ford	19,795	23,323	25,108	19,502	33,502	Sanyo
Honda	43,356	37,571	35,980	31,493	35,691	Sanyo
Nissan	0	0	8,388	8,819	9,357	Panasonic
Toyota	146,560	191,742	277,623	241,072	195,545	Panasonic
Total	209,711	252,636	352,274	312,386	290,271	

Table 4. Batteries Supplied by HEV Model

Calendar Year	2005	2006	2007	2008	2009	Battery Supplier
Cadillac Escalade	0	0	0	801	1,958	Panasonic
Chevy Malibu	0	0	0	2,093	4,162	Cobasys
Chevy Tahoe	0	0	0	3,745	3,300	Panasonic
Chrysler Aspen	0	0	0	46	33	Panasonic
Dodge Durango	0	0	0	0	9	Panasonic
Ford Escape	18,797	20,149	21,386	17,173	14,787	Sanyo
Ford Fusion	0	0	0	0	15,554	Sanyo
GMC Yukon	0	0	0	1,610	1,933	Panasonic
Honda Accord	16,826	5,598	3,405	196	0	Sanyo
Honda Civic	25,864	31,251	32,575	31,297	15,119	Sanyo
Honda Insight	666	722	0	0	20,572	Sanyo
Lexus GS 450h	0	1,784	1,645	678	469	Panasonic
Lexus HS 250h	0	0	0	0	6,699	Panasonic
Lexus LS600hL	0	0	937	907	258	Panasonic
Lexus RX400h	20,674	20,161	17,291	15,200	14,464	Panasonic
Mercury Mariner	998	3,174	3,722	2,329	1,693	Sanyo
Mercury Milan	0	0	0	0	1,468	Sanyo
Nissan Altima	0	0	8,388	8,819	9,357	Panasonic
Saturn Aura	0	0	772	285	527	Cobasys
Saturn Vue	0	0	4,403	2,920	2,656	Cobasys
Sierra/Silverado	0	0	0	0	1,598	Panasonic
Toyota Camry	0	31,341	54,477	46,272	22,887	Panasonic
Toyota Highlander	17,989	31,485	22,052	19,441	11,086	Panasonic
Toyota Prius	107,897	106,971	181,221	158,574	139,682	Panasonic
Total	209,711	252,636	352,274	312,386	290,271	

Source: *Estimated from HEV sales*

Table 5. Battery and Electric Powertrain Suppliers

Leading Suppliers in Batteries					
2005			2009		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Johnson Controls Inc.	8,924.0	(46%)	Johnson Controls Inc.	4,992.0	(39%)
Panasonic Automotive Systems	938.1	(30%)	Panasonic Automotive Systems	638.8	(25%)

Leading Suppliers in Electric Powertrains					
2005			2009		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Hitachi Automotive Systems Ltd	1,484.2	(29%)	Hitachi Automotive Systems Ltd	1,312.8	(20%)
			Valeo SA	1,040.0	(10%)

Source: "Top 100 Global Suppliers 2009" and "Top 100 Global Suppliers 2005", both by Automotive News. Note: figures include both light and heavy vehicles. Shares listed do not represent the share of batteries/powertrains.

GM and Chrysler undergo major restructuring

GM and Chrysler both filed for bankruptcy in 2009. At the direction of the Obama Administration, the Federal government intervened to facilitate a restructuring of the two companies. GM cancelled or spun-off the Pontiac, Hummer, Saturn, and Saab brands. Chrysler emerged from bankruptcy under the management control of Fiat (Fabbrica Italiana Automobili Torino) SpA.

Only two years before the bankruptcy, in May 2007, DaimlerChrysler agreed to a deal with Cerberus Capital Management to undo Daimler's merger with Chrysler, ending a 10-year partnership. Thus, data in the table labeled CHR is for DaimlerChrysler through 2007 and for Chrysler alone in 2008/2009. The recent complicated business history for Chrysler means that isolating Chrysler data is difficult. In this report, sales data are only for Chrysler and other business data, such as stock price, are omitted entirely since no continuous time-series is available.

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 five or fewer facilities each, which are spread across the United States. Though a few plants have opened in the past five years, many more have closed in 2008-2009 due to the decline in sales volumes. Those plants that have opened include Toyota's Tundra plant in San Antonio, Texas, 2006;

Table 6. Light-Vehicle Production Facilities by State and Manufacturer, 2009

State	GMC	CHR	FMC	TOY	HON	NIS	State Totals for Selected OEMs
AL					1		1
CA	1			1			1*
DE	1						1
IL		1	1				2
IN	1			2	1		4
KS	1						1
KY	1		1	1			3
LA	1						1
MI	6	3	3				12
MN			1				1
MO	1	1	2				4
MS						1	1
OH	2	2			2		6
TN	1					1	2
TX	1			1			2
OEM Total	**17**	**7**	**8**	**5**	**4**	**2**	**43**

** 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. The Subaru plant that produces Toyota Camrys is not included under Toyota.*

Source: *Ward's AutoInfobank*

General Motors, Lansing, Michigan, 2006; and Honda, Greensburg, Indiana, 2008. Between 2008 and 2009, the domestic manufacturers closed a total of ten plants, with General Motors accounting for half of that ten.

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

Due to economic difficulties in the United States, sales of cars and light trucks in 2009 were even lower than the 2008 sales. During a five-year period (2005 to 2009), sales of light trucks declined by more than 46%, while sales of cars declined nearly 30%. According to Ward's AutoInfoBank data, light-truck sales had declined slightly each year from 2005 to 2007, but the 2.1 million drop in vehicle sales from 2007 to 2008 was sudden and followed by another 1.4 million drop from 2008 to 2009. Car sales declined by 0.8 million from 2007 to 2008 and 1.35 million from 2008 to 2009 (Table 7).

In 2005, domestic manufacturers—General Motors (GMC), Ford (FMC), and DaimlerChrysler (DCC/CHR) —comprised 43% of car sales and 70% of light-truck sales. By 2009, the domestic share of car sales dropped sharply to 32% and light truck sales to about 59%. The change in car sales is even more dramatic when considered by company: in 2009, General Motors sold half of what they did in 2005 and Chrysler sold less than half the number of cars they sold in 2005. Both companies light truck sales were also down by more than half of what they sold in 2005.

The domestically owned automakers represented a 58% share of all light-vehicle sales in 2005 (Figure 10). By 2009, the domestic automaker's share of light-vehicle sales dropped to less than half (45%). Conversely, the foreign-owned manufacturers all gained market share during the same period. Toyota led the imports with 17% of all light-vehicle sales in 2009.

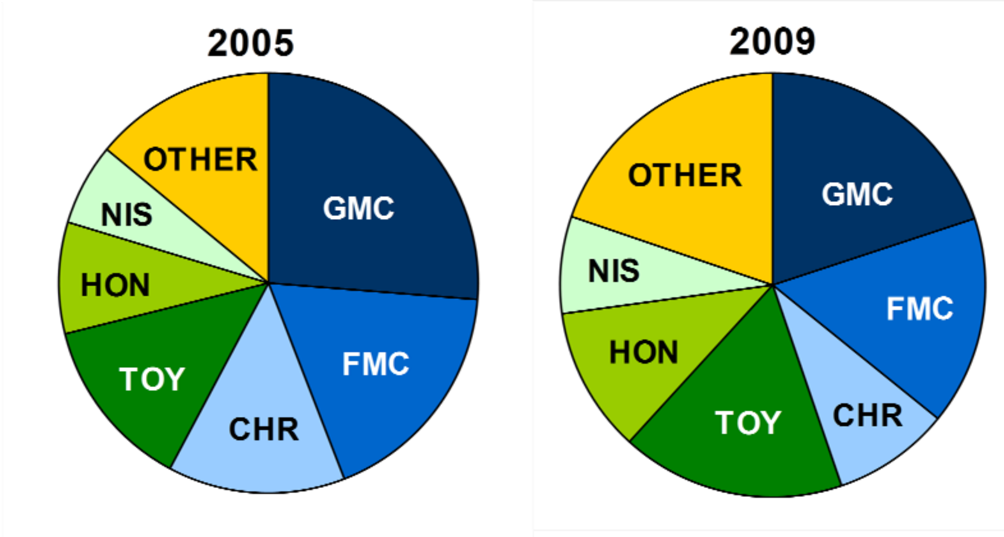
Table 7. New Vehicle Sales and Market Shares by Manufacturer

Car Sales Volumes (Millions of Vehicles)							Car Market Share	
Calendar Year	**2005**	**2006**	**2007**	**2008**	**2009**	**5-yr Δ**	**2005**	**2009**
GMC	1.74	1.62	1.49	1.26	0.87	-49.8%	22.5%	16.0%
FMC	1.01	1.07	0.82	0.72	0.63	-37.5%	13.1%	11.6%
CHR	0.58	0.55	0.57	0.41	0.23	-60.6%	7.5%	4.2%
TOY	1.29	1.46	1.51	1.36	1.05	-18.2%	16.7%	19.3%
HON	0.84	0.84	0.88	0.88	0.70	-16.6%	10.9%	12.8%
NIS	0.57	0.55	0.64	0.59	0.51	-9.8%	7.4%	9.4%
OTHER	1.69	1.73	1.71	1.59	1.45	-14.0%	21.9%	26.6%
ALL	7.72	7.82	7.62	6.81	5.46	-29.3%	100.0%	100.0%

Light Truck Sales Volumes (Millions of Vehicles)							LT Market Share	
Calendar Year	**2005**	**2006**	**2007**	**2008**	**2009**	**5-yr Δ**	**2005**	**2009**
GMC	2.71	2.45	2.34	1.70	1.20	-55.8%	29.4%	24.2%
FMC	2.02	1.71	1.62	1.23	1.02	-49.3%	21.9%	20.7%
CHR	1.73	1.59	1.51	1.04	0.70	-59.6%	18.7%	14.1%
TOY	0.97	1.08	1.11	0.86	0.72	-26.2%	10.5%	14.5%
HON	0.62	0.67	0.67	0.55	0.45	-27.3%	6.7%	9.1%
NIS	0.50	0.47	0.43	0.36	0.26	-48.8%	5.4%	5.2%
OTHER	0.68	0.71	0.79	0.64	0.60	-11.4%	7.4%	12.2%
ALL	9.23	8.68	8.47	6.38	4.95	-46.4%	100.0%	100.0%

Source: *Ward's AutoInfoBank*

Figure 10. New Vehicle Shares by Manufacturer



Source: *Ward's AutoInfoBank*

Federal scrappage program created demand for new cars

The Car Allowance Rebate System, also known as the Cash for Clunkers Program, provided Federal rebate money for consumers who traded old vehicles with an EPA combined fuel economy rating of 18 miles per gallon or less for brand new vehicles with improved fuel economy. The program was active from July 1 to August 24, 2009 and about 677,000 vehicles were traded. The average fuel economy for traded vehicles was 15.8 miles per gallon (mpg), while the average for the newly purchased vehicles was 24.9 mpg – a 58% improvement. The majority of vehicles traded were trucks (85%), but the vehicles purchased were mostly passenger cars (59%). The four-wheel drive Ford Explorer was the top trade-in vehicle, while the Toyota Camry was the top vehicle purchased (Table 8). In addition to creating a demand for new light vehicles, the program also made an impact by raising the average fuel economy of the fleet. Cars purchased under the program are, on average, 19% above the average fuel economy of all new cars.

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 five of the large auto manufacturers peaked in late 2007 (Figure 11). Chrysler historical stock prices are not shown due to company changes from Daimler-Chrysler to Chrysler to Fiat-Chrysler during this five year period. General Motors stock prices are from the company before bankruptcy in mid-2009. Though Figure 11 shows stock prices declining in 2008, the prices increase in 2009 to a level similar to that of 2005, with the exception of General Motors.

Real average vehicle costs are decreasing slightly

Average vehicle costs have slowly declined over the past five years to $23,186 in 2009 (Table 9). The last time vehicle costs were near $23,000 was in the mid-1980's (Figure 12). Real average vehicle cost has been near $25,000 since 1986. In addition, recent stability in regulatory policy—the CAFE Standards 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.

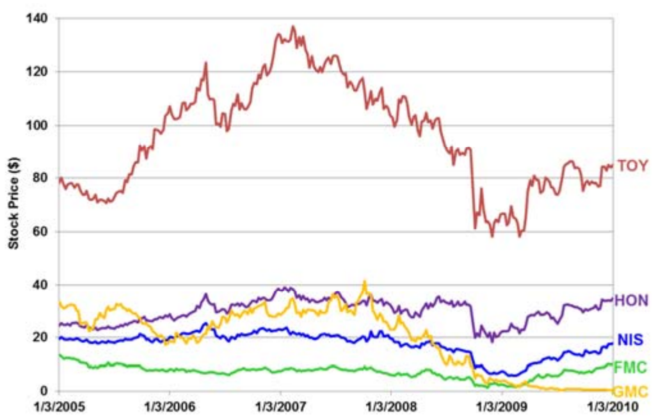
Table 8. Top 10 Vehicles in the Car Allowance Rebate System

Top 10 Trade-in Vehicles
Ford Explorer 4WD
Ford F150 Pickup 2WD
Jeep Grand Cherokee 4WD
Ford Explorer 2WD
Dodge Caravan/Grand Caravan 2WD
Jeep Cherokee 4WD
Chevrolet Blazer 4WD
Ford F150 Pickup 4WD
Chevrolet C1500 Pickup 2WD
Ford Windstar FWD Van
Top 10 New Vehicles Purchased
Toyota Corolla
Honda Civic
Toyota Camry
Ford Focus FWD
Hyundai Elantra
Nissan Versa
Toyota Prius
Honda Accord
Honda Fit
Ford Escape FWD

Note: *2WD = two-wheel drive; 4WD = four-wheel drive; FWD = front-wheel drive.*

Source: *NHTSA*

Figure 11. Stock Prices for Major Vehicle Manufacturers



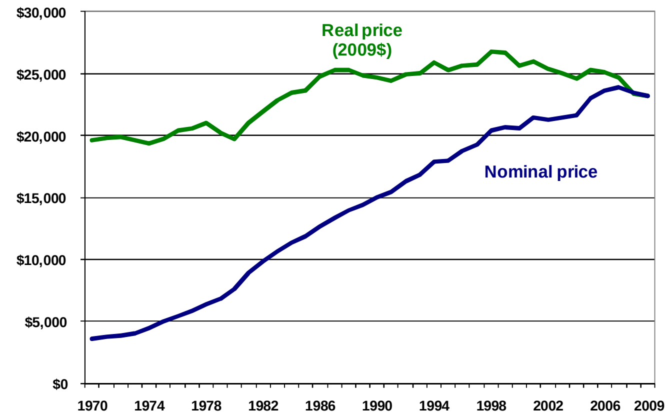
Source: *Yahoo Finance*

Table 9. Average Vehicle Cost

Calendar Year	Real Price ($2009)
2005	25,284
2006	25,151
2007	24,721
2008	23,334
2009	23,186
5-yr Δ	-8.3%

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

Figure 12. Average Price of a New Car



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

Light trucks make up 47.5 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 10 and Figure 13). 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 a sport utility vehicle (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 2009 signifies that consumers shifted toward cars.

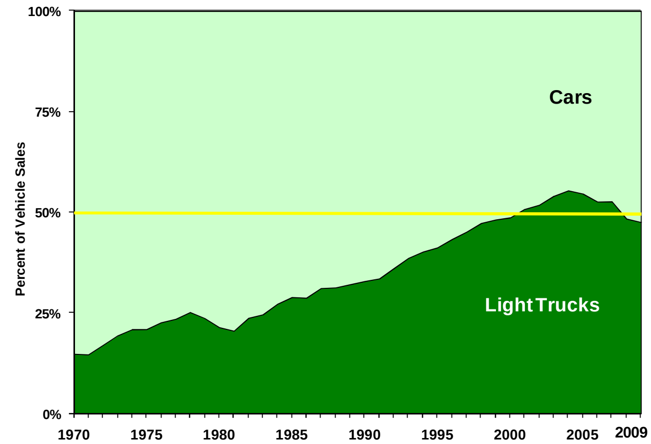
Table 10. Light Truck Share of Total Light Vehicle Sales

Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
GMC	16.0%	14.8%	14.5%	12.9%	11.5%	-28.0%
FMC	11.9%	10.4%	10.1%	9.3%	9.8%	-17.4%
CHR	10.2%	9.6%	9.4%	7.9%	6.7%	-34.2%
TOY	5.7%	6.5%	6.9%	6.5%	6.9%	20.2%
HON	3.7%	4.1%	4.2%	4.2%	4.3%	18.4%
NIS	2.9%	2.8%	2.7%	2.7%	2.5%	-16.6%
OTHER	4.0%	4.3%	4.9%	4.9%	5.8%	44.4%
ALL	54.5%	52.6%	52.6%	48.4%	47.5%	-12.7%

Source: *Ward's AutoInfoBank*

General Motors, Ford, and Chrysler depend heavily on light truck sales, which are more than half of their total light vehicle sales (Table 11). Light trucks are about 40% of Toyota and Honda light vehicle sales in 2009, while Nissan's light truck share is 33%. Though most manufacturers' light truck sales share declined from 2005 to 2009, there is no clear trend of decline in the intervening years – the shares are both up and down over the five-year period. The only manufacturer to increase their share of light trucks when comparing 2005 to 2009 data is Chrysler. However, because the 2005 data include Daimler and the 2009 data do not, it is not as accurate a comparison as the other manufacturers.

Figure 13. Share of New Vehicle Sales by Vehicle Type



Source: *Ward's AutoInfoBank*

Table 11. Light Trucks Sales Share by Manufacturer

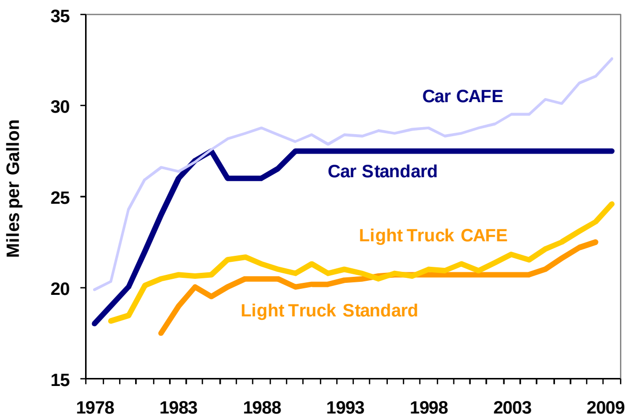
Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
GMC	60.9%	60.2%	61.1%	57.4%	57.8%	-5.1%
FMC	66.7%	61.5%	66.4%	63.1%	61.9%	-7.2%
CHR	74.9%	74.3%	72.6%	71.7%	75.3%	0.6%
TOY	42.9%	42.5%	42.4%	38.7%	40.4%	-5.8%
HON	42.5%	44.4%	43.2%	38.5%	39.2%	-7.8%
NIS	46.7%	46.1%	40.2%	37.9%	33.2%	-28.9%
OTHER	28.7%	29.1%	31.6%	28.7%	29.3%	2.2%
ALL	54.5%	52.6%	52.6%	48.4%	47.5%	-12.7%

Source: *Ward's AutoInfoBank*

CAFE has increased for cars and light trucks

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 21.0 mpg in model year (MY) 2005 to 23.1 in MY 2009 (an increase of 10%). The actual fuel economy improvement for cars during the past five years was 2.3 mpg (an increase of 7.6%), while the actual fuel economy increase for light trucks was 2.5 mpg (an increase of 11.3%) (Figure 14).

Figure 14. 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 2009 CAFE data among the top 6 OEMs, Honda sold the most fuel-efficient fleet of domestic passenger cars, while Toyota sold the most fuel- efficient fleet of import passenger cars and the most fuel-efficient fleet of light trucks (Table 12). Chrysler manufactured the least fuel-efficient domestic car fleet, Ford manufactured the least efficient import passenger cars, and General Motors manufactured the least fuel-efficient light truck fleet. Honda and Nissan achieved significant improvements in domestic passenger car fuel economy in the past five years. Nissan achieved a large gain in import passenger car fuel economy. Ford's and General Motors' import passenger cars and Chrysler's domestic passenger cars CAFE figures actually declined from 2005 to 2009. 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 12. CAFE by Manufacturer

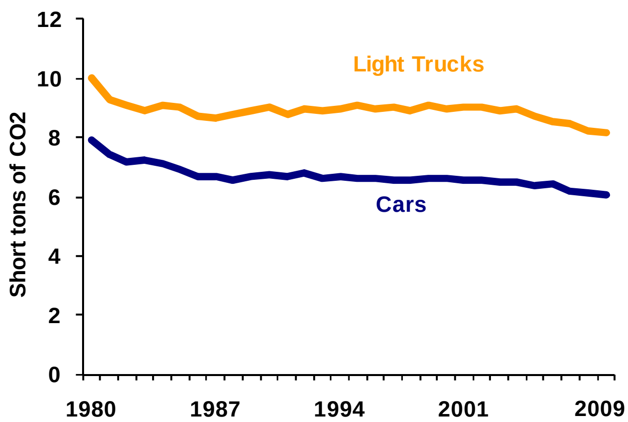
Corporate Average Fuel Economy (miles per gallon)						
Domestic Passenger Cars						
	2005	**2006**	**2007**	**2008**	**2009**	**5-yr Δ**
CHR	28.8	26.0	28.5	29.3	28.5	-1.04%
FMC	28.6	28.2	29.0	30.1	31.1	8.74%
GMC	29.3	29.9	30.0	29.6	31.0	5.80%
HON	33.2	33.8	33.5	36.0	36.5	9.94%
NIS	30.7	31.1	33.4	33.9	33.6	9.45%
TOY	34.4	34.6	31.3	34.0	35.8	4.07%
Import Passenger Cars						
	2005	**2006**	**2007**	**2008**	**2009**	**5-yr Δ**
CHR	25.9	24.7	24.7	26.5	*	*
FMC	27.7	28.4	29.8	31.1	26.8	-3.25%
GMC	30.5	29.0	32.3	31.5	30.2	-0.98%
HON	33.1	34.5	39.3	33.5	34.0	2.72%
NIS	24.8	24.3	29.6	29.2	32.2	29.84%
TOY	36.6	35.0	38.3	38.3	39.2	7.10%
Light Trucks						
	2005	**2006**	**2007**	**2008**	**2009**	**5-yr Δ**
CHR	21.4	21.7	22.9	23.6	24.1	12.62%
FMC	21.6	21.1	22.3	23.6	24.4	11.11%
GMC	21.8	22.8	22.4	23.2	23.5	8.72%
HON	24.9	24.7	25.1	25.5	26.0	7.23%
NIS	21.7	21.9	22.9	23.1	24.9	16.13%
TOY	23.1	23.7	23.7	23.9	26.1	15.58%

* Note that Chrysler sold no import passenger cars in 2009.

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 CO_2 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 15 shows that the average carbon footprint for cars and light trucks has not changed a lot during the past 20 years. Despite this apparent stagnation, engines and other performance metrics have improved, as later figures and discussion will show. Consumers have opted for bigger, more powerful vehicles, and their choosing power over fuel economy has effectively nullified any historical potential for fuel efficiency gains. Table 13 shows the average carbon footprint for a Ford Taurus over time. The recent change to a 6-speed, 3.5 liter engine reduced the amount of CO_2 that the average Taurus will emit, despite the increase in size (passenger volume).

Figure 15. 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*

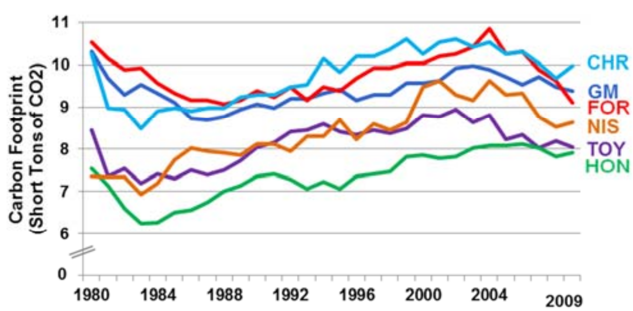
Table 13. Carbon Footprint for a Ford Taurus

Model Year	Annual Tons of CO2 per year	Engine Description	Passenger Volume (Cubic Feet)
1986	9.3	Automatic, 4-spd, 6 cyl, 3.0 L	100.00
1996	9.3	Automatic, 4-spd, 6 cyl, 3.0 L	102.00
2006	9.3	Automatic, 4-spd, 6 cyl, 3.0 L	105.00
2010	8.5	Automatic, 6-spd, 6 cyl, 3.5 L	108.00

Source: *DOE/EPA, Fueleconomy.Gov*

When looking at the average carbon footprint per vehicle on a manufacturer level, as shown in Figure 16, four of the six manufacturers had a smaller average footprint in 2009 than they did in 1980. Honda and Nissan, the two for which the average per-vehicle carbon footprint was greater in 2009, have added large trucks and vans to their vehicle line-up since 1980. The coincidence of most OEM's carbon footprint peak in 2004-2005 and the peak in the percentage of light truck sales can be seen by comparing this table with Figure 13.

Figure 16. Average Carbon Footprint per Vehicle by Manufacturer



Source: *EPA, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2009*

Most light vehicles gained weight

During the past five years, new cars gained an average of 70 pounds (2%) and light trucks gained an average of 44 pounds (1.3%) (Table 14). General Motors increased the average weight of their vehicles by more than 5% in that time period. New cars made by Nissan were actually lighter in 2009 than in 2005. (Because this is a sales-weighted average, it may not mean that the individual vehicles are lighter, but the average of vehicles sold is lighter.) For light trucks, General Motors and Ford increased the average weight of their vehicles by more than 5%. Ford had a substantial decrease in the weight of light trucks during this period (6.5%).

Table 14. Average New Vehicle Weight by Manufacturer

Model Year	2005	2006	2007	2008	2009	5-yr Δ
Cars						
GMC	3,462	3,562	3,566	3,640	3,649	5.4%
FOR	3,648	3,682	3,584	3,686	3,654	0.2%
CHR	3,756	3,949	3,822	3,786	3,873	3.1%
TOY	3,223	3,236	3,362	3,322	3,331	3.4%
HON	3,308	3,335	3,289	3,333	3,356	1.5%
NIS	3,521	3,525	3,483	3,463	3,410	-3.2%
ALL	3,463	3,534	3,507	3,527	3,533	2.0%
Light Trucks						
GMC	4,926	4,795	5,222	5,090	5,102	5.1%
FOR	4,869	5,003	4,899	4,653	4,643	-6.5%
CHR	4,561	4,645	4,592	4,618	4,720	4.6%
TOY	4,413	4,459	4,531	4,630	4,551	4.0%
HON	4,179	4,227	4,242	4,192	4,251	2.1%
NIS	4,752	4,746	4,667	4,744	4,692	-1.7%
ALL	4,668	4,665	4,752	4,710	4,712	1.3%

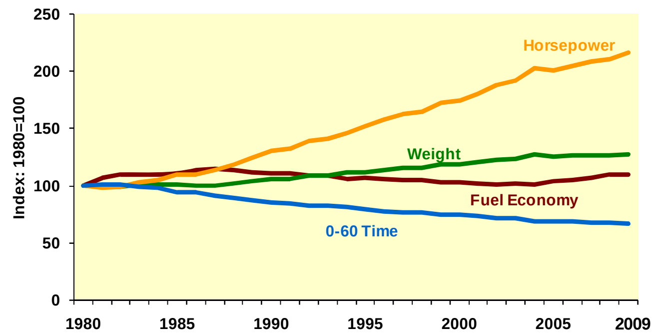
Source: *EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2009*

Consumers are purchasing more powerful engines

From 1980 to 2009, 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 9.5 seconds (Figure 17). 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 2.9% increase in average light-vehicle fuel economy between 1981 and 2009.

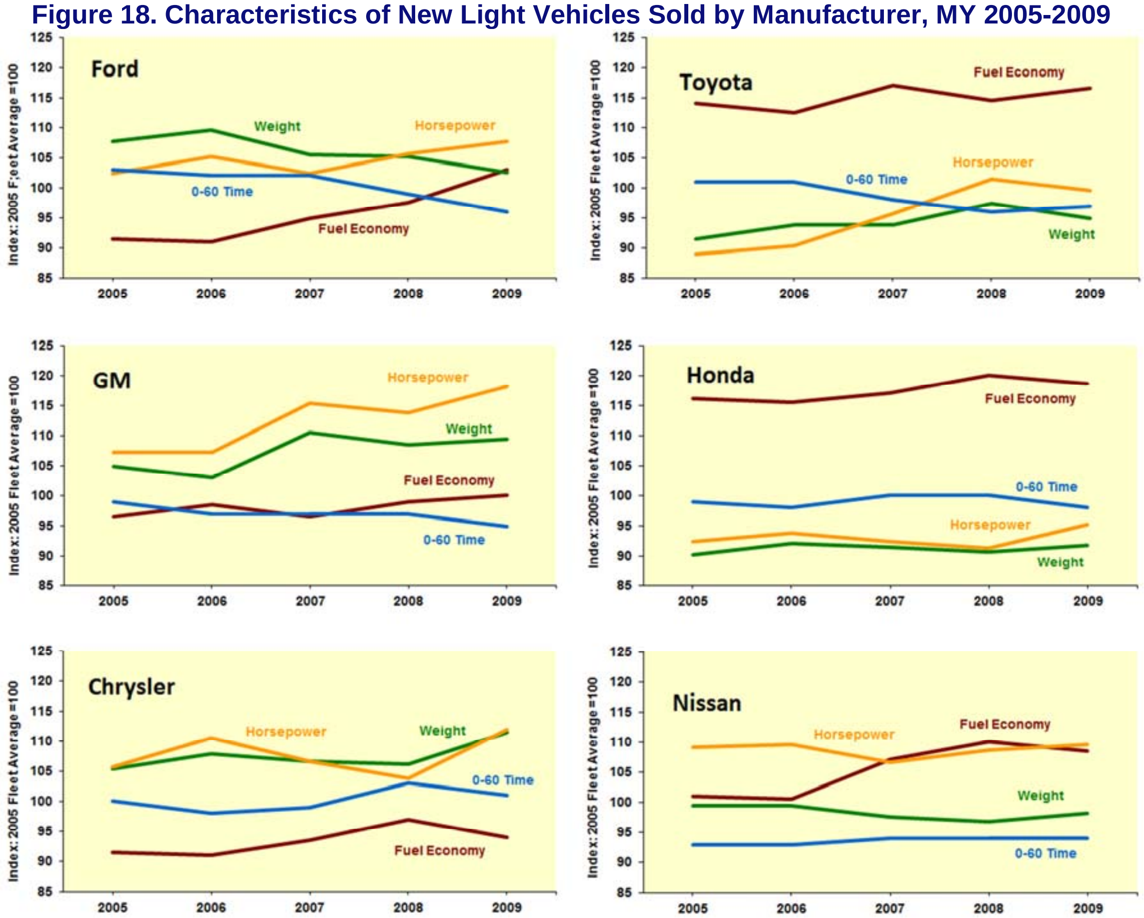
Figure 18 shows indices of the horsepower, weight, fuel economy, and 0-60 time by manufacturer from 2005 to 2009. Keeping in mind that each manufacturer is indexed to the fleet average in 2005, the figure shows not only how each manufacturer compares to the average, but also the changes that the manufacturers are making during this turbulent time in the light vehicle market. The changes to Ford's light vehicles over the past five years are noteworthy — fuel economy and horsepower are up, while weight and 0-60 time are down. However, the fuel economy average for Ford's light vehicles in 2005 was below the industry average. The 2006 introduction of the Ford Fusion is likely to have helped raise Ford's average fuel economy. The redesign of the Toyota Tundra in 2007, with a substantial increase in horsepower, is evident in the figure. Honda's light vehicles in 2009 are very similar to that of 2005. However, Honda's average fuel economy is well above the industry average, while weight and horsepower are below the industry average. The Nissan Versa, introduced in 2007, is likely responsible for Nissan's average fuel economy improvement.

Figure 17. Characteristics of New Light Vehicles Sold, MY 1980-2009



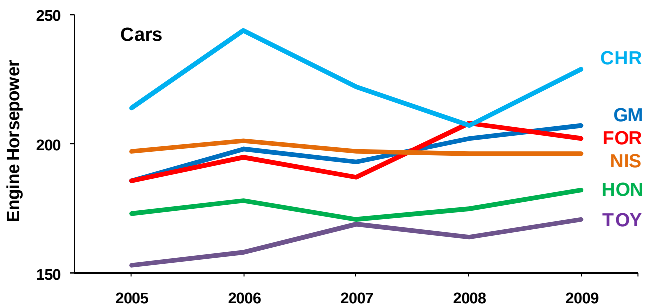
Source: *EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2009*

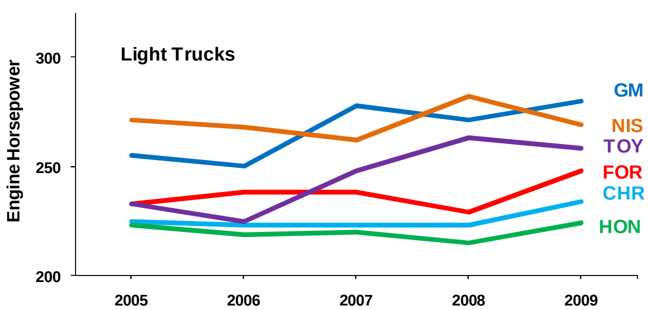
Figure 18. Characteristics of New Light Vehicles Sold by Manufacturer, MY 2005-2009



Engine displacement and horsepower are often closely related. Figure 19 shows an obvious spike in horsepower for DaimlerChrysler cars in 2006. This increase in horsepower from 2005 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.

Figure 19. 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 2.6%, while increasing horsepower 9% from 2005 to 2009 (Table 15). Honda also managed to increase the horsepower of their cars without increasing engine displacement. Nissan decreased engine displacement in cars, but held horsepower steady. For trucks, Ford and Chrysler reduced their overall engine displacement while increasing horsepower over the five-year period.

Table 15. Cubic Inch Displacement for Cars and Light Trucks

Model Year	2005	2009	5-yr Δ
Cars			
GM	189	190	0.5%
FOR	190	185	-2.6%
CHR	186	198	6.5%
TOY	137	145	5.8%
HON	141	141	0.0%
NIS	166	158	-4.8%
ALL	166	167	0.6%
Light Trucks			
GM	272	272	0.0%
FOR	254	226	-11.0%
CHR	250	246	-1.6%
TOY	221	232	5.0%
HON	188	187	-0.5%
NIS	258	246	-4.7%
ALL	244	238	-2.5%

Source: *EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008Manufacturers 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 16). With two more gears, the six-speed transmission allows the engine to operate at its optimum efficiency for a range of performance 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 (CVT). 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. A 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 16. New Light Vehicle Transmission Characteristics

Model Year	2005	2006	2007	2008	2009
Control System					
Manual	6.2%	6.5%	5.6%	5.3%	5.9%
Automatic	0.1%	0.0%	0.0%	0.0%	0.2%
Lockup	91.5%	90.7%	87.1%	86.8%	85.9%
CVT	2.3%	2.8%	7.2%	7.9%	8.1%
Speeds					
4	56.0%	47.7%	40.6%	38.8%	29.7%
5	37.3%	39.2%	36.2%	32.0%	33.2%
6	4.1%	8.8%	14.5%	19.5%	26.8%
7	0.2%	1.4%	1.5%	1.8%	2.3%
Variable	2.3%	2.8%	7.2%	7.9%	8.1%

Source: *EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2009*

The companies that started this particular shift toward efficiency are the transmission suppliers. Though most of the manufacturers make their own transmissions, seven of the top 100 global automotive suppliers in 2009 are in the transmission business (Table 17). However, as was the case with several engine suppliers, the U.S. share of global sales for Valeo, ZF Friedrichshafen, and BorgWarner have declined, suggesting that the market growth overseas is outpacing the U.S. growth.

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 18). From 2004 to 2008, the percentage of regular steel in an average light vehicle has decreased from 41% to 40%; while the portion of the car comprised of lightweight materials such as aluminum, magnesium, and plastics/composites has increased by 0.4 percentage points. The overall advanced materials share—defined here as aluminum, magnesium, plastics/composites, and advanced steels—has increased from 30.4% to 32.0%.

Table 17. Leading Suppliers of Transmissions, Excluding OEMs

Transmissions					
2005			2009		
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	12,768.0	(56%)	ZF Friedrichshafen AG	1,174.8	(10%)
Valeo SA	1,587.6	(15%)	BorgWarner, Inc.	1,109.4	(28%)
ZF Friedrichshafen AG	1,442.4	(16%)	Nemak	1,052.5	(54%)
BorgWarner Inc.	1,884.7	(43%:	Valeo SA	1,040.0	(10%)
Timken Co	1,196.6	(72%)	Magneti Marelli S.p.A.	236.6	(4%)
Hutchinson SA	434.0	(23%)	Hyundai-WIA Corp.	19.1	(1%)

Source: "Top 100 Global Suppliers 2009" and "Top 100 Global Suppliers 2005", both by Automotive News. Note: data include both light and heavy vehicle. Shares listed to not represent the actual share of transmissions, but all of North American sales.
Note: Many of the original equipment manufacturers (OEMs) produce their own transmissions and do not sell transmissions to others, thus, they are not included in this listing.

Table 18. Average Materials Content of North American Light Vehicles

Model Year	2004	2005	2006	2007	2008
Regular Steel	41.0%	40.7%	40.1%	40.3%	40.0%
High Strength Steel	11.9%	12.2%	12.4%	12.7%	12.9%
Stainless Steel	1.7%	1.8%	1.8%	1.8%	1.8%
Other Steel	0.8%	0.9%	0.9%	0.8%	0.8%
Aluminum	7.7%	7.9%	8.0%	7.7%	7.7%
Magnesium Castings	0.2%	0.2%	0.2%	0.2%	0.3%
Plastics and Plastic Composites	8.1%	8.3%	8.4%	8.1%	8.4%
Other Material	28.5%	28.1%	28.3%	28.2%	28.0%
All Advanced Materials	30.4%	31.2%	31.6%	31.4%	32.0%

Source: *2008 Ward's Motor Vehicle Facts and Figures*

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; three of the top 100 have a specialty in plastics and polymers, while two have a specialty in aluminum components (Table 19).

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 Magnesium Elektron, NEMAK, and Luoyang (non-U.S.).

DOE is recognized as a leading supporter of research for all of the aforementioned advanced automotive materials. Many companies are performing research on materials with assistance from DOE. For example, Arcelor-Mittal, U.S. Steel, and most of the large OEMs 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.

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. Ford's EcoBoost engines, first produced in 2009, combine GDi with turbocharging to allow the engine to have fewer cylinders without a performance penalty to the consumer. Engines equipped with EcoBoost technology are designed to deliver power and torque consistent with larger displacement, naturally aspirated engines while achieving approximately 20% better fuel efficiency and 15% reduced greenhouse emissions than these same engines.

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 United States

Diesel vehicles are more powerful and fuel efficient than similar-sized gasoline engines. Because of this, manufacturers may begin offering more light vehicles with diesel engines. Since 2004, 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 39 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.

Table 19. Leading Suppliers of Advanced Materials

Leading Suppliers in Automotive Steel

2005		2009	
Company	Million Metric Tons of Crude Steel Output	Company	Million Metric Tons of Crude Steel Output
Mittal Steel	63.0	ArcelorMittal	77.5
Arcelor	46.7	Baosteel	31.3
Nippon Steel	32.0	POSCO	31.1
POSCO	30.5	Nippon Steel	26.5
JFE	29.9	JFE	25.8

Leading Suppliers in Plastics, Polymers, and Components Comprised Thereof

2005			2009		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
DuPont	2,875.0	(50%)	Flex-N-Gate	2,238.1	(85%)
Collins & Aikman Corp.	2,800.0	(100%)	DuPont	1,800.0	(45%)
BASF Group	610.7	(22%)	BASF SE	1,700.0	(25%)
Plastic Omnium Co	602.5	(28%)	Toyoda Gosei Co	1,040.0	(20%)
Dow Automotive	593.8	(43%)	Bayer MaterialScience	451.2	(24%)
			Plastic Omnium Co	449.4	(20%)
			Magneti Marelli S.p.A.	236.6	(4%)

Leading Suppliers in Aluminum Components

2005			2009		
Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales	Company	Total U.S. Sales (Mil$)	U.S. % of Global Sales
Teksid Aluminum	485.6	(39%)	Nemak	1,052.5	(54%)
			Nissin Kogyo Co.	263.1	(21%)

Sources: "Top 100 Global Suppliers 2009" and "Top 100 Global Suppliers 2005", both by Automotive News. Note: figures include both light and heavy vehicles. Shares listed do not represent the share of transmissions.
Steel output from World Steel Association.

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 41 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 2010 (Table 20).

Table 20. MY 2010 Diesel Vehicles

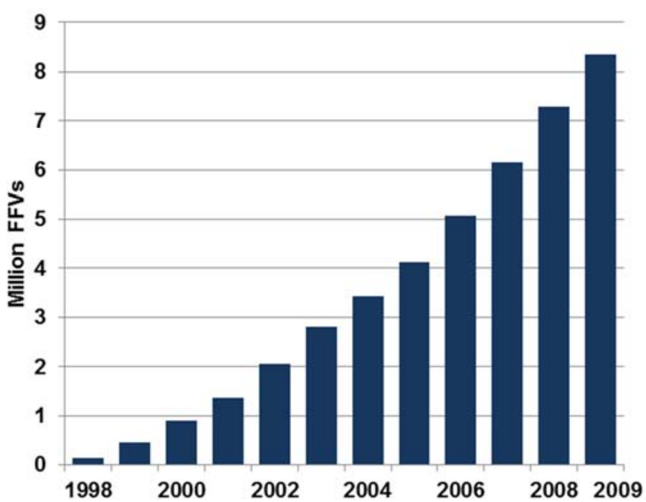
Audi A3
Audi Q7
BMW 335d
BMW X5 xDrive35d
Mercedes-Benz GL350 Blutec
Mercedes-Benz ML350 Blutec
Mercedes-Benz R350 Blutec
VW Golf
VW Jetta
VW Jetta SportWagen
VW Touareg

Source: *DOE/EPA, Fueleconomy.Gov*

Flex-fuel vehicles make their way into the population

Flex-fuel vehicles are designed to run on gasoline or a blend of up to 85% ethanol (E85). There are more than eight million flex-fuel vehicles (FFVs) in operation (Figure 20). These vehicles can be fueled by gasoline, E85 (a fuel made from 85% ethanol and 15% gasoline), or any combination of the two. Manufacturers first started making FFVs in the late 1990s; by 2005, there were 24 different FFV models on the market (Table 21). In 2009, however, there were 36 different FFV 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. Toyota and Mitsubishi have joined Nissan and Mercedes-Benz as the only foreign manufacturers to produce FFVs in 2009. In 2010, Toyota added the Sequoia to the list of FFVs.

Figure 20. Number of Flex-fuel Vehicles in Operation



Source: *Alternative Fuels and Advanced Vehicles Data Center*

Table 21. Flex-fuel Vehicle Models

Model Year	2005	2009
GMC	7	14
TOY	0	1
FMC	6	7
CHR	5	10
HON	0	0
NIS	1	2
OTHER	5	2
ALL	24	36

Source: *Alternative Fuels and Advanced Vehicles Data Center*

Toyota sells the most hybrid electric vehicles

Hybrid electric vehicles combine the benefits of gasoline engines and electric motors to improve fuel economy and/or increase power. The number of HEVs sold has increased from its 2005 level (Table 22 and Figure 21). Although HEV sales have grown during the five-year period, HEVs were not immune to the new car market decline beginning in 2008. In 2009, only five hybrid models experienced an increase in sales from 2008. The number of models available expanded from eight in 2005 to 23 in 2009. New HEV models that arrived in 2009 include the Dodge Durango, Ford Fusion, Mercury Milan, Lexus HS 250h, and Sierra/Silverado. 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 290,000 HEVs sold in 2009, only 50,000 (17% 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.

HEV incremental price has changed but has not decreased definitively

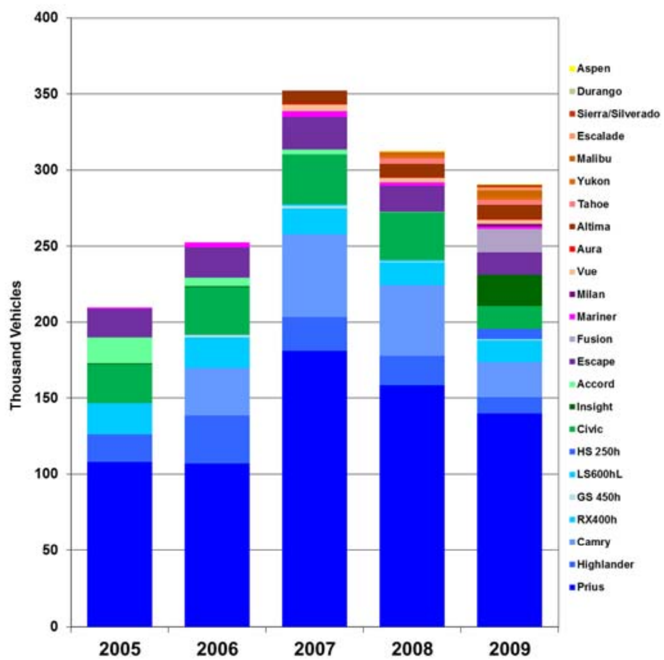
The average price of a hybrid vehicle has increased during the past five years, largely due to the introduction of a wider array of luxury hybrids (Table 23). But the average incremental price—the additional price of a hybrid over its non-hybrid counterpart—decreased from 2008 to 2009. In general, an 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 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. Hybrid Electric Vehicle Sales

Calendar Year	2005	2006	2007	2008	2009
Honda Insight	666	722	0	0	20,572
Toyota Prius	107,897	106,971	181,221	158,574	139,682
Honda Civic	25,864	31,251	32,575	31,297	15,119
Ford Escape	18,797	20,149	21,386	17,173	14,787
Honda Accord	16,826	5,598	3,405	196	0
Lexus RX400h	20,674	20,161	17,291	15,200	14,464
Toyota Highlander	17,989	31,485	22,052	19,441	11,086
Mercury Mariner	998	3,174	3,722	2,329	1,693
Lexus GS 450h		1,784	1,645	678	469
Toyota Camry		31,341	54,477	46,272	22,887
Nissan Altima			8,388	8,819	9,357
Saturn Vue			4,403	2,920	2,656
Lexus LS600hL			937	907	258
Saturn Aura			772	285	527
Chevy Tahoe				3,745	3,300
GMC Yukon				1,610	1,933
Chevy Malibu				2,093	4,162
Cadillac Escalade				801	1,958
Chrysler Aspen				46	33
Dodge Durango					9
Ford Fusion					15,554
Mercury Milan					1,468
Lexus HS 250h					6,699
Sierra/Silverado					1,598
Total	**209,711**	**252,636**	**352,274**	**312,386**	**290,271**

Source: *Alternative Fuels and Advanced Vehicles Data Center*

Figure 21. Hybrid Electric Vehicle Sales



Source: *Alternative Fuels and Advanced Vehicles Data Center*

Table 24 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.

Table 23. New Hybrid Vehicle Price

Model Year	2006	2007	2008	2009	2010
Cadillac Escalade	-	-	-	80,285	80,575
Chevy Malibu	-	-	23,895	25,555	-
ChevySilverado		28,813	-	42,663	43,080
Chevy Tahoe	-	-	50,993	51,858	52,123
Chrysler Aspen	-	-	-	45,270	-
Dodge Durango	-	-	-	45,040	-
Ford Escape	27,713	26,458	28,330	31,685	31,990
Ford Fusion	-	-	-	-	27,950
GMC Sierra	29,053	29,290	-	43,033	43,450
GMC Yukon	-	-	51,450	56,000	56,265
Honda Accord	30,990	31,090	22,600	-	-
Honda Civic	22,150	22,600	22,600	23,650	23,800
Honda Insight	20,430	-	-	-	20,550
Lexus GS 450h	-	54,900	55,800	56,550	57,450
Lexus HS 250h	-	-	-	-	35,980
Lexus LS600h	-	-	104,900	106,035	108,800
Lexus RX400h	45,360	41,880	42,780	-	43,480
Mazda Tribute	-	-	27,440	31,310	-
Mercury Mariner	29,225	27,950	29,035	30,965	30,980
Mercury Milan	-	-	-	-	28,180
Nissan Altima	-	24,990	25,480	26,650	26,780
Saturn Aura	-	22,045	23,900	26,325	-
Saturn Vue	-	22,870	25,645	28,160	-
Toyota Camry	-	26,200	25,200	26,150	26,150
Toyota Highlander	36,160	34,250	37,325	37,860	38,060
Toyota Prius	21,725	22,623	22,635	23,135	24,735

Source: *AOL Autos*

Table 24. Incremental Price of New Hybrid Vehicles

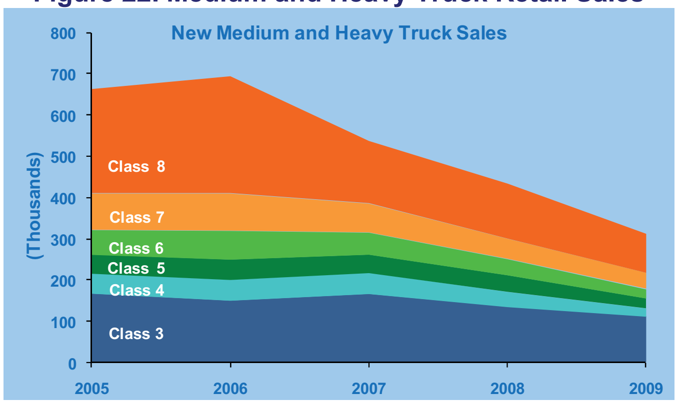
HEV Incremental Price					
Model Year	2006	2007	2008	2009	2010
Cadillac Escalade	-	-	-	6,525	6,525
Chevy Malibu	-	-	398	1,313	-
ChevySilverado	-	3,313	-	12,298	11,768
Chevy Tahoe	-	-	13,898	7,675	6,675
Chrysler Aspen	-	-	-	9,348	-
Dodge Durango	-	-	-	11,083	-
Ford Escape	4,683	3,608	5,668	7,633	7,793
Ford Fusion	-	-	-	-	3,925
GMC Sierra	1,745	1,808	-	11,335	9,808
GMC Yukon	-	-	9,038	10,583	6,145
Honda Accord	8,178	8,028	-	-	-
Honda Civic	2,650	2,900	445	3,403	3,403
Lexus GS 450h	-	-	-	-	-
Lexus HS 250h	-	-	-	-	-
Lexus LS 600h	-	-	-	-	-
Lexus RX 400h	-	-	-	-	-
Mazda Tribute	-	-	4,485	7,628	-
Mercury Mariner	5,143	3,955	5,143	5,883	5,510
Mercury Milan	-	-	-	-	3,010
Nissan Altima	-	1,815	1,835	2,010	1,780
Saturn Aura	-	-	860	1,373	-
Saturn Vue	-	2,278	233	1,053	-
Toyota Camry	-	2,955	1,855	2,230	1,930
Toyota Highlander	7,965	5,705	6,400	3,250	7,798
Average	**5,061**	**3,637**	**4,188**	**6,154**	**5,852**

Source: *AOL Autos*

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 22). Although the total-sale composition changed somewhat by class, the total sales of heavy and medium trucks increased slightly or changed little from 2005 through 2006. In 2007, heavy-truck sales had a sharp reduction, followed by declines in 2008 and 2009. By 2009, 53% fewer heavy and medium vehicles were sold than five years earlier (Table 25).

Figure 22. Medium and Heavy Truck Retail Sales



Source: *Ward's Motor Vehicle Facts and Figures*

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, with declines continuing to 2009. Class 7 heavy trucks experienced a less-drastic, but still sharp, decline. Sales of heavy trucks continued to decline in 2008 and 2009. Unlike sales of heavy trucks, medium-truck sales continued to increase slightly or stagnate in 2007 relative to their 2006 volumes, then declined drastically beginning in 2008 and continued to fall in 2009.

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 the three domestic manufacturers. The market share among these makers shifted considerably during the past five years (Figure 23 and Table 26). GM has increased its medium-truck market share from 2% in 2005 to 22% in 2009. Chrysler sold 32% more class 3 trucks in 2009 than in 2005. Ford, however, accounted for 74% of sales in 2005, but dropped to less than 35% of sales in 2009.

The recent downturn in the economy heavily affected 2008 and 2009 sales. From 2005 to 2009, total sales declined by 33%.

Table 25. Medium and Heavy Truck Retail Sales

Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
Class 3	166,856	149,844	165,896	134,839	111,704	-33%
Class 4	48,493	50,286	50,991	36,374	19,858	-59%
Class 5	46,278	49,466	44,922	40,300	23,942	-48%
Class 6	60,154	70,029	53,789	39,397	22,001	-63%
Class 7	88,858	90,792	70,426	48,880	39,087	-56%
Class 8	252,792	284,008	150,965	133,473	94,798	-62%
TOTAL	**663,431**	**694,425**	**536,989**	**433,263**	**311,390**	**-53%**

Source: *Ward's Motor Vehicle Facts and Figures*

Table 26. Class 3 Truck Retail Sales, by Manufacturer

Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
Chrysler	35,038	36,057	46,553	29,638	46,088	32%
Ford	122,903	105,955	81,155	60,139	38,664	-69%
Freightliner*	14	0	0	0	0	-100%
General Motors	2,788	2,578	33,507	41,559	24,760	788%
International	0	0	0	609	341	
Isuzu	5,167	4,929	4,350	2,568	1,473	-71%
Mitsubishi-Fuso	670	93	52	202	275	-59%
Nissan Diesel	276	232	279	112	0	-100%
Sterling	0	0	0	12	103	
Total	**166,856**	**149,844**	**165,896**	**134,839**	**111,704**	**-33%**

** Freightliner/Sterling/Western Star.*

Source: *Ward's Motor Vehicle Facts and Figures*

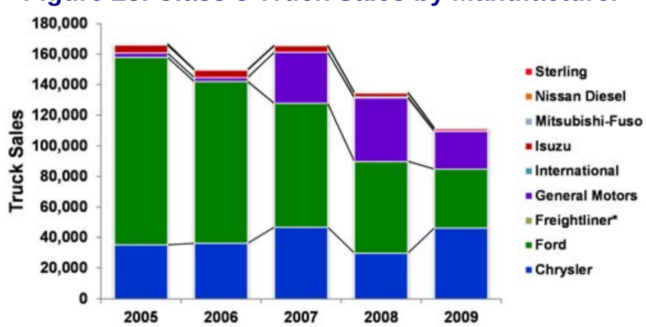
Table 27. Class 4-7 Truck Sales, by Manufacturer

Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
Ford	61,358	69,070	70,836	46,454	26,602	-57%
Freightliner*	51,639	51,357	42,061	30,809	20,450	-60%
GM	45,144	41,340	34,164	24,828	12,255	-73%
Hino	4,290	6,203	5,448	4,917	2,980	-31%
International	0	61,814	40,268	35,022	26,237	
Isuzu	10,620	10,822	9,639	6,157	3,530	-67%
Kenworth	3,874	5040	4,239	3,710	3,013	-22%
Mitsubishi-Fuso	4,842	5,967	5,218	2,136	1,283	-74%
Navistar	54,895	0	0	0	0	-100%
Nissan Diesel	2,382	2,551	2,080	1,273	0	-100%
Peterbilt	4,739	6,307	5,009	3,792	2,839	-40%
Sterling	0	102	578	467	609	
UD Trucks	0	0	0	0	888	
Total	**243,783**	**260,573**	**219,540**	**159,565**	**100,686**	-59%

Freightliner/Sterling/Western Star.

Source: *Ward's Motor Vehicle Facts and Figures*

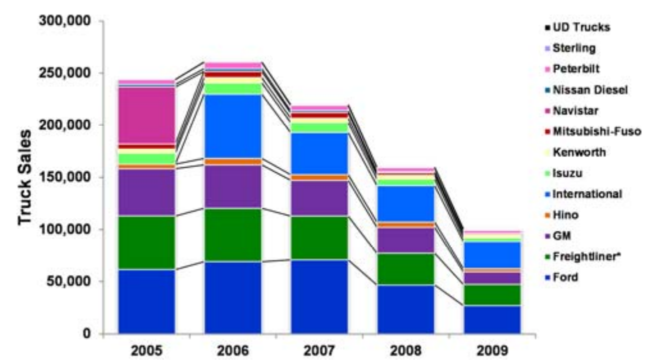
Figure 23. Class 3 Truck Sales by Manufacturer



**Freightliner/Sterling/Western Star*

Source: *Ward's Motor Vehicle Facts and Figures*

Figure 24. Class 4-7 Truck Retail Sales by Manufacturer



**Freightliner/Sterling/Western Star.*

Source: *Ward's Motor Vehicle Facts and Figures*

Class 4-7 truck sales have declined steadily since 2006

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, UD Trucks entered the market in 2009, while Nissan Diesel exited. For these four classes combined, Ford and International were each responsible for one-quarter of the sales in 2009; Freightliner held a 20% market share and General Motors was 12% (Figure 24 and Table 27).

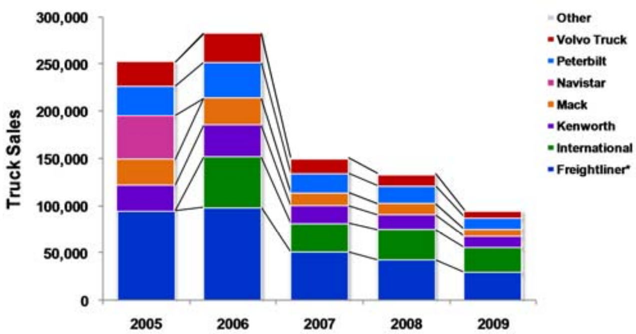
Sales volumes decreased notably in 2007 from their 2006 levels, probably because of new, more stringent diesel emission technologies—and a corresponding price increase and uncertainty—in response to the introduction of more stringent standards. General economic downturns are likely to blame for the low sales volumes in 2008 and 2009. Sales in 2009 were 59% lower than in 2005.

Class 8 truck sales dropped 47% in 2007 and continue to decline

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 seven percentage points since 2005 and International's increased (Figure 25 and Table 28).

Sales volumes decreased by 47% in 2007 from their 2006 levels perhaps due in part to the introduction of costly 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 and declined further in 2009 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 55% and 75% from 2005.

Figure 25. Class 8 Truck Retail Sales by Manufacturers



**Freightliner/Sterling/Western Star.*

***Source:** Ward's Motor Vehicle Facts and Figures*

Table 28. Class 8Truck Retail Sales, by Manufacturer

Calendar Year	2005	2006	2007	2008	2009	5-yr Δ
Freightliner*	94,900	98,603	51,706	42,639	29,576	-69%
International	0	53,373	29,675	32,399	26,581	
Kenworth	27,153	33,091	19,299	15,855	11,652	-57%
Mack	27,303	29,524	13,438	11,794	7,626	-72%
Navistar	46,093	0	0	0	0	-100%
Peterbilt	30,274	37,322	19,948	17,613	12,277	-59%
Volvo Truck	26,446	30,716	16,064	13,061	7,066	-73%
Other	623	1,379	835	112	20	-97%
Total	**252,792**	**284,008**	**150,965**	**133,473**	**94,798**	**-62%**

**Freightliner/Sterling/Western Star.*

***Source:** Ward's Motor Vehicle Facts and Figures*

Diesel engine sales have decreased significantly

Table 29 shows that the factory sales of diesel engines manufactured for heavy and medium trucks declined from 604,000 in 2005 to 221,000 in 2009.

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, and Mack/Volvo have employed such a process for the past several decades. 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.

Medium and heavy hybrid trucks are on the market

The first line production of commercial diesel electric hybrid trucks was the International DuraStar Hybrid which began production 2007. 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.

There are 17 models from eight different manufacturers of hybrid cargo trucks on the market today (Table 30). Two of those, Ford and Navistar, also manufacture fully electric trucks, along with Modec and Smith Electric Vehicles. Most of the hybrid trucks available are diesel-fueled and are used for a variety of purposes, ranging from delivery vehicles to long-haul trucks.

Table 29. Diesel Engines Manufactured by Truck Type

Diesel Engines Manufactured for Heavy Trucks					
	2005	**2006**	**2007**	**2008**	**2009**
Cummins	89,642	102,645	78,435	91,754	63,584
Navistar	34,342	41,942	26,804	31,160	24,716
Detroit Diesel	61,076	63,812	29,506	35,174	24,616
Mack	36,221	36,198	18,544	16,794	10,376
Mercedes Benz	37,670	40,148	31,101	18,647	6,613
Caterpillar	116,732	131,659	44,246	25,184	5,428
Volvo	19,298	23,455	9,850	8,822	4,116
PACCAR	0	0	9,072	5,333	2,661
Hino	814	1,497	1,319	730	745
GM	0	0	0	0	0
Grand Total	395,795	441,356	248,877	233,598	142,855
Diesel Engines Manufactured for Medium Trucks					
	2005	**2006**	**2007**	**2008**	**2009**
Navistar	159,927	138,910	120,724	78,922	66,939
Cummins	4,620	5,072	7,408	11,217	6,542
Hino	4,187	5,992	4,911	2,332	1,965
GM	19,244	18,086	13,544	13,118	1,872
Mercedes Benz	6,782	11,591	5,277	1,344	431
PACCAR	0	0	0	381	184
Caterpillar	12,424	10,954	3,679	1,184	83
Detroit Diesel	957	5	0	0	0
Mack	0	0	0	0	0
Volvo	0	0	0	0	0
Grand Total	208,141	190,610	155,543	108,498	78,016
Diesel Engines Manufactured for Medium and Heavy Trucks					
	2005	**2006**	**2007**	**2008**	**2009**
Cummins	249,569	241,555	199,159	170,676	130,523
Detroit Diesel	38,962	47,014	34,212	42,377	31,258
Caterpillar	65,263	69,804	34,417	37,506	26,581
Mack	55,465	54,284	32,088	29,912	12,248
Mercedes Benz	44,452	51,739	36,378	19,991	7,044
Volvo	116,732	131,659	44,246	25,565	5,612
Navistar	31,722	34,409	13,529	10,006	4,199
Hino	957	5	9,072	5,333	2,661
GM	814	1,497	1,319	730	745
PACCAR	0	0	0	0	0
Grand Total	603,936	631,966	404,420	342,096	220,871

Note: *These data include only factory sales of diesel trucks.*

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 31 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.

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 PM 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); NO_X was regulated at 2.5 g/HP-hr. In 2007, these regulations were

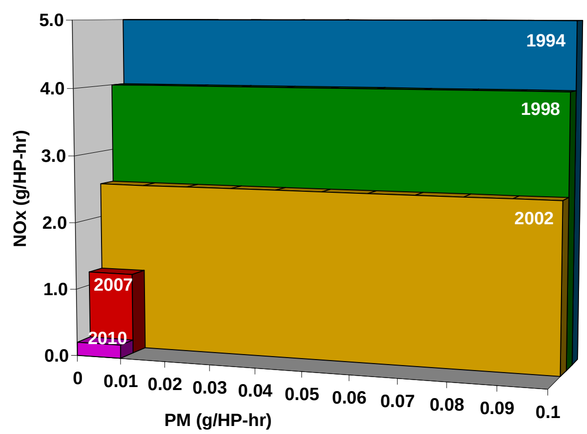
Table 30. Available Models of Hybrid and Electric Cargo Trucks

Truck OEM/Chassis	Model	Body Type/Application	Fuel	GVW Class
Bright Automotive	IDEA	Cargo Van	Gasoline hybrid	1
Ford	E450	Step Van, Shuttle Bus	Gasoline hybrid	3
GMC	TC5500	Utility	Gasoline hybrid	5
Freightliner	Business Class M2e Hybrid	City Delivery, Utility, Delivery Tractor	Diesel hybrid	7, 8
Freightliner CCC	MT-45, MT-55	Walk-in Van	Diesel hybrid	
Kenworth	T270	Delivery, Utility	Diesel hybrid	6
Kenworth	T370	Delivery, Utility	Diesel hybrid	7
Mack/Volvo	TerraPro Hybrid	Refuse	Diesel hybrid	8
Navistar, Inc	DuraStar Hybrid (Truck)	Beverage, Box Van, Refrigeration, Landscape Dump, Utility, Crane, Tree Trimmer, Recovery Towing, Armored Vehicle, Stake Flat, Grapple, Road Patch Truck, Refined Fuels, Propane Tank	Diesel hybrid	6, 7
Navistar, Inc	4300	Utility, Digger Derrick, Air Compressor	Diesel hybrid	6, 7, 8
Navistar, Inc	DuraStar Hybrid (4x2) Tractor	Beverage Diminishing Load	Diesel hybrid	7
Navistar, Inc	WorkStar Hybrid (Truck)	4x4 Utility, Landscape Dump, Snowplow, Digger Derrick, Utility, Crane, Stake Flat, Box Van, Recovery Towing, Refined Fuels, Propane Tank	Diesel hybrid	6, 7
Peterbilt	320 Hybrid (Hydraulic Launch Assist)	Refuse	Diesel hybrid	8
Peterbilt	330 Hybrid	Delivery van	Diesel hybrid	6
Peterbilt	337 Hybrid	City Delivery, Fire & Rescue, Beverage, Municipal, Refuse, Utility	Diesel hybrid	6, 7
Peterbilt	348 Hybrid	Municipal, Service, Utility	Diesel hybrid	7, 8
Peterbilt	386 Hybrid	Long Haul	Diesel hybrid	8
Ford	Transit Connect	Cargo Van	Full electric	1
Modec	Chassis Cab, Dropside & Box Van	Chassis Cab, Dropside, Box Van, Refrigerated Box Van, Tail Lift, Tipper	Full electric	3
Navistar, Inc	eStar	Delivery Van	Full electric	3
Smith Electric Vehicles	Newton	Food Distribution, Parcel Delivery, Chilled Food Distribution, Short Haul, Utility, Airport Operations, Public Sector	Full electric	5, 6, 7

Source: *Environmental Defense Fund, Innovation Exchange.*

made much more stringent: NO_X emissions were cut in half (to 1.2 g/HP-hr) and PM emissions were cut by 90% (to 0.01 g/HP-hr). NO_X emissions were cut another 83% to 0.2 g/HP-hr in 2010 (Figure 26). In response, the emissions by medium and heavy trucks were successfully cut accordingly. The sales of heavy trucks are shown in Figure 27 – the years in which new diesel emission regulations took place are noted by the darker bars.

Figure 26. Diesel Emission Regulations



Source: *EPA*

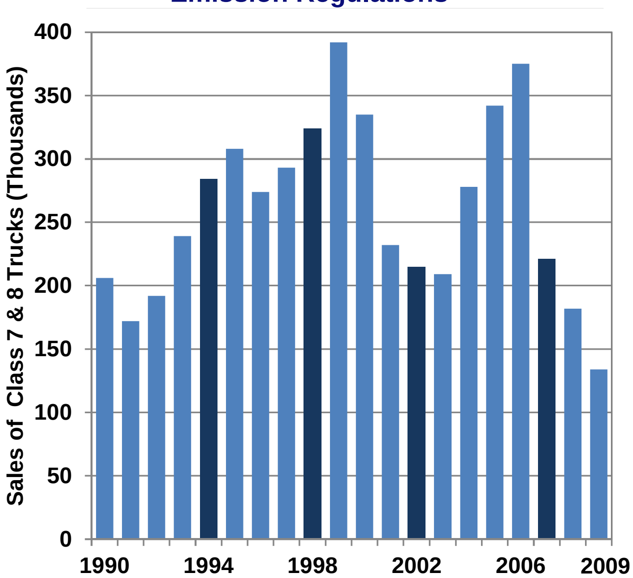
Table 31. Factors Affecting Fuel Economy

	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 aerodynamics	•Truck-trailer pairing •Vehicle speed •Driver behavior
Manufacturers	Navistar Cummins GM Detroit Diesel Caterpillar Mercedes-Benz Mack Volvo PACCAR	Daimler Trucks North America (Freightliner, Western 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*

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 32 shows the timeline of these technologies; Table 33 shows their means of operation and efficacies.

Figure 27. Heavy Truck Sales in Relation to Diesel Emission Regulations



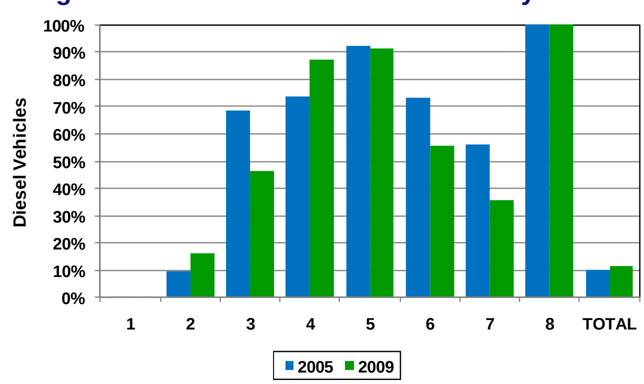
Note: Dark bars indicate years in which new diesel emission regulations are enacted.

Source: *Ward's Facts and Figures, EPA*

Medium and heavy trucks are more likely to be diesel vehicles

Most class 4–8 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. The diesel price spikes in late 2007 and early 2008 caused a minor shift away from diesel heavy trucks (Figure 28 and Table 34). Surprisingly, diesels plummeted to 35.7% of class 7 sales in 2009 from a high of 58.5% in 2006.

Figure 28. Diesel Truck Sales Shares by Class



Source: *Ward's Motor Vehicle Facts and Figures*

This shift was relatively small, because diesel fuel prices returned to levels similar to that of gasoline in 2009. 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.

Table 32. Emission Control Technologies

	2004	2005	2006	2007	2008	2009
Caterpillar	advanced combustion emissions reduction technology	advanced combustion emissions reduction technology	advanced combustion emissions reduction technology	diesel particulate filter & clean gas induction	diesel particulate filter & clean gas induction	diesel particulate filter & clean gas induction
Cummins	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation
Detroit Diesel	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation
Navistar	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation
Mack/Volvo	exhaust gas recirculation	exhaust gas recirculation	exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation	diesel particulate filter & exhaust gas recirculation

Source: *21st Century Truck Partnership Interviews and DieselNet*

Table 33. 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%	In commercial use.
Clean Gas Induction	Draws clean inert gas from downstream of the particulate filter and inserts into the intake air system.			In commercial use.
Selective Catalytic Reduction (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*

Truck stop electrification reduces idle fuel consumption

The U.S. Department of Transportation mandates that truckers rest for 10 hours after driving for 11 hours, during which time, truck operators often park at truck stops. 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. EPA 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. at one time operated single-system electrified parking spaces at 131 sites spread over 34 states, half of which were concentrated in six states. Over 150,000 professional drivers and more than 100 fleets were actively using IdleAire services, according to their website. IdleAire filed for Chapter 11 bankruptcy in 2008 and began restarting service in May 2010.

“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 eight 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 35).

Table 34. Diesel Truck Sales as a Percent of Total Truck Sales

Class	2005	2006	2007	2008	2009
1	0.1%	0.0%	0.0%	0.0%	0.0%
2	9.5%	10.1%	10.4%	12.9%	16.1%
3	68.6%	68.6%	42.5%	44.1%	46.5%
4	73.8%	75.7%	78.3%	80.9%	87.2%
5	92.2%	91.6%	91.8%	92.3%	91.3%
6	73.4%	75.3%	52.4%	58.0%	55.6%
7	55.8%	58.5%	50.4%	50.3%	35.7%
8	100.0%	100.0%	99.9%	99.7%	99.9%
TOTAL	10.3%	11.6%	9.3%	10.8%	11.7%

Source: *Ward's Motor Vehicle Facts and Figures*

Table 35. Truck Stop Electrification Sites

State	2006	2007	2008	2009
TX	12	19	22	21
CA	10	13	13	13
OH	–	10	11	11
PA	3	9	11	11
IL	–	7	7	7
AR	2	6	6	6
Other	19	66	66	69
Total	46	130	136	138

Source: *Alternative Fuels and Advanced Vehicles Data Center*

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, 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.”

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 36). In general, advanced materials penetrate the market as a function of the price.

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.

Table 36. 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*

Energy performance was relatively steady

The average fuel economy for medium- and heavy-duty trucks increased slightly from 2004 to 2008. 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, 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 37). Because fuel economies vary significantly among truck types, payloads carried, and duty cycles, it is not considered to be the best metric for truck efficiency. The variation of fuel consumption by truck configuration and vocation is demonstrated in the proposed EPA/NHTSA CO2 fuel consumption regulations for 2017, which are shown in this report in Figures 40 and 41 on page 44. Because these regulations refer to the future, Table 37 is still instructive as an indicator of medium and heavy trucks energy consumption today.

Table 37. Medium and Heavy Truck Fuel Economy (mpg)

Calendar Year	2004	2005	2006	2007	2008	5-yr Δ
Single-Unit	8.8	8.3	8.2	8.2	8.5	-3%
Combination	5.9	5.2	5.1	5.1	5.4	-8%
Single-Unit & Combination	6.7	6.0	5.9	5.9	6.2	-7%

Source: *FHWA, Highway Statistics*

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.

The National Academy of Sciences (NAS) has reviewed the appropriate metric to use for regulating truck fuel economy. They explored many different metrics, including miles per gallon, 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. The advisory principles resulting from the study were:

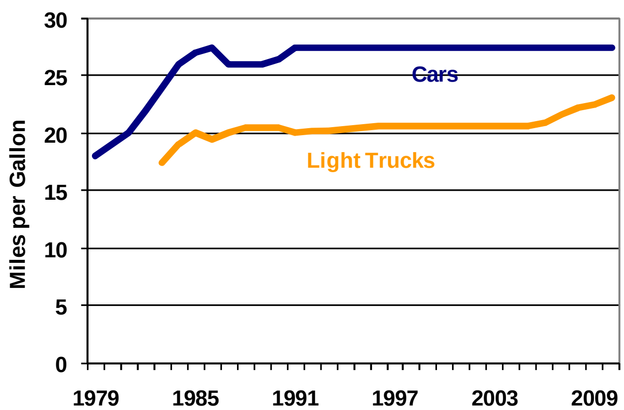
- The metric should incentivize subcomponent and total vehicle development;
- The metric should relate to the transport task or vehicle vocation;
- The metric should encourage energy conservation for a given task; and
- The metric should be based on energy or fuel consumption – e.g. equivalent diesel gallons/cargo ton-mile, normalizing to equivalent diesel fuel to take into account the differing energy densities of fuels.

Regulations on medium and heavy truck fuel economy and greenhouse gas emissions were proposed in 2010 and are based on gallons per ton-mile (and CO2 per ton-mile) as the Academy recommended. Additional details on the proposed standards are in a following section of the report.

Corporate average fuel economy rules require more fuel-efficient vehicles

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 2004 to 23.9 in 2009 (an increase of 10%) (Figure 29). Beginning in MY 2008, manufacturers have an additional choice of CAFE standards. Light trucks can be held to a reformed standard 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 through MY 2011. The reformed standard for 2009 is 23.4 mpg.

Figure 29. 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 FFVs. 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 38). Credits for cars have historically tended to be less for all manufacturers—until recently, when several manufacturers received the maximum credit.

Table 38. AMFA Flex Fuel CAFE Credits

	2004	2005	2006	2007	2008
Light Trucks					
CHR	0.0	0.1	0.1	1.0	1.5
FMC	1.3	1.1	0.8	1.5	1.2
GMC	1.2	1.0	1.1	2.7	2.0
NIS	0.0	0.8	0.9	1.1	1.4
Domestic Cars					
CHR	0.6	0.3	0.2	0.2	0.9
FMC	0.6	1.0	1.0	0.9	1.3
GMC	0.0	0.0	1.6	1.6	2.1
NIS	0.0	0.0	0.0	0.0	0.0
Import Cars					
CHR	0.5	0.6	0.0	1.9	2.0

Note: The maximum credit is 1.2 mpg; where the calculated credit exceeds the maximum credit, the maximum credit applies. Data on 2009 and 2010 credits for these manufacturers are not available.

Source: *NHTSA Flexible Fuel Credits 2003-2010*

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 39 shows the eight alternative bins (Bin 1 through Bin 8), 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 NO_X emission levels of 0.60/0.30 g/mi, 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.

Table 39. 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.

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.

Of the top 100 global suppliers in 2009, six were emission control suppliers (Table 40). Eaton Corp., which was not on the list in 2005, has 70% of their sales in the United States. Other companies, such as Faurenci and Benteler Automobilietechnik have increased their share of U.S. sales slightly over the five-year period.

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

The 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.

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

Table 40. Leading Suppliers in Emissions Control

Leading Suppliers in Emissions Control					
2005			**2009**		
Company	**Total U.S. Sales (Mil$)**	**U.S. % of Global Sales**	**Company**	**Total U.S. Sales (Mil$)**	**U.S. % of Global Sales**
Magneti Marelli Holding S.p.A.	27,000.0	(6%)	Benteler Automobiltechnik GmbH	1,902.4	(29%)
ArvinMeritor Inc.	4,498.7	(51%)	Faurecia	1,560.0	(12%)
Faurenci	1,540.0	(11%)	Tenneco Inc.	1,553.6	(43%)
Tenneco, Inc.	1,504.8	(44%)	CalsonicKansei Corp.	1,055.7	(17%)
CalsonicKansei Corp.	1,419.9	(22%)	Eaton Corp.	860.3	(70%)
Benteler Automobiltechnik GmbH	1,269.0	(27%)	Magneti Marelli S.p.A.	236.6	(4%)
Kolbenschmidt Pierburg AG	360.0	(15%)			
J. Eberspaecher GmbH	234.0	(13%)			

Source: "Top 100 Global Suppliers 2009" and "Top 100 Global Suppliers 2005", both by Automotive News. Note: figures include both light and heavy vehicles. Shares listed do not represent the share of emissions control components.

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 GVWR must meet Tier II Bin 8 requirements. No 2006, 2007, or 2008 diesel vehicles met the emissions requirements for credit; however, four vehicles in MY 2009 and seven vehicles in MY 2010 are eligible (Table 41).

Diesels enjoy economies of scale in Europe

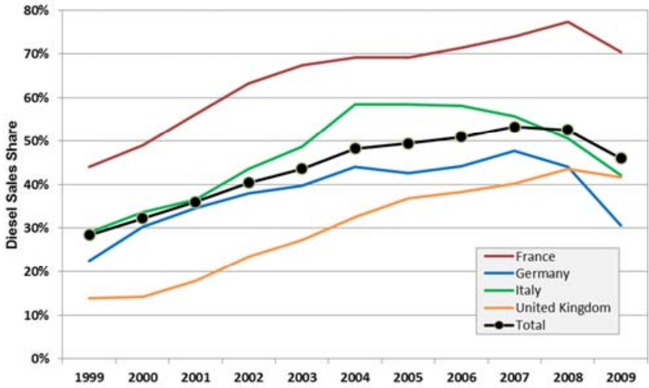
According to EEA, high diesel sales enable economies of scale, because every ten-fold increase in production cuts the cost by approximately 30% to 35%. Typical production levels for U.S. manufacturers planning to enter the diesel market are likely to be at 100,000 vehicles per year per engine model while European producers typically produce at four to eight times that level. From 2006 to 2008, more than 50% of new cars sold in Europe have been diesels (Figure 30). In 2009, the diesel penetration rate decreased to 46%, overall, likely due to sharp changes in the gasoline vs. diesel prices in Europe and the enactment of vehicle scrappage programs in several European countries.

Table 41. Federal Diesel Vehicle Credits

Vehicle Make & Model	Full Credit	Phase Out		No Credit
		50%	25%	
Audi	**Jan. 1, 2006**	**July 1 - Dec. 31, 2010**	**N/A**	**Jan. 1, 2011**
2010 Audi A3 2.0L TDI	$1,300	$650	--	$0
2009-10 Audi Q7 3.0L TDI	$1,150	$575	--	$0
BMW	**Jan. 1, 2006**	**TBD**	**N/A**	**Jan. 1, 2011**
2009-11 BMW 335d Sedan	$900	--	--	$0
2009-11 BMW X5 xDrive35d	$1,800	--	--	$0
Mercdes-Benz	**Jan. 1, 2006**	**TBD**	**N/A**	**Jan. 1, 2011**
2010 Mercedes-Benz GL 350 BlueTEC	$1,800	--	--	$0
2010 Mercedes-Benz ML 350 BlueTEC	$900	--	--	$0
2010 Mercedes-Benz R 350 BlueTEC	$1,550	--	--	$0
2009 Mercedes-Benz GL 320 BlueTEC	$1,800	--	--	$0
2009 Mercedes-Benz ML 320 BlueTEC	$900	--	--	$0
2009 Mercedes-Benz R 320 BlueTEC	$1,550	--	--	$0
Volkswagen	**Jan. 1, 2006**	**July 1 - Dec. 31, 2010**	**N/A**	**Jan. 1, 2011**
2010 Volkswagen Golf 2.0L TDI (automatic)	$1,700	$850	--	$0
2010 Volkswagen Golf 2.0L TDI (manual)	$1,300	$650	--	$0
2009-10 Volkswagen Jetta 2.0L TDI Sedan	$1,300	$650	--	$0
2009-10 Volkswagen Jetta 2.0L TDI SportWagon	$1,300	$650	--	$0
2009-10 Volkswagen Touareg 3.0L TDI	$1,150	$575	--	$0

Source: *DOE/EPA, Fueleconomy.Gov*

Figure 30. 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 42). 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.

Four states also have tax credits, and the state of Washington and the District of Columbia have tax exemptions that give consumers a financial incentive to purchase HEVs (Table 43). 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), P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass 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.

An alternative fuel blender is eligible for a $0.50 per gallon excise tax credit when producing an alternative fuel blend containing at least 0.1% gasoline, diesel, or kerosene. Qualified fuels are CNG, LNG, LPG, P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass. A $0.50 excise tax credit is also available for the sale or use of liquefied hydrogen used to produce a mixture containing a taxable fuel.

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, 2011. 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).

Table 42. Federal HEV Credits

Vehicle Make & Model		Full Credit	Phase Out 50%	Phase Out 25%	No Credit
BMW		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2011 BMW ActiveHybrid 750i		$900	--	--	--
2011 BMW ActiveHybrid 750Li		$900	--	--	--
2010 BMW ActiveHybrid X6		$1,550	--	--	--
Chrysler		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2009 Chrysler Aspen Hybrid		$2,200	--	--	--
2009 Dodge Durango Hybrid		$2,200	--	--	--
Ford Motor Company		**Jan. 1, 2006**	**Apr. 1 – Sep. 30, 2009**	**Oct. 1, 2009 – Mar. 31, 2010**	**Apr. 1, 2010**
2010 Ford Escape Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,600	$1,300	$650	$0
2010 Ford Fusion Hybrid		$3,400	$1,700	$850	$0
2010 Mercury Mariner Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,600	$1,300	$650	$0
2009 Ford Escape Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$1,950	$975	$487.50	$0
2009 Mercury Mariner 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
2008 Mercury Mariner Hybrid	2WD	$3,000	$1,500	$750	$0
	4WD	$2,200	$1,100	$550	$0
2006-07 Ford Escape Hybrid	2WD	$2,600	$1,300	$650	$0
	4WD	$1,950	$975	$487.50	$0
2006-07 Mercury Mariner Hybrid	4WD	$1,950	$975	$487.50	$0
2005 Ford Escape Hybrid	2WD	$2,600	$1,300	$650	$0
	4WD	$1,950	$975	$488	$0
Ford hybrids purchased after March 31, 2010, are not eligible for this tax credit.					
General Motors		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2010 Cadillac Escalade Hybrid (2WD & 4WD)		$2,200	--	--	--
2010 Chevrolet Malibu Hybrid		$1,550	--	--	--
2010 Chevrolet Silverado Hybrid (2WD & 4WD)		$2,200	--	--	--
2010 Chevrolet Tahoe Hybrid (2WD & 4WD)		$2,200	--	--	--
2010 GMC Sierra Hybrid (2WD & 4WD)		$2,200	--	--	--
2010 GMC Yukon 1500 Hybrid (2WD & 4WD)		$2,200	--	--	--
2010 GMC Yukon Denali 1400 Hybrid (2WD & 4WD)		$2,200	--	--	--
2009 Cadillac Escalade Hybrid	2WD	$2,200	--	--	--
	4WD	$1,800	--	--	--
2009 Chevrolet Malibu Hybrid		$1,550	--	--	--

Continued on next page.

Table 42. Federal HEV Credits (continued)

2009 Chevrolet Silverado Hybrid (2WD & 4WD)		$2,200	--	--	--
2009 Chevrolet Tahoe Hybrid (2WD & 4WD)		$2,200	--	--	--
2009 GMC Sierra Hybrid (2WD & 4WD)		$2,200	--	--	--
2009 GMC Yukon 1500 Hybrid (2WD & 4WD)		$2,200	--	--	--
2009 Saturn Aura Hybrid		$1,550	--	--	--
2009 Saturn Aura Hybrid		$1,550	--	--	--
2008 Chevrolet Malibu Hybrid		$1,300	--	--	--
2008 Chevrolet Tahoe Hybrid (2WD & 4WD)		$2,200	--	--	--
2008 GMC Yukon 1500 Hybrid (2WD & 4WD)		$2,200	--	--	--
2008 Saturn Aura Hybrid		$1,300	--	--	--
2008 Saturn Vue Hybrid		$1,550	--	--	--
2007 Chevrolet Silverado Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
2007 GMC Sierra Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
2007 Saturn Aura Hybrid		$1,300	--	--	--
2007 Saturn Vue Hybrid		$650	--	--	--
2006 Chevrolet Silverado Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
2006 GMC Sierra Hybrid	2WD	$250	--	--	--
	4WD	$650	--	--	--
Honda		**Jan. 1, 2006 - Dec. 31, 2007**	**Jan. 1- Jun. 30, 2008**	**July 1- Dec. 31, 2008**	**Jan. 1, 2009**
2008 Civic Hybrid CVT		$2,100	$1,050	$525	$0
2007 Accord Hybrid AT & Navi AT		$1,300	$650	$325	$0
2007 Civic Hybrid CVT		$2,100	$1,050	$525	$0
2006 Insight CVT		$1,450	$724	$362.50	$0
2006 Accord Hybrid AT & Navi AT		$650	$325	$162.50	$0
2006 Accord Hybrid AT & Navi AT		$1,300	$650	$325	$0
2006 Civic Hybrid CVT		$2,100	$1,050	$525	$0
2005 Insight CVT		$1,450	$725	$362.50	$0
2005 Accord Hybrid AT & Navi AT		$650	$325	$162.50	$0
2005 Civic Hybrid (SULEV) MT & CVT		$1,700	$850	$425	$0
Honda hybrids purchased after December 31, 2008, are not eligible for this tax credit.					
Mazda		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2009 Mazda Tribute Hybrid	2WD	$3,000	--	--	--
	4WD	$1,950	--	--	--
2008 Mazda Tribute Hybrid	2WD	$3,000	--	--	--
	4WD	$2,200	--	--	--

Continued on next page

Table 42. Federal HEV Credits (continued)

Mercedes-Benz		Jan. 1, 2006	TBD	TBD	TBD
2010 Mercedes-Benz ML 450 Hybrid		$2,200	--	--	--
2010 Mercedes-Benz S400 Hybrid		$1,150	--	--	--
Nissan		**Jan. 1, 2006**	**TBD**	**TBD**	**TBD**
2007-10 Altima Hybrid		$2,350	--	--	--
Toyota		**Jan. 1 – Sep. 30, 2006**	**Oct. 1, 2006 – Mar. 31, 2007**	**Apr. 1 – Sep. 30, 2007**	**Oct. 1, 2007**
2008 Prius		$3,150	$1,575	$787.50	$0
2008 Highlander Hybrid (2WD & 4WD)		$2,600	$1,300	$650	$0
2008 Lexus RX400h (2WD & 4WD)		$2,200	$1,100	$550	$0
2008 Camry Hybrid		$2,600	$1,300	$650	$0
2008 Lexus LS 600h		--	--	$450	$0
2007 Prius		$3,150	$1,575	$787.50	$0
2007 Highlander Hybrid (2WD & 4WD)		$2,600	$1,300	$650	$0
2007 Lexus RX400h (2WD & 4WD)		$2,200	$1,100	$550	$0
2007 Camry Hybrid		$2,600	$1,300	$650	$0
2007 Lexus GS 450h		$1,550	$775	$387.5	$0
2006 Prius		$3,150	$1,575	$787.5	$0
2006 Highlander Hybrid (2WD & 4WD)		$2,600	$1,300	$650	$0
2006 Lexus RX400h (2WD & 4WD)		$2,200	$1,100	$550	$0
2005 Prius		$3,150	$1,575	787.5	$0

Source: *DOE/EPA. Fueleconomy.Gov*

Table 43. State HEV Tax Credits and Exemptions

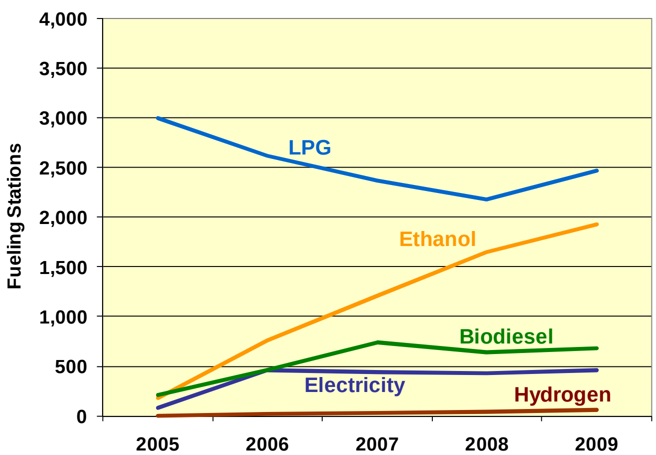
HEV Tax Credit	
Colorado	Income tax credits vary, with a maximum of $6,000.00
Oklahoma	Income tax credit of 50% of the incremental purchase cost.
	Tax credit of 10% of the total vehicle cost, up to $1,500, if the incremental cost of new AFV cannot be when AFV is resold, as long a tax credit was not previously taken on the vehicle.
Oregon	Residential tax credit 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	
D.C.	Vehicle excise tax exemption
Washington	Vehicle excise tax exemption

Source: *Alternative Fuels and Advanced Vehicles Data Center*

Consumers still face limited alternative fuel availability

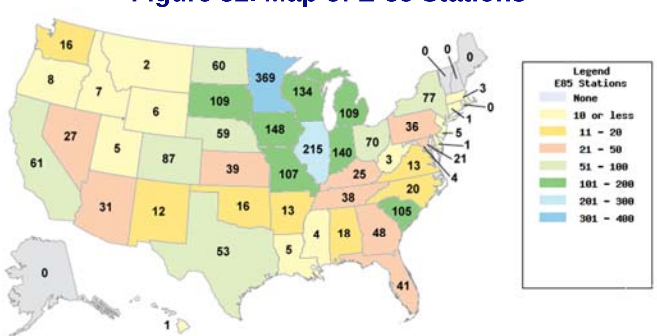
From 2005 to 2009, the total number of alternative fuel stations increased by 24%—from 5,164 in 2005 to 6,411 in 2009. Ethanol and biodiesel are the two fuels that have gained the most in the five-year period (Figures 31-35). There were 1,928 E85 stations in 2009; only five years earlier, there were only 177. Similarly, the number of biodiesel stations had grown to 679 in 2009 from only 208 in 2005. 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 2008, there were 161,786 retail gasoline outlets in the United States, thus, about 1% of stations offering gasoline also offer E85. In contrast, the numbers of LPG stations have decreased. There were about 500 fewer LPG stations in 2009 than in 2005.

Figure 31. Number of Alternative Fuel Stations



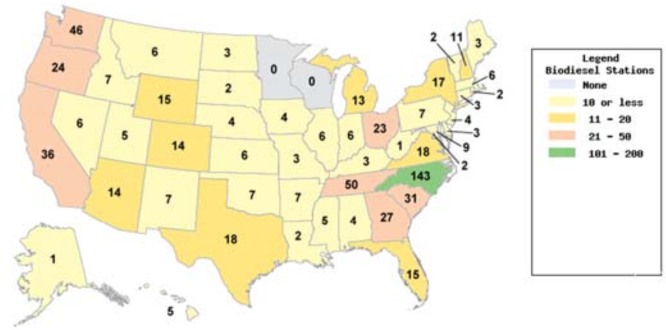
Source: *Alternative Fuels and Advanced Vehicles Data Center*

Figure 32. Map of E-85 Stations



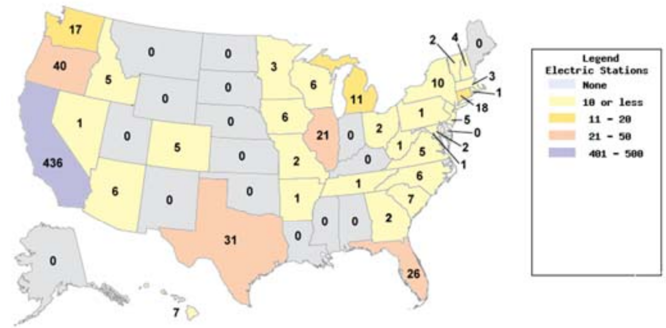
Source: *U.S. Department of Energy, Alternative Fuels Data Center*

Figure 33. Map of Biodiesel Stations



Source: *U.S. Department of Energy, Alternative Fuels Data Center*

Figure 34. Map of Electric Vehicle Charging Stations



Source: *U.S. Department of Energy, Alternative Fuels Data Center*

Figure 35. Map of Hydrogen Vehicle Charging Stations

Source: *U.S. Department of Energy, Alternative Fuels Data Center*

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 2004. 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 2005–2007 include stations offering low-level blends of biodiesel (usually B5); whereas, the 2008 and 2009 numbers only include 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 since 2003 (Table 44). 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 2003 level by 2007. These fuels comprise a greater portion of alternative fuels consumed each year

Table 44. Alternative Fuel Consumption

Year	2003	2004	2005	2006	2007	5-yr Δ
LPG	224,697	211,883	188,171	173,130	152,360	-32.2%
CNG	133,222	158,903	166,878	172,011	178,565	34.0%
LNG	13,503	20,888	22,409	23,474	24,594	82.1%
85% Ethanol (E85)	26,376	31,581	38,074	44,041	54,091	105.1%
Electricity	5,141	5,269	5,219	5,104	5,037	-2.0%
Hydrogen	2	8	25	41	66	3200.0%
Total Renewables	31,519	36,858	43,318	49,186	59,194	87.8%
Renewables % of Total	7.8%	8.6%	10.3%	11.8%	14.3%	
Total	402,941	428,532	420,776	417,801	414,713	2.9%

Source: *DOE Clean Cities Program*

SmartWay encourages efficient heavy truck purchases

EPA 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 45.

Table 45. SmartWay Certified Manufacturers

Tractors	Trailers	Tires
Daimler	Great Dane Trailers	BF Goodrich
Navistar International	Hyundai Translead	Bridgestone
Kenworth	Manac Inc.	Continental
Mack	Stoughton Trailers LLC	Double Coin
Peterbilt	Trailmobile Canada Limited	Dunlop Tire
Volvo	Utility Trailer Manufacturing Company	Falken
	Vanguard National Trailer Corporation	Firestone
	Wabash National Corporation	General
		Goodyear
		Hankook
		Michelin
		Toyo Tires
		Yokohama

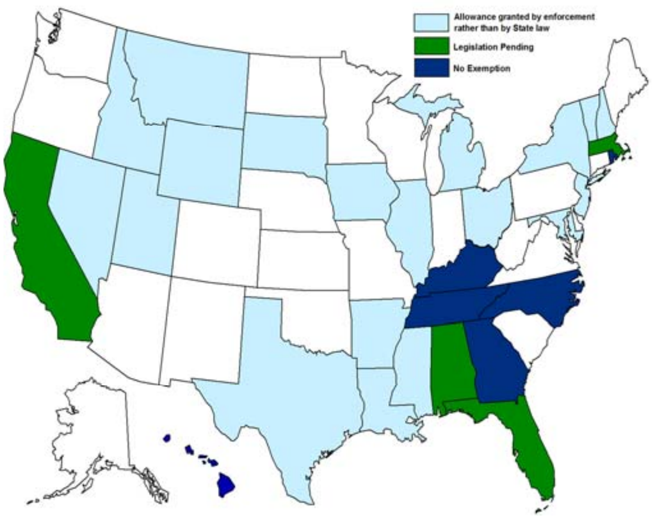
Source: *EPA*

Federal subsidies encourage idle reduction technologies

In order to encourage the use of idling reduction devices in large trucks, the Energy Policy Act of 2005 allowed for a 400-pound weight exemption for the additional weight of idling reduction technology. States were given the discretion of adopting this exemption without being subjected to penalty.

Since then, most States have passed laws which allow trucks to exceed the maximum gross vehicle weight limit by an additional 400 lbs (white States) (Figure 36). Other States have a 400 lb weight allowance which is granted by enforcement personnel (light blue States). Four States have legislation pending at this time (green States) and another four States have not adopted the weight exemption (dark blue States).

Figure 36. States Adopting 400-Pound Weight Exemption for Idling Reduction Devices, 2010



Source: *National Idling Reduction News, April 2010.*

An additional incentive for equipping large trucks with idle reduction technologies was in the Energy Improvement and Extension Act of 2008. The Act exempts certain idling reduction devices and advanced insulation from Federal excise taxes. Products which are eligible for the tax exemption include:

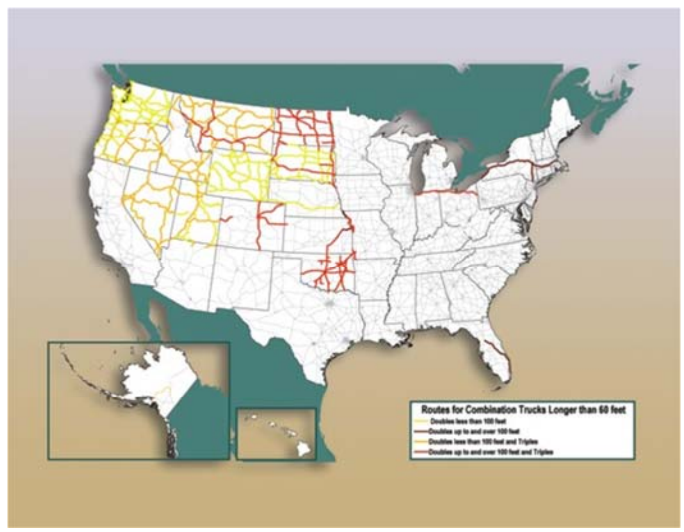
- fuel operated heaters,
- battery air conditioning/heating systems,
- auxiliary power units/generator sets,
- thermal storage systems, and
- shore connection systems.

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 37. Allowable routes for LCVs have been frozen since 1991.

The maximum truck speed limit is inconsistent among states (Figure 38). It ranges from 55 mph in three places (California, Oregon, and the District of Columbia) to 80 mph on certain roads in Utah. This 25-mph span means that there is not one common highway speed at which trucks travel. This multitude of speeds precludes truck manufacturers from 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%.

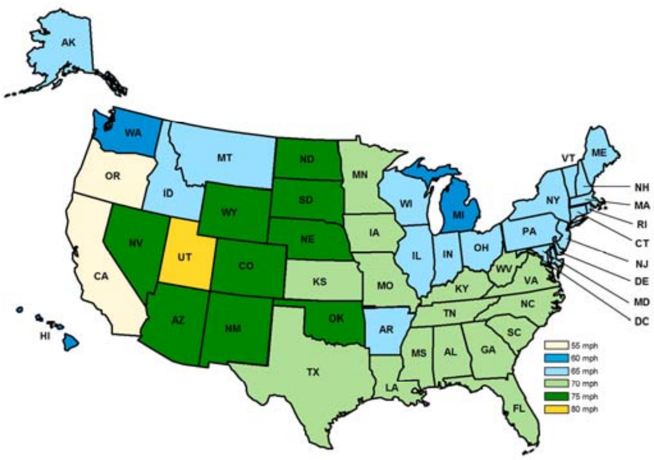
Figure 37. Routes Permitting Longer Combination Vehicles



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

Source: *FHWA, Office of Freight Management and Operations*

Figure 38. Maximum Truck Speed Limits



Source: *Insurance Institute for Highway Safety, Highway Loss Data Institute, October 2010.*

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.

Merck & Company, Inc., a pharmaceutical company, has the largest alternative fuel fleet; nearly all are flexible fuel vehicles. Schwan's Home Service Inc., a ready-made meal- and grocery-delivery company, also has a large alternative fuel vehicle fleet, which is comprised entirely of propane or propane bi-fuel vehicles (Table 46). A power company, National Grid, drives the fleet with the most natural gas-powered vehicles, and Johnson & Johnson drives the most hybrid-electric or all-electric vehicles. Nearly half of Delta airlines fleet are hybrid-electric or all-electric vehicles.

Nearly one quarter of Federal Government vehicles run on alternative fuels.

In 2009, the Federal Government owned over 650,000 vehicles; twenty-four percent of those vehicles were alternative fuel vehicles (Table 47). The alternative fuel fleet is predominantly made up of flex-fuel E-85 vehicles, though the Government owns vehicles that run on many different types of fuels. Unlike commercial fleets which tend to have only one or two different types of alternative fuel vehicles, the Federal Government owns vehicles that can run on six different fuels, not counting the gasoline and diesel fuel which run in hybrid engines.

Table 46. Commercial Fleet Alternative Fuel and Advanced Technology Vehicles

	Company	Total Alt-Fuel	CNG*	Propane*	Flex-Fuel	Hybrid/ Electric*	Biodiesel	Total Vehicles	Percent Alt-Fuel	Percent Hybrid
1	Merck & Co., Inc.	5,849			5,800	49		7,317	80%	1%
2	Schwan's Home Service Inc.	5,800		5,800				6,094	95%	0%
3	State Farm Mutual Auto Insurance Co	4,471			4,339	131	1	14,376	31%	1%
4	GE Healthcare	3,875			3,875			5,614	69%	0%
5	Xerox Corp.	3,825			3,675	150		10,450	37%	1%
6	Bristol-Myers Squibb Co.	3,562			3,550	12		5,557	64%	0%
7	Ferrellgas	3,530		3,530				3,733	95%	0%
8	Eli Lilly & Co.	3,174			3,000		174	5,113	62%	0%
9	Johnson & Johnson Services Inc.	3,037			912	2,125		9,850	31%	22%
10	Honeywell International Inc.	2,319			2,319			4,189	55%	0%
11	Consolidated Edison Company of NY	1,804	20			23	1,761	3,608	50%	1%
12	Florida Power & Light	1,524			10	263	1,251	1,851	82%	14%
13	United Parcel Service (UPS)	1,448	725	720		3		72,633	2%	0%
14	DSWaters of America	1,236		1,131		105		1,573	78%	7%
15	Monsanto Co.	1,131			1,125	6		3,365	34%	0%
16	Liberty Mutual Insurance	1,018			1,018			3,505	29%	0%
17	Delta Airlines	861	4	124	0	733		1,546	56%	47%
18	Comcast Corp.	852			756	96		40,158	2%	0%
19	National Grid	832	730	15	52	35		3,000	28%	1%
20	Ecolab Inc.	809			809			7,311	11%	0%
21	Alliant Energy	804			4		800	1,837	44%	0%
22	Novartis Pharmaceuticals	797				797		8,102	10%	10%
23	Federal Express Corp.	786	90	696				36,701	2%	0%
24	Schneider Electric/Square D	770			750	20		1,535	50%	1%
25	BMHC (BMC West/SelectBuild)	738		418	315	5		2,670	28%	0%
26	Cox Enterprises Inc.	676	6		413	257		13,130	5%	2%
27	Land O' Lakes Inc.	601			600	1		941	64%	0%
28	University of Michigan	578			483	5	90	1,081	53%	0%
29	Xcel Energy	578	112	7	102	4	353	3,280	18%	0%
30	Los Angeles World Airports	536	436	38		62		N/A	N/A	N/A
31	Southwest Gas Corp.	528	430		89	9		1,804	29%	0%
32	Questar Gas Company	502	502					N/A	N/A	N/A
33	PPG Industries	500			500			2,577	19%	0%
34	JEA Fleet Services	488			54	9	425	774	63%	1%
35	Dallas/Fort Worth International Airport	473	420	8		27	18	N/A	N/A	N/A
36	Consolidated Coca-Cola Bottling	402				402		2,537	16%	16%
37	University of California, San Diego	394	9			335	50	910	43%	37%
38	Peoples Gas Light and Coke Co.	352	352					N/A	N/A	N/A
39	Roche	339	97			242		1,906	18%	13%
40	Archer Daniels Midland	325			200		125	1,300	25%	0%
41	University of California Los Angeles	308	58	5		244	1	N/A	N/A	N/A
42	University of Washington	308			225	35	48	712	43%	5%
43	American Family Mutual Insurance Inc.	271			268	3		1,417	19%	0%
44	University of California Davis	269	71		65	73	60	800	34%	9%
45	Nicor Gas	252	26		226			1,580	16%	0%
46	University of Iowa	228			190		38	N/A	N/A	N/A
47	Santee Cooper	210		133		77		N/A	28%	N/A
48	Toshiba America Medical Systems	150		150				530	N/A	0%
49	Anixter Inc.	150		150				525	29%	0%
50	Walgreens	138		138				3,018	5%	0%

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

*Includes dedicated and bi-fuel vehicles.

Table 47. Federal Government-Owned Fleet Vehicles by Fuel Type

Fuel Type	2005	2006	2007	2008	2009
CNG	12,137	10,772	9,288	8,210	6,486
Diesel	82,687	79,954	83,285	84,326	83,794
Diesel Hybrid	*	*	*	*	53
E-85	82,864	96,229	113,046	129,858	143,652
Electric	185	111	100	83	57
Gasoline	454,452	443,318	436,168	422,758	411,870
Gasoline Hybrid	*	*	*	*	5,582
LNG	51	64	34	33	20
LPG	312	292	312	221	185
Hydrogen	0	0	0	2	4
Total	632,688	630,740	642,233	645,491	651,703

** Until 2009, hybrid vehicle sales were not reported separately.*

Source: General Services Administration, Federal Fleet Report 2005-2009.

Coming up in 2011 – 2015

As the preceding sections have shown, the economic recession of 2008 and 2009 took an especially hard toll on the American automotive industry. In the coming years, as the economy is expected to recover, so are automotive manufacturers and suppliers. Additionally, the Energy Independence and Security Act (EISA) of 2007 combined with the Obama Administration's direction to accelerate planned fuel economy regulations spell big news for the coming years: auto manufacturers are required to increase fuel economy significantly through 2016 and potentially beyond. 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 HEVs during the next five years.

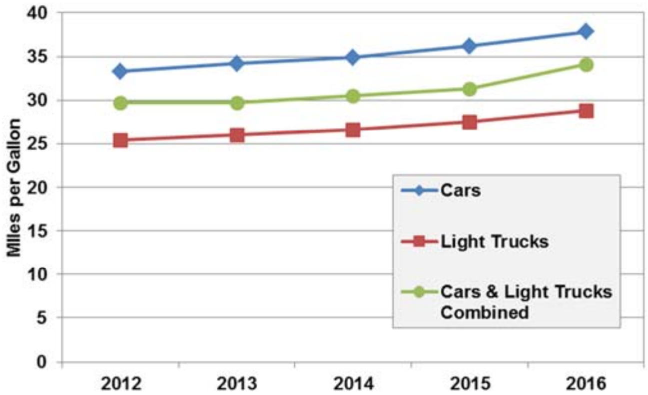
Light-vehicle CAFE standards will become more stringent

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.

For MY 2012 through MY 2016, NHTSA and EPA issued joint rulemaking to establish a new National program to regulate fuel economy and greenhouse gas emissions. The intention is not only to regulate cars and light trucks in this new program, but also medium and heavy vehicles, which have never been subject to fuel economy standards before.

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 MMT during that time. The average standards are shown in Figure 39. 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 39. Average CAFE Standards for MY 2012-2016

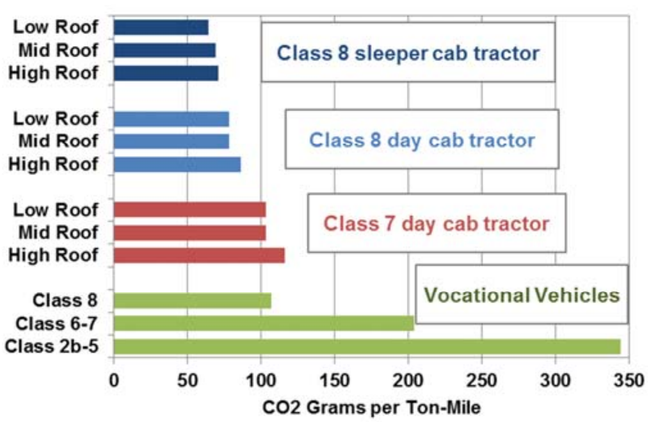


Source: *Federal Register, Vol. 74, No. 186, September 2009*

New heavy-truck fuel consumption and emissions standards will be finalized

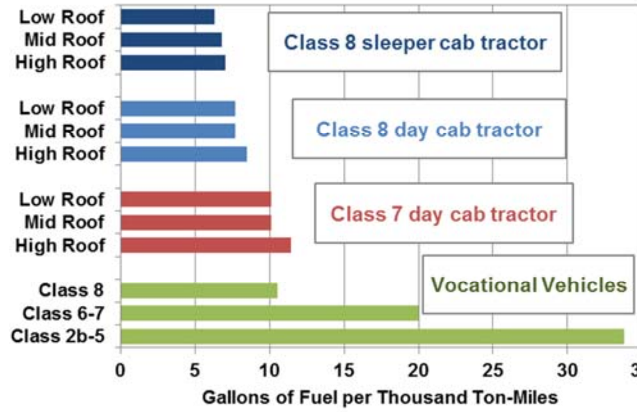
In November 2010, the EPA and NHTSA proposed new regulations on the fuel economy and greenhouse gas emissions of combination tractors, heavy-duty pickups and vans, and vocational vehicles. The standards would be phased in beginning in MY2014 and be in effect through at least 2017. There are differentiated standards for various subcategories of trucks and different methodologies of calculating standards for heavier trucks as opposed to the lighter trucks. Figure 40 shows the proposed CO2 standards for MY2017 for the different truck categories. Vocational vehicles include trucks such as smaller and larger van trucks, utility "bucket" trucks, tank trucks, refuse trucks, urban and over-the-road buses, fire trucks, flatbed trucks, and dump trucks, among others. The proposed fuel consumption standards follow in Figure 41.

Figure 40. Proposed CO2 Standards for MY 2017



Source: *Federal Register, Vol. 75, No. 229*

Figure 41. Proposed Fuel Consumption Standards for MY 2017



Source: *Federal Register, Vol. 75, No. 229*

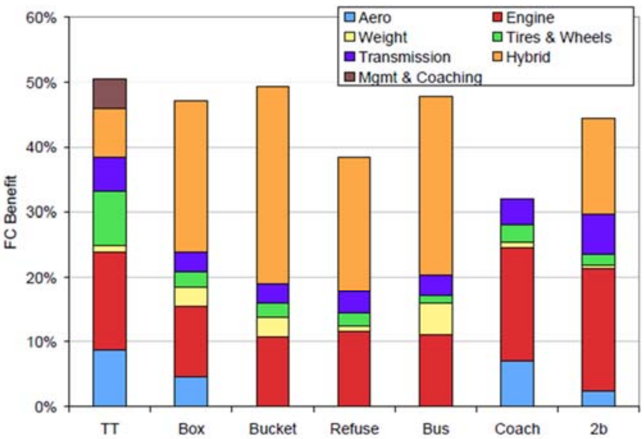
New heavy-truck technologies will be deployed in response to tighter fuel economy and emissions regulations

As a precursor to the Federal heavy truck fuel economy/greenhouse gas emission standards recently announced, NAS produced a study of the technologies and approaches to reducing fuel consumption in medium and heavy trucks. They determined that the most effective technologies in terms of fuel consumption reduction are:

- Hybridization;
- Replacement of gasoline engines with diesel engines;
- Improvement in diesel engine thermal efficiency;
- Improvement in gasoline engine thermal efficiency;
- Aerodynamics, especially on tractor-trailer applications;
- Reduced rolling resistance;
- Weight reduction.

A myriad of technologies were evaluated in the NAS study. Figure 42 shows seven fuel reduction methods and their potential for savings on various types of trucks in the 2015 to 2020 time frame. Hybridization and other engine technologies show the most promise for reducing fuel consumption in the coming years. "Management and Coaching" represent the fuel economy gains made possible by education truck drivers how to drive efficiently (smart acceleration, etc.).

Figure 42. Comparison of 2015 – 2020 New Vehicle Potential Fuel Savings Technology by Truck Type



Note: FC Benefit = fuel consumption benefit. Aero = aerodynamics. Mgmt = management.

Source: *National Research Council, Transportation Research Board, Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles*

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 HEV production and the expected introduction of plug-in HEVs at the end of 2010. Electric drive concept and production vehicles that have been announced for possible release within the next five years and the characteristics of each, where known, are summarized in Table 48.

Additionally, a greater number of batteries used in light vehicles are expected to be produced in the United States. The 2009 American Reinvestment and Recovery Act invested $2 billion in domestic battery manufacturing facilities, and these facilities, which have been under construction since awards were made in 2010, will soon begin producing batteries. The Administration has stated as its goal sufficient domestic vehicle battery production capacity to supply 500,000 electric-drive vehicles each year.

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

The economic recession of 2008-2009 severely affected the trucking industry: New Class 8 truck sales in 2009 were 95,000 units, down nearly 30% from 133,000 in 2008. The hard times 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 constrain demand for freight transport, and, therefore, for new medium and heavy trucks. Engine production volumes were at historical lows into 2009. As industries that drive freight transportation recover, fleets are expected to increase buying engine and vehicles to make up for the lag during the recession. In 2010, the production of class 6-8 trucks rose 11% and freight tonnage increased by that same amount. Truck sales volumes tend to increase just ahead of increases in GDP, thus as the economy recovers, truck sales are expected to rise.

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.

Natural gas production in the United States will grow

Due to the large natural gas discovery in Louisiana in 2009, the outlook for natural gas has changed significantly. As recent as 2006, predictions were that natural gas production was on a steady decline. But the new large discoveries (not only in Louisiana, but in other states, too) along with new technologies, have changed the outlook.

With the increase in U.S. natural gas production, the outlook is more favorable for natural gas vehicles to replace conventional vehicles in the future, especially in medium and heavy vehicle applications that have access to central refueling stations. The number of light-duty natural gas vehicles for sale to the public by the OEMs has dwindled; in the 2011 model year, the Honda Civic GX is the only light-duty CNG vehicle offered. However, a rise in natural gas production, and the price decline that will follow, may lead to a brighter future for natural gas as a transportation fuel.

Table 48. (P)HEV Demonstration and Upcoming Models

Organization	Specific Product(s) Planned	US Release	MPG	AER	Engine	Battery	Motor	Additional
AFS Trinity	XH-150 Extreme Hybrid	2013-2014	150	40		Li-Ion	8 kWh	electric traction motor
Aptera Motors	Aptera 2e	Late 2011	350	100		10-13kWh		gas, electric and PHEV models planned
Audi	R8 E-tron	Late 2012	107	31	TDI V6	Li-Ion	230kWh combined	4 asynchronous motors
Balqon Corp.	Mule M-150	Available		150		280 kWhr	300 hp	electric motor
Balqon Corp.	XE20 Yard Tractor	Available		60		140 kWhr	200 hp	electric motor
Balqon Corp.	XE30 Yard Tractor	Available		150		280 kWhr	300 hp	electric motor
BMW	Megacity	2013		160		35 kWh	150 hp	electric motor
BMW	Mini-E	2013		156		35 kWh Li-ion	150 kW	electric motor
BMW	Vision Efficient Dynamics	2013	60.6	31	1.5L turbodiesel	Li-Ion, 10.8 kWh	33 hp & 80 hp	two electric motors
BYD	e6	2011	205	186		75 kW - 160 kW	75/450	electric motor
BYD	F6-DM	N/A		60	2.0-2.4L	lithium iron phosphae		
BYD	F3-DM	2012		60	1.6L	Fe	50 hp	dual mode
Chrysler LLC	ecoVoyager	Concept	300	40		Li-ion	286 hp electric	
Chrysler	Fiat 500EV	2012	59	50		Li-ion		
Chrysler LLC	Jeep Renegade PHEV	Concept	110 equiv	40	1.5L 3 cyl	Li-ion	268 hp	electric motor
Chrysler LLC	Jeep Wrangler Range Extended EV	2010/2011	50	40	1.0L 3-4 cyl	27 kWh Li-ion	268 hp	
Chrysler LLC	Chrysler Town & Country EV minivan	2010/2011	50	40	1.0L 3-4 cyl	22 kWh Li-ion	190 kW	
Citroen	C-ZERO	Late 2010		80		330 volt Li-ion	47 kW, 64 hp	permanent magnet synchronous motor
Citroen	Survolt	Prototype		124		140 Li-Ion (2)	300 hp	race car w/ two electric motors
Coda Automotive	Coda Electric Sedan	End 2011		100		33.8 kWh Li-ion		100 kW electric drive system
Daimler	MT-WIV	2011		100		120 kW Li-ion		all electric, walk-in van
Daimler (w/ EPRI)	Sprinter PHEV Van	N/A		20	2.7L or 2.3L D	NiMH or Li-Ion	90 kW	
Daimler	Smart ED ForTwo Electric Vehicle	2012		100		16.5 kWh Li-Ion	30 kW	
Dodge	Circuit EV	2013		150-120		Li-Ion?	200 kW	electric
Exagon	Furtive e-GT	Late 2012		122-252		VL 4 - 125 kW	340 hp	dual engines
Enova Systems	PHEV School Bus	available			VT365 V8 D			electric motor
Eaton	medium-duty trucks	available			multiple	multiple	multiple	
ePower	XT320E	available		60 x 2		2 13 kWh swappable		all electric
Fisker Automotive	Quantum Karma Plug-In Hybrid	2011	100	50	2.0L direct injection	Li-ion	201 hp (2)	
Ford (w/ DOE)	AirStream HySeries	Concept	305	25		336 V Li-ion		hydrogen-powered fuel cell
Ford	C-Max PHEV	2012			1.6-2.0L 4 cyl	Li-ion		
Ford (w/ DOE)	Ford F-550 Trouble Truck	2011		10		Li-ion		
Ford (w/EPRI, Southern CA Edison & Argonne National Lab.)	PHEV Escape	2012	120	30	2.3L 4 cyl	10 kWh Li-ion		internal combustion engine
Ford	Focus EV	End 2011		100		23 kWh liquid cooled		
Ford	Transit Connect EV	2011		80		28 kWh Li-ion	28 kWH	

(Continued on next page)

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

Organization	Specific Product(s) Planned	US Release	MPG	AER	Engine	Battery	Motor	Additional
General Motors	Cadillac Provoq	Concept	300	20		Li-ion		5th generation hydrogen fuel cell
General Motors	Chevrolet Volt	available	35-40	25-50	1.4L 4 cyl	16 kWh Li-ion	150-hp electric	backup generator
General Motors	Opel Ampera	2011	311	37		16 kWh Li-ion	150-hp electric	"range extender"
Hyundai	BLUE-WILL	2012	55	20-40	1.6L	lithium polymer	100kW electric	
Infiniti	M35h	2012	32.2		67hp 3.5L V6	1.3 kWh Li-Ion	50 kW electric	
Jaguar	C-X75	Concept	560	68	2 @ 145kW	plug in Li-Ion	580kW total	4 195 hp electric motors
Kia	Electric SUV	2013		80				
Land Rover	Land Rover LRX	Late 2011	49.9					CO2 Offset Program
Land Rover	Land Rover range_3	2013		20	3.0L V6	Li-Ion	25kW electric	plug-in diesel
Lotus	Lotus CityCar Concept	Late 2013	200	35	1.2L 3 cyl	Li-Ion		plug-in hybrid powertrain
Mercedes-Benz	Vito E-Cell	2011		80	4-6 cyl	32 kWh Li-Ion	60 kW electric	
Mitsubishi	Innovative Electric Vehicle (iMiEV)	2011		80-100		330V 16kWh		all electric
Mitsubishi-Fuso	Canter E-CELL	Concept		74.5		40 kWh Li-Ion	70kW	
Navistar	eStar Delivery Vehicle	available		100		80 kWhr Li-Ion Cassette	70kW 102 hp	all electric
Nissan	PHEV	2012	300	100		24 kWh Li-Ion		
Nissan	Leaf	available		62-138		24 kWh Li-Ion	80kW synchronous	all electric
Optimal Energy	Joule EV	2014		143		36 kWh Li-ion traction	75 kW	all electric
Pininfarina	Bluecar	2011		155		L.M.P.	50 kW electric	electric
Proterra	EcoRide BE35	available		30		72 kW-h Li-Ion	150 PM 150kW	electric bus
Proterra	HFC35 Plug-in Hybrid Fuel Cell Bus	available		250			150 kW	hydrogen-powered fuel cell
Raser Technologies	Hummer H3	2011	100	40	2.0L turbo	3 Li-ion battery packs	200 kW	100 kW generator
Smith Technologies	Newton Electric Truck	2010		100		80-120kwh Li-Ion	120kw Electric	
Tessla	Roadster	2011		245	375 Volt AC Induction	Li-Ion	air-cooled electric	
Tessla	Model S	2012		160-300		42-95 kWh		45 minute quick charge - 14 hr charge (95 kWh)
Toyota	Prius PHEV	2012	50	13		5.2 hWh		
Velozzi	Solo Crossover	2011	1,000	200	770-hp AC-induction electric	30-kW microturbine		
Volkswagen	E-Up	2013		80		18 kWh Li-ion	50 kW electric	
Volkswagen	Golf TwinDrive	2011		30		Li-Ion	82 hp electric	TwinDrive connected directly to gasoline engine
Volvo	ReCharge	2012		60				
Volvo	Volvo C30 Battery Electric Vehicle	2013		90		24 KWh, 617 lb Li-Ion		8 hr recharging time

Source: *Plug-In Vehicle Activities Summary, October 2010.*

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.

Class I Freight Railroads

Seven railroads are considered Class I Railroads

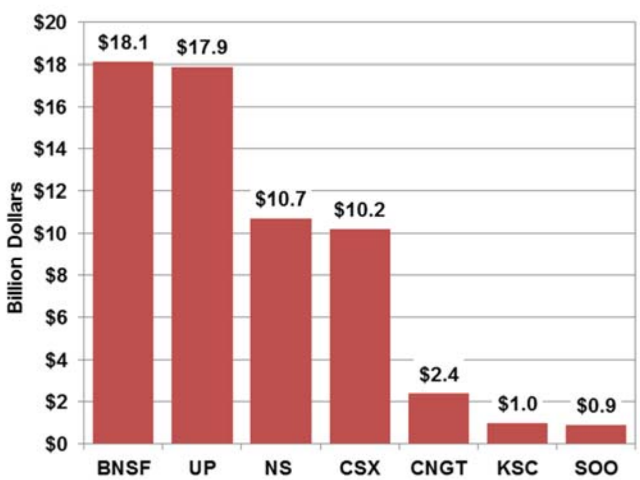
A railroad is designated as a Class I Railroad based on its operating revenue. To be a Class I Railroad in 2008, operating revenue must be $401.4 million or more. This threshold is adjusted for inflation annually. There are currently seven Class I Railroads (Table 49), all of which greatly exceed the minimum operating revenue criteria for Class I (Figure 43). The active rail network by company is shown in Figure 44. There are 94,209 road miles in the Class I railroad mileage, not including parallel tracks at sidings and yards.

Table 49. List of Class I Railroads

Name	Acronym
BNSF Railway Company	BNSF
Union Pacific Railroad Company	UP
Norfolk Southern Railway Company	NS
CSX Transportation, Inc.	CSX
Grand Trunk Corporation	CNGT
Kansas City Southern Railway Company	KCS
Soo Line Railroad Company	SOO

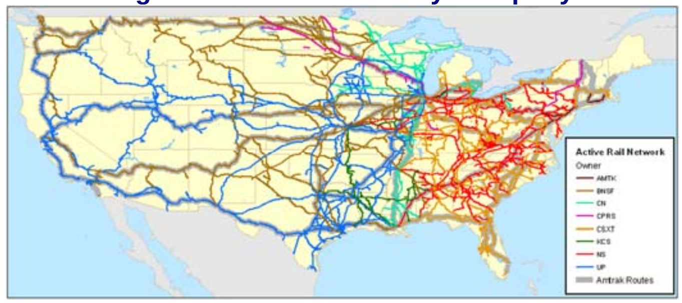
Source: *American Association of Railroads. Railroad Facts, 2008. Washington, DC. 2009.*

Figure 43. Operating Revenue for Class I Railroads, 2008



Source: *American Association of Railroads. Railroad Facts, 2008. Washington, DC. 2009.*

Figure 44. Rail Network by Company

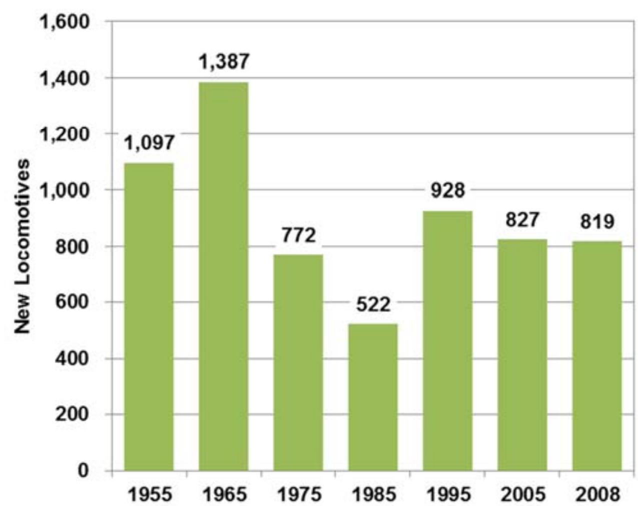


Source: *ORNL Rail Network Database.*

Locomotive manufacturers have a long history

There are two American manufacturers of locomotives: Electo-Motive Diesel and General Electric Transportation. Both manufacturers have been selling locomotives for more than 80 years and currently sell their products worldwide. The demand for new locomotive units varies from year to year; Figure 45 shows the historical trend of new locomotive installations going back to 1955. In the last five years, new locomotive installations have been about 4% of the total locomotive population; about 24,000 locomotives were in service in 2008.

Figure 45. New Locomotive Units for Class I Railroads

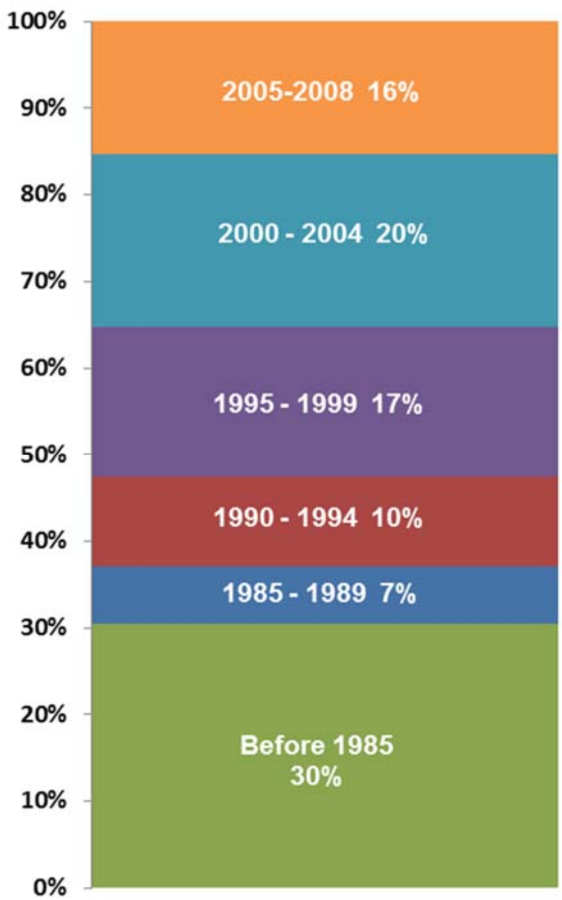


Source: *American Association of Railroads.* Analysis of Class I Railroads, 2008. *Washington, DC. 2009.*

Old locomotives are still in service

There are about 24,000 locomotives in service. Many of the locomotives on the tracks today are more than 20 years old; thirty-percent of all locomotives in service in 2008 were built before 1985 (Figure 46). Sixteen percent of all locomotives were manufactured are 1-4 years old.

Figure 46. Locomotives in Service in 2008 by Date of Manufacture



Source: *American Association of Railroads.* Railroad Facts, 2008. *Washington, DC. 2009.*

New locomotives on the tracks

In 2008, there were a total of 819 new diesel-electric locomotives installed into service, mainly by BNSF, UP and CSX (Table 50). A total of 143 rebuilt locomotives were installed by UP and NS. The locomotives in the "Other" category include mostly "slugs" (with traction motors to assist locomotives, but no motive power) and some battery-powered switching locomotives. There were 129 rebuilt locomotives installed in 2008, with BNSF and SOO accounting for the majority of those.

Table 50. Locomotives Installed into Service, 2008

New Locomotives Installed			
	Diesel-Electric	Other	Total
BNSF	382	0	382
UP	179	0	179
NS	40	0	40
CSX	181	35	216
CNGT	0	0	0
KCS	37	0	37
SOO	0	0	0
Total	**819**	**35**	**854**
Rebuilt Locomotives Installed			
BNSF	0	0	0
UP	103	0	103
NS	26	14	40
CSX	0	0	0
CNGT	0	0	0
KCS	0	0	0
SOO	0	0	0
Total	**129**	**14**	**143**
Other/Used Locomotives Installed			
BNSF	28	39	67
UP	3	0	3
NS	2	0	2
CSX	2	0	2
CNGT	1	0	1
KCS	0	0	0
SOO	54	0	54
Total	**90**	**39**	**129**

Source: *American Association of Railroads.* Analysis of Class I Railroads, 2008. *Washington, DC. 2009.*

Covered hoppers and tank cars carry the goods

Railroad equipment not only includes locomotives, but freight cars as well. Though the population of locomotives has been fairly stable over the past five years, the number of freight cars in service has grown by 8% (Table 51). In 2008, 30% of the freight cars were covered hoppers, and another 20% were tank cars. Plain boxcars and refrigerated cars were on the decline from 2004 to 2008. The types of cargo carried by each freight car type are listed in Table 52.

Table 51. Railroad Equipment (Thousands)

	2004	2005	2006	2007	2008	2008 Freight Car Share
Locomotives in Service	22	23	24	24	24	
Freight Cars in Service	1,288	1,317	1,361	1,386	1,393	100%
Boxcar - Plain	19	20	20	16	16	1%
Boxcar - Equipped	115	114	113	105	99	7%
Covered Hoppers	378	383	398	412	415	30%
Hoppers	143	151	162	167	168	12%
Flat cars	159	169	174	172	170	12%
Refrigerator cars	24	24	23	22	19	1%
Gondolas	201	202	209	218	220	16%
Tank Cars	244	249	257	269	281	20%
Others	5	5	5	5	5	0%

Sources: *American Association of Railroads. Railroad Facts, 2008. Washington, DC. 2009. and the four previous editions of Railroad Facts.*

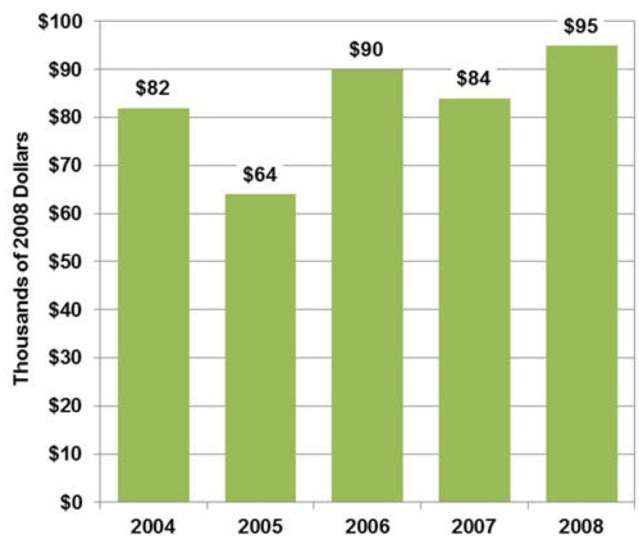
Table 52. Examples of Commodities Moved by Freight Cars

Boxcar - Plain	General commodities or mixed freight with protection from weather and theft.
Boxcar - Equipped	Same as other boxcars, but equipped with permanent racks for carrying a specific commodity or equipped with a loading device.
Covered Hoppers	Dry bulk commodities, such as grain, fertilizer, cement, and sand.
Hoppers	Bulk commodities, such as coal, ore, and grain. Hoppers discharge cargo on the underside of the car.
Flat cars	Larger objects, such as heavy machinery and pipes. Some flat cars carry intermodal trailers or containers.
Refrigerator cars	Perishable foodstuffs.
Gondolas	Loose bulk commodities, such as scrap metal and construction material.
Tank Cars	Liquids and gases, such as petroleum, solvents, food products, and chemicals.
Others	There are many other types of freight cars that are specialized for a commodity, such as automobiles cars, livestock cars, and wood chip cars.

Average cost of a new freight car is $95,000

The average cost of a new freight car in 2004 was $82,000 (in real 2008 dollars), but that average rose to $95,000 in 2008 (Figure 47). The average can change significantly from year to year due to the types of freight cars purchased in that year and how much specialization is required. A special service flat car costs about $224,000, while a gondola costs $75,000.

Figure 47. Average Cost of a New Freight Car

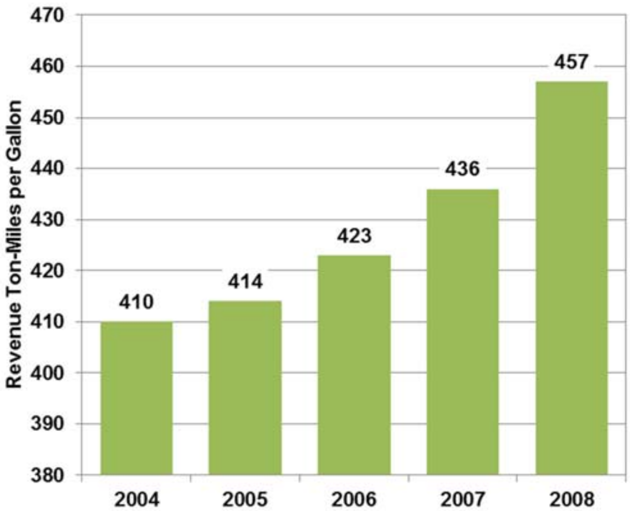


Source: *American Association of Railroads.* Railroad Facts, 2008. *Washington, DC. 2009.*

Railroad fuel efficiency is improving

The efficiency of a locomotive engine depends on many variables, such as the weight of the freight cars, length of the train, and slope of the terrain. A good measure for railroad efficiency is the number of revenue ton-miles per gallon of fuel that is consumed. Since 2004, that measure has grown from 410 to 457 – an 11% improvement (Figure 48).

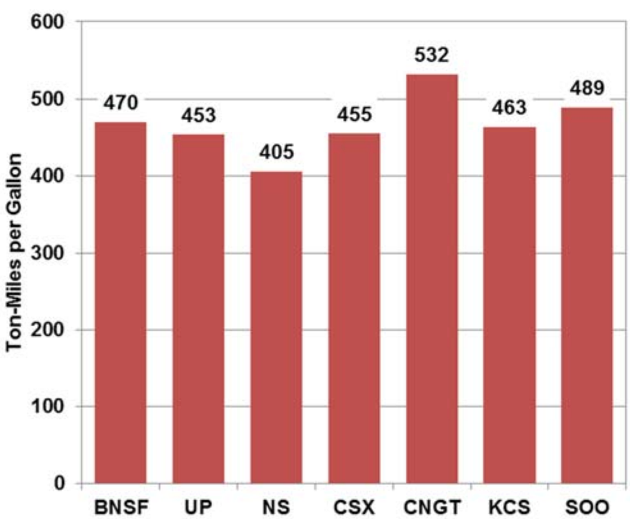
Figure 48. Trend of Revenue Ton-Miles per Gallon of Fuel Consumed



***Source:** American Association of Railroads.* Railroad Facts, 2008. *Washington, DC. 2009.*

On a company basis, CNGT has the highest efficiency in 2008, with 532 revenue ton-miles per gallon (Figure 49). The other Class I Railroads have efficiencies between 450 and 500 revenue ton-miles per gallon, with the exception of NS, with 405.

Figure 49. Revenue Ton-Miles per Gallon of Fuel Consumed, 2008



***Source:** American Association of Railroads.* Analysis of Class I Railroads, 2008. *Washington, DC. 2009.*

Ultralow sulfur diesel makes a difference

The Clean Air Rules of 2004 limited sulfur in nonroad diesel fuel to a maximum of 500 parts per million (ppm) by 2007 and 15 ppm by 2010 – a 97% reduction. The ULSD allows engine manufacturers to use advanced emission-control systems that reduce both PM and NO_X, similar to those for heavy-duty diesel trucks.

Tier 3 and Tier 4 Locomotive emission standards are set

Once a locomotive is worn out or in disrepair, it is often more cost effective to rebuild the locomotive than it is to purchase a new replacement. When the locomotive engines are rebuilt they are typically upgraded to include newer engine technology. Thus, when EPA set emission standards for locomotives, they were set not only for locomotives produced in the future, but also for rebuilds of locomotives that were already manufactured. The most recent regulation of locomotive emissions was in 2008. The older model years have less strict standards than the newer model years.

Tier 0-2 standards for criteria pollutants were strengthened for existing locomotives and new near term (Tier 3) and long-term (Tier 4) standards were set. The regulated pollutants include hydrocarbons (HC), CO, NO_X, and PM. Tables 53 and 54 contain a summary of the standards for line-haul locomotives and switch locomotives. Older locomotives that are remanufactured after 2010 must be upgraded to meet the Tier 0-2 standards, depending on the model year of the locomotive. It is expected that Tier 4 standards will be met with the use of exhaust gas aftertreatment technologies.

The standards address line-haul and switch locomotives separately. Line-haul locomotives have powerful engines to carry many rail cars over a long distance. Switch locomotives assemble and disassemble trains in a train yard, thus they are typically low-powered but have a high starting tractive effort for getting heavy cars rolling quickly.

Rail accounts for less than 3% of transportation greenhouse gas emissions

According to EPA, rail accounted for about 51 MMT of CO_2 equivalents in 2008, down from 53.0 MMT three years earlier (Table 55). Most of the greenhouse gas emissions are CO2, but small amounts of methane (CH4), nitrous oxide (N2O), hydrofluorocarbon (HFCs), and other gases are also emitted from rail operations. In terms of total transportation sector greenhouse gas emissions, rail is only responsible for 2.7%.

Table 53. Emission Standards for Line-Haul Locomotives That are Manufactured or Remanufactured after the Effective Date (Grams per Brake Horsepower-Hour)

Tier	MY	Effective Date	HC	CO	NOx	PM
Tier 0[a]	1973-1992[c]	2010	1	5	8	0.22
Tier 1[a]	1993[c]-2004	2010	0.55	2.2	7.4	0.22
Tier 2[a]	2005-2011	2010	0.3	1.5	5.5	0.10[d]
Tier 3[b]	2012-2014	2012	0.3	1.5	5.5	0.1
Tier 4	2015 or later	2015	0.14[e]	1.5	1.3[e]	0.03

a - Tier 0-2 line-haul locomotives must also meet switch standards of the same tier.
b - Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
c - 1993-2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
d - 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).
e - Manufacturers may elect to meet a combined NOx+HC standard of 1.4 g/bhp-hr.

Source: DieselNet, http://www.dieselnet.com/standards/us/loco.php.

Table 54. Emission Standards for Switch Locomotives That are Manufactured or Remanufactured after the Effective Date (Grams per Brake Horsepower-Hour)

Tier	MY	Effective Date	HC	CO	NOx	PM
Tier 0	1973-2001	2010	2.1	8	11.8	0.26
Tier 1[a]	2002-2004	2010	1.2	2.5	11	0.26
Tier 2[a]	2005-2010	2010	0.6	2.4	8.1	0.13[b]
Tier 3	2011-2014	2011	0.6	2.4	5	0.1
Tier 4	2015 or later	2015	0.14[c]	2.4	1.3[c]	0.03

a - Tier 1-2 switch locomotives must also meet line-haul standards of the same tier.
b - 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).
c - Manufacturers may elect to meet a combined NOx+HC standard of 1.3 g/bhp-hr.

Source: DieselNet, http://www.dieselnet.com/standards/us/loco.php.

Table 55. Rail Greenhouse Gas Emissions (MMT of CO2 Equivalents)

	2005	2006	2007	2008
CO2	50.3	52.4	51.6	47.9
CH4	0.1	0.1	0.1	0.1
N2O	0.4	0.4	0.4	0.4
HFCs	2.2	2.2	2.2	2.3
Other	0.1	0.1	0.1	0.1
Total Rail	53.0	55.1	54.3	50.6
Total Transportation	2,020.9	1,997.6	2,008.6	1,890.8
Rail Share of Total Transportation	2.6%	2.8%	2.7%	2.7%

Source: *U.S. EPA,* Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2008, *April 2010.*

Future technologies for locomotives

Hybrid diesel-electric locomotives are being developed that will capture the energy dissipated during braking and store it for future use. This has the potential to reduce fuel consumption by up to 15% and emissions by 50% compared to most locomotives currently in use. In addition, the hybrid will operate more efficiently in higher altitudes and up steep inclines.

Automatic engine start/stop technologies are also being developed that can reduce engine idle time, thus reduce fuel use and emissions.

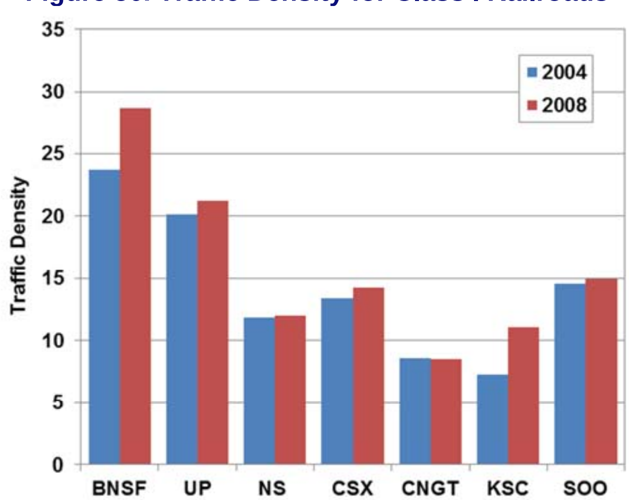
Deregulation of the railroad industry has been successful

The Staggers Act of 1980 removed many regulatory restraints on the railroad industry, thus providing the rail companies increased pricing flexibility while still protecting the shippers. This balanced regulation has helped the rail industry to gain financial health, gain market share, and increase productivity, all while rates have declined (55% decline from 1981 to 2009, according to the American Association of Railroads).

Traffic density has increased for most Class I Railroads

BNSF and KSC had the largest increases in traffic density from 2004 to 2008, which is measured as million revenue ton-miles per owned mile of road (Figure 50). Traffic density is an indicator of the utilization of the railroad infrastructure. A higher traffic density means greater utilization efficiency. In 2008, BNSF and UP had the highest traffic densities, followed by the SOO, one of the smallest Class I railroads.

Figure 50. Traffic Density for Class I Railroads



Note: *Traffic Density = Million revenue ton-miles per owned mile of road.*

Source: *American Association of Railroads.* Railroad Facts, 2008. *Washington, DC. 2009. American Association of Railroads.* Railroad Facts, 2004. *Washington, DC. 2005.*

Average railcar capacity is expanding

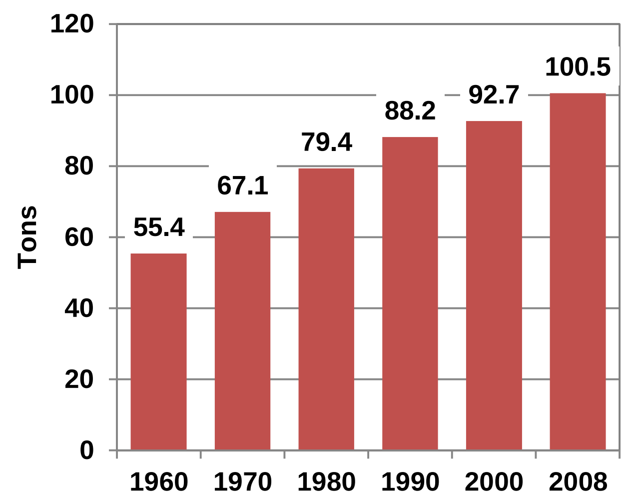
There are many different types of railcars which are designed to haul the various products moved by rail. The railcar with the highest capacity is the Flat TOFC/COFC; due to the ability to double stack the trailers/containers on the railcar, the capacity is nearly double that of any other rail car type (See Table 56). Gondola and hopper cars all average above 100 tons per car, while boxcars, refrigerator cars, and other types typically hold less. The average capacity for all cars has increased significantly over the last 50 years (Figure 51).

Table 56. Average Capacity Per Rail Car, 2008 (Tons)

Box - Plain 40'	60
Box - Plain 50 '	95
Box - Equipped	83
Gondola - Plain	115
Gondola - Equipped	101
Covered Hopper	106
Open Hopper - General Service	104
Open Hopper - Special Service	106
Refrigerator - Mechanical	81
Refrigerator - Non-Mechanical	79
Flat TOFC/COFC*	223
Flat Multi-Level	39
Flat General Service	77
Flat All Other	97
All Other Types	59
Average Freight Car Capacity	100
* TOFC = trailer on flatcar. COFC = container on flatcar	

Source: *American Association of Railroads. Analysis of Class I Railroads, 2008. Washington, DC. 2009.*

Figure 51. Average Freight Car Capacity per Rail Car



Source: *American Association of Railroads. Railroad Facts, 2008. Washington, DC. 2009.*

Productivity of Class I Railroads is at an all-time high

Productivity, measured as revenue ton-miles per employee-hour, has increased 10% over the last five years (Table 57). Impressive as that is, data show that the productivity rate in 2008 is *five times* that in 1980 when deregulation of the freight railroad industry was first enacted.

Table 57: Productivity Rates

Year	Revenue Ton-miles per Employee	Revenue Ton-Miles per Employee-Hour
1980	2.1	863
Deregulation in 1980		
2004	10.6	3,908
2005	10.5	4,019
2006	10.6	4,059
2007	10.6	4,182
2008	10.8	4,307

Source: *American Association of Railroads. Railroad Facts, 2008. Washington, DC. 2009.*

Summary

The economic downturn in 2008 and 2009 affected the transportation sector. Declines in energy use, vehicle sales, and vehicle-miles of travel were experienced during this period, along with volatility of fuel prices. Despite this, new engine and vehicle technologies are entering the market. Alternative fuels and cleaner fuels are also becoming more readily available. Railroad locomotives and freight cars are advancing too.

In the coming years, the new technologies will help the transportation sector to become more efficient in the movement of people and goods.

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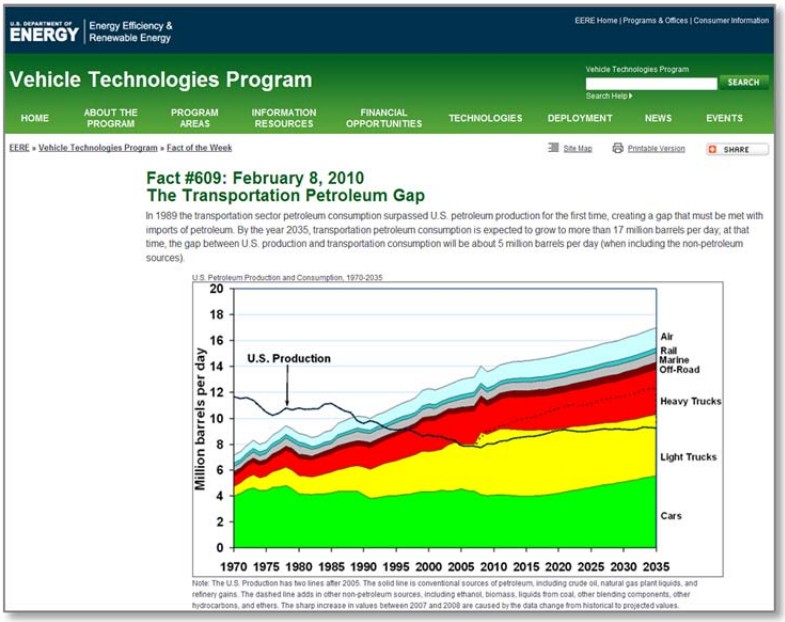

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