Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2010

Executive Summary

United States Environmental Protection Agency

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Compliance and Innovative Strategies Division
and
Transportation and Climate Division

Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

EPA United States Environmental Protection Agency

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I. Executive Summary

Introduction

This report summarizes key trends in carbon dioxide (CO_2) emissions, fuel economy and technology usage related to model year (MY) 1975 through 2010 light-duty vehicles sold in the United States. Light-duty vehicles are those vehicles that EPA classifies as cars or light-duty trucks (sport utility vehicles, minivans, vans, and pickup trucks with gross vehicle weight ratings up to 8500 pounds). The data in this report supersede the data in previous reports in this series.

Earlier this year, EPA, in conjunction with the National Highway Traffic Safety Administration (NHTSA), published the first-ever light-duty vehicle greenhouse gas emissions standards, under the Clean Air Act, for MY2012-2016 (75 Federal Register 25324, May 7, 2010). These standards are part of a joint, harmonized National Program that also includes corporate average fuel economy (CAFE) standards for the same years established by NHTSA. By MY2016, the average industry-wide compliance levels are projected to be 250 grams per mile (g/mi) CO_2 and 34.1 miles per gallon (mpg) CAFE. The 250 g/mi CO_2 compliance level is equivalent to 35.5 mpg if all CO_2 emissions reductions are achieved through fuel economy improvements. On May 21, 2010, the President announced that EPA and NHTSA would be extending the National Program for MY2017 and beyond, and on October 13, 2010 the agencies published a Notice of Intent to propose new greenhouse gas emissions and CAFE standards by the fall of 2011 (75 Federal Register 62739). Accordingly, this is the second year that Section IV of this report includes tailpipe CO_2 emissions data in addition to the fuel economy data that have been the cornerstone of this report since 1975. Tailpipe CO_2 emissions data represent 90 to 95 percent of total light-duty vehicle greenhouse gas emissions.

Final MY2009 data are based on formal end-of-year CAFE reports submitted by automakers to EPA and will not change. MY2009 was a year of considerable turmoil in the automotive market. Due primarily to the economic recession, light-duty vehicle production totalled 9.2 million units, the lowest of any year since this database began in 1975. This represented a 34% reduction in total vehicle production compared to MY2008, and a 40% drop since MY2007. The Car Allowance Rebate System (or "Cash for Clunkers") likely impacted consumer demand. Fuel prices remained high relative to historic levels, though lower than in the previous three years. The turmoil introduced by these factors is demonstrated by the fact that the final MY2009 values for CO_2 emissions and fuel economy in this report are 25 g/mi lower and 1.3 mpg higher, respectively, than the projected MY2009 values that were provided in last year's report.

The preliminary MY2010 data in this report are based on confidential pre-model year production volume projections provided to EPA by automakers during the MY2009 market turmoil. Accordingly, there is uncertainty in the MY2010 data (for example, total projected vehicle production is significantly higher than actual sales as reported by trade sources). This report will often focus on the final MY2009 data, rather than on the preliminary MY2010 data.

The great majority of the CO_2 emissions and fuel economy values in this report are adjusted (ADJ) EPA "real-world" estimates provided to consumers and based on EPA's 5-cycle test methodology. Appendix A provides a detailed explanation of the method used to calculate these adjusted fuel economy and CO_2 values, which last changed with the 2007 version of this report. On August 30, 2010, EPA and NHTSA proposed to revise the fuel economy labels to include, among other things, tailpipe CO_2 emissions levels, but

this proposal does not affect the methodology for calculating the adjusted CO_2 emissions and fuel economy levels provided in this report (75 Federal Register 58078, September 23, 2010). In a few cases, the report also provides unadjusted EPA laboratory (LAB) values, which are based on a 2-cycle test methodology and used for automaker compliance with CO_2 emissions and CAFE standards. All combinations of adjusted or laboratory, and CO_2 emissions or fuel economy values, may be reported as city, highway, or, most commonly, as composite (combined city/highway, or COMP).

Since 1975, overall new light-duty vehicle CO_2 emissions have moved through four phases:

1. A rapid decrease from 1975 through 1981;
2. A slower decrease until reaching a valley in 1987;
3. A gradual increase until 2004; and
4. A decrease for the six years beginning in 2005, with the largest decrease in 2009.

The fleetwide average adjusted (or real world) MY2009 light-duty vehicle CO_2 emissions value is 397 g/mi, which is a 27 g/mi reduction relative to MY2008 and an all-time low since the database began in 1975. The projected fleetwide average MY2010 level is 395 g/mi. This projected MY2010 value is essentially the same as the final MY2009 value, and it is impossible to know, at this time, whether the actual MY2010 value will be higher or lower than the MY2009 value.

Since fuel economy has an inverse relationship to tailpipe CO_2 emissions, overall new light-duty vehicle fuel economy has also moved through four phases, with the trends in fuel economy mirroring those of CO_2 emissions:

1. A rapid increase from 1975 through 1981;
2. A slower increase until reaching its peak in 1987;
3. A gradual decline until 2004; and
4. An increase for the six years beginning in 2005, with the largest increase in 2009.

The fleetwide average adjusted MY2009 light-duty vehicle fuel economy is 22.4 mpg, an increase of 1.4 mpg since MY2008, and the highest since the database began in 1975. The projected fleetwide average MY2010 value is 22.5 mpg. Again, it is impossible to predict whether actual MY2010 fuel economy will be higher or lower than the preliminary MY2010 value.

Because the underlying methodology for generating unadjusted laboratory CO_2 emissions and fuel economy values has not changed since this series began in the mid-1970s, these values provide an excellent basis for comparing long-term CO_2 emissions and fuel economy trends from the perspective of vehicle design, apart from the factors that affect real-world driving that are reflected in the adjusted values. These unadjusted laboratory values form the basis for automaker compliance with CO_2 emissions and CAFE standards. Laboratory composite values represent a harmonic average of 55 percent city and 45 percent highway operation, or "55/45." For 2005 and later model years, unadjusted laboratory composite CO_2 emissions values are, on average, about 20 percent lower than adjusted composite CO_2 values, and unadjusted laboratory composite fuel economy values are, on average, about 25 percent greater than adjusted composite fuel economy values. The final MY2009 unadjusted laboratory composite values of 316 g/mi and 28.2 mpg represent a record low for CO_2 emissions and an all-time high for fuel economy since the database began in 1975.

NHTSA has the overall responsibility for the CAFE program. For 2010, the CAFE standards are 27.5 mpg for cars and 23.5 mpg for light trucks (for light trucks, individual manufacturers can choose between the fixed, unreformed 23.5 mpg standard and a reformed vehicle footprint-based standard which yields different compliance targets for each manufacturer). In March 2009, NHTSA promulgated new footprint-based CAFE standards for MY2011. These standards projected average MY2011 industry-wide compliance levels of 30.2 mpg for cars (including a 27.8 mpg alternative minimum standard for domestic cars for all manufacturers) and 24.1 mpg for light trucks. Because of real world adjustments, alternative fuel vehicle credits, and test procedure adjustments, fleetwide NHTSA CAFE values are a minimum of 25 percent higher than EPA adjusted fuel economy values.

Characteristics of Light Duty Vehicles for Six Model Years

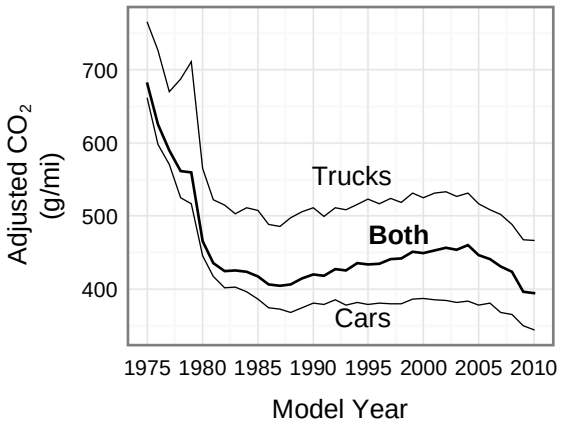
	1975	1987	1998	2008	2009	2010
Adjusted CO_2 Emissions (g/mi)	681	405	442	424	397	395
Adjusted Fuel Economy (MPG)	13.1	22.0	20.1	21.0	22.4	22.5
Weight (lb)	4060	3221	3744	4085	3917	4009
Horsepower	137	118	171	219	208	220
0 to 60 Time (sec.)	14.1	13.1	10.9	9.7	9.7	9.5
Percent Truck Production	19%	28%	45%	47%	40%	41%
Percent Front-Wheel Drive	5%	58%	56%	54%	63%	59%
Percent Four-Wheel Drive	3%	10%	20%	27%	24%	24%
Percent Four-Cylinder Engine	20%	55%	36%	38%	51%	48%
Percent Eight-Cylinder Engine	62%	15%	18%	17%	12%	16%
Percent Multi-Valve Engine	-	11%	41%	76%	84%	86%
Percent Variable Valve Timing	-	-	-	58%	72%	86%
Percent Cylinder Deactivation	-	-	-	7%	7%	7%
Percent Gasoline Direct Injection	-	-	-	2.3%	4.2%	8.5%
Percent Turbocharger	-	-	1.4%	3.0%	3.3%	3.2%
Percent Manual Transmission	23%	29%	13%	5%	5%	7%
Percent Continuously Variable Transmission	-	-	0%	8%	10%	10%
Percent Hybrid	-	-	-	2.5%	2.3%	4.3%
Percent Diesel	0.2%	0.3%	0.1%	0.1%	0.5%	0.4%

Highlight #1: MY2009 had the lowest CO_2 emission rate and highest fuel economy, partly due to the economic conditions that led to the lowest vehicle production, since the database began in 1975.

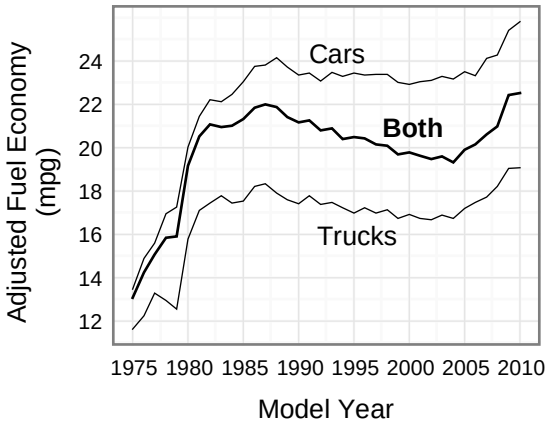
MY2009 adjusted composite CO_2 emissions were 397 g/mi, a record low for the post-1975 database. The 27 g/mi (6 percent) decrease compared to MY2008 was the largest yearly CO_2 decrease since 1981. MY2009 adjusted composite fuel economy was 22.4 mpg, an all-time high since the database began in 1975, and the 1.4 mpg (7 percent) increase over MY2008 was the biggest fuel economy increase since 1980. Vehicle production totalled 9.2 million units, the lowest for any year in the database. Projected MY2010 values of 395 g/mi CO_2 emissions and 22.5 mpg fuel economy, reflecting slight improvements over MY2009, are uncertain given the market turmoil when these projections were provided to EPA.

The previous records for lowest CO_2 emissions and highest fuel economy were in MY1987, and the recent improvements in CO_2 emissions and fuel economy reverse an opposite trend from MY1987 through MY2004. Compared to the previous best year of MY1987, MY2009 CO_2 emissions were 8 g/mi (2 percent) lower, and fuel economy was 0.4 mpg (2 percent) higher. From MY2004 to MY2009, CO_2 emissions decreased by 64 g/mi (14 percent), and fuel economy increased by 3.1 mpg (16 percent).

Adjusted CO_2 Emissions by Model Year



Adjusted Fuel Economy by Model Year



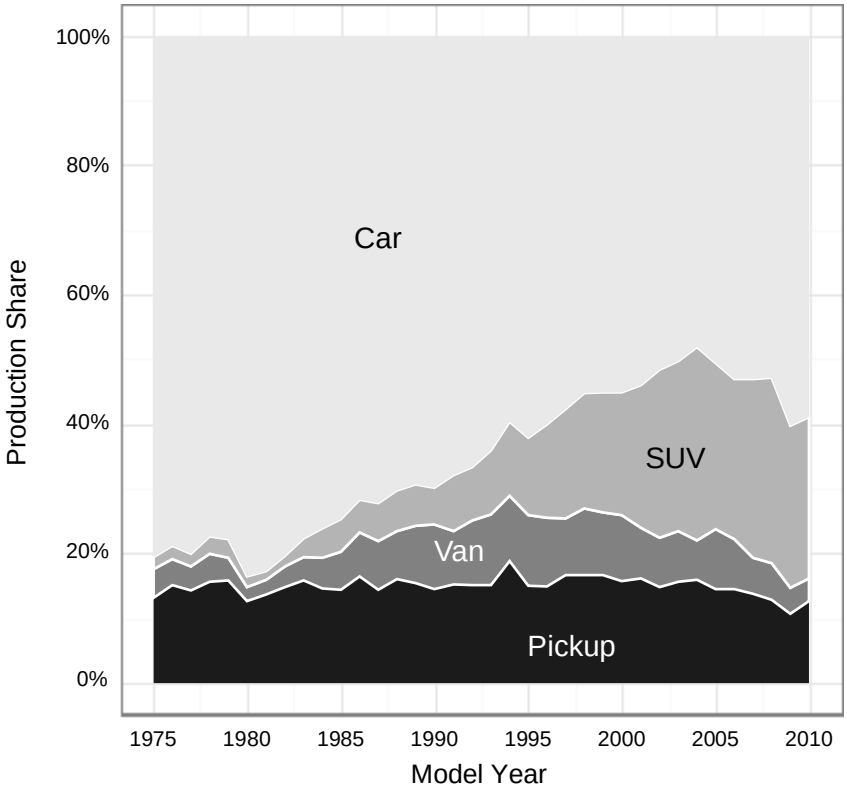
MY2009 unadjusted laboratory composite values, which reflect vehicle design considerations only and do not account for the many factors which affect real world CO_2 emissions and fuel economy performance, were also at an all-time low for CO_2 emissions (316 g/mi) and a record high for fuel economy (28.2 mpg) since the database began in 1975. These values are 27 g/mi (8 percent) lower and 2.3 mpg (9 percent) higher than the previous best values in MY1987.

Highlight #2: MY2009 truck market share dropped by 8 percent to its lowest level since 1995.

Light trucks, which include SUVs, minivans/vans, and pickup trucks, accounted for 40 percent of all light-duty vehicle sales in MY2009, an 8 percent decrease since MY2008 and a 12 percent decrease since the peak in MY2004. Truck market share is now at the lowest level since MY1995. The MY2010 light truck market share is projected to be 41 percent, based on pre-model year production projections by automakers.

Historically, growth in the light truck market was primarily driven by the explosive increase in the market share of SUVs (EPA does not have a separate category for crossover vehicles and classifies many crossover vehicles as SUVs). The SUV market share increased from 6 percent of the overall new light-duty vehicle market in MY1990 to a peak of about 30 percent in MY2004, dropping to 25 percent in MY2009. By comparison, market shares for both vans and pickup trucks have declined since 1990, with van market share falling by over half from 10 percent to 4 percent. The increased overall market share of light trucks, which in recent years have averaged 120 – 140 g/mi higher CO_2 emissions and 6 – 7 mpg lower fuel economy than cars, accounted for much of the increase in CO_2 emissions and decline in fuel economy of the overall new light-duty vehicle fleet from MY1987 through MY2004.

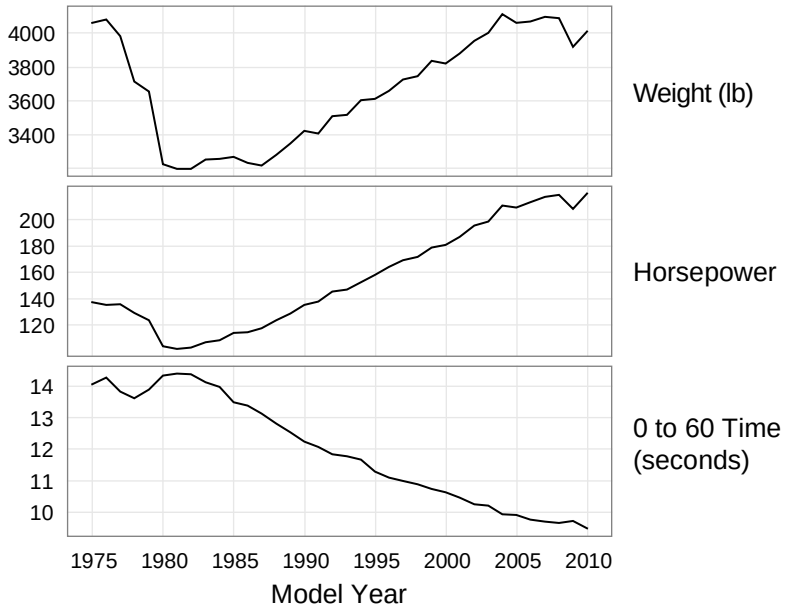
Production Share by Vehicle Type



Highlight #3: MY2009 had the largest annual decrease in vehicle weight and power since 1980.

MY2009 vehicle weight averaged 3917 pounds, the lowest average weight since MY2001. This reflects a decrease of 168 pounds (4 percent) from MY2008, and the largest annual decrease since MY1980. The average truck weight dropped by about 100 pounds, the average car weight dropped by about 60 pounds, and the remaining difference was due to lower truck market share. In MY2009, the average vehicle power was 208 horsepower, the lowest value since MY2003. Average horsepower dropped by 11 horsepower (5 percent), the largest annual decrease since MY1980, with most of the decrease explained by cars having lower horsepower levels and trucks having a lower market share. The four-cylinder engine market share grew from 38 percent in MY2008 to 51 percent in MY2009 (and comprised nearly 70 percent of the car market). Estimated MY2009 0-to-60 acceleration time remained constant at 9.7 seconds.

Weight, Horsepower and 0-to-60 Performance



Vehicle weight and performance are two of the most important engineering parameters that help determine a vehicle's CO_2 emissions and fuel economy. All other factors being equal, higher vehicle weight (which supports new options and features) and faster acceleration performance (e.g., lower 0-to-60 mile-per-hour acceleration time), both increase a vehicle's CO_2 emissions and decrease fuel economy. Automotive engineers are constantly developing more advanced and efficient vehicle technologies. From MY1987 through MY2004, on a fleetwide basis, this technology innovation was utilized exclusively to support market-driven attributes other than CO_2 emissions and fuel economy, such as vehicle weight, performance, and utility. Beginning in MY2005, technology has been used to increase both fuel economy (which has reduced CO_2 emissions) and performance, while keeping vehicle weight relatively constant.

MY2010 projections are for an increase in both vehicle weight and performance, but these projections are uncertain.

Highlight #4: Nearly every manufacturer increased fuel economy in MY2009, resulting in lower CO_2 emission rates.

All but one of the 14 highest-selling manufacturers increased fuel economy (which also reduced CO_2 g/mi emission rates) from MY2008 to MY2009, the last two years for which we have definitive data, and 7 manufacturers increased fuel economy by 1 mpg or more.

Adjusted CO_2 emissions and fuel economy values are shown for the 14 highest-selling manufacturers, which accounted for 99 percent of the market in MY2009. Manufacturers are defined in accordance with current NHTSA CAFE guidelines, and these definitions are applied retroactively for the entire database back to 1975 for purposes of maintaining integrity of trends over time. In MY2009, the last year for which EPA has final production data, Toyota had the lowest fleetwide adjusted composite CO_2 emissions (and highest fuel economy) performance, followed by Hyundai and Honda. Chrysler, the one manufacturer that did not improve in MY2009, had the highest CO_2 emissions (and lowest fuel economy), followed by Daimler and Ford. Toyota had the biggest improvement in adjusted CO_2 (and fuel economy) performance from MY2008 to MY2009, with a 40 g/mi reduction in fleetwide CO_2 emissions (and 2.6 mpg fuel economy improvement), followed by Nissan (29 g/mi reduction in CO_2 emissions) and Ford (22 g/mi reduction in CO_2 emissions).

Preliminary MY2010 values suggest that most manufacturers will improve further in MY2010, though these projections are uncertain and EPA will not have final data until next year's report.

MY2008–2010 Manufacturer Fuel Economy and CO_2 Emissions (Adjusted Composite Values)

Manufacturer	MY2008 MPG	MY2008 CO_2 (g/mi)	MY2009 MPG	MY2009 CO_2 (g/mi)	MY2010 MPG	MY2010 CO_2 (g/mi)
Toyota	22.8	389	25.4	349	24.5	363
Hyundai	24.4	364	25.1	355	25.9	343
Honda	23.9	372	24.6	361	25.6	346
Kia	22.9	388	24.2	367	25.1	354
VW	22.3	398	23.8	379	24.6	367
Nissan	21.9	406	23.6	377	23.8	373
Mitsubishi	22.3	399	23.5	379	24.2	367
Mazda	23.1	385	23.2	383	22.7	391
Subaru	22.3	399	22.6	393	23.3	382
BMW	21.2	419	21.9	407	22.3	399
GM	19.6	452	20.6	432	20.8	427
Ford	19.3	459	20.3	437	20.5	434
Daimler	19.3	464	19.5	457	19.4	459
Chrysler	19.3	460	19.2	464	19.2	463
All	21.0	424	22.4	397	22.5	395

EPA data is based on model year production, as is CAFE data. This means that year-to-year comparisons can be affected by longer or shorter model year designations by the manufacturers. Section VII has greater detail on the fuel economy and CO_2 emissions for these 14 manufacturers, as well as for these manufacturers' individual makes (i.e., brands).

Important Notes with Respect to the Data Presented in This Report

Most of the CO_2 emissions and fuel economy values in this report are *adjusted* composite (combined city/highway) CO_2 emissions or fuel economy values, consistent with the real-world estimates for city and highway fuel economy provided to consumers on new vehicle labels, in the EPA/DOE *Fuel Economy Guide,* and in EPA's *Green Vehicle Guide*. These adjusted values are based on 5-cycle testing where additional test procedures provide a more accurate representation of real world vehicle usage.

In some tables and figures, *laboratory* composite (combined city/highway) CO_2 or fuel economy values are also shown. These laboratory composite values are based on the 2-cycle results from the EPA Federal Test Procedure and Highway Fuel Economy Test, which are two of the five cycles used for the adjusted CO_2 and fuel economy values. Because the underlying methodology for generating and reporting laboratory values has not changed since this series began in the mid-1970s, these laboratory values provide an excellent basis for comparing long-term CO_2 emissions and fuel economy trends from the perspective of vehicle design, apart from the factors that affect real-world CO_2 and fuel economy that are reflected in the adjusted values. For 2005 and later model years, laboratory composite fuel economy values are, on average, about 25 percent greater than adjusted composite fuel economy values, and laboratory composite CO_2 emissions values are, on average, about 20 percent lower than adjusted composite CO_2 values.

Formal CAFE compliance data as reported by NHTSA do not correlate precisely with either the adjusted or laboratory fuel economy values in this report. While EPA's laboratory composite fuel economy data form the cornerstone of the CAFE compliance database, NHTSA must also include credits for alternative fuel vehicles and test procedure adjustments (for cars only) in the official CAFE calculations. Accordingly, NHTSA CAFE values are at least 25 percent higher than EPA adjusted fuel economy values for model years 2005 through 2010.

This report supersedes all previous reports in this series. In general, users of this report should rely exclusively on data in this latest report, which covers the years 1975 through 2010, and not make comparisons to data in previous reports in this series. There are two main reasons for this.

One, EPA revised the methodology for estimating real-world fuel economy values in December 2006. This is the fourth report in this series to reflect this revised real-world fuel economy methodology, and every adjusted (ADJ) fuel economy value in this report for 1986 and later model years is lower than given in reports in this series prior to the 2007 report. Accordingly, adjusted fuel economy values for 1986 and later model years should not be compared with the corresponding values from pre-2007 reports. These new downward adjustments are phased in, linearly, beginning in 1986, and for 2005 and later model years the new adjusted composite (combined city/highway) values are, on average, about six percent lower than under the methodology previously used by EPA. See Appendix A for more in-depth discussion of the current methodology and how it affects both the adjusted fuel economy values for individual models and the historical fuel economy trends database. This same methodology is used to calculate adjusted CO_2 emissions values as well.

Two, when EPA changes a manufacturer or make definition to reflect a change in the industry's current financial arrangements, EPA makes the same adjustment in the historical database as well. This maintains a consistent manufacturer/make definition over time, which allows the identification of long-term trends. On the other hand, it means that the database does not necessarily reflect actual past financial arrangements. For example, the 2010 database, which includes data for the entire time series 1975 through

2010, accounts for all Chrysler vehicles in the 1975-2010 timeframe under the Chrysler manufacturer designation, and no longer reflects the fact that Chrysler was combined with Daimler for several years.

In general, car/truck classifications in this database parallel classifications made by NHTSA for CAFE purposes and EPA for vehicle emissions standards. However, this report relies on engineering judgment, and there are occasional cases where the methodology used for classifying vehicles for this report results in differences in the determination of whether a given vehicle is classified as a car or a light truck. See Appendix A for a list of these exceptions.

Vehicle population data in this report represent production delivered for sale in the U.S., rather than actual sales data. Automakers submit production data in formal end-of-year CAFE compliance reports to EPA, which is the basis for this report. Accordingly, the production data in this report may differ from sales data reported by press sources. In addition, the data presented in this report are tabulated on a model year basis. In years past, manufacturers typically used a consistent approach toward model year designations, i.e., from fall of one year to the fall of the following year. More recently, however, many manufacturers have used a more flexible approach and it is not uncommon to see a new or redesigned model be introduced in the spring or summer, rather than the fall. This means that a model year for an individual vehicle can be "stretched out." Accordingly, year-to-year comparisons can be affected by these model year anomalies, though, these even out over a multi-year period. In addition, some of the figures in this report use three-year moving averages that effectively smooth the trends, and these three-year moving averages are tabulated at the midpoint. For example, the midpoint for model years 2008, 2009, and 2010 is MY2009. Figures are based on annual data unless otherwise noted.

All of the data in this report are from vehicles certified to operate on gasoline or diesel fuel, from laboratory testing with test fuels as defined in EPA test protocols. There are no data from the very small number of vehicles that are certified to operate only on alternative fuels. The data from ethanol flexible fuel vehicles, which can operate on both an 85 percent ethanol/15 percent gasoline blend or gasoline or any mixture in between, are from gasoline operation.

While CO_2 emissions values can be arithmetically averaged, all average fuel economy values were calculated using harmonic rather than arithmetic averaging, in order to maintain mathematical integrity. See Appendix A.

The EPA database for this report was frozen in June 2010.

Through MY2009, the CO_2 emissions, fuel economy, vehicle characteristics, and vehicle production volume data used for this report were from the formal end-of-year submissions from automakers obtained from EPA's fuel economy database that is used for CAFE compliance purposes. Accordingly, values for all model years through 2009 can be considered final.

For MY2010, EPA has exclusively used confidential pre-model year production volume projections. Accordingly, MY2010 projections are uncertain, particularly given the recent changes in the automotive marketplace driven by the economic recession, fuel prices, and other factors. Historically, the differences between the initial estimates based on vehicle production projections and later, final values have ranged between 0.4 mpg lower to 0.6 mpg higher. But, the market turmoil in MY2009 proved to be a major exception in this regard, as the final MY2009 value reported herein is 1.3 mpg higher than the preliminary value for MY2009 in last year's report based on projected production volumes.

For More Information

Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2010 (EPA420-R-10-023) is available on the Office of Transportation and Air Quality's (OTAQ) Web site at:

www.epa.gov/otaq/fetrends.htm

Printed copies are available from the OTAQ library at:

U.S. Environmental Protection Agency
Office of Transportation and Air Quality Library
2000 Traverwood Drive
Ann Arbor, MI 48105
(734) 214-4311

A copy of the *Fuel Economy Guide* giving city and highway fuel economy data for individual models is available at:

www.fueleconomy.gov

or by calling the U.S. Department of Energy at (800) 423-1363.

EPA's *Green Vehicle Guide* providing information about the air pollution emissions and fuel economy performance of individual models is available on EPA's web site at:

www.epa.gov/greenvehicles

For information about the Department of Transportation (DOT) Corporate Average Fuel Economy (CAFE) program, including a program overview, related rulemaking activities, and summaries of the fuel economy performance of individual manufacturers since 1978, see:

http://www.nhtsa.dot.gov/fuel-economy