Cars and Climate Change

  

Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

The goal of the International Council on Clean Transportation (ICCT) is to dramatically reduce conventional pollution and greenhouse gas emissions from personal, public, and goods transportation in order to improve air quality and human health, and mitigate climate change. The Council is made up of leading government officials and experts from around the world that participate as individuals based on their experience with air quality and transportation issues. The ICCT promotes best practices and comprehensive solutions to improve vehicle emissions and efficiency, increase fuel quality and sustainability of alternative fuels, reduce pollution from the in-use fleet, and curtail emissions from international goods movement.

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Governments around the world are currently grappling with two distinct but interconnected issues—how to reduce emissions of climate-changing greenhouse gases (GHG) and how to reduce dependence on finite, and often imported, supplies of petroleum.

Vehicle standards, either designed to reduce fuel consumption or GHG emissions, can play an important role in addressing both of these policy goals. There is a great deal of policy activity around these issues today: the European Union is working out the specific regulatory policy to reduce carbon dioxide (CO_2) emissions from passenger vehicles; Canada is expected to propose new fuel economy standards in the fall; the U.S. Congress and a group of federal agencies are developing separate proposals to address fuel economy and climate change respectively; China recently revised its vehicle tax policy to diminish demand for larger, inefficient passenger vehicles; and the State of California is awaiting news on a waiver from the U.S. government to regulate GHG emissions and facing litigation from automakers for trying to do so.

This report compares on an equal basis the vehicle standards that have recently been put in place, updated or proposed by governments around the world to address these two policy goals. Japan and Europe currently lead, and will continue to lead, the world in controlling GHG emissions and fuel consumption from passenger vehicles, partly due to fuel and vehicle taxation policies that favor more efficient vehicles. In terms of absolute improvement, California and Canada are posed to make the largest gains in the next decade, provided that legal and technical barriers to implementing and enforcing their standards can be overcome.

Other countries could make meaningful strides in the coming years, depending on how policy actions play out. The U.S. and China are both poised to make important decisions in coming years on the next stages of their fuel economy regulations. The most prominent U.S. proposal will bring fuel economy close to current Chinese levels, but considering these two countries together account for close to 40 percent of global sales, each will have a great deal more to do to reduce petroleum consumption in coming years (Automotive News 2007). A few countries with significant and growing vehicle sales, such as India and Mexico, are notably absent from this report and others, such as Brazil and South Korea, could enact stronger vehicle standards to support their policy goals. Decisions on how to meet and enforce fuel economy or GHG emission goals will not only affect their own domestic affairs, but worldwide conditions for generations to come.

In 2004, the Pew Center on Global Climate Change published a groundbreaking report that compiled and compared GHG emission standards and passenger vehicle fuel economy from seven governments around the world. The report, *Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards Around the World* (An and Sauer 2004), developed a methodology for directly comparing vehicle standards in terms of European-style grams of CO_2 per kilometer and U.S.-style miles per gallon (mpg). Such a methodology is needed since different parts of the world use different test procedures to determine fuel consumption and GHG emissions. Since the report's publication in 2004, sustained high oil prices and the growing scientific evidence and real world consequences of global climate change have added urgency to these important vehicle performance policies, increasing the need for accessible and reliable benchmarking across jurisdictions.

This report presents a significant update to the 2004 Pew Report. Major changes in vehicle standards have occurred in Japan, Europe and the United States. In addition, the methodology of how standards are converted—in order to compare them on an equal basis—was updated to reflect a broader mix of vehicles sold in the European and Japanese markets and a new Japanese vehicle test cycle. This report identifies new fiscal policies enacted in China and Canada that are designed to promote fuel-efficient vehicles and to discourage larger, inefficient vehicles. While these fiscal policies are not reflected in our comparisons of regulatory vehicle standards, their importance should not be overlooked or underestimated.

Important findings from this report include:

- While Japan and Europe continue to lead the world with the most stringent passenger vehicle greenhouse gas and fuel economy standards, recent regulatory actions have moved these two important governments in opposite directions.

- In 2006, Japan increased the stringency of its fuel economy standards, while Europe is in the process of weakening its CO_2 standards. As a result, Japan's standards are expected to lead to the lowest fleet average greenhouse gas emissions for new passenger vehicles in the world (125 g CO_2/km) in 2015.

- California's GHG emission standards for passenger vehicles are expected to achieve the greatest absolute emission reductions from any policy in the world.

- U.S. passenger vehicle standards continue to lag behind other industrialized nations, both in absolute terms as well as in the relative improvements required under current regulations to 2011. If targets under discussion in the U.S. Congress are enacted, the U.S. could move ahead of Canada, Australia, South Korean and California by 2020.

- Canada has established the world's only active feebate program with significant incentives and levies for vehicles based on fuel consumption. At the same time, Canada plans to issue an attribute-based fuel economy regulation this fall to take effect in 2011, while it continues to implement its voluntary agreement with automakers.

- The Chinese government warrants significant notice for reforming the passenger vehicle excise tax to encourage the production and purchase of smaller-engine vehicles, and to eliminate the preferential tax rate that applied to sport utility vehicles (SUVs).

- South Korea is the only nation in the world with fuel economy standards for new passenger vehicles where fleet average fuel economy is projected to decline over the next five years. The South Korean government is considering policy options to address this negative trend.

A comparison of the relative stringency and implementation schedules of GHG emissions and fuel economy standards around the world

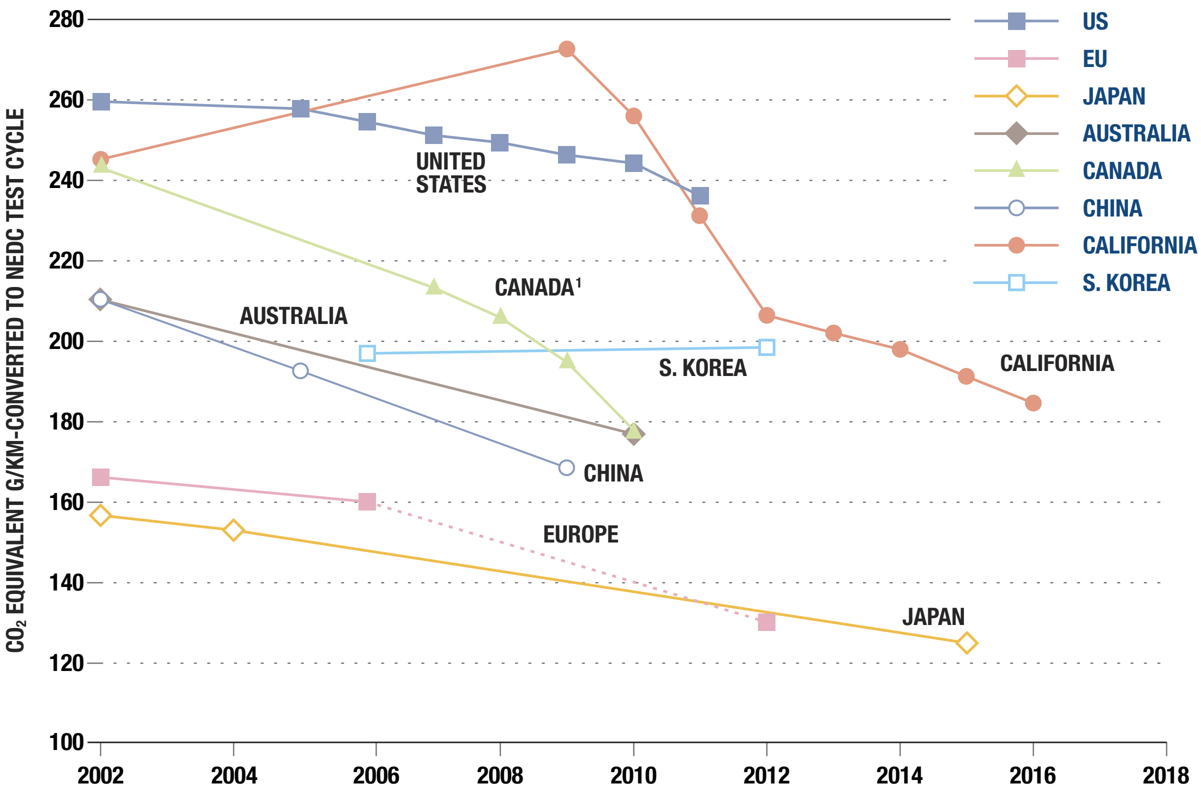

FIGURE ES-1. Actual and Projected GHG Emissions for New Passenger Vehicles by Country, 2002-2018.

Note: Solid lines denote actual performance or projected performance due to adopted regulations; dotted lines denote proposed standards; Values normalized to NEDC test cycle in grams of CO_2-equivalent per km.

[1] For Canada, the program includes in-use vehicles. The resulting uncertainty on new vehicle fuel economy was not quantified.

can be found in Figure ES-1 and Figure ES-2. In order to fairly compare across standards, each country's standard has been converted to units of grams of carbon dioxide equivalent per kilometer traveled on the New European Drive Cycle (NEDC) and miles per gallon on the U.S. Corporate Average Fuel Economy (CAFE) test procedure.

Vehicle performance standards serve multiple priorities—simultaneously mitigating petroleum dependency, reducing greenhouse gas emissions and increasing consumer welfare.

Achieving the maximum feasible standard is a careful regulatory balance that is strengthened by robust benchmarking. This benchmarking exercise proves that there is substantial room for improvement by many governments' policies. Building on this work, future analyses will examine the significant role that regulatory design issues can play in ameliorating competitiveness concerns while achieving ambitious targets.

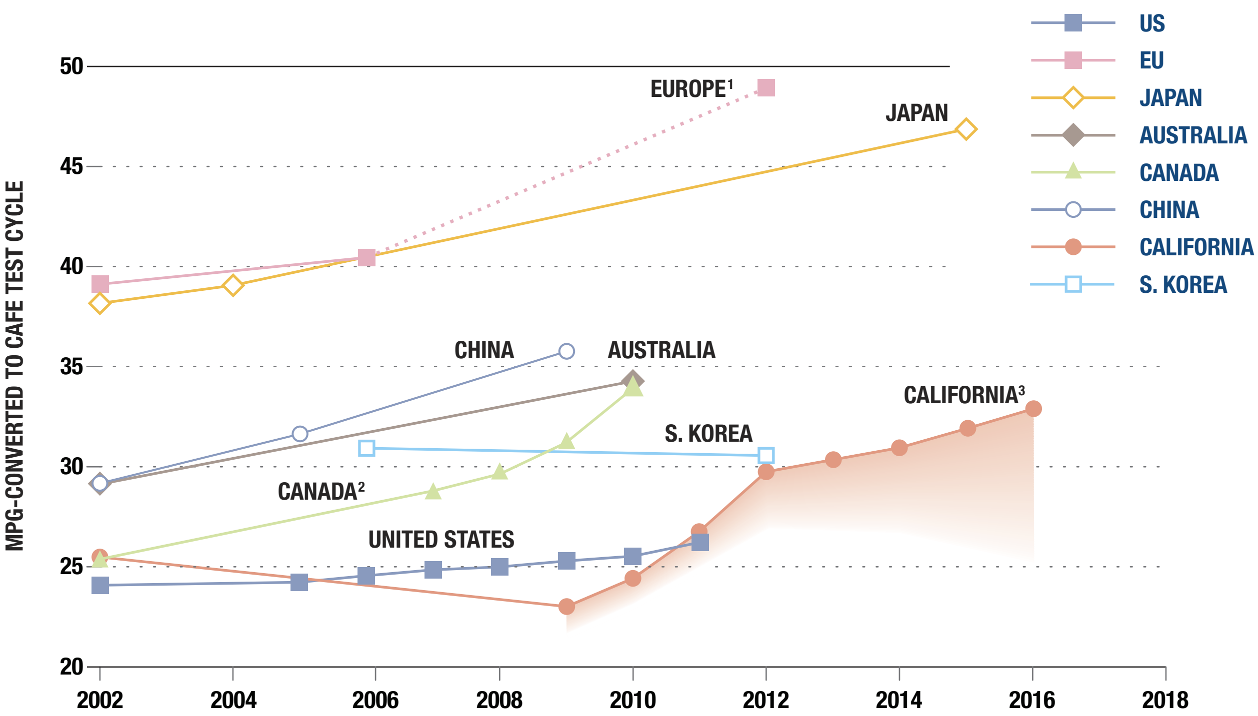

FIGURE ES-2. Actual and Projected Fuel Economy for New Passenger Vehicles by Country, 2002-2018.

[1] The relative stringency of Europe's CO_2-based standards is enhanced under a fuel economy standard because diesel vehicles achieve a boost in fuel economy ratings due to the higher energy content of diesel fuel.

[2] For Canada, the program includes in-use vehicles. The resulting uncertainty of this impact on new vehicle emissions was not quantified.

[3] Shaded area under the California trend line represents the uncertain amount of non-fuel economy related GHG reductions (N_2O, CH_4, HFCs, and upstream emissions related to fuel production) that manufacturers will generate from measures such as low-leak, high efficiency air conditioners, alternative fuel vehicles, and plug-in hybrid electric vehicles.

1. THE STATE OF VEHICLE GHG EMISSION AND FUEL ECONOMY REGULATIONS AROUND THE WORLD

Nine government entities worldwide—Japan, the European Union, United States, California, Canada, China, Australia, South Korea, and Taiwan, China—have proposed, established, or are in the process of revising light-duty vehicle fuel economy or GHG emission standards. Of the 30 Organization for Economic Cooperation and Development (OECD) nations, only five—Iceland, Mexico, Norway, Switzerland, and Turkey—do not currently have programs to reduce GHG emissions or petroleum use from passenger vehicles.

A number of different test procedures, formulas, baselines, and approaches to regulating fuel economy and GHG emissions have evolved over the last several decades. The policy objectives of these regulations vary depending on the priorities of the regulating body, but most standards are applied to new vehicles in order to reduce either fuel consumption or GHG emissions. There are important differences between these two approaches. Fuel economy standards seek to reduce the amount of fuel used by the vehicle per distance driven. Methods to do so may include more efficient engine and transmission technologies, improved aerodynamics, hybridization, or improved tires. GHG emission standards, on the other hand, may target either CO_2 or the whole suite of GHG emissions from the vehicle, such as refrigerants from the air conditioning system or nitrous oxide (N_2O) from the catalytic converter. GHG emissions standards may even extend beyond the vehicle to encompass the GHG emissions generated from the production of fuels.

The four largest automobile markets—North America, the European Union, China, and Japan—approach these new vehicle standards quite differently. Within North America alone, a wide variety of approaches have been taken: the U.S. federal government has relied on CAFE standards requiring each manufacturer to meet specified fleet average fuel economy levels for cars and light trucks[1]; the state of California has passed fleet average GHG emission standards for new vehicles sold in the state; and Canada's voluntary agreement with automakers is intended to reduce GHG emissions from new and in-use vehicles. The European Union recently announced that it would replace a voluntary agreement with automakers with an enforceable regulatory program because automakers were not on track to meet their voluntary targets. China and Japan have set tiered, weight-based fuel economy standards. Japan's standards allow for credits and trading between weight classes, while China sets minimum standards that every vehicle must achieve or exceed.

Certification of GHG emission and fuel economy performance for new vehicles is based on test procedures intended to reflect real world driving conditions and behavior in each country. The European

Union, Japan, and the U.S. have each established their own test procedures. China and Australia use the European Union's test procedures. California, Canada, and Taiwan, China follow the U.S. CAFE test procedures, while South Korea adopts the U.S. City test procedure."

1.1 JAPAN

The Japanese government first established fuel economy standards for gasoline and diesel powered light-duty passenger and commercial vehicles in 1999 under its "Top Runner" energy efficiency program. Fuel economy targets are based on weight class, with automakers allowed to accumulate credits in one weight class for use in another, subject to certain limitations. Penalties apply if the targets are not met, but they are minimal. The effectiveness of the standards is enhanced by highly progressive taxes levied on the gross vehicle weight and engine displacement of automobiles when purchased and registered. These financial incentives promote the purchase of lighter vehicles with smaller engines. For example, the Japan Automobile Manufacturers Association estimates that the owner of a subcompact car (750 kg curb weight) will pay $4,000 less in taxes relative to a heavier passenger car (1,100 kg curb weight) over the lifetime of the vehicle (JAMA 2007).

In December 2006, Japan revised its fuel economy targets upward, and expanded the number of weight bins from nine to sixteen (Figure 1). This revision took place before the full implementation of the previous standards because the majority of vehicles sold in Japan in 2002 already met or exceeded the 2010 standards. This new standard is

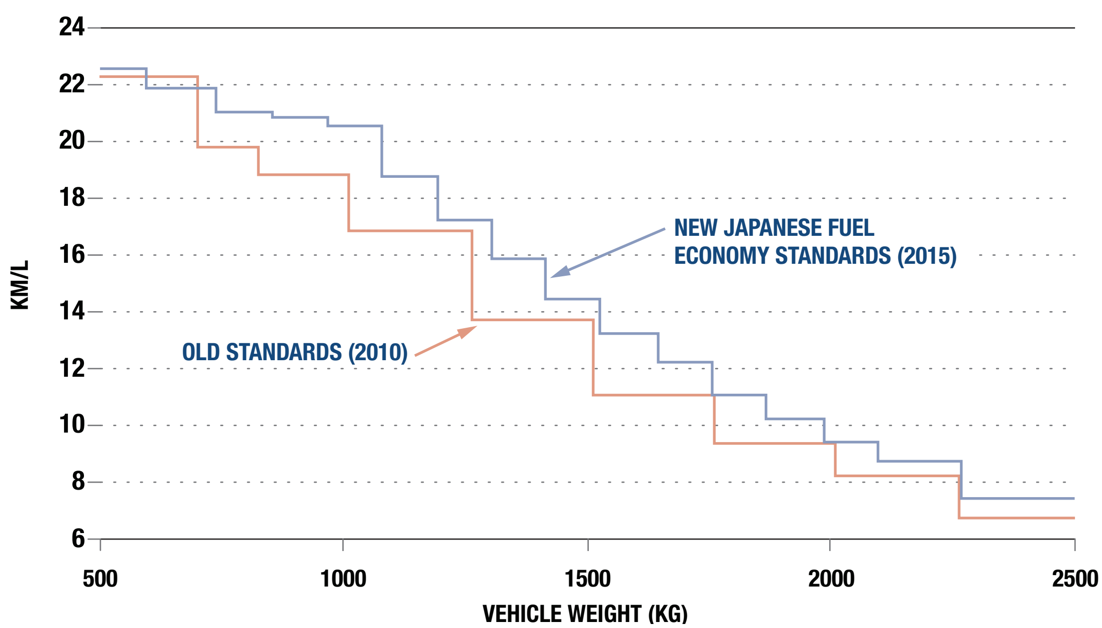

FIGURE 1. New (2015) Japanese Standards Compared to Previous (2010) Standards.

projected to improve the fleet average fuel economy of new passenger vehicles from 13.6 km/L in 2004 to 16.8 km/L in 2015, an increase of 24 percent. Based on our analysis, the new target reaches an average of 125 g/km for CO_2 emissions on the NEDC test cycle (see Figure 5).

In 2010 Japan will introduce a new test cycle, the JC08, to measure progress toward meeting the revised 2015 targets. Relative to the previous 10-15 test cycle, the JC08 test cycle is longer, has higher average and maximum speeds and requires more aggressive acceleration. These differences are illustrated in Figure 2.

According to the Japanese government, the JC08 cycle's higher average speed[2], quicker acceleration, and new cold start increased the stringency of the test by 9 percent. The government determined the relative stringency by measuring fuel economy of 2004 model year vehicles under each test cycle. The fleet average fuel economy for MY2004 vehicles was 15.0 km/L under the 10-15 test cycle (MLIT 2006) and 13.6 km/L under the JC08 test cycle (ANRE/MLIT 2006). The more-rigorous JC08 test cycle serves to further increase the stringency of the 2015 standards beyond the difference seen in Figure 1.

1.2 THE EUROPEAN UNION

A decade ago, the European Union entered into a series of voluntary agreements with the associations of automobile manufacturers that sell vehicles in the European market to reduce CO_2 tailpipe emissions. These agreements apply to each manufacturer's new vehicle fleet, and set an industry-wide target of 140 grams CO_2 per kilometer. (Other GHGs were not included in the agree-

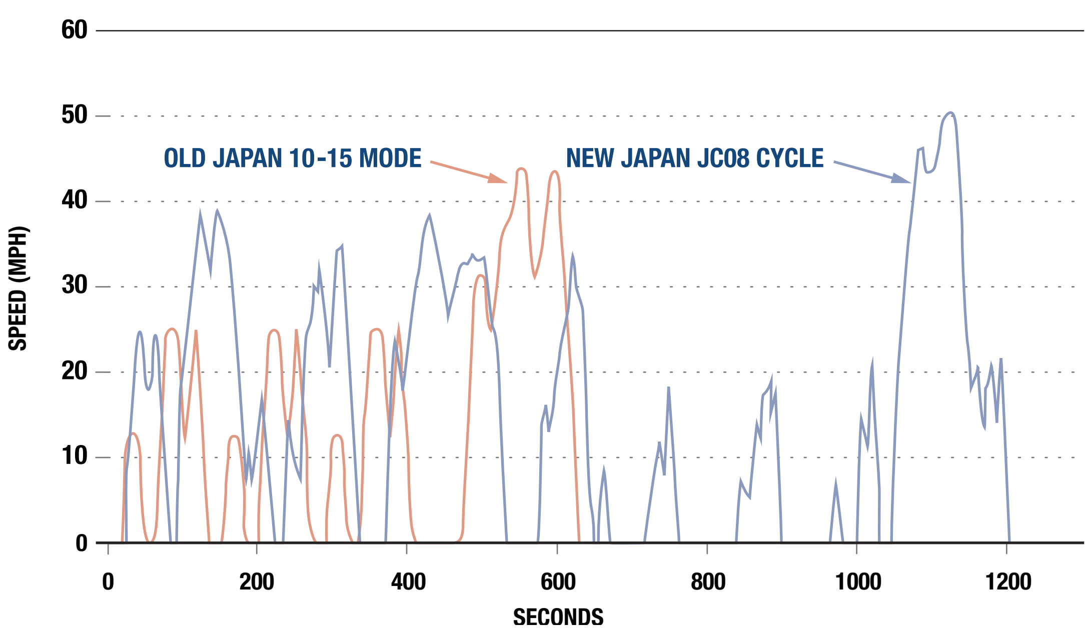

FIGURE 2. New Versus Old Japanese Vehicle Emission Test Cycles

ment.) This target was designed to achieve a 25 percent reduction in CO_2 emissions from passenger cars from 1995. The original agreement with the European Car Manufacturers Association (ACEA) had an initial compliance date of 2008, while the Asian manufacturers (represented by South Korean and Japanese associations, KAMA and JAMA) were given until 2009 to comply[3].

Current trends strongly suggest that the automakers will not comply with the 2008 target. In 2006, manufacturer-fleet average CO_2 emissions ranged from 142–238 g/km, with an industry-wide average of 160 g/km (Figure 3). By 2008, the passenger vehicle fleet average CO_2 emissions are projected to reach 155 g/km instead of the 140 g/km target.

In its 2007 review of the EU CO_2 and cars strategy, the European Commission announced that the EU objective of 120 g CO_2/km by 2012 would be met through an "integrated approach". In June 2007, the Council of Environment Ministers formally adopted a resolution to approve the shift to mandatory standards and an integrated approach to achieve 120 g/km, with carmakers achieving 130 g/km through technical improvements and the remaining 10 g/km coming from complementary measures. Those measures could include efficient tires and air conditioners, tire pressure monitoring systems, gear shift indicators, improvements in light-commercial vehicles, and increased use of biofuels. The Commission has announced that it will propose a legislative framework for vehicle standards and complementary policies if possible in 2007 and, at the latest, by 2008. The Council expressed a desire to include a longer-term vehicle emissions target for 2020 within the context of an overall strategy to address climate change.

The Council of Environment Ministers insisted that the regulatory framework should be as competitively neutral as possible. A review of 2006 data on European passenger vehicles and CO_2 emissions reveals a wide range of fleet averages from 142 to 238

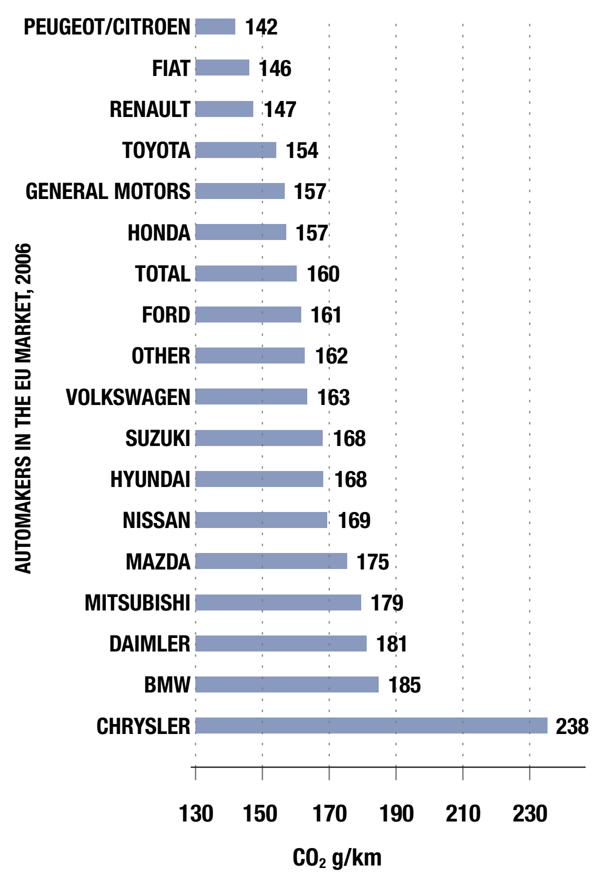

FIGURE 3. Average CO_2 Emission Rates (g/km) by Automakers, EU Market, 2006

g CO_2/km. Several European automakers—Peugeot/Citroen, Fiat, Renault, and Volkswagen—are currently selling vehicles with lower CO_2 emissions in the EU than most Asian manufacturers. This gives these European automakers an advantage in their own market under the forthcoming CO_2 standards. However, two of the three German auto manufacturers—BMW and Daimler—have relatively high CO_2 emissions, while Volkswagen is much closer to the 2006 EU fleet-wide average of 160 g/km. The recent sale of Chrysler has helped Daimler substantially lower its passenger fleet CO_2 emissions.

1.3 CHINA

China is one of the newest entrants to the field of regulating vehicular fuel economy. Since 2005, the country's rapidly growing new passenger vehicle market has been subject to fuel economy standards, which are geared toward reducing China's dependence on foreign oil and encouraging foreign automakers to bring more fuel-efficient vehicle technologies to the Chinese market. The new standards set up maximum fuel consumption limits by weight category and are implemented in two phases. Phase 1 took effect on July 1, 2005 for new models and a year later for continued models. Phase 2 is due to take effect on January 1, 2008 (new models) and January 1, 2009 (continued models). According to a recent study by CATARC, Phase 1 has increased overall passenger vehicle (including SUVs) fuel efficiency by approximately 9 percent, from 26 mpg in 2002 to 28.4 mpg in 2006, despite increases in gross weight and engine displacement (CATARC 2007).

China has recently revised its taxation of motor vehicles to strengthen incentives for the sale and purchase of vehicles with smaller engines. The taxation has two components: an excise tax levied on automakers and a sales tax levied on consumers. The excise tax rates are based on engine displacement. In 2006, the Chinese government updated excise tax rates to further encourage the manufacture of smaller-engine vehicles. Specifically, the tax rate on small-engine (1.0-1.5 liter) vehicles was cut from 5 to 3 percent, while the tax rate on vehicles with larger-engines (more than 4 liters) was raised from 8 to 20 percent. Also, as the preferential 5 percent tax rate that applied to SUVs has been eliminated, all SUVs are now subject to the same tax schedule as other vehicles with the same engine displacement.

1.4 CANADA

Canada's Company Average Fuel Consumption (CAFC) program was introduced in 1976 to track the fuel consumption of the new light duty vehicle fleet. CAFC is similar to the U.S. CAFE program with the exception that the CAFC program does not distinguish between domestic and imported vehicles. Also, the CAFC program has been voluntary since Canadian automakers made a commitment to meet the targets in the early 1980s. The fuel consumption goals set out by the program have historically been equivalent to CAFE standards. Since Canadian consumers tend to buy more fuel-efficient vehicles than U.S. consumers, the auto industry, as a whole, has consistently met or exceeded CAFC targets.

In 2000, the Government of Canada signaled its intention to seek significant improvements in GHG emissions under a voluntary agreement with automakers. Negotiations culminated in 2005 with the signing of a voluntary Memorandum of Understanding (MOU) between the government and automakers. Under the MOU, the automakers committed to reducing on-road GHG emissions from vehicles by 5.3 megatonnes CO_2 equivalent (CO_2eq) per year in 2010 (MOU 2005). The 5.3 Mt target is measured from a "reference case" level of emissions based on a 25 percent reduction target in fuel consumption that is designed to reflect the actions of automakers that would have occurred in the absence of action on climate change. Under the MOU, automakers can receive credits for reductions in: CO_2 achieved by reducing vehicle fuel consumption; exhaust N_2O and methane (CH_4) emissions; hydrofluorocarbon (HFC) emissions from air-conditioning systems; and reductions in the difference between lab-tested and actual in-use fuel consumption. Since the MOU covers all GHGs emitted by both the new and in-use vehicle fleet, the need to improve new vehicle fuel efficiency will depend on what other GHG reductions will be achieved by industry and counted towards the target. For this reason, the impact of the MOU on fuel efficiency of the new fleet cannot be forecast with precision. The MOU includes three interim reduction goals for 2007, 2008 and 2009, and a report on progress to the 2007 goal is due in mid-2008.

In October 2006, the Canadian government announced a number of additional measures to reduce air pollutants and GHG emissions. Among these measures was a commitment to formally regulate motor vehicle fuel consumption beginning with the 2011 model year, signaling the end of the voluntary CAFC program. The government plans to issue a consultation paper on the development of these standards in the fall of 2007.

In the 2007 budget, the Canadian Government also introduced a program called the Vehicle Efficiency Incentive (VEI), which came into effect March 2007. The program includes a rebate and tax component, both of which are based on vehicle fuel efficiency. The performance-based rebate program, run by Transport Canada, offers $1,000 to $2,000 for the purchase or long-term lease (12 months or more) of an eligible vehicle. Transport Canada maintains a list of the eligible vehicles, which currently includes new cars achieving 6.5 L/100km (36 mpg) or better, new light trucks getting 8.3L/100km (28 mpg) or better, and new flexible fuel vehicles with combined fuel consumption E85 ratings of 13L/100km (18 mpg of combined fuel) or better (Transport Canada 2007). The new excise tax, called a "Green Levy", is administered by the Canada Revenue

Agency on inefficient vehicles. The sliding tax of up to $4,000 applies only to passenger cars with a weighted average fuel consumption of 302 g CO_2/km or greater and 18 mpg or less (Canada Revenue Agency 2007).

In addition to actions taken by the federal government, some Canadian provinces have also announced their own plans to further reduce GHG emissions from motor vehicles. The provinces of Québec, British Columbia and Nova Scotia have announced plans to adopt new vehicle standards that are consistent with California's GHG emission standard.

1.5 CALIFORNIA

In 2002, California enacted the first state law (AB 1493) requiring GHG emission limits from motor vehicles[4]. As directed by the statute, the California Air Resources Board (CARB) issued regulations in September 2004 limiting the "fleet average greenhouse gas exhaust mass emission values from passenger cars, light-duty trucks, and medium-duty passenger vehicles" (California Code of Regulations 2004). The fleet average caps first apply to model year 2009 vehicles. The standards become more stringent annually, so that by 2016, the new vehicle fleet average standard would be 30 percent below the 2009 level.

Baseline GHG emissions as of 2004 were estimated at 386,600 CO_2 equivalent tons per day. The California Air Resources Board (CARB) estimates that the proposed GHG emission standards will reduce projected GHG emissions from the full light-duty vehicle fleet from baseline levels by 17 percent in 2020 and by 25 percent in 2030 (CARB 2004). After accounting for increases in vehicle miles traveled (VMT), GHG emissions are expected to stabilize around 2007 levels until 2020, with a modest increase from 2020 to 2030 as shown in Figure 4.

The California standards cover the whole suite of GHG emissions related to vehicle operation and use. These include:

- CO_2, CH_4 and N_2O emissions resulting directly from vehicle operation;
- CO_2 emissions resulting from energy consumption in operating the air conditioning (A/C) system;
- HFC emissions from the A/C system due to either leakage, losses during recharging, or release from scrappage of the vehicle at the end of life; and
- Upstream emissions associated with the production of the fuel used by the vehicle.

Reductions of non-fuel economy-related GHG emissions are expected to come from a variety of measures. Methane emissions are present in vehicle exhaust at low levels, and three-way catalysts are an effective means of lowering these emissions. Nitrous oxide (N_2O) emissions from mobile sources accounted for 13 percent of total U.S. N_2O

emissions in 2001. A recent pilot study of N_2O emissions from vehicles found that certain newer vehicles have substantially lower N_2O emissions than 1990s vintage vehicles, but the technical reason has not been determined (CARB 2004). The use of improved compressors, reduced refrigerant leakage systems, and alternative refrigerants in mobile air conditioners could also lead to substantial GHG reductions[5]. Alternative fuel vehicles, including plug-in hybrids, can generate credits for the vehicle manufacturer in proportion to the upstream emissions mitigated by an alternative fuel and the amount of that fuel used over a year (CARB 2004).

Since their passage, the California standards have been adopted by eleven other states. If the program withstands legal challenge, these standards will reduce GHG emissions from more than one in three new vehicles sold in the U.S., impacting emissions from the entire U.S. vehicle fleet.

In December 2005, California requested a waiver from the U.S. Environmental Protection Agency (EPA), as required by Section 209 of the Clean Air Act, to promulgate GHG emission regulations. EPA delayed its response until the U.S. Supreme Court settled the question as to whether the Clean Air Act granted the Agency the authority to regulate CO_2. With the April 2007 Massachusetts v. EPA Supreme Court decision identifying CO_2 as an air pollutant recognized under the Clean Air Act, California's waiver has a greater likelihood of approval.

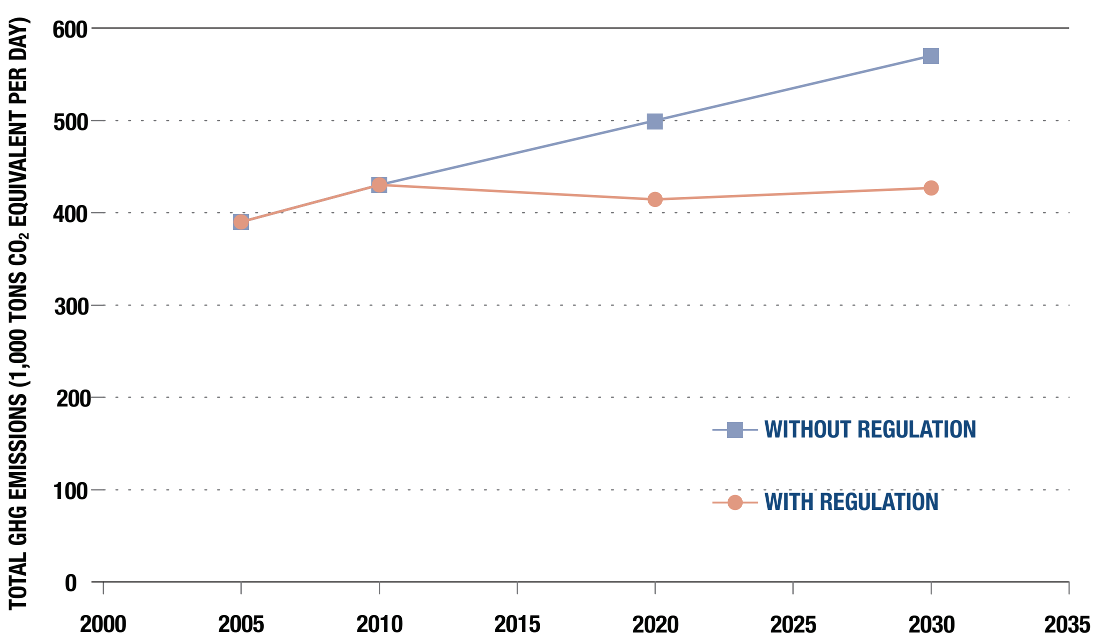

FIGURE 4. California Motor Vehicle Greenhouse Gas Emission Projections (CARB 2004)

1.6 THE UNITED STATES

The U.S. adopted its CAFE standards as part of a broad energy policy package in the wake of the 1973 oil crisis. At the time the standards were adopted, the expressed goal was to reduce the country's dependence on foreign oil; environmental outcomes were not an explicit policy goal. The CAFE standards are set by the National Highway Traffic and Safety Administration (NHTSA), while EPA is responsible for administering and reporting fuel economy tests procedures.

When CAFE standards were introduced, light trucks were a small percentage of the vehicle fleet used primarily for business and agricultural purposes. In order to protect small businesses and farmers, light trucks were subject to a less stringent fuel economy standard. Since that time, automakers have introduced a number of crossover vehicles, such as minivans and SUVs, that combine features of cars and light trucks. The use of these vehicles has shifted to primarily personal transport and market share has now surpassed passenger cars. As a result, there has been a 7 percent decrease in fuel economy of the overall light duty fleet since 1988 (EPA 2004).

Two separate CAFE standards remain in effect for passenger vehicles. The CAFE standard for passenger cars has remained unchanged since 1985 at 27.5 miles per gallon (mpg), although it was rolled back for several years in the late 1980s in response to petitions filed by several automakers. The standard for light trucks was increased in two rulemakings from 20.7 mpg in 2004 to 24.0 mpg for 2011 over seven model years from 2005 to 2011. In its most recent rulemaking, NHTSA began setting CAFE standards for light trucks based on vehicle size as defined by their "footprint" (the bottom area between the vehicle's four wheels). The new standard is based on a complex formula matching fuel economy targets with vehicle sizes. For the first three years, manufacturers can choose between truck-fleet average targets of 22.7 mpg in 2008, 23.4 mpg in 2009, and 23.7 mpg in 2010, or size-based targets. Beginning in 2011, manufacturers will be required to meet the size-based standards that are expected to result in a fleetwide average of 24.0 mpg (NHTSA 2006).

An analysis by NHTSA shows that, due to a wide variety of size compositions of the light-duty truck fleet, each automaker would have its own fuel economy targets depending on the footprints of the vehicles they sell. As demonstrated in Table 1, the major U.S. automakers, DaimlerChrysler (DCX)[6], General Motors (GM) and Ford, along with the Japanese automaker, Nissan, are expected to have the lowest fuel economy targets of all automakers while Hyundai, BMW and Toyota have the most stringent fuel economy standards in 2011 (NHTSA and DOT 2006).

Responding to consumer complaints, EPA recently readjusted the fuel economy test procedures to more accurately report real world consumer experience. While this does not affect the CAFE standard or compliance by automakers, it does give consumers a more accurate reflection of expected fuel use. Designing tests that represent real-world driving styles and conditions is an issue in every nation that regulates fuel economy and GHG emissions. EPA's new testing method—which apply to model year 2008 and later vehicles—includes the city and highway tests used for previous models along with additional tests to represent faster speeds and acceleration, air conditioning use, colder outside temperatures, and wind and road surface resistance.

In April 2007, the U.S. Supreme Court ruled, in a 5-4 decision, that GHG emissions are air pollutants potentially subject to federal regulation under the Clean Air Act. In response, the Bush Administration signed an executive order directing the U.S. EPA, in collaboration with the Departments of Transportation and Energy, to develop regulations that could reduce projected[7] oil use by 20 percent within a decade (Executive Order 2007). The Administration suggested that the "Twenty in Ten" goal be achieved by: (1) increasing the use renewable and alternative fuels, which will displace 15 percent of projected annual gasoline use; and (2) by further tightening the CAFE standards for cars and light trucks, which will bring about a further 5 percent reduction in projected gasoline use.

The U.S. Congress is currently considering several bills that would increase car and

TABLE 1. Estimates of U.S. Light-Duty Truck Fuel Economy Targets and Projected Percentage Gains

	FUEL ECONOMY TARGETS (MILES PER GALLON)				PERCENTAGE GAINS 2008-2011
	2008	2009	2010	2011	
General Motors	21.9	22.6	22.9	23.2	5.94%
Isuzu	22.2	22.9	23.2	23.4	5.41%
Toyota	22.6	23.0	23.2	23.8	5.31%
Nissan	22.3	23.3	23.7	23.9	7.17%
Ford	22.7	23.2	23.8	23.9	5.29%
Volkswagen	23.1	23.7	24.0	24.2	4.76%
Porsche	23.0	23.7	24.0	24.2	5.22%
Daimler Chrysler	23.2	23.7	24.1	24.3	4.74%
Honda	23.3	24.0	24.4	24.6	5.58%
Hyundai	23.9	25.0	25.0	25.4	6.28%
BMW	24.5	25.1	25.5	25.8	5.31%
Subaru	25.4	26.4	26.3	26.8	5.51%
Mitsubishi	25.1	25.8	26.3	27.0	7.57%
Suzuki	25.5	26.3	26.6	27.1	6.27%

Source: National Highway Traffic Safety Administration (NHTSA), Department of Transportation, 2006 truck CAFE standards or establish federal GHG emissions standards for motor vehicles. For the first time in many years, the Senate passed a bill (S.357 "Ten in Ten") that increasing passenger vehicle fuel economy standards by 10 mpg over a decade to 35 mpg in 2020.

1.7 SOUTH KOREA

South Korea established mandatory fuel economy standards in 2004 to replace a voluntary system. Starting in 2006 for domestic vehicles and 2009 for imports, standards are set at 34.4 CAFE-normalized mpg for vehicles with engine displacement under 1,500 cubic centimeters (cc) and 26.6 mpg for those over 1,500 cc. Credits can be earned to offset shortfalls. The program has shown encouraging progress in its early years. However, the market share of vehicles with larger engine size has been gradually increasing since recent years, while the standards remain static from 2006 and thereafter. As a result, the fleet average fuel economy in South Korea is projected to decline overtime. This trend is shown in Table 2. The Korean Ministry of Commerce and the Ministry of Environment are discussing countermeasures such as redesigning the fuel economy standards or introducing passenger vehicle CO_2 emissions standards, according to Dr. Youngil Jeong, Director of Center for Environmentally Friendly Vehicles in Korea.

1.8 OTHER REGIONS

- In Australia, a voluntary agreement calls on the industry to reduce fleet average fuel consumption for passenger cars by 15 percent by 2010 (over a 2002 baseline). There are no specific enforcement mechanisms or non-compliance penalties identified under this agreement.

- Taiwan, China's fuel economy standards, established before the mainland Chinese standards, are based on seven categories of engine size (measured in volume). The standards cover all gasoline and diesel passenger cars, light trucks, and commercial vehicles (<2,500 kg) and range

TABLE 2. Number of Registered Passenger Vehicles (current and projected) by Engine Size and Fleet Average Fuel Economy Levels in South Korea

CATEGORY BY ENGINE SIZE	NUMBER OF VEHICLES REGISTERED						
	2006	2007	2008	2009	2010	2011	2012
<1,500 cc	5,651,382	5,832,221	6,043,342	6,286,954	6,509,959	6,724,541	6,907,027
≥ 1,500 cc	4,744,232	5,032,690	5,322,161	5,608,959	5,901,817	6,180,446	6,450,052
	SHARE						
<1,500 cc	54.4%	53.7%	53.2%	52.8%	52.4%	52.1%	51.7%
≥ 1,500 cc	45.6%	46.3%	46.8%	47.2%	47.6%	47.9%	48.3%
	FLEET AVERAGE FUEL ECONOMY						
	30.8	30.8	30.7	30.7	30.7	30.7	30.6

Source: Youngil Jeong, Center for Environmentally Friendly Vehicles, 2007 from 16.9 mpg for vehicles with engine displacement over 4,201 cc to 36.2 mpg for vehicles less than 1,200 cc.

- Brazil put in place a fuel economy program called Escolha Certo (Right Choice) in the 1980s, which was discontinued in the early 1990s. In 1991, the country launched the National Program for the Rational Use of Oil and Gas (CONPET) to promote the efficient use of nonrenewable energy in all major economic sectors that consume oil derivatives, including transportation. A voluntary fuel economy labeling program for passenger vehicles is now under discussion as an important component of CONPET. Flex fuel vehicles, which can run on pure ethanol or gasohol (a blend of 75 percent gasoline and 25 percent ethanol—the only gasoline-based fuel sold in Brazil), now dominate new vehicle sales in Brazil. Because of its considerable use of non-gasoline fuels, Brazil's CO_2 emission from the light duty fleet is relatively low compared with other nations. For example, a recent study by Center for Clean Air Policy estimated that average CO_2 emissions from the 2004 light duty fleet are as low as 124 g/km (Krug et al 2006).

2. COMPARING VEHICLE STANDARDS AROUND THE WORLD

This section compares the passenger vehicle standards for both fuel economy and GHG emissions in Australia, California, Canada, China, the European Union, Japan, South Korea, the United States, and Taiwan, China. Each standard's stringency is strongly influenced by the test procedure used to measure fuel economy or GHG emissions. Over the last several decades, Europe, Japan and the United States have developed unique test procedures reflecting local real world driving conditions; as a result, the same vehicle tested on the Japanese test procedure may generate a markedly different fuel economy rating or GHG emissions than the identical vehicle tested on the U.S. or European test cycle.

To allow for comparison on an equal basis, each national standard has been adjusted to common reference standards by the methodology originally developed in An and Sauer (2004). The appendix to this report outlines this methodology, while also describing how it was updated to include the new Japanese test procedure and refined to reflect a broader mix of vehicles sold in the European and Japanese markets.

2.1 OVERVIEW OF GLOBAL GHG EMISSION AND FUEL ECONOMY STANDARDS

Depending on the policy priorities in place, passenger vehicle standards are designed to either lower GHG emissions or reduce fuel consumption. GHG emission standards are intended to mitigate climate change and help achieve emission reduction goals associated with international agreements. Stated aims of fuel economy standards include protecting consumers from rising fuel prices and price spikes, reducing oil imports, and reducing reliance on unstable oil-producing nations.

Policymakers are faced with many choices when drafting either type of standard: whether to set a single fleet-average standard or take a tiered approach, with multiple standards disaggregated according to vehicle footprint, weight, class, engine size, or interior size; which test cycle to adopt; and whether the standard should be voluntary or incorporate formal sanctions for non-compliance. Table 3 summarizes the specific policy approaches adopted by the countries included in this report.

While the regulations of the countries above display considerable diversity, common traits are evident from Table 3. The most common policy is a mandatory fuel economy standard affecting new vehicles only and measured in terms of distance traveled per volume of fuel consumed, generally under the composite CAFE test cycle or one of its subcomponents. Many of the new programs developed in recent years (e.g. California, Canada, Europe) display a preference for GHG or CO_2 emission standards. But the trend is not definitive as China recently adopted a fuel economy standard, and Canada seems poised to replace its GHG program with a fuel economy program.

TABLE 3. Fuel Economy and GHG Emissions Standards Around the World

COUNTRY/ REGION	STANDARD	MEASURE	STRUCTURE	TARGETED FLEET	TEST CYCLE	IMPLEMENTATION
Japan	Fuel	km/l	Weight-based	New	JC08	Mandatory
European Union*	CO_2	g/km	Single standard	New	NEDC	Voluntary
China	Fuel	l/100-km	Weight-based	New	NEDC	Mandatory
Canada*	GHG (CO_2, CH_4, N_2O, HFCs)	5.3 Mt reduction	Vehicle class-based	In-use and new	U.S. CAFE	Voluntary
California	GHG (CO_2, CH_4, N_2O, HFCs)	g/mile	Vehicle class-based	New	U.S. CAFE	Mandatory
United States	Fuel	mpg	Single standard for cars and size-based standards for light trucks	New	U.S. CAFE	Mandatory
Australia	Fuel	l/100-km	Single standard	New	NEDC	Voluntary
South Korea	Fuel	km/l	Engine size-based	New	U.S. EPA City	Mandatory
Taiwan, China	Fuel	km/l	Engine size-based	New	U.S. CAFE	Mandatory

*Europe and Canada are shifting to mandatory regulatory programs.

2.2 COMPARISON OF PASSENGER VEHICLE STANDARDS

For this study, we adopted reference standards corresponding to two of the most common ways to measure and regulate fuel consumption and GHG missions from passenger vehicles: a GHG emission standard measured in terms of grams of carbon dioxide equivalent per kilometer measured on the EU NEDC cycle, and a fuel-economy based standard measured in terms of CAFE-adjusted miles per gallon.

Figure 5 compares country standards in terms of grams of CO_2-equivalent per kilometer adjusted to the European NEDC test cycle. Europe and Japan lead the world in reducing GHG emissions from their vehicle fleets. For most of years out to 2015, Japan's fuel efficiency targets translate to the most stringent passenger vehicle GHG emission standards in the world, with Europe as a close second. At the end of their regulatory periods, Japan's new passenger fleet CO_2 emissions are estimated to be equivalent to 125 g/km in 2015; Europe is projected to achieve 130 g/km three years earlier, in 2012.

The U.S. new vehicle fleet is expected to remain the world's most carbon intensive for

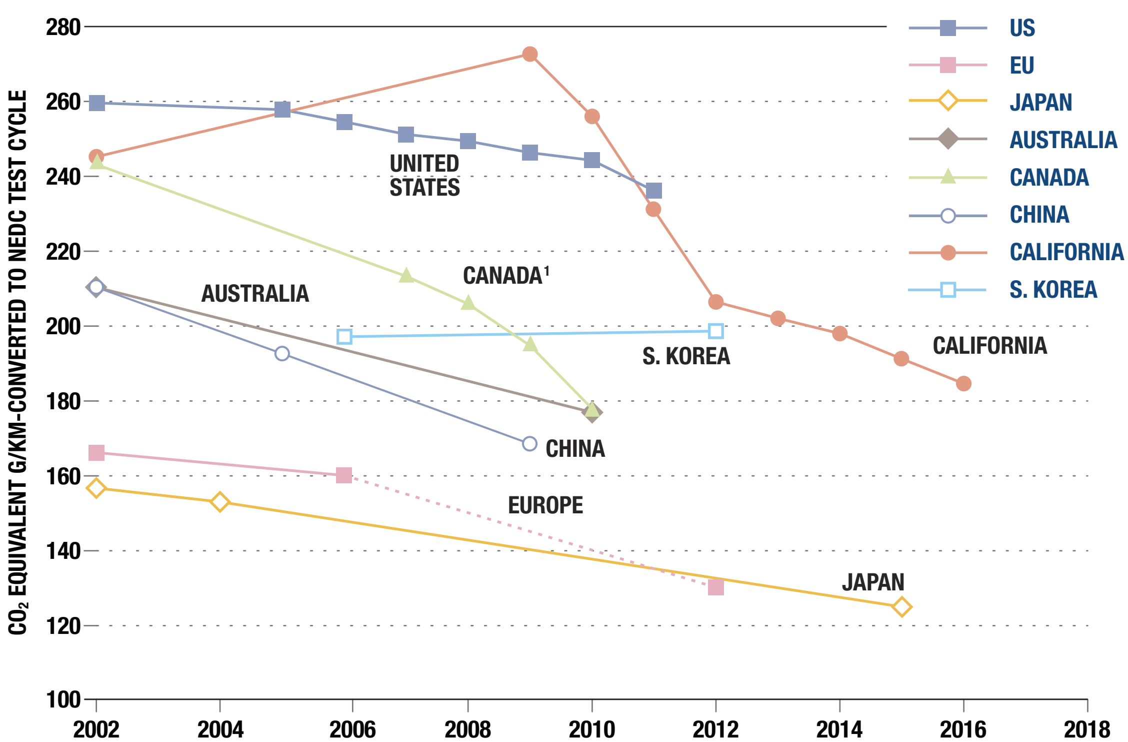

FIGURE 5. Actual and Projected GHG Emissions for New Passenger Vehicles by Country, 2002-2018.

Note: Solid lines denote actual performance or projected performance due to adopted regulations; dotted lines denote proposed standards; Values normalized to NEDC test cycle in grams of CO2-equivalent per km.

[1] For Canada, the program includes in-use vehicles. The resulting uncertainty on new vehicle fuel economy was not quantified.

the foreseeable future, although significant improvements could be achieved should the U.S. government enact the U.S. Senate CAFE legislation or the President's "Twenty in Ten" Executive Order. California is notable for its steep improvement in GHG emission standards, particularly in the early years of the program from 2009 to 2012. Interestingly, countries as diverse as China, Canada[8], and Australia have adopted substantively equivalent regulations, with the carbon intensities of new vehicles sold in each country in the 2009-2010 time frame projected to be 168, 178, and 176 grams of CO_2-equivalent per kilometer, respectively.

Figure 6 shows actual and projected fleet average fuel economy from 2002 to 2018 for new vehicles in CAFE-normalized miles per gallon. In each case, we assume that a given country's fleet exactly meets adopted or anticipated future standards. In 2006, Europe and Japan had the most stringent fuel economy standards for passenger vehicles in the world, with an estimated 40 mpg for both governments. Europe is expected to lead the world in fuel economy through at least 2015 if not longer, primarily due to the expanded use of efficient diesel engines in its light-duty vehicle fleet. The apparent discrepancy between Europe and Japan's

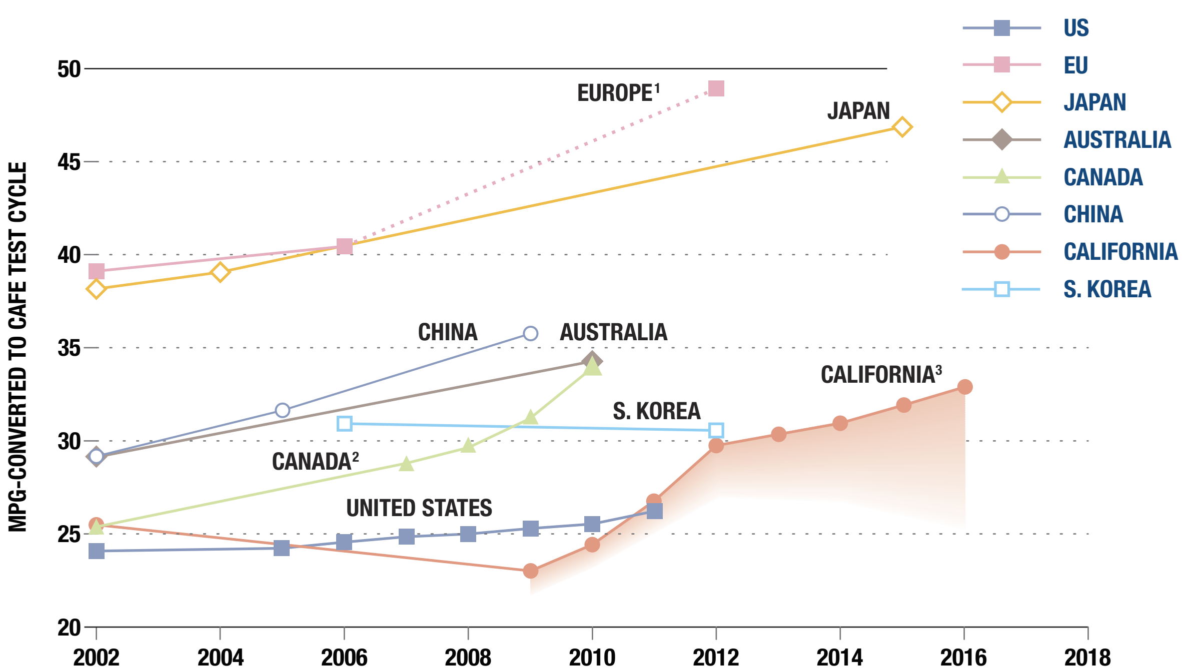

FIGURE 6. Actual and Projected Fuel Economy for New Passenger Vehicles by Country, 2002-2018.

[1] The relative stringency of Europe's CO_2-based standards is enhanced under a fuel economy standard because diesel vehicles achieve a boost in fuel economy ratings due to the higher energy content of diesel fuel.

[2] For Canada, the program includes in-use vehicles. The resulting uncertainty of this impact on new vehicle emissions was not quantified.

[3] Shaded area under the California trend line represents the uncertain amount of non-fuel economy related GHG reductions (N_2O, CH_4, HFCs, and upstream emissions related to fuel production) that manufacturers will generate from measures such as low-leak, high efficiency air conditioners, alternative fuel vehicles, and plug-in hybrid electric vehicles.

performance on a mpg and grams of CO_2eq/km basis is due to the large numbers of diesel vehicles in the European fleet. Diesel fuel contains about 10 percent more carbon and more energy than gasoline. As a result, the fuel economy of diesel vehicles is augmented by both the energy efficiency and the greater energy content of the fuel when measured using miles per gallon. However, when considered under a GHG-basis, the higher carbon content of the fuel is taken into account and offsets the fuel-related improvement found on a mpg-basis[9].

The shaded area under the California line in Figure 6 represents the range of uncertainty generated when those standards are converted to units of miles per gallon. There are two sources of this uncertainty: CARB's air conditioner credit, which allows automakers who have improved their A/C systems to "offset" some portion of measured exhaust emissions, and the use of biofuels in flex-fuel vehicles (FFVs) as a possible compliance mechanism. The air conditioner credit was calculated based upon data provided directly by CARB. The range of uncertainty attributable to biofuels is dependent on three variables: the sales rate of FFVs (assumed to be 50 percent in 2020); the biofuels use rate of the FFV buyers, and the relative GHG-intensity of those fuels. The uncertainty band shown in Figure 6 was determined by varying both the biofuels use rate and relative GHG savings of biofuels between 25 and 50 percent, which we have identified as reasonable upper and lower bounds for those values; the resulting uncertainty range was then added to the A/C credit. In each case, the mileage of FFVs on E85 was assumed to be 75 percent that of the same vehicle operated on gasoline, which is consistent with the average of all FFVs in model years 2004-2007 according to the EPA test cycle.

In contrast to Europe and Japan, the United States has the most lax national standards included in our survey, a position that could change if either the President's Executive Order or the Senate Bill are adopted or enacted. As in Figure 5, China, Australia, and Canada represent intermediate cases: neither of the former two countries have changed standards since the 2004 report, but China has made substantial progress through changes in its tax code. The impact of Canada's GHG emissions standard, and the uncertainties surrounding it, were discussed above. Finally, South Korea is the only national government included in this survey where fleet average fuel economy is projected to fall through 2012, primarily due to growing sales of larger, more powerful vehicles.

Figures 5 and 6 provide an apples-to-apples comparison of passenger vehicle fuel economy and GHG emission standards in eight regions. This analysis demonstrates that, despite the substantial improvements that proposed standards would require, a large gap remains between the stringency of passenger vehicle standards in different parts of the world. A number of factors play important roles in determining vehicle fleet performance for these metrics, such as technology deployment, vehicle size and weight, engine size and horsepower, and local driving conditions. Some factors are well known. The sharp increase in sales of diesel passenger vehicles in Europe—now approximately 50 percent of new sales—has lowered CO_2 emissions from the fleet. By contrast, the increasing popularity of larger, heavier vehicles with large engines has degraded the efficiency of passenger fleets in several nations, including the U.S. and South Korea. While it is beyond the scope of this analysis to explore with analytical rigor the relationship between various factors affecting vehicle performance in different countries, this would certainly be a useful area for further research.

One way to partially control for the impact of variations in vehicle size, weight, technology penetration, and engine performance across countries is to compare standards in terms of the absolute improvement required over each regulatory implementation period. Figure 7 shows the improvement required in passenger vehicle GHG emissions by country and/or region for each respective implementation period as measured under Europe's NEDC test cycle.

As Figure 7 demonstrates, the largest absolute reductions are expected in countries and regions with relatively high baselines but which have recently adopted aggressive policies to reduce GHG emissions from light-

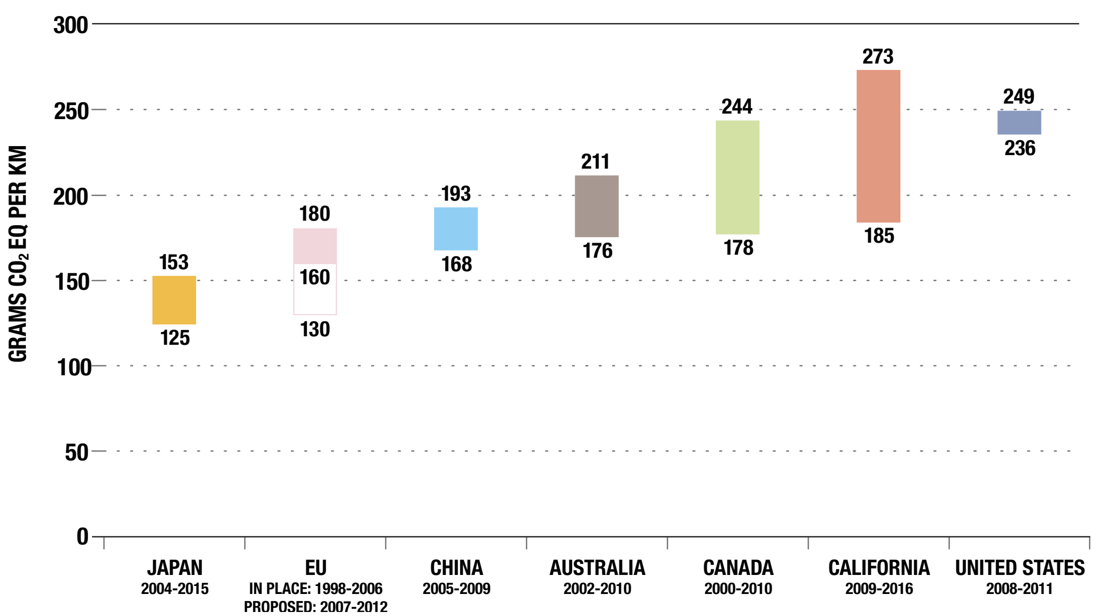

FIGURE 7. GHG Emission Reduction Associated with the Most Recent Regulations By Country

Note: Shaded bars denote in-place regulations; unshaded bars denote proposed regulations. Emissions data for Figure 7 are measured in grams CO_2-equivalent per kilometer under the NEDC test cycle. California and Canada's programs include reductions in non-tailpipe and non- CO_2 emissions.

duty vehicles. When fully implemented, California's standards will cut average GHG emissions from new passenger vehicles by almost 90 grams of CO_2 equivalent per kilometer, by far the largest absolute reduction in our survey. Second to California is Canada's voluntary program, which, if successfully implemented, is expected to reduce GHG emissions by 66 g/km from 2000 to 2010. Other notable countries shown in Figure 7 include Japan, which is on target to reduce GHG emissions by 28 g/km off of its already low 2004 baseline, and the U.S., which, despite starting with the highest baseline, expects only meager reductions (13 g/km) under its CAFE program between 2008 and 2011.

FINDINGS AND CONCLUSIONS

A great deal of regulatory action has taken place, and will continue to evolve, as governments around the world work to reduce GHG emissions and fuel consumption from passenger vehicles. Japan and Europe are leading the way on GHG emission reductions and fuel economy improvements in their light-duty vehicle fleets. California's GHG emission regulations have now been adopted by 11 other states across the United States and received a legal boost from the U.S. Supreme Court. The EU is currently designing a legislative framework to deliver ambitious reductions in tailpipe CO_2 emissions, partially by moving from a voluntary approach to formal standards. Fuel economy standards in the U.S. are also undergoing an important public debate. Canada is planning to issue new fuel economy regulations this fall. China has adopted new tax policies to dampen demand for larger, less efficient vehicles. The nations with the greatest motor vehicle GHG emissions and fuel consumption will be critical actors on global energy and environmental issues. Decisions on how to meet and enforce GHG and fuel economy goals will affect not only domestic affairs, but also worldwide conditions for generations to come.

APPENDIX: METHODOLOGY FOR ADJUSTING STANDARDS

Section 2 of the report compares eight government's fuel economy and GHG emission standards. In order to correct for differences in test cycles, this report uses a methodology similar to that described in the appendix of An and Sauer (2004). This appendix summarizes that methodology and describes in detail several changes made for this report, including the following:

- The Japanese test cycle was updated to the new JC08 test cycle and two new multipliers were developed to translate Japanese vehicle standards: JC08 to U.S. CAFE and JC08 to the European NEDC test cycle.
- Additional vehicles were added to the simulation model to better capture the small-car bias of the Japanese and European fleets.
- A constant test cycle multiplier was replaced with a variable multiplier to reflect the fact that the leniency of the CAFE test cycle relative to other test cycles declines as vehicle fuel economy improves.

As Figure A-1 demonstrates, this analysis starts with regulatory fuel economy or GHG emissions standards for each of the eight regions. Each standard is converted to an adjusted fuel economy and GHG emission standard by a two-step process. First, all vehicle standards are converted to the same pair of units—CO_2 g/km and mpg. Second, multipliers are then used to normalize the stringency of each vehicle standard to the same test cycle. The original 2004 report used the European NEDC test cycle for CO_2 and the U.S. CAFE test cycle for miles per gallon, and we have continued that convention here. Of course, the U.S. fuel economy standard (CAFE-adjusted fuel economy standard) and the European CO_2 emission reduction target (NEDC-adjusted CO_2 standard) require no adjustment. A flowchart of the two-step conversion process is produced below.

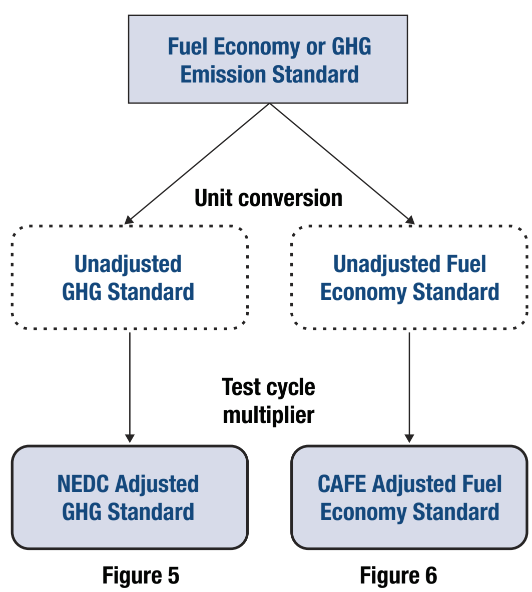

FIGURE A-1. Study Methodology

TABLE A-1. Important Unit Conversions

METRIC	STANDARD X	STANDARD Y	CONVERSION
Fuel economy	km/L	mpg	Y = X * 2.35
	L/100 km	mpg	Y = 235.2/X
	CO_2 g/km	mpg*	Y = 5469/X
GHG standard	km/L	CO_2 g/km	Y = 2325/X
	L/100 km	CO_2 g/km	Y = X * 23.2
	mpg	CO_2 g/km	Y = 5469/X

* For diesel vehicles, Y = 6424/X was used to reflect the higher carbon content of diesel fuel.

In simplified mathematical form, a given country standard is converted to its CAFE-adjusted fuel economy and NEDC-adjusted GHG equivalent through the following process:

Regulatory standard x Unit conversion x Test cycle multiplier = Adjusted standard

Table A-1 shows the unit conversion factors used in this study. In each case, mpg refers to gasoline only.

Europe, Japan, and the United States have each developed their own test procedures to determine fuel economy and GHG emissions from new passenger vehicles. The U.S. test cycle is a combination of two cycles, one representing city driving and the other highway driving. Table A-2 summarizes salient characteristics from these five test cycles—the EPA city and highway test cycles, the composite CAFE cycle, the European NEDC cycle, and the JC08 test cycle. The European NEDC cycle is used to measure compliance under the EU's voluntary CO_2 emission standards for passenger vehicles. The Japanese JC08 test cycle will be used starting in 2010 to measure progress toward Japan's 2015 "Top Runner" fuel economy standards for light-duty passenger vehicles.

As the table indicates, significant differences exist between the five test cycles, which then translate into differences in measured fuel economy for identical vehicles. The EPA highway cycle is the shortest cycle and averages 48 miles per hour, or more than double

TABLE A-2. Summary of International Test Cycles

CYCLE	LENGTH (SECONDS)	AVERAGE SPEED (MPH)	MAX SPEED (MPH)	MAX ACCELERATION (MPH/S)
EPA Highway	766	48.2	59.9	3.3
EPA City	1375	19.5	56.7	3.3
CAFE	-------	32.4*	59.9	3.3
NEDC	1181	20.9	74.6	2.4
JC08	1204	15.2	50.7	3.8

* Based on 45/55 CAFE highway/city weighting, not test cycle length.

the average speed of the other cycles. Generally speaking, up to a point (approximately 55 mph) higher average speeds generate better fuel economy. As a result, a vehicle tested on the EPA highway test cycle (and thus under CAFE) will appear to have superior energy efficiency (i.e., a higher miles per gallon rating) compared to the same vehicle measured under the other cycles. A similar relationship is expected between the NEDC to JC08 cycles. NEDC has a higher average speed and more gentle acceleration and should result in a higher fuel economy rating compared to the same vehicles tested on the Japanese JC08.

This report, and the original 2004 report, uses the Modal Energy and Emissions Model (MEEM), a well-established model allowing for the simulation of fuel economy or CO_2 emissions across a wide variety of test cycles. Unlike the 2004 report, this study incorporates non-CO_2 greenhouse gas emissions through adjustments outside of the model. The MEEM inputs key physical and operating parameters for vehicles and engines (i.e. vehicle weight, engine size, rated power, vehicle air and tire resistance, etc.), uses those parameters to estimate engine power demand based on second-by-second speed-time traces of a given drive cycle, and converts the simulated power demand into vehicle fuel consumption and carbon dioxide emissions[10]. By inputting representative vehicles and modeling them over a variety of test cycles, we have been able to estimate factors (here called multipliers to distinguish from unit-only conversion factors) by which to compare the standards of individual countries on an equal basis.

In the 2004 study, factors to convert the fuel economy of vehicles measured under European and Japanese test cycles to a CAFE equivalent were derived by modeling and comparing the fuel economies of six vehicles representative of the US fleet under the CAFE, NEDC, and Japanese test cycles. Those six vehicles included a small car, a large car, a minivan, a SUV, a pick-up truck and a crossover vehicle. Because this study includes a greater focus on the regulatory changes that have taken place recently in Europe and Japan, we have expanded the number of vehicles to include six additional makes and models of small cars which are more representative of the European and Japanese fleets. Particular effort was made to include vehicles sold internationally and in the same general fuel economy range of current and future standards in Europe and Japan.

Table A-3 shows the vehicles included in our analysis, their mpg fuel economies as estimated by the MEEM model under the NEDC, CAFE, and JC08 test cycles, and the multiplier required to normalize the results between test cycles.

As the table indicates, the expectation that testing under the CAFE cycle will result in higher fuel economies than under the NEDC and JCO8 cycles is supported by the modeling results. The simple (non-sales weighted) average fuel economy gap between the JC08 and CAFE cycles is around 30% (i.e. a CAFE-JC08 multiplier of 1.29). The gap between JC08 and the European NEDC cycle is estimated to be on the order of 15%, and the gap between CAFE and NEDC is about 12%. At the same time, Table A-3 suggests that the discrepancy between test cycles is not constant, but tends to rise and fall depending on vehicle fuel economy. For example, the smallest difference between the CAFE-JC08 test cycles is 1.17, which belongs to the most efficient vehicle, the 42 mpg Toyota Yaris. Consistent with the trend, the highest ratio of 1.39 belongs to the least efficient vehicle, the 19 mpg Chevrolet Silverado.

There is a technical basis for the modeled relationship between vehicle fuel economy and differences in test cycle results. In general, vehicles with higher fuel economies have smaller engines that operate more frequently under higher efficiency conditions. As a result, the fuel economy of those vehicles is less sensitive to driving conditions – thus the smaller test cycle multiplier. Many advanced engines not included in this report, notably hybrid electric drivetrains, also perform better than conventional internal combustion engines under the stop-and-go driving conditions simulated by the NEDC and JC08 test cycles.

TABLE A-3. Simulation Results for Gasoline Vehicle Fuel Economy Ratings Under Various Test Cycles

TYPE	MAKE	MODEL	TEST CYCLE FE (MPG)			TEST CYCLE MULTIPLIER		
			NEDC	CAFE	JC08	NEDC-JC08	CAFE-JC08	CAFE-NEDC
Small Car	Ford	Focus	26.0	29.8	22.9	1.14	1.30	1.15
	Toyota	Corolla	32.4	34.8	27.6	1.17	1.26	1.08
	Toyota	Yaris	40.6	42.2	36.1	1.12	1.17	1.04
	Honda	Fit	36.0	40.1	31.8	1.13	1.26	1.11
	Hyundai	Accent	35.1	39.0	32.1	1.09	1.21	1.11
	Kia	Rio	35.4	39.1	32.2	1.10	1.21	1.10
	Daewoo	Aveo	31.2	35.5	26.1	1.19	1.36	1.14
Large Car	Toyota	Camry	24.7	26.6	21.5	1.15	1.24	1.08
Minivan	Dodge	Grand Caravan	20.5	23.9	17.2	1.19	1.39	1.17
SUV	Ford	Explorer	17.6	20.2	14.6	1.20	1.38	1.15
Pickup	Chevrolet	Silverado	15.9	18.8	13.5	1.18	1.39	1.18
Crossover	Saturn	Vue	23.0	26.3	19.8	1.16	1.33	1.14
		Simple Average				1.15	1.29	1.12

Figure A-2 plots vehicle fuel economy against the MEEM test cycle ratio, or test cycle multiplier, for the CAFE-JC08 test cycles. Also shown on the graph is the approximate location of the 2004 Japanese passenger vehicle fleet average, and the 2015 standard in km/L (solid vertical lines). The numbers located to the right of the right axis indicate the CAFE adjusted fuel economy of the Japanese passenger fleet emission standards at different test cycle multipliers[11]. The logarithmic correlation of the vehicle models is shown as a dotted line (R^2 = 0.75) extrapolated out two units for illustrative purposes.

Figure A-2 clearly shows the inverse relationship between the CAFE-JC08 multiplier and fuel economy, with more fuel efficient vehicles performing relatively better on the JC08 cycle than less efficient models. For vehicles representative of the 2015 standard of 16.8 km/L, the multiplier is in the range of 1.19, corresponding to a CAFE adjusted standard of 47 mpg. This value compares to an unadjusted (multiplier of 1.0) fuel economy of 40 mpg, and 55 mpg for a conversion factor of 1.4, corresponding to the least fuel efficient vehicles included in this report.

The finding that the CAFE-JC08 test cycle multiplier falls as vehicles become more fuel efficient means that care must be taken when adjusting a fleet average fuel economy to a different cycle: as fuel economy improves, the multiplier changes, so using a constant multiplier over time will introduce bias into the analysis. Table A-4 shows the four equations used to estimate the test cycle multipliers for this study.

As the table indicates, the sensitivity of a given multiplier to increasing fuel economy

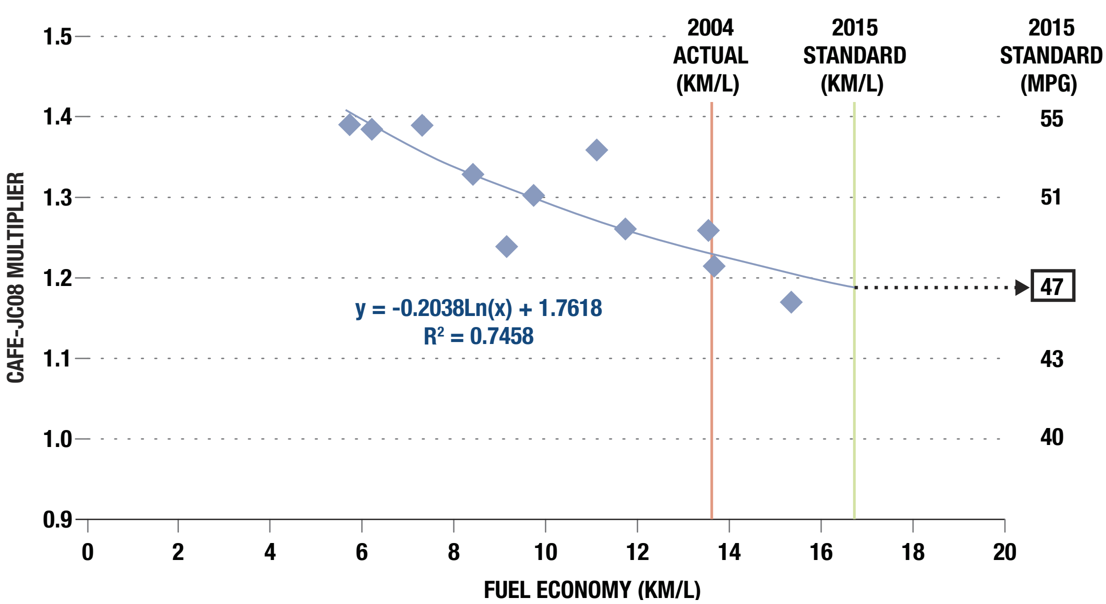

FIGURE A-2. Modeled Fuel Economy, CAFE-JC08 Multiplier, and CAFE Adjusted 2015 Japanese Fuel Economy Standard

TABLE A-4. Driving Test Cycle Multiplier Equations

TEST CYCLE CONVERSION	MULTIPLIER	CORRELATION
CAFE-JC08	-0.2038 x Ln(JC08) + 1.7618	0.7458
NEDC-JC08	-0.0841 x Ln(JC08) + 1.3464	0.5607
NEDC-CAFE	0.0816 x Ln(CAFE) + 0.6243	0.5622
CAFE-NEDC	0.1021 x Ln(NEDC) + 0.5787	0.5800

Units: JC08 = km/L; CAFE =mpg; NEDC = g/km. The multiplier itself is dimensionless.

varies between different test cycles. The largest sensitivity is between the JC08 and CAFE test cycles, which is more than double that the NEDC-CAFE multiplier. This is perhaps not surprising given that, as summarized in Table A-1, the JC08 and composite CAFE test cycles are the most divergent in terms of average test speed. Furthermore, the sensitivity of test cycle multipliers to changes in fuel economy suggests that each cycle-to-cycle conversion must be conducted independently.

Figure A-3 shows how the current and projected fuel economy for new vehicles in Japan from 2005 to 2015 was adjusted to units of CAFE mpg in this report, a methodology that was adopted for all other countries and test cycles. Three lines are shown. The solid line represents the fuel economy adjusted year by year using the log relationship derived in Figure A-2. The dotted red line represents the adjusted fuel economy based on a static multiplier equal to the most fuel efficient vehicle in our sample. The third, the dotted green line, represents the adjusted fuel economy based on a static multiplier factor derived from the least fuel efficient vehicle in our sample. The approximate multiplier factor used in each time period is provided in the boxes next to the appropriate line.

Several conclusions can be drawn. First, Figure A-3 demonstrates that Japan's fleet

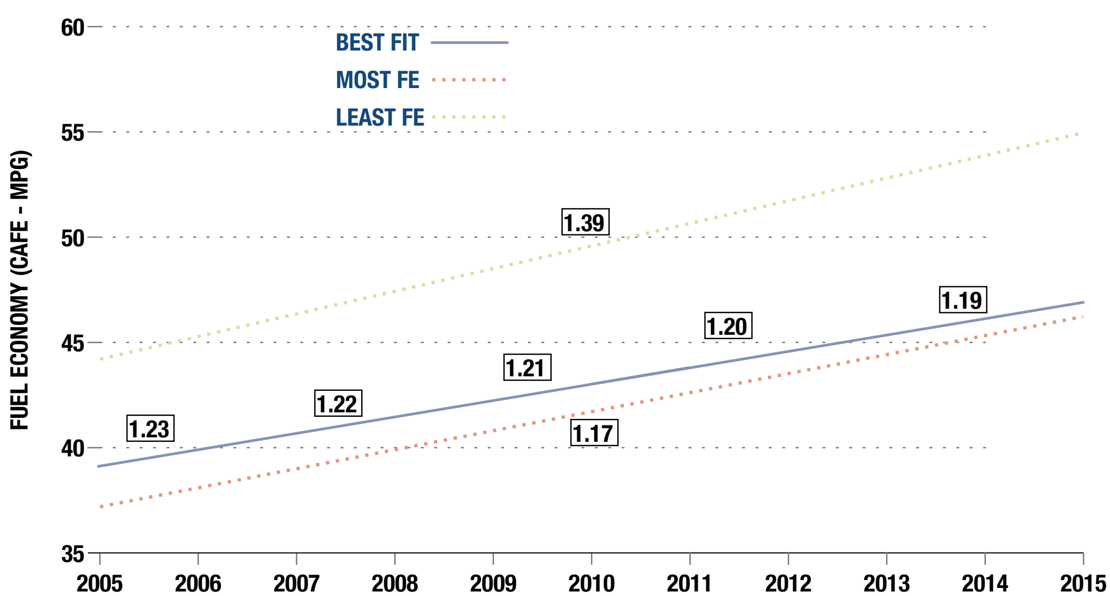

FIGURE A-3. CAFE Adjusted Projected New Vehicle Average Fuel Economy in Japan, 2005-2015

* Boxed numbers denote test cycle multiplier.

was already relatively fuel efficient in 2005, with a test cycle multiplier close to the lower bound set by the most fuel-efficient vehicle included in this report, the Toyota Yaris. In addition, the figure shows the slight "bend" that occurs in the best fit line as the fleet average fuel efficiency improves further over time. Finally, Figure A-3 illustrates the conservative nature of our methodology, with the adjusted standard value of 47 mpg presented in the main body of this report falling well on the low side of the 46 to 55 mpg range delineating by the most and least fuel-efficient vehicles included in our survey.

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ENDNOTES

[1] Starting as an option in model year (MY) 2008 and required in MY2011, the fleet average standards in light truck CAFE will change to a size-based, continuous function standard. See section 1.6 for more detail.

[2] Because Japanese vehicles are calibrated to slower driving conditions, increases in test speeds are claimed to increase fuel consumption, in contrast to results for vehicles sold in the U.S. market.

[3] The ACEA included BMW, DaimlerChrysler, Fiat, Ford, GM, Porsche, PSA Peugeot Citroen, Renault, and VW Group. The Korean Automobile Manufacturers Association (KAMA) includes Daewoo, Hyundai, Kia, and Sangyong. The Japanese Automobile Manufacturers Association (JAMA) includes Diahatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, Toyota.

[4] AB 1493, also known as the California Vehicle Global Warming Law, was signed into law by Governor Gray Davis on July 22, 2002.

[5] The industry-standard mobile air conditioner refrigerant HFC-134a has a Global Warming Potential of 1300; alternative refrigerants such as HFC 152a and CO2 have GWPs of 120 and 1, respectively (CARB 2004).

[6] Daimler and Chrysler merged in 1998. On May 14, 2007, Daimler sold Chrysler to Cerberus Capital Management. The data in Table 1 are drawn from the final CAFE rule in 2006, when the transaction had not occurred. Later in this report, Chrysler will be split out from Daimler.

[7] Choosing to set reductions goals from a baseline of projected emissions rather than a firm baseline, such as the year in which the policy was adopted or a point in the past, can limit the total expected emission reductions substantially.

[8] The Canada GHG emissions trend shown in Figure 5 is based on the 2005 Memorandum of Understanding between the Canadian government and the auto manufacturers to achieve a 5.3 Mt GHG emissions reduction by 2010. The Canadian program cannot be forecast with precision since the MOU covers all GHG emissions from new and existing passenger vehicles. The actual reductions in GHG emissions from new vehicles, and the improvements in fuel economy shown in Figure 6, may be lower depending on the reductions achieved by the means discussed in the Section 1.4.

[9] Historically, diesels have required some tradeoff between fuel economy and pollutant emissions. Diesel vehicles sold in Europe continue to have higher emissions of nitrogen oxide and particulate matter, which can negatively impact both local air quality and climate change. Stricter emissions standards have thus far played a significant role in restricting the market share of diesels in light-duty fleets in the U.S. and Japan. However, new emissions control technologies are expected to allow diesels to meet the strictest passenger vehicle standards currently in place.

[10] For further information regarding the MEEM model, see Barth, M., et. al, 2000; An and Rousseau. 2001.

[11] Note that mpg equivalent numbers at the far right of the graph are specific to the 2015 standard. As such, the CAFE equivalent for the 2004 fleet average (39 mpg) cannot be read directly off this graph.

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