Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards Around the World

Prepared for the Pew Center on Global Climate Change

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Executive Summary

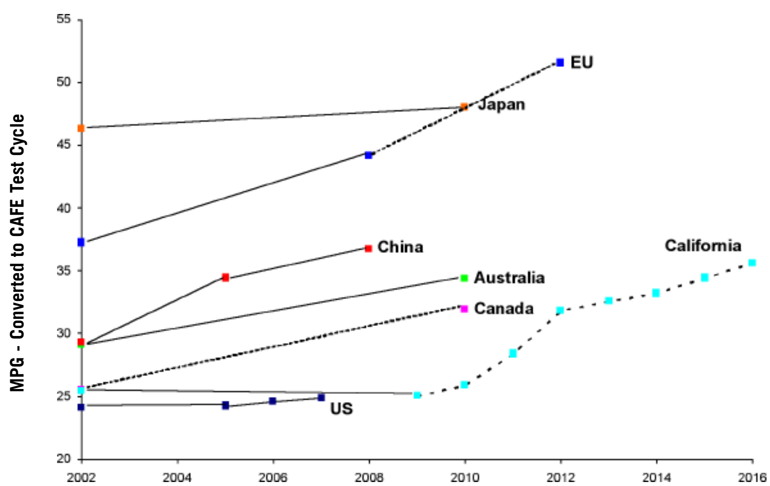
Nine major regions around the world have implemented or proposed various fuel economy and greenhouse gas (GHG) emission standards. Yet these standards are not easily comparable, due to differences in policy approaches, test drive cycles, and units of measurement. This paper develops a methodology to compare these programs to better understand their relative stringency. The results are summarized by Figure ES. Key findings from the report include:

- The European Union (EU) and Japan have the most stringent standards in the world.
- The fuel economy and greenhouse gas emission performance of the U.S. cars and light trucks—both historically and projected based on current policies—lags behind most other nations. The United States and Canada have the lowest standards in terms of fleet-average fuel economy rating, and they have the highest greenhouse gas emission rates based on the EU testing procedure.
- The new Chinese standards are more stringent than those in Australia, Canada, California, and the United States, but they are less stringent than those in the European Union and Japan.
- If the California GHG standards go into effect, they would narrow the gap between U.S. and EU standards, but the California standards would still be less stringent than the EU standards.

The relevant stringency and implementation years of fuel economy and GHG emissions standards around the world is shown in the figure below.

Figure ES

Comparison of fuel economy and GHG emission standards **normalized by CAFE-converted mpg**



Notes: (1) dotted lines denote proposed standards
(2) MPG = miles per gallon

I. Introduction

Automobile fuel economy standards have proven to be one of the most effective tools in controlling oil demand and greenhouse gas (GHG) emissions from the transportation sector in many regions and countries around the world. While fuel economy standards for light-duty vehicles have been largely stagnant in the United States over the past two decades, the rest of the world—especially the European Union, Japan, and recently China and California—has moved forward, establishing or tightening GHG or fuel economy standards. This paper attempts to analyze the relative stringency of fuel economy and GHG standards worldwide to better inform policy-makers considering what actions to take in the face of rising oil prices, increasing worldwide oil demand, and rising GHG emissions from the transportation sector.

Directly comparing vehicle standards among different regions and countries is challenging. Automobile fuel economy standards can take many forms, including numeric standards based on vehicle fuel consumption (such as liters of gasoline per hundred kilometers of travel [L/100-km]) or fuel economy (such as miles per gallon [mpg], or kilometers per liter [km/L]). Automobile GHG emission standards (expressed as grams per kilometer or grams per mile), even though they are not designed to directly control oil consumption, also affect vehicle fuel consumption.

Before discussing fuel economy policies in detail, it is important to keep in mind that a variety of other approaches to reduce automobile fuel consumption have been introduced in different parts of the world. They include, but are not limited to: fuel taxes, fiscal incentives, research and development (R&D) programs, technology mandates and targets, and traffic control measures. While some of these measures are designed to promote fuel-efficient vehicles, others are designed to curb travel or vehicle demand.

Many tax, fiscal, and technology approaches have been used in combination with fuel economy and GHG standards with varying degrees of success. For example, higher fuel taxes in EU member countries are considered to be a major contributing factor to the generally small and fuel-efficient vehicle models in the EU market, as well as to fewer annual vehicle miles traveled (VMT). These taxes reinforce efforts on the part of automakers to meet lower GHG emission targets. California's zero-emission vehicle (ZEV) mandate may have contributed to a large increase in R&D efforts in promoting electric-drive vehicles such as battery electric vehicles and hybrid electric vehicles. These technologies will contribute to the industry's success in meeting the proposed California GHG emission standards starting in 2009. In addition, California recently proposed to allow hybrid electric vehicles with fuel economy ratings higher than 45 mpg to use high occupancy vehicle (HOV) lanes to stimulate consumer demand for fuel-efficient vehicles. Currently only the Toyota Prius, Honda Civic hybrid, and Honda Insight hybrid meet this threshold. Table 1 summarizes major approaches applied around the world for the purpose of promoting fuel-efficient automobiles.

Table 1

Measures to promote fuel-efficient vehicles around the world

Fuel efficiency approach	*Measures/forms*	*Country/region*
Fuel economy standards	Numeric standard in mpg, km/L, or L/100-km	United States, Japan, Canada, Australia, China, Taiwan, South Korea
GHG emission standards	Grams/km or grams/mile	European Union, California
High fuel taxes	Fuel taxes at least 50% greater than crude oil base price	European Union, Japan
Fiscal incentives	Tax relief based on engine size, efficiency, and carbon dioxide emissions	European Union, Japan
R&D programs	Incentives for particular technologies and alternative fuels	United States, Japan, European Union
Economic penalties	Gas guzzler tax	United States
Technology mandates and targets	Sales requirement for ZEVs	California
Traffic control measures	Hybrids allowed in HOV lanes; ban on SUVs	Several U.S. States (hybrid HOV lanes); Paris (SUV ban)

Note: This list is not exhaustive.

While all of these fuel-efficiency measures deserve in-depth study, this paper focuses on comparing automobile fuel economy and GHG emission standards that currently exist or are being proposed around the world. The remaining part of the paper is structured as follows: Section 2 provides a detailed overview of countries and regions that have established or proposed vehicle standards. Section 3 addresses issues associated with different kinds of vehicle standards and describes a new methodology to compare them. Based on this methodology, section 4 compares the relative stringency of vehicle standards around the world.

II. Overview of Countries and Regions with Vehicle Fuel Economy and GHG Standards

Nine countries and regions have established or proposed their own motor vehicle fuel economy or GHG emission standards (Table 2). These countries and regions cover most of the developed world and include the United States, European Union, Japan, Canada, and Australia. China and South Korea have recently adopted new vehicle fuel efficiency standards, while Taiwan has had its own fuel economy standards for more than a decade. The European Union negotiated voluntary vehicle carbon dioxide (CO_2) emission rate targets as a means to control GHG emissions. The state of California has also recently proposed its own GHG emission standards for vehicles. Of the 30 Organization of Economic Cooperation and Development (OECD) countries, only Mexico and Iceland do not currently have some form of fuel economy or GHG emission program for vehicles.

Due to various historic, cultural, and political reasons, different countries and regions have chosen to adopt different fuel economy or GHG standards. These standards differ in stringency, by their apparent forms and structures and by how the vehicle fuel economy or GHG emission levels are measured—that is, by testing methods. They also differ by implementation requirements, such as mandatory vs. voluntary approaches.

Table 2

Fuel economy and GHG standards for vehicles around the world

Country/region	*Type*	*Measure*	*Structure*	*Test method*[a]	*Implementation*
United States	Fuel	mpg	Cars and light trucks	U.S. CAFE	Mandatory
European Union	CO_2	g/km	Overall light-duty fleet	EU NEDC	Voluntary
Japan	Fuel	km/L	Weight-based	Japan 10-15	Mandatory
China	Fuel	L/100-km	Weight-based	EU NEDC	Mandatory
California	GHG	g/mile	Car/LDT1 and LDT2[b]	U.S. CAFE	Mandatory
Canada	Fuel	L/100-km	Cars and light trucks	U.S. CAFE	Voluntary
Australia	Fuel	L/100-km	Overall light-duty fleet	EU NEDC	Voluntary
Taiwan, South Korea	Fuel	km/L	Engine size	U.S. CAFE	Mandatory

[a]Test methods include U.S. Corporate Average Fuel Economy (CAFE), New European Drive Cycle (NEDC), and Japan 10-15 Cycle. See Appendix for more details.

[b]LDT1 and LDT2 are categories of light-duty trucks.

Almost all industrialized countries use standards on new vehicles to reduce vehicle oil consumption and CO_2 emissions. Yet the three largest automobile markets, the United States, the European Union and Japan, approach these standards quite differently.

The United States uses Corporate Average Fuel Economy (CAFE) standards, which require each manufacturer to meet specified fleet average fuel economy levels for cars and light trucks. Canada's automobile industry has voluntarily agreed to follow the U.S. CAFE standards in Canada; however, the government has announced its intention to decrease fuel consumption of passenger vehicles by 25 percent by 2010. California recently proposed a GHG emission standard that requires each manufacturer to meet fleet average GHG targets for two separate categories of light-duty vehicles.

In the European Union, the automobile industry has signed a voluntary agreement with the government to reach an overall fleet CO_2 emission level of 140 g CO_2/km by 2008. In Australia, the automobile industry has signed a similar voluntary agreement with the government, committing to reach an overall fleet average fuel consumption of 6.8 liters per km by 2010. Approaches in which the entire industry must meet one target contrast with the U.S. CAFE policy, which requires each company to meet standards for cars and light trucks.

In Japan, as in China, fuel economy standards are based on a weight classification system where vehicles must comply with the standard for their weight class. Similarly, the fuel economy standards in Taiwan and South Korea are based on an engine size classification system. China, however, is following the EU's testing procedures, and Taiwan and South Korea are following testing methods similar to U.S. CAFE procedures. Japan maintains its own testing procedures.

The following sections describe country or region-specific standards in greater detail. Some of these standards have been converted into U.S. CAFE-equivalent mpg figures, based on the methodology described in section 3.

2.1. The United States

In the wake of the 1973 oil crisis, the U.S. Congress passed the Energy Policy and Conservation Act of 1975 with the goal of reducing the country's dependence on foreign oil. Among other things, the act established the CAFE program, which requires automobile manufacturers to meet a standard for the sales-weighted fuel economy of light-duty passenger vehicles sold in the United States.

The CAFE program maintains an important distinction between passenger cars and light trucks, with each having their own standard. Under the regulations, passenger cars are classified as any four-wheeled vehicle not designed for off-road use that transports 10 people or fewer. Light trucks, on the other hand, include four-wheeled vehicles that are designed for off-road operation or vehicles that weigh between 6,000 and 8,500 lbs and have physical features consistent with those of a truck.

The distinction between cars and light trucks was originally included in the CAFE legislation at a time when light trucks were a small percentage of the vehicle fleet, with the most common light trucks being pickups, used primarily for business and agricultural purposes. Since that time, however, the distinction between passenger cars and light trucks has become increasingly fuzzy. Automakers have introduced "cross-over" vehicles that combine features of both cars and light trucks. Meanwhile, light-duty vehicles classified as trucks (such as minivans and SUVs) are now used primarily as personal transport vehicles. The result has been a 7 percent decrease in the overall light-duty fleet fuel economy since 1988, associated with the rapid growth of light trucks used as passenger vehicles beginning in the mid-1980s.[1]

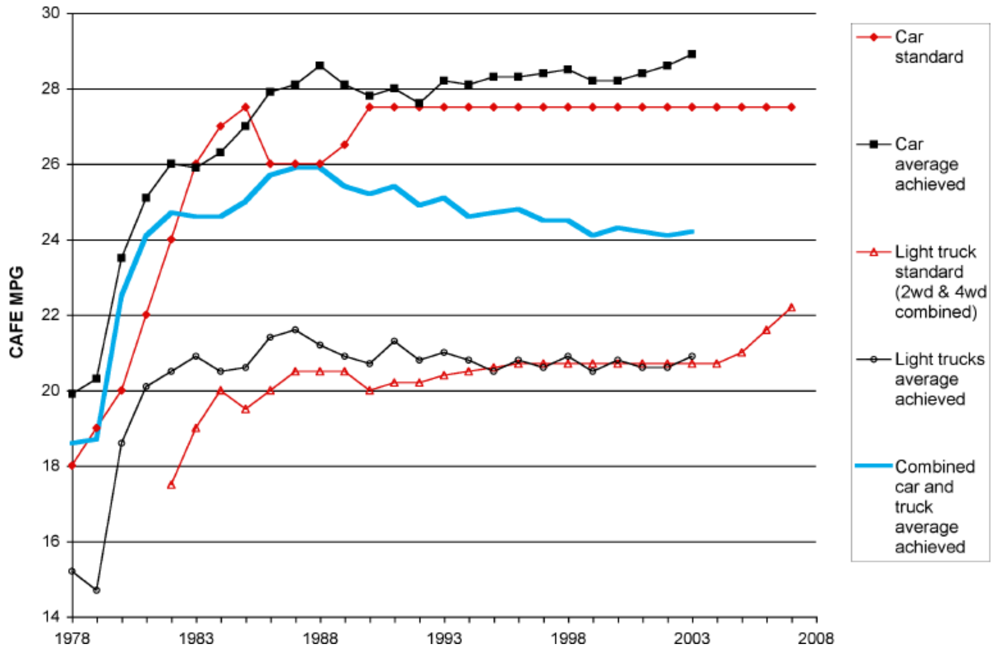
The CAFE standard for passenger cars has remained unchanged since 1985 at 27.5 mpg (however, this standard was rolled back for several years in the late 1980s due to automakers' petitions).[2] The standard for light trucks has recently been increased from the existing standard of 20.7 mpg in 2004 to 21.0 mpg for 2005, 21.6 mpg for 2006, and 22.2 mpg for 2007.[3] See Figure 1 for a history of fuel economy standards and actual fuel economy averages for cars, light trucks, and the overall light-duty vehicle fleet. Figure 1 demonstrates a continuous declining trend in fleet-average CAFE fuel economy since 1988.

Competitive considerations among automakers can figure prominently in the design of fuel economy standards. For example, to protect domestic auto employment, lawmakers included a provision in the original CAFE legislation that requires a manufacturer's domestic and import fleets to separately meet the 27.5 mpg CAFE standard.[4] Specifically a vehicle, irrespective of who makes it, is considered a part of the "domestic fleet" if 75 percent or more of the cost of the content is either U.S., Canadian, or Mexican in origin. If not, it is considered an import (however, Nissan has been granted an exemption to the two-fleet rule for model years 2006-2010).[5] This distinction between domestic and import fleets for light trucks no longer exists.

There are a couple of noteworthy exceptions to the CAFE regulations for passenger vehicles. First, the standards only apply to vehicles up to 8,500 lbs gross vehicle weight (GVW), meaning that many pickups and some of the largest SUVs and trucks (including GM's Hummer and Ford's Excursion) are classified as heavy-duty vehicles (over 8,500 lbs) and are not included in their manufacturer's CAFE calculation. A study prepared for the U.S. Department of Energy in February 2002 by the Oak Ridge National Laboratory[6] found that 521,000 trucks with vehicle weights from 8,500 to 10,000 lbs were sold in calendar year 1999. The vast majority (82 percent) of these trucks were pickups, and a significant number (24 percent) were diesel. At the end of 1999, 5.8 million of these trucks were on the road, accounting for 8 percent of the annual miles driven by light trucks and 9 percent of light truck fuel use.

Figure 1

CAFE standards vs. actual for cars and light trucks*



Note: The two red lines represent CAFE standards for cars and light trucks respectively. The two black lines represent fleet-average fuel economy achieved separately by cars and light trucks. The light-blue line represents fleet average fuel economy achieved for both cars and light trucks. When achieved fuel economy levels are higher than the standards, it indicates that companies are able to meet the standards; otherwise, they would be subject to financial penalties. However, CAFE calculations may also include "dual-fuel" and "alternative" vehicles, as well as credits earned by companies in prior or subsequent years to offset noncompliance.

The second noteworthy exception to the CAFE law is that it provides special treatment of vehicle fuel economy calculations for dedicated alternative fuel vehicles and dual-fuel vehicles. The fuel economy of a dedicated alternative fuel vehicle is determined by dividing its fuel economy in equivalent miles per gallon of gasoline or diesel fuel by 0.15. Thus a 15-mpg dedicated alternative fuel vehicle would be rated as if it were a 100-mpg vehicle. For dual-fuel vehicles, this calculation is applied only to the percentage of fuel use expected from alternative fuels. However, in reality dual-fuel vehicles are often run on only gasoline or diesel instead of on an alternative fuel mix, thus inflating the fuel economy rating of the vehicle for CAFE purposes. From 1993 to 2004, the CAFE increase attributable to dedicated or dual-fuel vehicles in a manufacturer's passenger car or light truck fleet was capped at 1.2 mpg. In October 2004, this special treatment of alternative fuel vehicles was extended for model years 2005 to 2008, although the maximum CAFE increase allowed to a manufacturer's fleet was reduced to 0.9 mpg.[7]

The penalty for failing to meet CAFE standards recently increased from $5.00 to $5.50 per tenth of a mile per gallon under the standard for each vehicle manufactured for a given model year. Moreover, CAFE violation can carry a criminal liability that has further inhibited U.S.-based firms from failing to comply; to date, only foreign-based automakers have been in CAFE violation and paid fines. To avoid such penalties, manufacturers can earn CAFE "credits" to offset deficiencies in their CAFE performances. Specifically, when the average fuel economy of either the passenger car or light truck fleet for a particular model year exceeds the established standard, the manufacturer earns credit. The amount of credit manufacturers earn is determined by multiplying the tenths of miles per gallon by which the manufacturers exceeded the CAFE standard in that model year by the number of vehicles they manufactured in that model year. These credits can be applied to any three consecutive model years immediately prior to or subsequent to the model year in which the credits are earned.

2.2. California

In 2002, California enacted legislation directing the California Air Resources Board (CARB) to achieve the maximum feasible and cost-effective reduction of GHGs from California's motor vehicles. In September 2004, the draft regulations were approved by the CARB Board and are now under a year-long review process with the state legislature. If the legislature does not modify the regulation, it becomes state law on January 1, 2006. The standard will take effect with the 2009 model year passenger vehicles. The states of New York, Massachusetts, New Jersey, Maine, Connecticut, Rhode Island, Vermont and Washington[8] are considering adopting the California regulation for their use. Canada has also expressed its intention to follow California's lead. Along with California, these states and Canada represent approximately 30 percent of all cars sold in North America excluding Mexico.[9]

CARB has proposed near-term standards to be phased in from 2009 through 2012, and mid-term standards to be phased in from 2013 through 2016. The GHG emission standards will be incorporated directly into the current low emission vehicle (LEV) program, along with other light- and medium-duty automotive emission standards.[10] Accordingly, there would be a GHG emission fleet-average requirement for the passenger car/light-duty truck 1 (PC/LDT1) category, which includes all passenger cars regardless of weight and light-duty trucks weighing less than 3,750 lbs equivalent test weight (ETW). The second category is light-duty truck 2 (LDT2) for light trucks weighing between 3,751 lbs ETW and 8,500 lbs gross vehicle weight (GVW).[11] Furthermore, vehicles weighing 8,500 to 10,000 lbs that are classified as medium-duty passenger vehicles (MDPVs) will be included in the LDT2 category for GHG emission standards.

The legislation will be phased in for both the near-term and medium-term standards. Table 3 outlines the GHG emission standards approved by CARB.

Table 3

California Air Resources Board approved standards

Timeframe	Year	GHG emission standard (CO_{2e} in g/mi) PC/LDT1	GHG emission standard (CO_{2e} in g/mi) LDT2	CAFE-equivalent standard (mpg) PC/LDT1	CAFE-equivalent standard (mpg) LDT2
Near-term	2009	323	439	27.6	20.3
	2010	301	420	29.6	21.2
	2011	267	390	33.3	22.8
	2012	233	361	38.2	24.7
Medium-term	2013	227	355	39.2	25.1
	2014	222	350	40.1	25.4
	2015	213	341	41.8	26.1
	2016	205	332	43.4	26.8

Source: California Air Resources Board, August 2004

The legislation also directs that emission reduction credits be granted for any reductions in GHG emissions achieved prior to the date the regulations take effect (model years 2000 through 2008). Under the early credit proposal, manufacturer fleet average emissions for model years 2000 to 2008 will be compared to the near-term standard on a cumulative basis. Manufacturers that had cumulative emissions below the near-term standards would earn credit. Similarly, credits can be accumulated during the phase-in years and used to offset compliance shortfalls up to one year after the end of the phase-in at full value, or at a discounted rate in the second and third years after the end of the phase-in.

CARB estimates that the proposed GHG emission standards will reduce projected GHG emissions from the light-duty vehicle fleet by 17 percent in 2020 and by 25 percent in 2030.[12] In absolute terms, however, total GHG emission reductions due to the legislation would be more than offset by growth in vehicle population and travel by 2020, and vehicle GHG emissions would stabilize at today's level by 2030.

In December 2004, the automobile industry filed a lawsuit to challenge the CARB rules in court on the basis that GHG emissions are closely related to fuel economy, and that only the federal government has the authority to regulate fuel economy under the CAFE legislation. California officials, including the governor, remain committed to seeing these regulations come into force, arguing that they regulate greenhouse gases, not fuel economy, and that the state is permitted to do so under the Clean Air Act.[13]

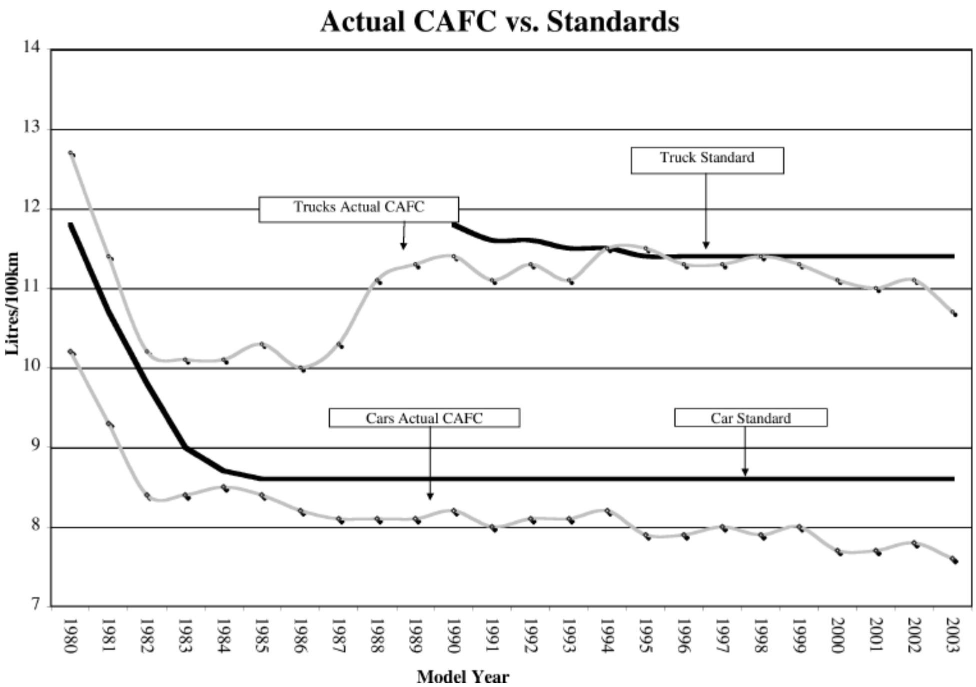
2.3. Canada

Canada's Company Average Fuel Consumption (CAFC) goal was introduced in 1976 for the new passenger vehicle fleet. This voluntary goal is equivalent to CAFE but measured in L/100-km. Legislation was introduced in 1982 to make the fuel efficiency program mandatory instead of voluntary, with penalties for non-compliance. Although the legislation was passed by Parliament, it did not go into effect because the motor vehicle industry agreed to comply voluntarily with the requirements of the act. This legislation closely matched key provisions in the U.S. CAFE program, including a credit system, penalties for non-compliance, and the use of the U.S. CAFE test driving cycle to determine fuel consumption. One difference between the U.S. CAFE system and Canada's CAFC goal is that the Canadians do not distinguish between domestic and import fleets whereas the United States does.

Canadian goals have continued to match the U.S. standards each year for new passenger car and new light-duty truck fleets, with the Canadian vehicle fleet outperforming the U.S. fleet overall for average fuel economy by about 3 percent. See Figure 2 for a graph of Canada's average fuel consumption and standards. This is due in part to different tax provisions (fuel, vehicle, and income), and also to the different sales mix of vehicles in the two countries. Overall, Canadians purchase slightly fewer pickups and SUVs and more minivans than do their U.S. counterparts.[14] Also, the split between passenger cars and light trucks has been relatively steady since 1997 -- at about 55 percent vs. 45 percent[15], while in the United States, the market share of light trucks continues to increase and for the first time in Model Year 2003, light trucks out-sold cars.[16]

Figure 2

Actual Corporate Average Fuel Consumption vs. Standards in Canada



Source: Natural Resources Canada

Note: The two solid lines represent CAFC standards for cars and light trucks respectively. The two gray lines represent fleet-average fuel consumption levels achieved separately by cars and light trucks. When achieved fuel consumption levels are lower than the standards, it indicates that companies are able to meet the standards; otherwise, they would be subject to financial penalties.

Recently the Canadian government declared that it would require reduction of the average oil consumption of the entire fleet by 25 percent as part of Canada's plan to meet its CO_2 obligations under the Kyoto Protocol. This reduction target has generated a heated debate between the Environment Minister and the auto industry over the feasibility of such a proposal. The baseline year has yet to be specified. Canada has also indicated that it is considering adopting the California standards, which would also constitute a 25 percent improvement in GHG emissions from passenger vehicles.[17] The Canada's passenger vehicle sales are close to 10 percent of sales in the United States.

2.4. European Union

The European automotive industry is currently committed to reducing passenger vehicle CO_2 emissions through a voluntary agreement with the European Commission. Signed in March 1998, the "ACEA Agreement" is a collective undertaking by the European automobile manufacturers association, Association des Constructeurs Européens d'Automobiles (ACEA), and its members to reduce voluntarily the CO_2 emission rates of vehicles sold in the European Union. Specifically, the agreement establishes industry-wide targets for average vehicle emissions from new vehicles sold in Europe to be reduced to 140 grams of CO_2 per kilometer (gCO_2/km) by 2008, with the possibility of extending the agreement to 120 gCO_2/km by 2012. Furthermore there is an intermediate target range in 2003 of 165-170 gCO_2/km. The last monitoring report indicates that the European and Japanese auto companies are on track to meet this target, while the Korean companies lag behind.[18]

The agreement covers all vehicles produced or imported into the European Union by member companies (BMW, DaimlerChrysler, Fiat, Ford, GM, Porsche, PSA Peugeot Citroën, Renault, and VW Group). As part of the agreement with ACEA, the European Commission initiated similar negotiations in 1998 with the Korean and Japanese manufacturers (the Korean Automobile Manufacturers Association [KAMA] includes Daewoo, Hyundai, Kia, and Ssangyong; the Japanese Automobile Manufacturers Association [JAMA] includes Daihatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, and Toyota). JAMA and KAMA agreed to similar commitments to those of ACEA, with the following modifications agreed to during later negotiations: (1) KAMA has until 2004 to achieve the 2003 intermediate target; (2) JAMA's 2003 intermediate target range is wider, at 165-175 gCO_2/km; and (3) both JAMA and KAMA have an extra year to achieve the final 140 gCO_2/km target. All together, vehicles sold by companies under the voluntary agreement make up nearly 90 percent of total EU vehicle sales.

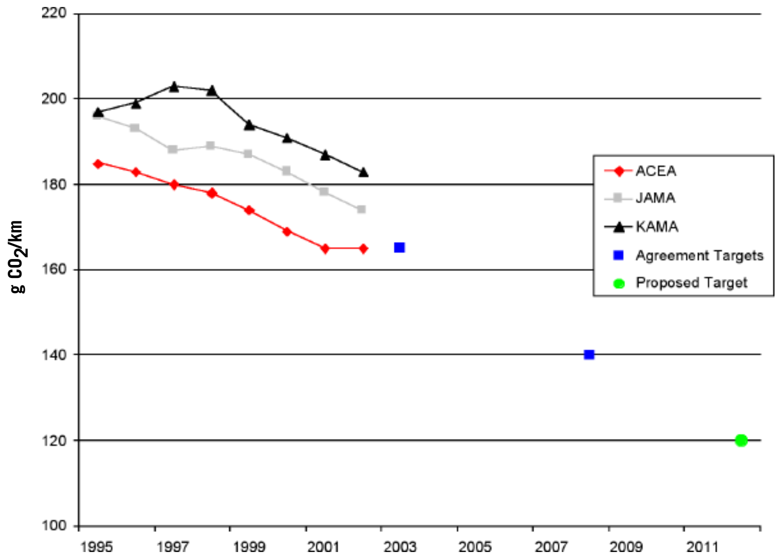
According to EU member states data, in 2002 the average CO_2 emissions from ACEA's new vehicle fleet was 165 gCO_2/km (gasoline-fueled cars: 172 g/km; diesel-fueled cars: 155 g/km; alternative-fueled cars: 177 g/km). These emissions are in line with the 2003 intermediate target range of 165-170 gCO_2/km.[19] Compared with 2001, these levels represent a reduction of 1.2 percent in new vehicle emissions. In the final period of the commitment, companies will need to accelerate their efforts. See Figure 3 for ACEA's, JAMA's, and KAMA's progress under the ACEA Agreement compared to future targets.

The growth in sales of diesel vehicles made it easier for companies to meet their intermediate 2003 target and is likely to contribute greatly towards reaching the 2008 final target. Diesel has grown from 14 percent of European vehicles in 1990 to 44 percent in 2003, and it is expected to grow to 52 percent of market share by 2007. The reasons for strong diesel demand are mainly tax incentives (with lower taxes on diesel fuel and lower import taxes on diesel cars in some EU countries), high fuel prices (because diesel-fueled vehicles achieve about 25 percent greater fuel economy than their gasoline-fueled counterparts), and the superior driving capabilities of diesel engines. While diesel sales have allowed companies to make progress toward the 2008 target of 140 gCO_2/km, however it will be quite difficult for the sale of these vehicles alone to advance them to the proposed 2012 target of 120 gCO_2/km.

Despite reluctance on the part of industry to extend the ACEA Agreement to the 120 gCO_2/km target in 2012, the European Commission has recently reaffirmed its objective to reduce average per-car CO_2 emissions to this goal.[20] The 2012 commitment is likely to be based on a broader set of instruments, including tax incentives, greener driving initiatives, and alternative fuels. Natural gas-based fuels and biofuels are the likely candidates for alternative fuels, given the beneficial well-to-wheels (life cycle) emission characteristics.

Figure 3

Progress and targets under the ACEA Agreement



2.5. Japan

The Japanese government has established a set of fuel economy standards for gasoline and diesel powered light-duty passenger and commercial vehicles, with fuel economy targets based on average vehicle fuel economy by weight class. The targets for gasoline vehicles are to be met by 2010, while 2005 is the target year for diesel vehicles. The regulations were revised in 2001 to allow automakers to accumulate credits in one weight class and use them in another weight class (although with many limitations). Table 4 and Figure 4 illustrate the improvements required by fuel economy standards for gasoline vehicles.

Table 4

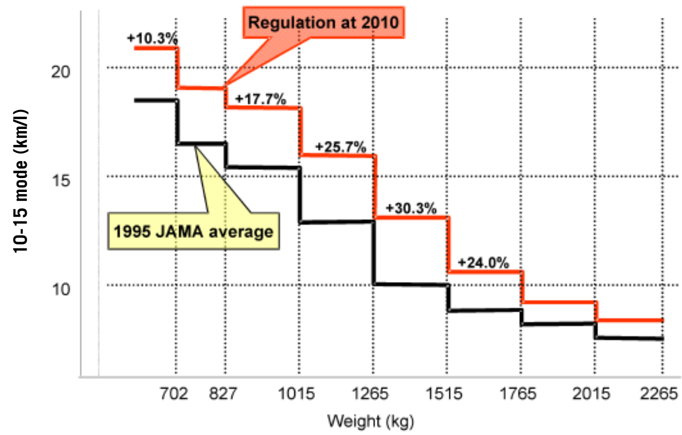
Japanese weight class fuel economy Standards for gasoline passenger vehicles

Vehicle classes by maximum vehicle curb weight		Fuel economy fleet average target by class	
kg	lbs	km/L	mpg (CAFE-equivalent)
<702	<1,548	21.2	49.8
703–827	1,550–1,824	18.8	44.2
828–1,015	1,826–2,238	17.9	42.1
1,016–1,265	2,240–2,789	16.0	37.6
1,266–1,515	2,791–3,341	13.0	30.6
1,516–1,765	3,343–3,892	10.5	24.7
1,766–2,015	3,894–4,443	8.9	20.9
2,016–2,265	4,445–4,994	7.8	18.3
>2,266	>4,997	6.4	15.0

Assuming no change in the vehicle mix, these targets imply a 23 percent improvement in 2010 in gasoline passenger vehicle fuel economy and a 14 percent improvement in diesel fuel economy compared with the 1995 fleet average of 14.6 km/L. According to the Japanese government, this improvement will result in an average fleet fuel economy of Japanese vehicles of 35.5 mpg[21] by 2010. The regulations include penalties if the targets are not met, but these penalties are very small. Furthermore, the majority of vehicles sold in Japan in 2002 were already in compliance with the 2010 standards.

Figure 4

Japanese weight class fuel economy Standards for gasoline passenger vehicles



Source: Ministry of Transport, Japan

2.6. Australia

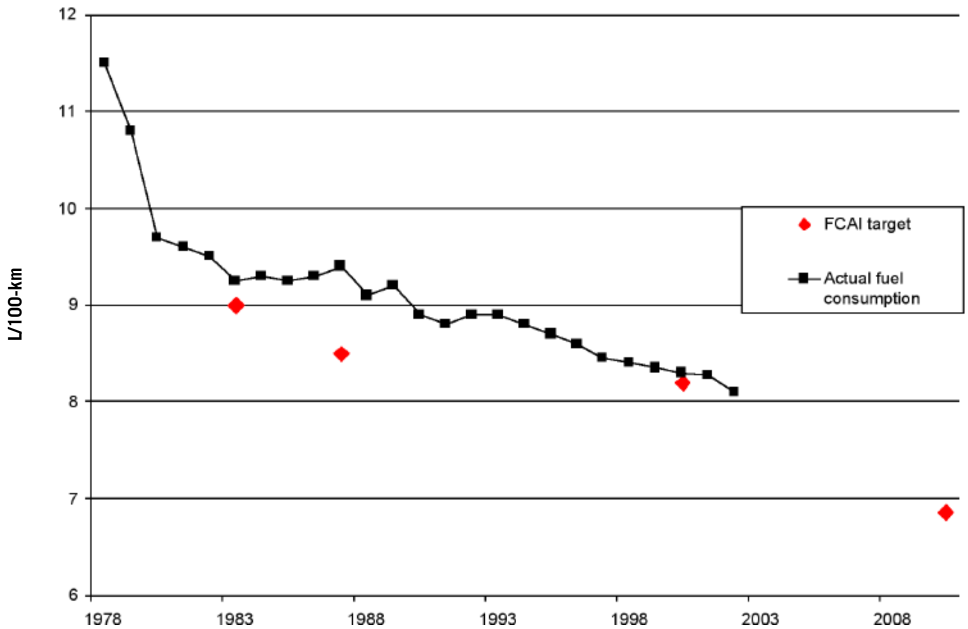
The Federal Chamber of Automotive Industries (FCAI) established several voluntary codes of practice for reducing the fuel consumption of new passenger cars sold in Australia over the past 25 years. The first code was in force between 1978 and 1987. As can be seen in Figure 5, the industry failed to achieve the FCAI targets during the 1980s. Nonetheless, there were significant reductions in fuel consumption over that period.

The second voluntary code of practice was endorsed by the Ministers for Transport and Primary Industries and Energy in early 1996. Under the code, FCAI members declared their intent (subject to certain conditions) to reduce the passenger car National Average Fuel Consumption (NAFC) to 8.2 L/100-km (approximately 29 mpg) in the year 2000. Furthermore, FCAI members agreed to seek to maintain the rate of improvement in NAFC achieved for the period up to the year 2000 in their planning for the period 2000 to 2005. This voluntary code of practice remained in force until July 2001.

In 2003, Australia announced a third voluntary fuel consumption agreement between the FCAI and the government. This agreement calls on the industry to reduce fleet average fuel consumption for passenger cars by 18 percent by 2010, based on the fuel consumption of the 2002 vehicle fleet. Members of FCAI that have agreed to this target include the four domestic passenger motor vehicle manufacturers and all major international brands importing and marketing passenger vehicles in Australia. As with the first two agreements, there are no specified enforcement or non-compliance penalties under this agreement.

Figure 5

Australian average fuel consumption and FCAI targets



Source: The Australian Automobile Association and FCAI

2.7. China

China recently approved regulations for new fuel economy standards for its passenger vehicle fleet to regulate the country's rapidly growing vehicle market. These standards are primarily designed to mitigate China's increasing dependence on foreign oil, but another objective is to encourage foreign automakers to bring more fuel-efficient vehicle technologies to the Chinese market. The new standards will be implemented in two phases: Phase 1 will take effect on July 1, 2005, for new vehicle models, and on July 1, 2006, for continued vehicle models.[22] Phase 2 will take effect on January 1, 2008, for new models and on January 1, 2009, for continued vehicle models.

The standards will be classified into 16 weight classes, ranging from vehicles weighing less than 750 kg (approximately 1,500 lbs) to vehicles weighing more than 2,500 kg (approximately 5,500 lbs). The standards cover passenger cars, SUVs and multi-purpose vans (MPVs), collectively defined as M1-type vehicles (under the EU definition), with separate standards for passenger cars with manual and automatic transmissions. SUVs and MPVs, regardless of their transmission types, share the same standards as passenger cars with automatic transmissions. Commercial vehicles and pickup trucks are not regulated under the standards. See Table 5 for the new Chinese standards, with maximum limits for fuel consumption (L/100-km) and minimum CAFE-equivalent mpg limits. Figure 6 shows minimum CAFE-equivalent mpg limits of Chinese standards for vehicles with automatic transmissions and SUVs/MPVs.

One distinctive feature of the Chinese standards is that, rather than being based on fleet average, they set up maximum allowable fuel consumption limits by weight category. Every individual vehicle model sold in China will be required to meet the standard for its weight class. The system does not include a credit system to allow vehicles that exceed compliance to offset those that do not.

The current level of fuel economy of the Chinese vehicle fleet is not well known as the data have not become publicly available, and thus the relative stringency and effect of these standards is not well understood. However, the standards were designed to be "bottom heavy," meaning that they become relatively more stringent in the heavier vehicle classes than in the lighter weight classes.[23] This will help to create incentives for manufacturers to produce lighter vehicles for the Chinese market.

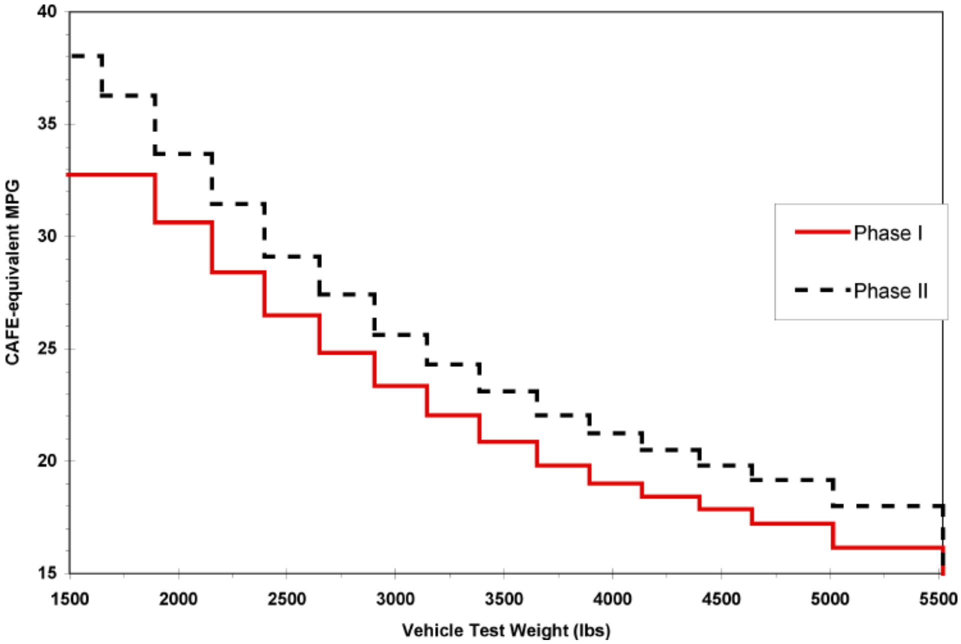
Table 5

Maximum limits for fuel consumption (L/100-km)[24] and minimum CAFE-equivalent mpg limits, for passenger vehicles in China (excluding Taiwan)

	Maximum fuel consumption limits, based on NEDC cycle (L/100-km)				Minimum fuel economy limits, based on U.S. CAFE-equivalent (mpg)			
	Phase I [2005]		Phase II [2008]		Phase I [2005]		Phase II [2008]	
Weight (lbs)	Manual	Auto/SUV	Manual	Auto/SUV	Manual	Auto/SUV	Manual	Auto/SUV
≤ 1,667	7.2	7.6	6.2	6.6	36.9	35.0	42.9	40.3
≤ 1,922	7.2	7.6	6.5	6.9	36.9	35.0	40.9	38.5
≤ 2,178	7.7	8.2	7.0	7.4	34.5	32.4	38.0	35.9
≤ 2,422	8.3	8.8	7.5	8.0	32.0	30.2	35.4	33.2
≤ 2,678	8.9	9.4	8.1	8.6	29.9	28.3	32.8	30.9
≤ 2,933	9.5	10.1	8.6	9.1	28.0	26.3	30.9	29.2
≤ 3,178	10.1	10.7	9.2	9.8	26.3	24.8	28.9	27.1
≤ 3,422	10.7	11.3	9.7	10.3	24.8	23.5	27.4	25.8
≤ 3,689	11.3	12.0	10.2	10.8	23.5	22.2	26.1	24.6
≤ 3,933	11.9	12.6	10.7	11.3	22.3	21.1	24.8	23.5
≤ 4,178	12.4	13.1	11.1	11.8	21.4	20.3	23.9	22.5
≤ 4,444	12.8	13.6	11.5	12.2	20.8	19.5	23.1	21.8
≤ 4689	13.2	14.0	11.9	12.6	20.1	19.0	22.3	21.1
≤ 5066	13.7	14.5	12.3	13.0	19.4	18.3	21.6	20.4
≤ 5578	14.6	15.5	13.1	13.9	18.2	17.1	20.3	19.1
> 5578	15.5	16.4	13.9	14.7	17.1	16.2	19.1	18.1

Figure 6

China's automotive fuel economy standards for passenger vehicles with automatic transmissions and for SUVs/MPVs (CAFE-equivalent mpg)



2.8. Taiwan

Taiwan established fuel economy standards for new vehicles well before the rest of China established its standards. These standards are based on seven categories of engine size (as measured in volume). The standards include all gasoline and diesel passenger vehicles, light trucks, and commercial vehicles (< 2,500 kg). There is a separate standard for motorcycles. The Taiwanese standards use the U.S. CAFE test driving cycle to determine fuel consumption. Table 6 shows Taiwan's fuel economy standards by engine size.

Table 6

Taiwan's fuel economy standards

Vehicle engine size (by cylinder volume displacement)	Fuel economy standard	
(cm^3)	km/L	mpg (CAFE-equivalent)
<1,200	15.4	36.2
1,200–1,800	11.6	27.3
1,801–2,400	10.5	24.7
2,401–3,000	9.4	22.1
3,001–3,600	8.5	20.0
3,601–4,200	7.8	18.3
>4,201	7.2	16.9

2.9. South Korea

South Korea announced in March 2004 that it will implement mandatory fuel economy standards for the first time. The country's Average Fuel Economy (AFE) standard will replace the current system in which the existing voluntary standard is not enforced (see Table 7 for the current voluntary targets for standard passenger cars). Vehicles will be evaluated for compliance with the AFE standard using the U.S. EPA City test cycle. The new AFE regulation is in part a response to declining average fuel economy, largely due to an increase in the sales of SUVs. The new standards will be enacted in 2006 for domestic cars and in 2009 for imported cars with sales less than 10,000 vehicles. However, companies manufacturing or importing more than 10,000 vehicles per year will be subject to U.S. CAFE standards per South Korean law. See Table 8 for the new AFE standards for both standard passenger cars and multi-purpose passenger vehicles; the standards by design appear to target small-scale manufacturers and importers.

Table 7

Existing voluntary fuel economy targets for general (standard) passenger cars in South Korea

Existing fuel economy targets				
Vehicle engine size (by cylinder volume displacement) (cm^3)	1996		2000	
	km/L	mpg CAFE	km/L	mpg CAFE
<800	23.4	64.9	24.6	68.2
800–1,100	20.3	56.3	21.3	59.1
1,100–1,400	17.3	48.0	18.1	50.2
1,400–1,700	15.4	42.7	16.1	44.6
1,700–2,000	11.4	31.6	12	33.3
2,000–2,500	9.9	27.5	10.4	28.8
2,500–3,000	8.5	23.6	8.9	24.7

Table 8

South Korea's new Average Fuel Economy Standards for light-duty vehicles

New fuel economy standard		
Vehicle engine size (by cylinder volume/ displacement) (cm^3)	km/L	mpg CAFE
≤1,500	14.4	39.9
>1,501	9.6	26.6

Under the AFE system, if a vehicle exceeds the requirement in one engine size class, it earns credits that can be used to offset shortfalls in the other class. For example, credits earned for vehicles with engine sizes smaller than 1,500 cm^3 can be applied to any shortfall the manufacturer has for its over 1,500 cm^3 fleet. While the Korean manufacturers will likely be able to benefit from a credit system, the importers do not sell vehicles in the small engine size category, and therefore they will not be able to benefit from the credit system.

If any automaker fails to meet the standard, the South Korean government will issue an order to improve the automaker's fuel efficiency within a certain period of time. All car manufacturers will be granted an almost six year grace period (until the end of 2009), before the issuance of an order for improvement, if necessary, will be given. If the requirement is still not met, the penalty is in effect a public shaming. There is no monetary or criminal penalty. Instead, the South Korean government will publish a list of non-complying, and therefore fuel-inefficient, vehicles.

III. Issues and Methodologies Involved with Comparing Vehicle Standards around the World

The previous sections provided detailed descriptions of the various fuel economy and GHG standards around the world. Because these standards differ greatly in structure, form, and underlying testing methods, it is challenging to compare them directly. This section identifies key issues involved with comparing these diverse standards, and devises a generic methodology with which to compare them.

3.1. Differences in test driving cycles

Several countries have developed their own testing protocols to measure vehicle emission and fuel economy levels. These test protocols have been variously adopted by other countries. One key element of the testing protocol is the selection of a driving cycle, which ideally is designed to represent on-road vehicle driving patterns in a given country.[25] Because vehicle emission and fuel consumption levels are sensitive to how vehicles are driven, fuel economy or GHG emission levels of a given vehicle can be quite different from one country to another. This poses a special challenge when comparing vehicle standards around the world.

Countries and regions use essentially three different test cycles to determine fuel economy and GHG emission levels: The New European Drive Cycle (NEDC), the Japan 10-15 cycle, and the U.S.-based "CAFE" cycle. Table 9 provides average speeds of these three cycles. In the table, a sample vehicle model (MY2002 Ford Focus) is used to demonstrate different fuel economy ratings under these three cycles.[26] More detailed discussion regarding impacts of test cycles on vehicle fuel economy ratings is given in the Appendix.

The U.S. CAFE cycle has two test cycle components, city driving and highway driving; the combined CAFE cycle is composed of 55 percent city driving and 45 percent highway driving.[27] However, some countries, such as South Korea, only use City Cycle component of the US "CAFE" cycle. These test cycles are very different in terms of average speed, duration, distance, acceleration and deceleration characteristics, and frequencies of starts and stops. All these factors significantly affect fuel economy ratings. In general, average speeds of the test cycles and associated fuel economy ratings are positively correlated.

Table 9

Comparisons of U.S., European Union, and Japanese test cycles

Test cycle	*Average speed (mph)*	*Sample vehicle[a] mpg rating*	*Average adjustment to match CAFE*	*Country/region applied*
U.S. combined "CAFE" cycle	29.8	30.9	1.00	United States, Canada, Taiwan, California
NEDC	20.9	27.0	1.13	European Union, China, Australia
U.S. EPA City[b]	19.5	26.8	1.18	South Korea
Japan 10-15	14.8	22.5	1.35	Japan

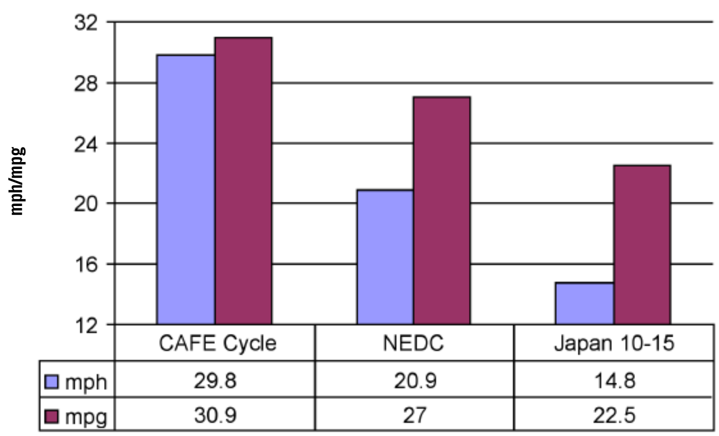
[a] MY2002 Ford Focus was used as the sample vehicle.
[b] Some countries, such as South Korea, use only the City Cycle component of U.S. CAFE test procedure

Note that the U.S. combined CAFE cycle has the highest average speed of close to 30 mph, and the highest fuel economy rating of about 31 mpg for the sample vehicle. The average speed of NEDC is about 21 mph, with the fuel economy rating of the same vehicle about 27 mpg. The average speed of U.S. City Cycle (20 mph) and fuel economy rating (27 mpg) are very similar to that NEDC cycle. The average speed of the Japanese cycle is about 15 mph, with a fuel economy rating of 23 mpg. The variations in fuel economy ratings among these cycles may change somewhat from vehicle model to model. On average, based on the computer simulation model described in the Appendix, the authors estimate that the CAFE cycle values are about 13 percent higher than NEDC cycle values, and CAFE cycle values are about 35 percent higher than Japan 10-15 cycle values.[28] In other words, to roughly convert fuel economy rating based on the EU cycle to the rating based on the U.S. CAFE cycle, one multiplies by a factor of 1.13. Similarly, to roughly convert a fuel economy rating based on the Japanese cycle to one based on the U.S. CAFE cycle, one multiplies by 1.35. Figure 7 shows the correlation between the average speed and fuel economy rating (based on MY02 Ford Focus) of these three cycles.

Among the countries and regions that have vehicle standards, the United States, California, Canada, Taiwan, and South Korea use the U.S. CAFE cycle; the European Union, China and Australia use NEDC; and Japan's fuel economy rating is based on Japan 10-15 cycle.

Figure 7

Average speed and mpg ratings (based on MY02 Ford Focus) of the three test cycles



3.2. Fuel economy vs. fuel consumption vs. GHG emissions

The relationship between GHG emissions and fuel consumption is important because CO_2 is the dominant source of GHG emissions from an automobile and the level of CO_2 emissions from automobiles is directly linked to vehicle fuel consumption. California's proposed rule would regulate all GHG emissions (in terms of CO_2-equivalent emissions), and the European Union regulates CO_2 emissions only. Because the vast majority of automobiles consume petroleum-based fuels such as gasoline and diesel, the conversion factors from CO_2 to gasoline and diesel fuels were treated in this analysis as constants among most countries and regions, even though small variations do exist due to differences in fuel quality and additives. However, these differences are likely to remain relatively minor unless use of alternative fuels that are not petroleum based becomes widespread.

Table 10 provides conversion factors among fuel economy (mpg and km/L), fuel consumption (L/100-km), and CO_2 emission rate (g/km and g/mi). Because diesel fuel has a different heat content and density from gasoline fuel, a gasoline-equivalent fuel economy (MPGge) measure was adopted for conversion purposes. The conversion from diesel fuel to CO_2 emissions is also different from that for gasoline fuel.

The left four columns of the table give the conversion factors from any given measures (X) to MPGge; and the right four columns of the table gives the conversion factors from measures (X) to CO_2 emission rate in grams/kilometer. Some of these relationships are proportional ones (expressed as X *), some are reciprocally proportional ones expressed as (1/X *). Strictly speaking, the conversions among these measures should not depend on test cycles.

Table 10

Conversion factors among different measures of fuel economy, fuel consumption and GHG emissions

From measure (X)	To	Relation-ship	Conversion factor	From measure (X)	To	Relation-ship	Conversion factor
mpg (gasoline)	MPGge	X *	1.00	mpg (gasoline)	CO_2 g/km[29]	1/(X) *	5,469
mpg (diesel)	MPGge	X *	0.90	mpg (diesel)	CO_2 g/km[30]	1/(X) *	6,424
km/L	MPGge	X *	2.35	km/L	CO_2 g/km	1/(X) *	2,325
L/100-km	MPGge	1/(X) *	235.8	L/100-km	CO_2 g/km	X *	23.2
CO_2 g/mi	MPGge	1/(X) *	8,800	CO_2 g/mi	CO_2 g/km	X *	0.62
CO_2 g/km	MPGge	1/(X) *	5,469	CO_2 g/km	CO_2 g/km	X *	1.00

When standards of one region to another are compared, however, it is necessary to introduce the cycle conversion factors presented in Table 11. It is also noteworthy that in California, CARB uses a gasoline to CO_2 conversion factor (8.9 kg/gallon) that is slightly different from the national average (8.8 kg/gallon). Taking this into consideration, the authors generated a table of conversion factors from measures associated with different regions to U.S. CAFE-equivalent mpg ratings, EU-equivalent CO_2 emission rates (in g/km); and California-equivalent CO_2 emission rates (in g/mi).

Table 11

Conversion factors to CAFE-equivalent mpg, EU-equivalent CO_2 (in g/km), and California-equivalent CO_2 emission rate (in g/mi)

Country	Cycle	Type	Measure (Y)	Converted to CAFE-equivalent mpg		Converted to EU-equivalent CO_2 (g/km)		Converted to CA-equivalent CO_2 (g/mi)	
United States	U.S. CAFE	Fuel	mpg	Y *	1.00	1/(Y) *	6,180	1/(Y) *	8,900
Taiwan	U.S. CAFE	Fuel	km/L	Y *	2.35	1/(Y) *	2,627	1/(Y) *	3,783
South Korea	U.S. City	Fuel	km/L	Y *	2.78	1/(Y) *	2,226	1/(Y) *	3,206
Canada	U.S. CAFE	Fuel	L/100-km	1/(Y) *	235.8	Y *	26.2	Y *	37.7
California	U.S. CAFE	CO_2	g/mi	1/(Y) *	8,900	Y *	0.69	Y *	1.00
European Union (gasoline)	NEDC	CO_2	g/km	1/(Y) *	6,180	Y *	1.00	Y *	1.44
European Union (diesel)	NEDC	CO_2	g/km	1/(Y) *	7,259	Y *	1.00	Y *	1.44
Japan	Japan	Fuel	km/L	Y*	3.18	1/(Y) *	1,946	1/(Y) *	2,803

3.3. Regulatory vs. voluntary approaches

There is a clear difference between a regulatory and voluntary approach to fuel economy and GHG emission standards. While a regulatory target with sufficient enforcement and penalties for non-compliance can be more or less guaranteed in the future, a voluntary target is less certain. However, in this analysis the authors directly compare both regulatory and voluntary targets, and assume that voluntary targets will be met in future years.

3.4. Corporate fleet averages vs. minimum requirements

Among all the standards, only the Chinese standards are based on minimum fuel economy requirements that are applicable to individual vehicle models, while all other existing or proposed standards throughout the world are based on sales-weighted averages either by a whole vehicle fleet, or by a corporate vehicle fleet. The Chinese standards pose a special challenge to cross-country comparisons, because a number of assumptions need to be made to translate the minimum requirements into a fleet average. The minimum requirement simply provides a "floor" for all the vehicle models. The fleet average fuel economy level should be above the minimum requirement. This analysis assumes that all vehicle models will at least meet the "floor" requirements. For vehicle models that are already performing better than the standards, this analysis assumes that they will maintain their current fuel economy levels in the future years.

3.5. Vehicle categories and weight classes

As discussed in section 2 the countries' standards are structured with significant differences in definitions of vehicle categories and weight classes. It is difficult to compare one standard against another because of these differences; this analysis therefore compares them on an entire fleet average basis. Such a comparison requires vehicle databases for these countries and regions that provide sales figures and fuel economy ratings for individual vehicle models, which is difficult to obtain for some countries. For this analysis, such information was available for all the countries and regions studied with the exception of the Taiwan and South Korea markets.[31]

Another distinct challenge is to project future fleet average fuel economy figures for these regions. Thus, fuel economy projection efforts usually require a projection into future years of sales breakdowns by vehicle weight classes and categories defined by the standards themselves. Historical data in the United States and Japan have shown significant shifts in sales from one category to another, mostly from lighter vehicle groups to heavier ones. However, it is beyond the scope of this analysis to make such projections. This analysis assumes that the current sales composition of vehicle categories will be maintained, and future fleet average fuel economy was projected under such assumptions.

IV. Comparison of Vehicle Standards around the World

This section compares fuel economy standards and GHG emission standards based on the assumption and methodology discussed in the previous sections. Specifically, fleet average fuel economy and CO_2 or GHG standards in the United States, California, the European Union, Japan, Canada, Australia, and China are compared. There are three steps to create comparisons for these standards:

1. **Convert fuel economy/GHG standards into fleet averages**. For standards designed as a fleet average, including the EU and Australia, this step is not necessary. For regions with standards designed by categories (vehicle type, weight or engine size), assumptions about future fleet composition will need to be made. See Table 13 for information on the authors' assumptions.

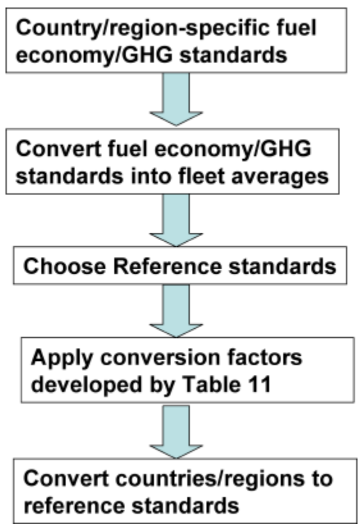
2. **Choose Reference standards.** For this analysis the authors chose U.S. CAFE equivalent MPG and EU NEDC equivalent g CO_2/km as the reference standards.

3. **Convert countries/regions to reference standards.** Use Table 11 for conversion factors to convert from fleet average for countries/regions to reference standards.

The following schematic flow-chart demonstrates this process.

Figure 8

Methodology to compare fuel economy and GHG emission standards



Based on the above steps 1 to 3, Table 12 shows the fleet average fuel economy levels of these countries and regions. Table 12 presents fuel economy levels normalized by CAFE cycle (including the test cycle correction, Steps 1 to 3), as well as fuel economy levels without test cycle correction (Step 1 only). More detailed assumptions associated with Table 12 can be found in Table 13.

Table 12

Comparison of fuel economy and GHG emission standards with and without test cycle correction

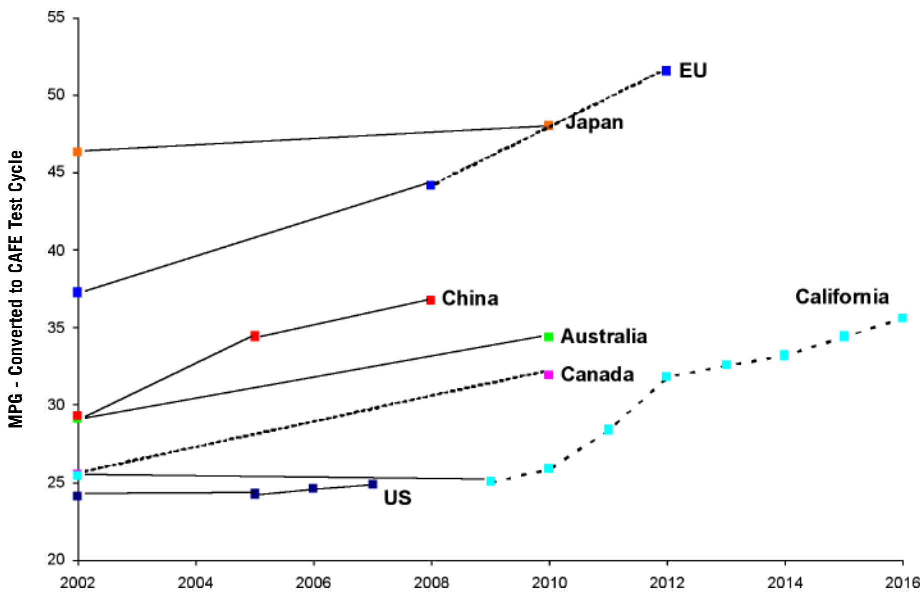
Region	2002 fleet fuel economy averages for new vehicles		Future fleet average fuel economy average for new vehicles	
	mpg normalized by CAFE test cycle (Steps 1-3)	mpg – not normalized by test cycle (Step 1 only)	mpg normalized by CAFE test cycle (Steps 1-3)	mpg – not normalized by test cycle (Step 1 only)
United States	24.1	24.1	24.3 by 2005	24.3 by 2005
			24.6 by 2006	24.6 by 2006
			24.9 by 2007	24.9 by 2007
California	25.4	25.4	25.0 by 2009	25.0 by 2009
			25.9 by 2010	25.9 by 2010
			28.4 by 2011	28.4 by 2011
			31.8 by 2012	31.8 by 2012
			32.6 by 2013	32.6 by 2013
			33.2 by 2014	33.2 by 2014
			34.4 by 2015	34.4 by 2015
			35.6 by 2016	35.6 by 2016
Canada	25.6	25.6	32.0 by 2010 (proposed)	32.0 by 2010 (proposed)
European Union	37.2	32.9	44.2 by 2008	39.2 by 2008
			51.5 by 2012 (proposed)	45.6 by 2012 (proposed)
Japan	46.3	34.3	48.0 by 2010	35.6 by 2010
Australia	29.1	25.3	34.4 by 2010	29.9 by 2010
China	29.3	25.9	34.4 by 2005	30.4 by 2005
			36.7 by 2008	32.5 by 2008

4.1 Comparisons of regulations standardized around CAFE-converted mpg and NEDC-converted g CO_2/km

Figures 9 and 10 show comparisons of fuel economy and GHG emission standards normalized around metrics and vehicle test cycles as described in the above procedure. Figure 9 shows that the European Union and Japan have the most stringent standards, and that the United States and Canada have the lowest standards in terms of fleet-average fuel economy rating. Figure 10 shows that the United States and Canada have the highest CO_2 emission levels based on EU testing procedures, and that the EU and Japan have the lowest GHG emission levels. Figures 9 and 10 also show that the new Chinese standards are more stringent than those in Australia, Canada, California, and the United States, but they are less stringent than those in the European Union and Japan. These comparisons do not address the implications of changing the vehicle size or weight composition of the current fleet.[32] If the California GHG standards go into effect, they would narrow the gap between U.S. and EU standards, but the California standards would still be less stringent than the EU standards.

Figure 9

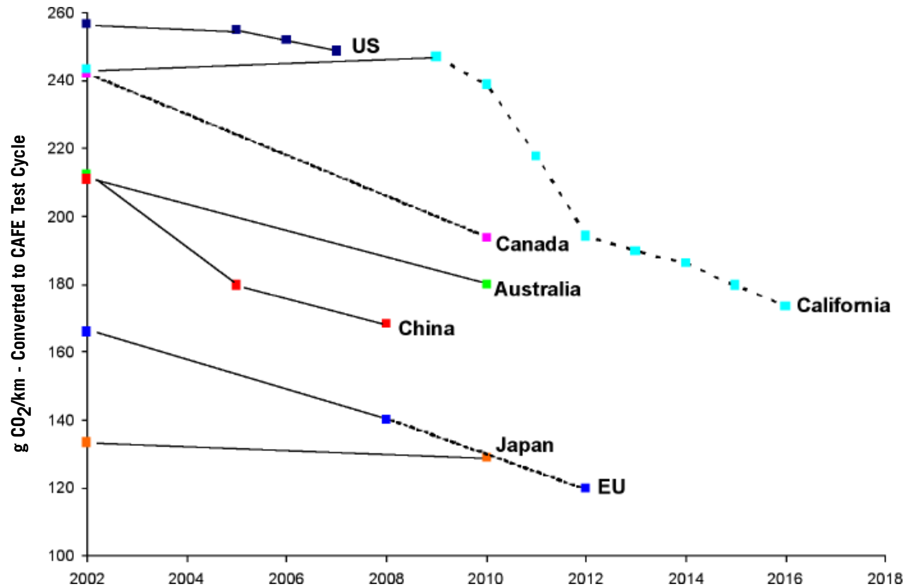
Comparison of fuel economy and GHG emission standards normalized by CAFE-converted mpg



Notes: (1) dotted lines denote proposed standards
(2) MPG = miles per gallon

Figure 10

Comparison of fuel economy and GHG emission standards normalized by NEDC-converted g CO_2/km



Note: dotted lines denote proposed standards

4.2 Table of regulations standardized around mpg-CAFE cycle and g CO_2/km-NEDC cycle

Table 13 summarizes the data, graphed in Figures 9 and 10, underlying the comparison of fuel economy and GHG emission standards around the world.

Table 13

Data sources and assumptions used in methodology

Region	2002 fleet fuel economy averages for new vehicles		Future fleet average fuel economy average for new vehicles	
	mpg	Data source	mpg & year	Data sources and assumptions
United States	24.1	U.S. EPA laboratory value for 2002, CAFE combined cycle (55/45)	24.3 by 2005 24.6 by 2006 24.9 by 2007	• Based on enacted standards • Vehicle fleet remains 50% cars and 50% light trucks
California	25.4	Calculation based on data provided by CARB: • 2009 CO_2 emissions will be 1% less than in 2002 • 2009 value is 307 g/mi	25.0 by 2009 25.9 by 2010 28.4 by 2011 31.8 by 2012 32.6 by 2013 33.2 by 2014 34.4 by 2015 35.6 by 2016	• Based on approved standards under legislative review for each year • Assumes vehicle fleet remains 53% PC/LDT1 (percentage reported by CARB)
Canada	25.6	2002 combined fleet average from Transport Canada	32.0 by 2010 (proposed)	• Based on statements by government as part of plan to meet Kyoto commitment • 2002 baseline year for the 25% increase proposed for 2010 is assumed (however the official baseline has not yet been proposed).
European Union	37.2	2002 value reported in progress report on the voluntary agreement with industry	44.2 by 2008 51.5 by 2012 (proposed)	• Based on targets specified in agreement between industry and the European Union • Converted to gasoline equivalent mpg (does not account for diesel)
Japan	46.3	2002 average fleet fuel economy value reported by JAMA	48.0 by 2010	• Standards state a 23% improvement in fuel consumption from 1995 baseline year • 1995 average fuel consumption of 14.3 L/km • Fleet composition remains constant
Australia	29.1	Industry agreement states an 18% improvement to 6.8 L/100-km by 2010	34.4 by 2010	• 2010 car average value stated in voluntary agreement with industry
China	29.3	2002 baseline data based on assessment from China Automotive Technology and Research Center (CATARC)	34.4 by 2005	Future values based on WRI dataset • Used fuel economy values and vehicle weights from similar vehicles sold in other market to estimate the effect of new regulations on the Chinese fleet • Future fleet weight distribution assumed to remain constant • Used standards for automatic vehicles

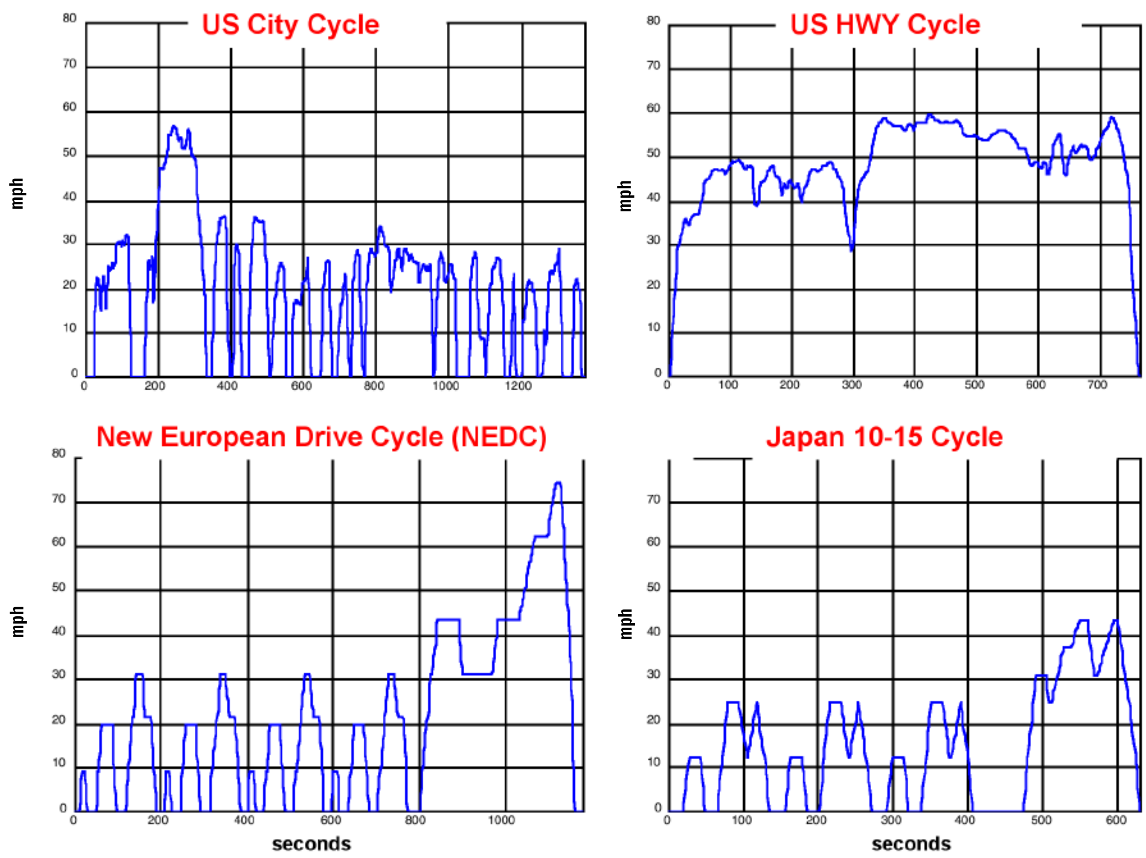
Appendix: Methodology to Assess Impacts of Test Cycles on Vehicle Fuel Economy Ratings

Section 3.1 of the report briefly discusses the effect of various test cycles on vehicle fuel economy ratings. This appendix explains in greater detail the methodology and modeling tools used to assess these effects.

As mentioned in section 3.1, three different test cycles are being used around the world to determine fuel economy and GHG emissions: the New European Drive Cycle (NEDC), the Japanese 10-15 cycle, and the United States-based Corporate Average Fuel Economy (CAFE) cycle (the U.S. CAFE cycle is composed of 55 percent city and 45 percent highway driving cycles). Figure A1 illustrates these cycles, and it shows that they differ in terms of speed profiles, duration in seconds, acceleration and deceleration profiles (slopes of rising and declining vehicle velocity), and frequencies of starts and stops. All of these factors contribute to differences in the fuel economy rating of the same vehicle models under these test cycles.

Figure A1

Speed trace of four test cycles **X-axis represents seconds, y-axis represents speed in miles per hour (mph)**



Ideally, to assess the effects of these cycles on vehicle fuel economy, a large number of testing results of the same vehicle models on the different cycles should be collected and compared. However, such an assessment would be difficult for several reasons. First, a large number of such testing results may not be readily available. Second, for vehicle models that are available in different markets (e.g., both in the United States and the European Union, or the United States and Japan), some adjustments may need to be made to account for the fact that many vehicle models may not be truly identical to the "same" vehicle models in different markets. For example, different engine or transmission options may be provided in the same vehicle models for different markets. Finally, empirical data may not be available for certain vehicle segments. For example, there are few SUV models in the Japanese and EU markets, thus a direct comparison to SUV models between these markets and the U.S. market is not available.

In this report, we rely on a well-established computer simulation model, the Modal Energy and Emissions Model (MEEM), to assess the effect of test cycles on fuel economy ratings for a wide variety of vehicle models. One distinct advantage of using computer simulation models is that one can estimate the fuel economy level of a given vehicle model under a broad range of operating conditions.

MEEM was originally developed by one of the authors of this report at the University of Michigan and the University of California, and further enhanced at Argonne National Laboratory.[33] MEEM is capable of simulating vehicle fuel consumption and emissions over any given test cycles. Based on a set of vehicle operating parameters, MEEM simulates vehicle power demand and vehicle operating conditions to predict vehicle emissions and fuel consumption. Over the past several years, MEEM has been used extensively to assess current and future fuel economy levels in several studies.[34]

Tables A1 and A2 summarize modeling results for selected gasoline and diesel vehicle models respectively. For gasoline vehicles, six representative vehicle models are selected and modeled under four test cycles (CAFE results are derived from a combination of EPA city and EPA highway results). The last four rows in Table A1 show the ratios between results based on CAFE and NEDC, Japan 10-15 and EPA City cycles, as well as ratios between NEDC and Japan 10-15 cycles. Generally speaking, there are some variations in fuel economy ratios among these vehicle models. The variation in CAFE/NEDC ratios is relatively small, with ratios averaging about 1.13. The variation in CAFE/Japan ratios is somewhat larger, with heavier vehicle models having higher values than smaller vehicle models. Considering that most Japanese models are car models, the authors chose to use average ratios of 1.35 for small and large cars. These values are used in Table 9 of the report.

The trend for diesel vehicle models is similar. Table A2 lists the modeling results for these same vehicle models, but with hypothetical diesel engine options.[35] However, in general, the fuel economy disparities among test cycles are smaller for diesel vehicle models than for gasoline vehicle models.

Table A1

MEEM simulation results for gasoline vehicle fuel economy ratings (mpg) under selected test cycles

Gasoline Vehicles	Vehicle and engine options	Small car	Large car	Minivan	SUV	Pickup	Crossover
		2004 Ford Focus	2003 Toyota Camry	2003 Dodge Grand Caravan	2003 Ford Explorer	2004 Chevrolet Silverado 1500	2003 Saturn Vue
		ZTS 4 dr Sedan	SE V6 4dr Sedan (3.0L 6cyl 4A)	ES FWD 4dr Minivan (3.8L 6cyl 4A)	XLT 4wd 4dr SUV (4.0L 6cyl 5A)	4dr Extended Cab LS Rwd SB (4.8L 8cyl 4A)	AWD 4dr SUV (3.0L 6cyl 5A)
Test Cycles	Ave. speed (mph)	mpg	mpg	mpg	mpg	mpg	mpg
Japan 10-15	14.8	22.5	20.1	16.9	13.9	12.8	18.7
EPA city	19.5	26.8	22.1	20.2	16.9	15.4	22.0
NEDC	20.9	27.0	24.7	21.1	17.6	15.8	22.8
CAFE	32.4	30.9	26.6	24.1	20.2	18.2	25.7
EPA hwy	48.2	38.1	35.8	31.6	26.5	23.4	32.1
Ratios	Average						
CAFE/NEDC	1.13	1.14	1.08	1.14	1.15	1.15	1.13
CAFE/Japan*	1.35	1.37	1.32	1.43	1.46	1.43	1.37
CAFE/City	1.18	1.15	1.21	1.20	1.19	1.18	1.16
NEDC/Japan	1.23	1.20	1.23	1.25	1.27	1.24	1.22
* Average for cars only							

Table A2

MEEM simulation results for diesel vehicle fuel economy ratings (mpg) under selected test cycles

Diesel Vehicles	Hypothetical diesel option	**Small car**	**Large car**	**Minivan**	**SUV**	**Pickup**
		Diesel Cavalier	Diesel Taurus	Diesel Caravan	Diesel Explorer	Diesel Silverado
		2.0 L VW TDI Engine	2.7 L VW TDI Engine	3.1 L VW TDI Engine	3.8 L VW TDI Engine	3.7 L VW TDI Engine
Test Cycles	Ave. speed (mph)	mpg	mpg	mpg	mpg	mpg
Japan 10-15	14.8	33.3	30.3	26.2	23.5	24.2
EPA city	19.5	37.8	33.9	28.8	25.6	26.2
NEDC	20.9	38.5	35.0	29.4	26.4	26.2
CAFE	32.4	43.6	39.5	32.7	28.7	29.4
EPA hwy	48.2	53.7	49.3	39.2	33.7	34.5
Ratios	Average					
CAFE/NEDC	1.12	1.13	1.13	1.12	1.09	1.12
CAFE/JAP*	1.31	1.31	1.30	1.25	1.22	1.21
CAFE/City	1.14	1.15	1.16	1.14	1.12	1.12
NEDC/JAP	1.13	1.16	1.16	1.12	1.12	1.08
* Average for cars only						

Endnotes

1. EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2004.

2. For further information on these petitions, see Union of Concerned Scientists, Life in the Slow Lane, 2003.

3. Federal Register Docket Number 68 FR 16867; April 7, 2003.

4. The import/domestic distinction was created to deter U.S. auto companies from simply importing efficient vehicles to offset the inefficiency of domestically produced vehicles. This distinction, which ensures the manufacture of efficient vehicles in the United States to meet CAFE requirements for the domestic car fleet, has had less and less effect over time as more and more vehicles are composed of components from different parts of the world.

5. Department of Transportation Docket Number NHTSA 2004-17015; Notice 2.

6. Oak Ridge National Laboratory. Center for Transportation Analysis. Transportation Data Energy Book: 2002.

7. Department of Transportation Docket Number 2001-10774; Notice 3.

8. Hal Bernton, "Tighter vehicle emission standards proposed for state," Seattle Times, December, 2004.

9. Calculation based on data from Ward's Vehicle Facts & Figures 2003.

10. The LEV program applies to passenger cars, light-duty trucks, and medium-duty vehicles (vehicles weighing 8,500 to 10,000 lbs), and it establishes exhaust emission standards.

11. ETW includes the vehicle curb weight plus passenger weight of 300 lbs, and rounded by every 250 lbs. GVW is mostly used for Class 2b to Class 8 trucks, including vehicle curb weight plus rated vehicle load.

12. Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles, CARB, August, 2004

13. Because California state regulations preceded the enactment of the Clean Air Act (CAA), California has a special status under the CAA that allows the state to design its own air pollution regulations for vehicles. Other states must follow either federal regulations or California regulations.

14. Canadians not only buy different types of cars but have a lower vehicle ownership level than the United States. In 2004, 70 percent of the driving age population owned cars in Canada vs. 102 percent in the United States.

15. Personal Communication with Paul Khanna, Natural Resources Canada, November 2004.

16. Calculation based on data from Automotive News' Data Center. http://www.autonews.com/datacenter.cms

17. Danny Hakim, "Canada Sets Goal to Cut Car Emissions" The New York Times, November 18, 2004.

18. Commission of the European Communities, *Implementing the Community Strategy to Reduce CO_2 Emissions from Cars: Fourth annual report on the effectiveness of the strategy (Reporting year 2002).* 2004.

19. See Commission of the European Communities, *Implementing the Community Strategy to Reduce CO_2 Emissions from Cars (Reporting year 2002)* for more information on the intermediate targets.

20. Dan Thisdell and Wim Oude Weernink, "Brussels Readies for CO_2 Fight," Automotive News Europe, November 15, 2004.

21. This number has not converted to CAFE test cycle. Please note that the far right column in Table 4 is converted to CAFE-equivalent mpg and therefore the fleet average of all of the weight-class standards listed in this column will not be exactly 35.5 mpg.

22. “Continued vehicle models”refers to existing vehicle models that continue to be produced at the effective date of the regulation. For further information on the Chinese standards, see note 24.

23. For example, a WRI analysis shows that 66% of cars currently sold in the United States would meet the Chinese standards, while only 4% of light trucks would. For more information see Sauer and Wellington, "Taking the High (Fuel Economy) Road," World Resources Institute, November 2004.

24. Source: China Automotive Industry Information Website: http://www.autoinfo.gov.cn/zfwj/040330fg.htm

25. However, in reality, these driving cycles could be far different from how the vehicles are actually driven on the road, resulting in gaps or shortfalls between certified fuel economy levels and real-world fuel economy levels.

26. Results are based on a computer simulation model, the Modal Energy and Emissions Model (MEEM)

27. CAFE mpg = 1/(0.55/mpgCity + 0.45/mpgHWY), where mpgCity is the fuel economy rating under EPA City cycle, and mpgHWY is the fuel economy rating under EPA Highway cycle.

28. Based on the MEEM simulation model, the mpg gaps between Japan and CAFE cycles vary somewhat among vehicle types. For example, they are larger for light trucks than for cars; the "gaps" for diesel vehicles are smaller than those for gasoline vehicles; see Appendix.

29. Based on 8,800 grams of CO_2 per gallon of gasoline, and 1.609 km per mile

30. Based on 10,336 grams of CO_2 per gallon of diesel

31. In the case of China, data was not available but the authors were able to derive a dataset for the purpose of this analysis.

32. That is, this analysis assumes that the vehicle fleet mix in each country stays constant from 2002 throughout the time period modeled.

33. An, F. 1992. Automobile Fuel Economy and Traffic Congestion. Ph.D. dissertation. University of Michigan, Ann Arbor, Michigan.

An, F., M. Barth, M. Ross, and J. Norbeck. 1997. The Development of a Comprehensive Modal Emissions Model: Operating under Hot-Stabilized Conditions. Transportation Research Board Record, Series 1587: 52-62, Washington, DC.

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An, F., and A. Rousseau. 2001. Integration of a Modal Energy and Emissions Model into a PNGV Vehicle Simulation Model PSAT. SAE Paper No. 2001-01-0954, SAE Special Publication (SP-1607) on Advanced Hybrid Vehicle Powertrains. Society of Automotive Engineers, Warrendale, PA.

34. An, F., M. Barth, and G. Scora. 1997. Impacts of Diverse Driving Cycles on Electric and Hybrid Electric Vehicle Performance. SAE Technical Paper 972646. SAE Special Publication (SP-1284) on Electric/Hybrid Vehicles: Alternative Powerplants, Energy Management, and Battery Technology. Society of Automotive Engineers, Warrendale, PA.

An, F., J. DeCicco, and M. Ross. 2001. Assessing the Fuel Economy Potential of Light-Duty Vehicles. SAE Paper No. 2001-01FTT-31, SAE Special Publication (SP-1637) on New Energy Systems and Environmental Impacts. Society of Automotive Engineers, Warrendale, PA.

An, F., F. Stodolsky, A. Vyas, R. Cuenca, and J. Eberhardt. 2001. Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles. SAE Technical Paper 2000-01-0989. SAE Transaction: Journals of Engine, 109-3, 2001. Society of Automotive Engineers, Warrendale, PA.

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35. The authors accomplished this by simply substituting gasoline engines with hypothetical diesel engines for these vehicle models, while holding all other components unchanged.

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