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

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.

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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 2009 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 or SUVs, 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.

On September 15, 2009, EPA proposed the first-ever light-duty vehicle greenhouse gas emissions standards, under the Clean Air Act, for MY2012-2016 (74 Federal Register 49454, September 28, 2009). These proposed standards are part of a new, harmonized National Policy that also includes proposed corporate average fuel economy (CAFE) standards for the same years by the Department of Transportation's National Highway Traffic Safety Administration (NHTSA). Accordingly, while past reports in this series focused exclusively on fuel economy data, this year's report provides some key industry-wide tailpipe CO_2 emissions data for the 1975 – 2009 time series as well. Tailpipe CO_2 emissions data represent 90 to 95 percent of total light-duty vehicle greenhouse gas emissions. Section IV of this report discusses the CO_2 emissions data in more detail and also provides guidance for how readers can calculate CO_2 emissions values, not shown in Section IV, that are equivalent to other fuel economy values in this report.

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 five years beginning in 2005.

The projected fleetwide average real world MY2009 light-duty vehicle CO_2 emissions level is 422 grams per mile (g/mi). The fleetwide average MY2008 value is 424 g/mi. The MY2008 value is essentially a final value as the database for 2008 includes formal production data for nearly the entire MY2008 fleet, while the projected MY2009 value is based on pre-model year production projections provided by automakers and are therefore much more uncertain. Actual MY2009 sales are expected to be 30 to 40 percent lower than the projected MY2009 production volumes provided by automakers to EPA in the spring and summer of 2008. At this time, it is not possible to predict whether the market turmoil in 2009 will yield an actual CO2 emission value that is higher or lower than the preliminary MY2009 value reported here. The preliminary 422 g/mi value for model year 2009 represents a 39 g/mi, or eight percent, decrease relative to the 461 g/mi value for 2004, which was the highest CO_2 emissions value since 1980.

Since fuel economy has an inverse relationship to tailpipe CO_2 emissions, overall new light-duty vehicle fuel economy has moved through four "opposing" phases:

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 five years beginning in 2005.

The projected fleetwide average real world MY2009 light-duty vehicle fuel economy is 21.1 miles per gallon (mpg), while the fleetwide average MY2008 value is 21.0 mpg. Again, EPA has much greater confidence in the MY2008 value, which is 0.2 mpg higher than the value that we projected for MY2008 in last year's report based on pre-model year production volume projections. The fact that the revised MY2008 value is higher than the preliminary value in last year's report is to be expected given that gasoline prices peaked in spring and summer of 2008. There is much less certainty associated with the projected MY2009 value of 21.1 mpg as it is based on pre-model year production projections provided by automakers, and 2009 has continued to

be a year of turmoil in the automotive market. It is impossible to predict whether actual MY2009 fuel economy will be higher or lower than the preliminary MY2009 value. The projected model year 2009 value of 21.1 mpg represents a 1.8 mpg, or nine percent, increase over the 19.3 mpg value for 2004, which was the lowest fuel economy value since 1980.

The CO_2 emissions and fuel economy values in this report are either *adjusted* (ADJ) EPA "real-world" estimates (provided to consumers), or unadjusted EPA *laboratory* (LAB) values. All CO_2 emissions and fuel economy values in this report are adjusted values unless explicitly identified as laboratory data. 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). In 2006, EPA revised the methodology by which EPA estimates adjusted fuel economy to better reflect changes in driving habits and other factors that affect fuel economy such as higher highway speeds, more aggressive driving, and greater use of air conditioning. This is the third report in this series to reflect this new real-world fuel economy methodology, and every adjusted fuel economy value in this report for 1986 and later model years is lower than values in pre-2007 reports in this series. To reflect that these changes did not occur overnight, these new downward adjustments are phased in, gradually, beginning in 1986, and for 2005 and later model years the new adjusted composite fuel economy values are, on average, about six percent lower than under the methodology used by EPA in older reports. This same methodology is used to generate adjusted CO_2 emissions values as well. See Appendix A for more details.

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, they provide an excellent basis for comparing long-term CO_2 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. 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 projected MY2009 unadjusted laboratory composite values of 337 g/mi and 26.4 mpg represent a record low for CO_2 emissions and an all-time high for fuel economy.

While EPA establishes vehicle CO_2 emissions standards, NHTSA has the overall responsibility for the CAFE program. For 2009, the CAFE standards are 27.5 mpg for cars and 23.1 mpg for light trucks (for light trucks, individual manufacturers can choose between the fixed, unreformed 23.1 mpg standard and a reformed vehicle footprint-based standard which yields different compliance levels for each manufacturer). In March 2009, NHTSA promulgated new footprint-based CAFE standards for MY2011, for which NHTSA projected average 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. EPA provides laboratory composite fuel economy data, along with alternative fuel vehicle credits and test procedure adjustments, to NHTSA for CAFE enforcement. Because of real world adjustments, alternative fuel vehicle credits, and test procedure adjustments, current NHTSA CAFE values are a minimum of 25 percent higher than EPA adjusted fuel economy values.

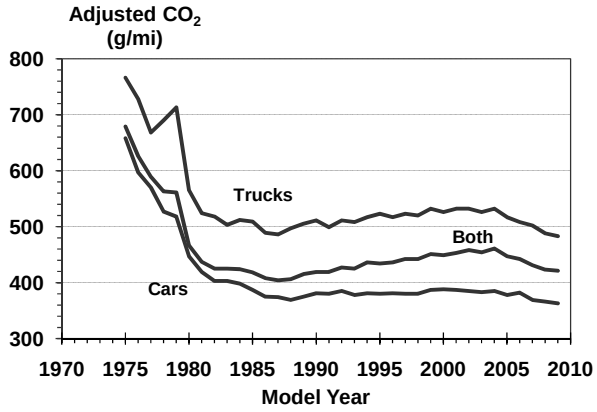
Characteristics of Light Duty Vehicles for Four Model Years

	1975	1987	1998	2009
Adjusted CO_2 Emissions (g/mi)	679	405	443	422
Adjusted Fuel Economy (mpg)	13.1	22.0	20.1	21.1
Weight (lbs.)	4060	3220	3744	4108
Horsepower	137	118	171	225
0 to 60 Time (sec.)	14.1	13.1	10.9	9.5
Percent Truck Sales	19%	28%	45%	49%
Percent Front-Wheel Drive	5%	58%	56%	55%
Percent Four-Wheel Drive	3%	10%	20%	27%
Percent Multi-Valve Engine	-	-	40%	79%
Percent Variable Valve Timing	-	-	-	65%
Percent Cylinder Deactivation	-	-	-	9%
Gasoline-Direct Injection	-	-	-	3.5%
Percent Turbocharger	-	-	1.4%	3.1%
Percent Manual Trans	23%	29%	13%	6%
Percent Continuously Variable Trans	-	-	-	8%
Percent Hybrid	-	-	-	1.8%
Percent Diesel	0.2%	0.2%	0.1%	0.5%

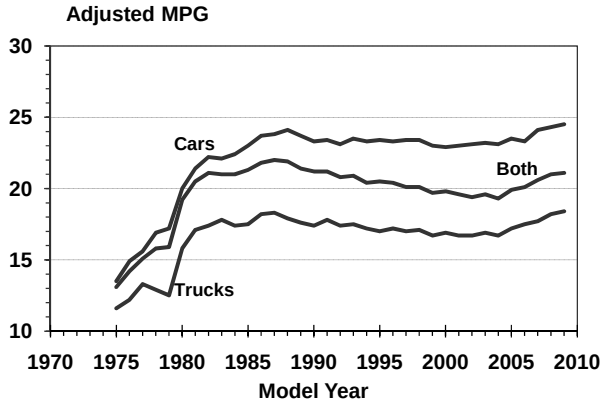
Highlight #1: Carbon Dioxide Emissions Decreases and Fuel Economy Increases Over the Last 5 Years Reverse the Long-Term Trend From 1987 through 2004.

Average adjusted composite CO_2 emissions have decreased from 461 g/mi in MY2004 to a projected level of 422 g/mi in MY2009, accounting for a 39 g/mi and 8 percent decrease. The preliminary MY2009 adjusted composite fuel economy value of 21.1 mpg represents a 1.8 mpg, or 9 percent, increase over MY2004. Actual MY2009 values will likely differ from these preliminary MY2009 values, but it is impossible to know the direction or magnitude of any changes. For both CO_2 emissions and fuel economy, the last 5 years reverse a longer-term trend over the period 1987 through 2004 and essentially return CO_2 emissions and fuel economy levels to those of the early 1980s.

Adjusted CO_2 Emissions by Model Year (grams/mile)



Adjusted Fuel Economy by Model Year (Annual Data)

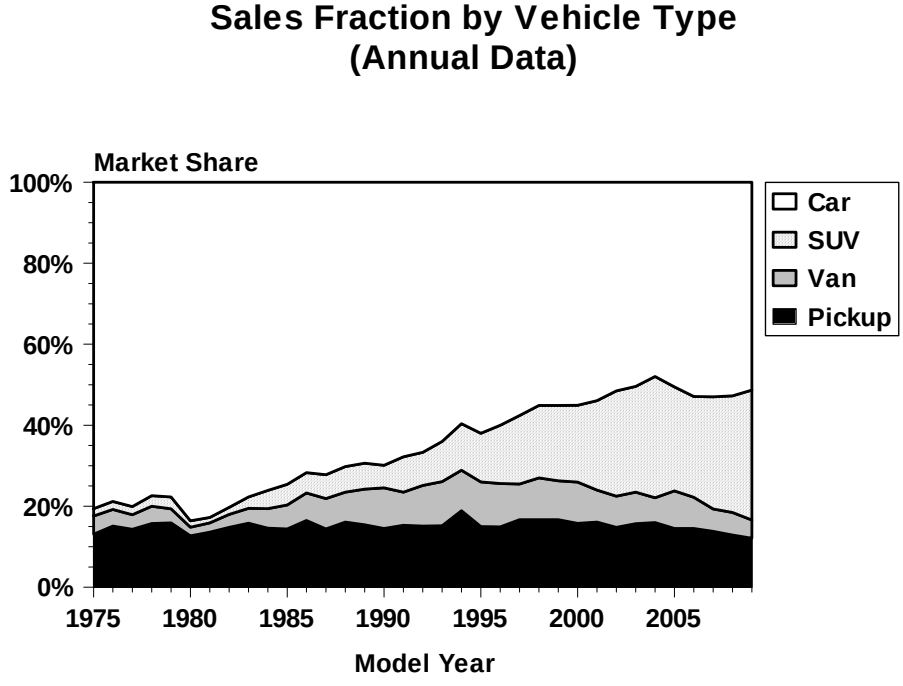


MY2009 unadjusted laboratory composite values, which reflect vehicle design considerations only and do not account for the many factors which affect real world CO_2 emissions and fuel economy performance, are at an all-time low for CO_2 emissions (337 g/mi) and a record high for fuel economy (26.4 mpg).

Highlight #2: Trucks Continue To Represent About Half of New Vehicle Production.

> *Light trucks, which include SUVs, vans, and pickup trucks, have accounted for about 50 percent of the U.S. light-duty vehicle market since MY2002. After two decades of constant growth, light truck market share has been relatively stable from 2002 through 2009. The MY2009 light truck market share is projected to be 49 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 six percent of the overall new light-duty vehicle market in MY1990 to about 30 percent of vehicles built each year since 2004. By comparison, market shares for both vans and pickup trucks have declined since 1990, with van market share falling by about one-half from 10 percent to five 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 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.



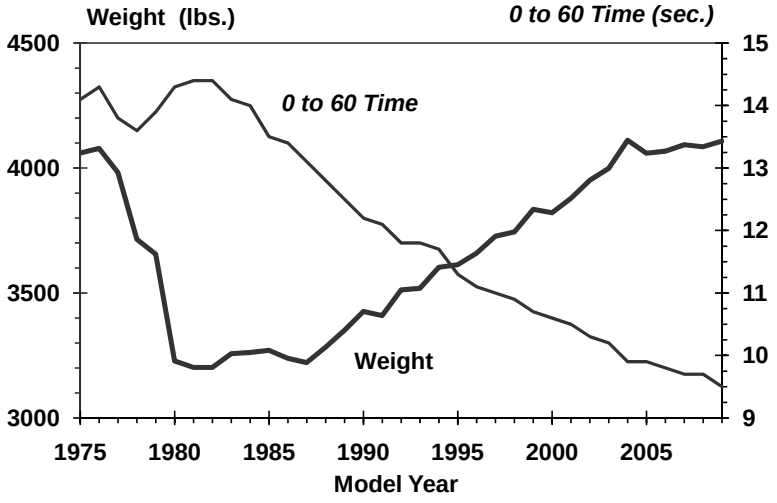
Highlight #3: Technological Innovation Since 2005 Has Resulted in Lower CO_2 Emissions, Higher Fuel Economy and Greater Performance.

Automotive engineers are constantly developing more advanced and efficient vehicle technologies. From 1987 through 2004, 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 (which supports vehicle content and features), 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.

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. Average vehicle weight and performance had increased steadily from the mid-1980s through 2004.

Average light-duty vehicle weight has been fairly constant since 2004, with a small increase in weight of cars offset by a small decrease in truck market share. Average fleetwide performance has continued to improve just about every year. The projection for MY2009 is for an increase in both vehicle performance and weight.

Weight and Performance
(Annual Data)



Highlight #4: Many Marketing Groups Are Increasing Fleetwide Fuel Economy, Resulting in Lower CO_2 Emissions.

Seven of the nine highest-selling marketing groups increased fuel economy (which also reduced CO_2 emissions) from MY2007 to MY2008, the last two years for which we have solid information based on final CAFE reports. Preliminary values suggest that four of the nine marketing groups will increase fuel economy (thereby reducing CO_2 emissions) in MY2009, and one marketing group will maintain constant levels, based on projected production provided to EPA by automakers prior to the start of the model year. Actual MY2009 values will likely be different than the preliminary MY2009 values reported here.

In MY2008, the last year for which EPA has essentially complete formal production data, Honda had the lowest fleetwide adjusted composite CO_2 emissions (and highest fuel economy) performance, followed closely by Hyundai-Kia. Chrysler had the highest CO_2 emissions (and lowest fuel economy), with Ford having slightly lower CO_2 emissions. Chrysler had the biggest absolute improvement from MY2007 to MY2008, with an 19 g/mi, or 4.0 percent, reduction in fleetwide CO_2 emissions, followed by Hyundai-Kia with a 14 g/mi and 3.6 percent reduction in CO_2 emissions.

Preliminary MY2009 values suggest that Honda will continue to have the lowest fleetwide CO_2 emissions (and highest fuel economy), followed closely by Hyundai-Kia and Toyota. Chrysler is projected to have the highest MY2009 CO_2 emissions, reversing most of its gains from the previous year. Ford is projected to show the largest CO_2 reductions, with its projected MY2009 CO_2 emissions being 37 g/mi lower than MY2007 and 25 g/mi lower than MY2008. Ford and General Motors are the two marketing groups that showed improvement in MY2008 and are projected to do so again in MY2009.

MY2007 – 2009 Marketing Group Fuel Economy and Carbon Dioxide Emissions (Adjusted Composite Values)

Marketing Group	<-------- MY2007 -------->		<-------- MY2008 -------->		<-------- MY2009 -------->	
	Fuel Economy (mpg)	CO_2 (g/mi)	Fuel Economy (mpg)	CO_2 (g/mi)	Fuel Economy (mpg)	CO_2 (g/mi)
Honda	23.3	382	23.9	372	23.6	376
Hyundai-Kia	22.9	388	23.7	374	23.4	380
Toyota	23.3	382	22.8	389	23.2	383
Volkswagen	21.9	405	22.3	398	22.8	398
Nissan	21.3	418	21.9	406	21.6	411
BMW	21.5	415	21.2	419	21.6	412
General Motors	19.2	463	19.7	452	19.9	447
Ford	18.9	471	19.4	459	20.5	434
Chrysler	18.6	479	19.3	460	18.7	476
All	**20.6**	**432**	**21.0**	**424**	**21.1**	**422**

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 a single *adjusted* composite (combined city/highway) CO_2 emissions or fuel economy value, 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*.

This 2009 report supersedes all previous reports in this series, which date back to the early 1970s. In general, users of this report should rely exclusively on data in this 2009 report, which covers the years 1975 through 2009, and not try to make comparisons to data in previous reports in this series. There are at least two reasons for this.

One, EPA revised the methodology for estimating real-world fuel economy values in December 2006. This is the third report in this series to reflect this new 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 this new 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 marketing group definition to reflect a change in the industry's current financial arrangements, EPA makes the same adjustment in marketing group composition in the historical database as well. This maintains a consistent marketing group definition over time, which allows the identification of trends over time. On the other hand, it means that the database does not necessarily reflect actual past financial arrangements. For example, the 2009 database, which includes data for the entire time series 1975 through 2009, no longer reflects the fact that Chrysler was combined with Daimler for several years.

In some tables and figures in this report, a single *laboratory* composite (combined city/highway) value is also shown. 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 Corporate Average Fuel Economy (CAFE) compliance data as reported by the Department of Transportation's National Highway Traffic Safety Administration (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 2009.

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 typically there are a few cases each model year 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.

The data presented in this report were tabulated on a model year basis, but 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 2007, 2008, and 2009 is MY2008. 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 arithmetical averaging, in order to maintain mathematical integrity. See Appendix A.

The EPA database used to generate the CO_2 emissions and fuel economy values in this report was frozen in April 2009, yielding additional data beyond that used in last year's report for model years beginning in 2006, although additional data for MY2008 was added in June 2009.

Through MY2007, 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 up to 2007 can be considered final.

For MY2008, the data used in this report are based almost exclusively on formal end-of-year CAFE submissions by automakers. Accordingly, the MY2008 data are essentially final and EPA has a very high level of confidence in the data for MY2008. It is noteworthy that the 21.0 mpg adjusted fuel economy value for MY2008 in this report is 0.2 mpg higher than the projected 20.8 mpg adjusted fuel economy value for MY2008 in the 2008 report. This suggests that higher gasoline prices have led to actual 2008 production volumes that differ from the projected 2008 production levels provided to EPA by automakers in 2007.

For MY2009, EPA has exclusively used confidential pre-model year production volume projections. Accordingly, MY2009 projections are much more uncertain, particularly given the changes in the automotive marketplace driven by the economic recession and volatile fuel prices. For model years 1998 through 2006, the final laboratory fuel economy values for a given model year have varied from 0.4 mpg lower to 0.4 mpg higher compared to original estimates for the same model year that were based exclusively on projected production levels.

In the various appendices to this report, when there is no entry under “Model Year,” that means there was no production volume for the data in question.

For More Information

Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2009 (EPA420-R-09-014) 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:

www.nhtsa.dot.gov and click on "Fuel Economy"