CHAPTER 9

International Comparison of Policies to Reduce Greenhouse Gas Emissions from Passenger Vehicles

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Recent world events in the oil market, natural disasters, and Mideast conflicts bring renewed attention in the United States to energy security and climate changes. Securing energy from developing countries such as China and India, coupled with hurricanes on the Gulf Coast, generated a "perfect storm" in late 2005 that pushed oil prices over $70 per barrel and retail gasoline prices spiked over $3 per gallon in the United States.

Oil demands have been steadily increasing not just in rapidly motorizing developing countries but also in the developed world. Oil demand growth is primarily driven by the growth in passenger vehicle population and total vehicle miles of travel in all regions of the world. Greenhouse gas (GHG) emissions associated with passenger vehicle uses not only are soaring in non-Kyoto countries such as the United States and developing countries, but also threaten the commitments to the Kyoto treaty by the European Union (EU) nations, Japan, and Canada.

How to control energy demand and GHG emissions from personal use vehicles becomes a major challenge faced by today's world. Clearly, curbing vehicle growth, reducing travel demand, and improving vehicle fuel efficiency are three key elements to reducing oil demand. Indeed, a wide variety of approaches to address these three areas have been introduced in different parts of the world.

Nearly every major country in the world has established a program to address climate change resulting from transportation emissions. Most of these programs are more ambitious than the program underway in the United States. Fuel economy programs and GHG emission targets, either mandatory or voluntary, have proven to be among the most effective tools in controlling oil demand and GHG emissions from the transportation sector. While fuel economy standards for passenger vehicles have been largely stagnant in the United States over the past two decades, the rest of world—especially EU nations, Japan, and recently China and the U.S. state of California—has moved forward, establishing or tightening GHG or fuel economy standards. This chapter reviews and compares the programs under way around the world.

In a broader sense, fuel economy programs include both numeric standards and fiscal incentives to improve energy efficiency of individual vehicles per unit of travel distance. In today's technology-driven world, new technologies offer great promise to drastically improve vehicle fuel economy. However, realizing such technological promise has proven to be a big challenge. Historical trends in United States have clearly demonstrated that technological advancement tended to be used to boost vehicle size and performance over fuel economy, given a lack of regulatory pressure, as trends demonstrated from the mid-1980s to today. However, technology development has also been capable of responding to regulatory requirements to improve vehicle fuel economy, when such requirements were in place from mid-1970s and mid-1980s (An and DeCicco, 2005).

Fiscal incentive programs have improved fuel economy or reduced fuel use, especially in combination with standards. Incentives can be directed at improving the efficiency of the vehicle fleet, through variable registration fees or taxes, or at limiting vehicle use, through fuel taxes and road use fees. Many European countries have established vehicle tax systems either based on engine size, fuel efficiency, or carbon dioxide (CO_2) emission rates, in support of mandatory standards. Higher fuel taxes in the EU reinforce efforts on the part of automakers to meet voluntary GHG emission targets. Taxes are a major factor in the predominance of smaller and more fuel-efficient vehicle models and the limited growth in vehicle miles traveled (VMT) in Europe. Table 9-1 summarizes major approaches for the purpose of reducing automobile fuel consumption and GHG emissions.

Comparison of Vehicle Standards around the World

Research at Energy and Transportation Technologies, LLC, indicates that at least nine countries and regions around the world have established or proposed their own motor vehicle fuel economy or GHG emission standards, as shown in Table 9-2. Motor vehicle fuel economy standards have been established for most of the developed world, including the United States, EU nations, Japan, Canada, and Australia. The EU has also negotiated voluntary vehicle CO_2 emission rate targets as a means to control GHG

TABLE 9-1. Measures to Promote Fuel-Efficient Vehicles Around the World

Approach		*Measures/Forms*	*Country/Region*
Standards	Fuel economy	Numeric standard averaged over fleets or based on vehicle subclasses	U.S., Japan, Canada, Australia, China, Taiwan, South Korea
	GHG emissions	Grams/km or grams/mile	EU, California
Fiscal Incentives	High fuel taxes	Fuel taxes at least 50% greater than crude price	EU, Japan
	Differential vehicle fees and taxes	Tax or registration fee based on engine size, efficiency & CO_2 emissions	EU, Japan
	Economic penalties	Gas guzzler tax	U.S.
Support for new technologies	R&D programs	Funding for advanced technology research	U.S., Japan, EU
	Technology mandates and targets	Sales requirement for ZEVs	California
Traffic control measures	Incentives	Allowing hybrids to use HOV lanes	California, Virginia, and others states in the U.S.
	Disincentives	Banning SUVs on city streets	Paris

Source: Based on Table 1 in An & Sauer, 2004.

TABLE 9-2. Fuel Economy and GHG Standards for Vehicles Around the World

Country/Region	*Type*	*Measure*	*Structure*	*Test Method*	*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	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

Source: Energy and Transportation Technologies, LLC.

emissions. The state of California in the United States has also recently proposed its own GHG emission standards for vehicles. China and South Korea have their own recently adopted new vehicle fuel efficiency standards, while Taiwan has had its own fuel economy standards for more than a decade.

Directly comparing vehicle standards among different regions and countries is challenging. Different countries and regions have chosen to adopt different fuel economy or GHG standards for various historic, cultural, and political reasons. 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 versus voluntary approaches.

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 are usually expressed as grams per kilometer (g/km) or grams per mile (g/mile). Test methods include the U.S. Corporate Average Fuel Economy (CAFE) test, New European Drive Cycle (NEDC) test, and the Japan 10-15 Cycle test.

Comparison of Countries and Regions

Recently announced fuel economy regulations by the Chinese government have inspired new interest in analyzing and understanding fuel economy and GHG programs around the world. An and Sauer recently wrote a report published by the Pew Center called "Global Climate Changes: Comparison of Passenger Fuel Economy and GHG Emissions Standards around the World" (An and Sauer, 2004). In the report, they proposed a methodology to directly compare fleet average fuel economy of passenger vehicle fleets in different regions and countries. The significance of the report is that, prior to the study, fuel economy programs in different countries and regions had largely been isolated issues. These international comparisons have put these programs in the spotlight and put pressures on countries that either are lagging behind or lack the standards of the rest of the world.

The three largest automobile markets—the United States, the EU, and Japan—approach the regulation of fuel economy quite differently. The United States uses the 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.

In Japan and 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. However, China is following testing procedures developed by the EU, and Taiwan and Korea are following testing methods that are similar to U.S. CAFE procedures. Japan maintains its own test procedures.

In the EU and Australia, the automobile industry has signed a voluntary agreement with the government to reach an overall fleet average fuel economy or CO_2 emissions level by a specific date. The entire industry must meet one target. This contrasts with the U.S. CAFE approach where each company must individually meet standards for cars and light trucks. Tracking of compliance in EU nations is left up to the Association des Constructeurs Européens d'Automobiles (ACEA) and the other automaker associations.

In order to create comparisons among the programs underway in different countries, the vehicle fuel economy or GHG standards must first be converted into fleet averages, using the methodology developed by An and Sauer. For standards already designed as fleet averages, including those in the United States, EU, and Australia, this step is not necessary. For regions with standards designed by categories—such as vehicle type, weight, or engine size—this analysis assumes that the vehicle fleet mix in each country stays constant from 2002 throughout the time period analyzed. In other words, the comparisons do not address the implications of changing the vehicle size or weight composition of the current fleet. Next, the U.S. CAFE equivalent mpg and EU NEDC equivalent standard measuring grams of CO_2 per kilometer (km) are selected as the reference standards. Finally, conversion factors to convert local standards to the reference standards are developed and applied where necessary.

Figures 9-1 and 9-2 show comparisons of fuel economy and GHG emission standards normalized around metrics and vehicle test cycles as described in the preceding procedure. These figures show that the EU and Japan have the most stringent standards and that the United States and Canada have the weakest standards in terms of fleet-average fuel economy rating. These figures also show that the United States and Canada also have the highest CO_2 emission levels based on EU testing procedures. 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 9-3 shows that the EU, China, Canada, and California all will have fleet average fuel economy improvements within the next decade equal to or greater than 25 percent over their corresponding 2002 baseline cases. Figure 9-4 shows the fleet average GHG and fuel reduction over 2002 baseline year for these countries and regions.

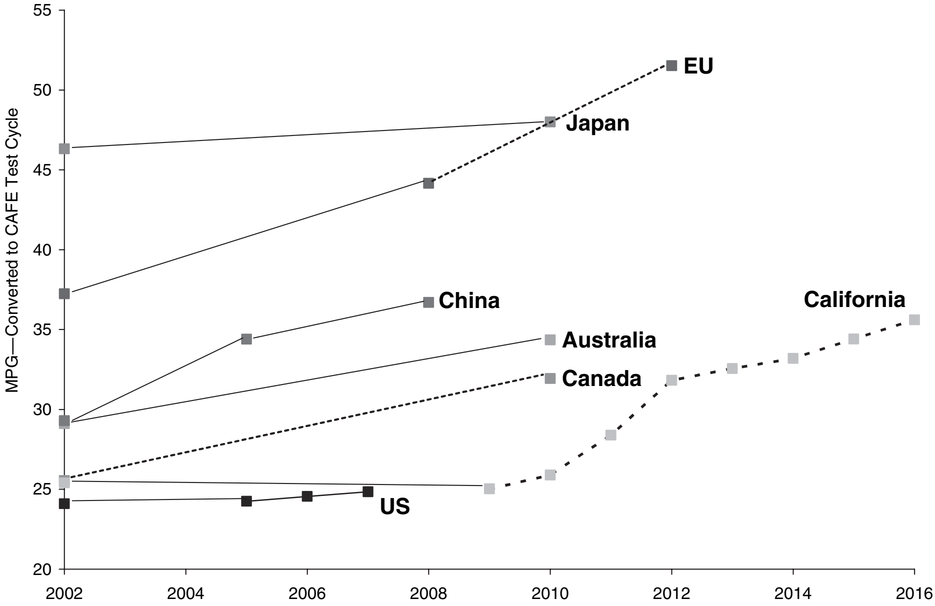

FIGURE 9-1. Comparison of fuel economy and GHG emission standards normalized by CAFE-converted mpg. *Source:* An and Sauer, 2004. *Note:* Dotted lines denote proposed standards.

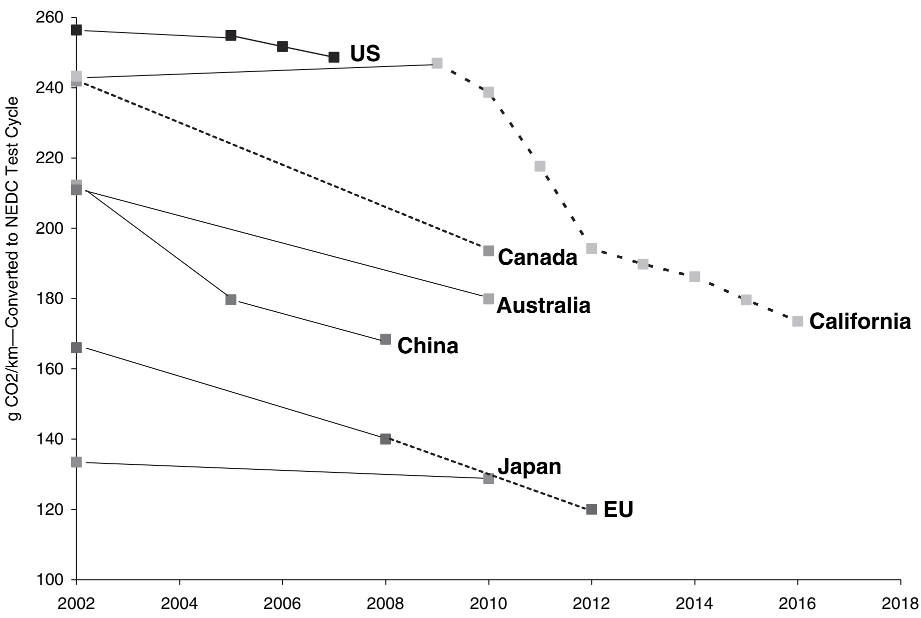

FIGURE 9-2. Comparison of fuel economy and GHG emission standards normalized by NEDC-converted g CO_2/km. *Source:* An and Sauer, 2004. *Note:* Dotted lines denote proposed standards.

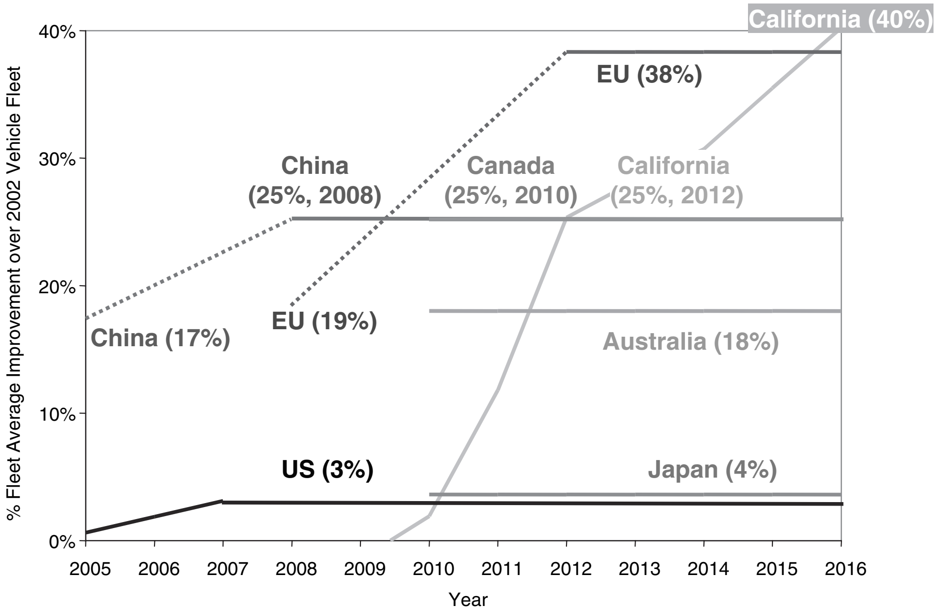

FIGURE 9-3. Fleet average fuel economy improvements over the 2002 level. *Source:* Feng An, Energy and Transportation Technologies LLC.

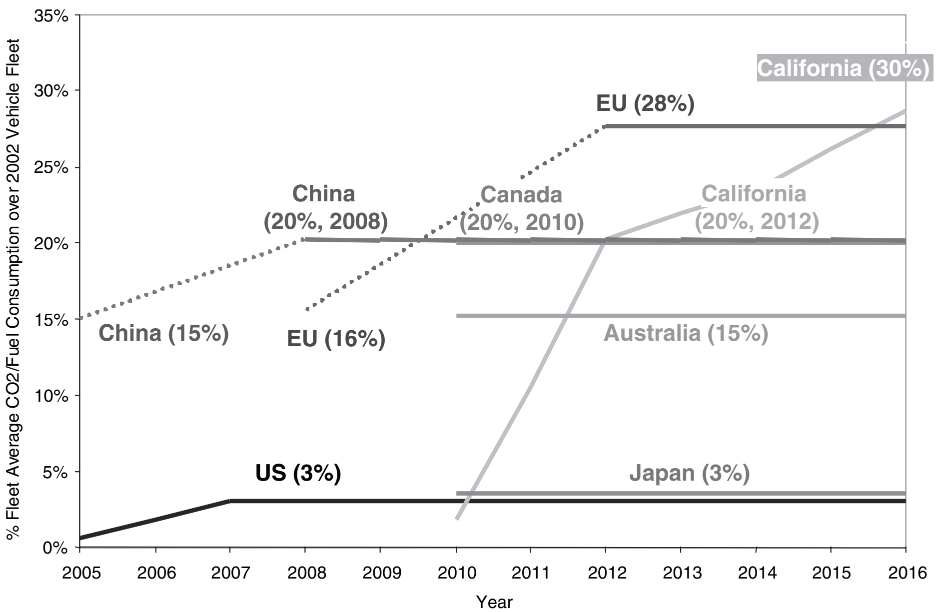

FIGURE 9-4. Fleet average GHG/fuel reduction over the 2002 level. *Source:* Feng An, Energy and Transportation Technologies LLC.

The international comparison clearly highlighted the fact that the fuel economy and GHG emission performance of the U.S. automobile fleet—both historically and projected based on current policies—lag behind most other nations. The United States not only has the lowest standards in terms of fleet-average fuel economy rating and the highest GHG emission rates based on the EU testing procedure but also has the lowest percentage improvement targets in the foreseeable future.

Country and Regional Profiles

More detailed profiles of the programs in effect in the countries and regions that have established or proposed, in the case of California, vehicle GHG emission or fuel economy standards are included in this section.

The United States

The United States was the first country to establish vehicle fuel economy standards. 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 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 ten 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 pounds and have physical features consistent with those of a truck.

The distinction between cars and light trucks was originally included in the CAFE legislation when light trucks were a small percentage of the vehicle fleet, with the most common light truck 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, in part because automakers have introduced crossover vehicles that combine features of both cars and light trucks. Meanwhile, light-duty vehicles classified as trucks, such as minivans and sport utility vehicles (SUVs), are 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 (EPA, 2004).

The CAFE standard for passenger cars has remained unchanged since 1985 at 27.5 mpg, although the standard was rolled back for several years in the late 1980s in response to petitions filed by several automakers (Union of Concerned Scientists, 2003). 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 (Federal Register, 2003).

TABLE 9-3. Examples of Proposed Size-based Fuel Economy Target

Footprint	*Fuel Economy Target*			
	2008	*2009*	*2010*	*2011*
20	28.5	30.0	29.9	30.4
30	28.2	29.5	29.6	30.2
40	26.7	27.6	27.9	28.6
50	23.3	23.9	24.3	24.4
60	20.8	21.6	21.9	22.2
70	20.1	21.0	21.3	21.8
80	20.0	20.9	21.2	21.8
100	20.0	20.9	21.2	21.8

Source: National Highway Traffic Safety Administration 49 CFR Parts 523, 533 and 537 [Docket No. 2006-24306] RIN 2127-AJ61 Average Fuel Economy Standards for Light Trucks Model Years 2008–2011.

"In April 2006, the National Highway Traffic and Safety Administration (NHTSA) adopted a reformed CAFÉ scheme that is based vehicle size defined by light-truck footprints (areas between four wheels). A complicated formula correlate fuel economy targets with vehicle sizes would be applied. Example of the new schemes is shown in Table 9-3 [Federal Register, 2006]". For the first three years, from 2008 through 2010, however, manufacturers can choose between size-based targets and truck-fleet average targets of 22.5, 23.1, and 23.5 mpg, respectively.

The short- and long-term impacts of the newly proposed rules are still unclear. However, an analysis by the NHTSA shows that, as a result of the different compositions of automakers' truck fleets, each company would have its own fuel economy targets, as shown by Table 9-4. The table shows that the major U.S. automakers—DaimlerChrysler (DCX), General Motors (GM), and Ford—and Nissan, the Japanese automaker, would have the lowest fuel economy targets among all automakers.

California

California has long been a world leader in imposing stringent vehicle tailpipe criteria pollutions. Frustrated by the lack of efforts and substantial progress toward tightening CAFE standards at the federal level, 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. 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 have all recently approved adopting the California regulation for their use (Bernton, 2004). Canada has also expressed its intention to follow California's lead.

TABLE 9-4. Estimates of Required Fuel Economy Levels and Gains Based on the Proposed Target Levels and Current Information

	Fuel Economy Targets (MPG)				*MPG Gains over 2008*		
	2008	*2009*	*2010*	*2011*	*2009*	*2010*	*2011*
Hyundai	24.2	25.9	25.7	26.3	7.0%	6.2%	8.7%
BMW	23.8	24.8	25.1	25.7	4.2%	5.5%	8.0%
Toyota	23.2	24.1	24.5	25.0	3.9%	5.6%	7.8%
VW	22.7	23.9	24.3	24.8	5.3%	7.0%	9.3%
Honda	23.1	24.0	24.2	24.8	3.9%	4.8%	7.4%
DCX	22.8	23.5	23.7	24.2	3.1%	3.9%	6.1%
GM	22.2	22.8	23.2	23.7	2.7%	4.5%	6.8%
Nissan	22.1	22.8	23.2	23.7	3.2%	5.0%	7.2%
Ford	22.4	22.9	23.1	23.6	2.2%	3.1%	5.4%

Source: Federal Register, 29 CER Part 533, Table 7, Light Trucks, Average Fuel Economy; Model Years 2008–2011; Proposed Rules, August 2005.

Calculations suggest that these states, including California, and Canada represent approximately 30 percent of all cars sold in North America, excluding Mexico (Ward's Vehicle Facts & Figures, 2003).

CARB has proposed near-term standards to be phased in from 2009 through 2012, and midterm 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. The LEV program applies to passenger cars, light-duty trucks, and medium-duty vehicles weighing 8,500 to 10,000 pounds, and it establishes exhaust emission standards. 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 pounds equivalent test weight (ETW). The second category is light-duty truck 2 (LDT2) for light trucks weighing between 3,751 pounds ETW and 8,500 pounds gross vehicle weight (GVW). ETW includes the vehicle curb weight plus passenger weight of 300 pounds and rounded by every 250 pounds. GVW is mostly used for Class 2b to Class 8 trucks, including vehicle curb weight plus rated vehicle load. Furthermore, vehicles weighing 8,500 to 10,000 pounds 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 9-5 outlines the GHG emission standards approved by CARB.

The California legislation also authorizes the granting of emission reduction credits for any reductions in GHG emissions achieved in model

TABLE 9-5. California Air Resources Board Approved Standards

Time Frame	*Year*	*GHG Emission Standard (g/mi)*		*CAFE-Equivalent Standard (mpg)*	
		PC/LDT1	*LDT2*	*PC/LDT1*	*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 Environmental Protection Agency Air Resources Board, August 2004.

year 2000 through 2008 vehicles built prior to the date the regulations take effect. 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 credits. 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 (CARB, 2004). 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 they would stabilize at today's GHG emission 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. 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 are mandated to follow either federal regulations or California regulations.

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 the targets set in the U.S. CAFE program but measured in terms of L/100-km of driving. Legislation was introduced in 1982 to make the fuel efficiency program mandatory instead of voluntary, with penalties for noncompliance. This legislation closely matched key provisions in the CAFE program, including a credit system and the use of the CAFE test driving cycle to determine fuel consumption. 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.

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 as they do in the United States. 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. This is due in part to different tax provisions for fuels, vehicles, 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. Canadians also exhibit a lower vehicle ownership level than U.S. car owners. In 2004, 70 percent of the driving age population owned cars in Canada. Car ownership in the United States is nearly universal. Also, the split in Canada between passenger cars and light trucks has been relatively steady since 1997—at about 55 percent versus 45 percent—while the market share of light trucks in the United States continues to increase, and for the first time in model year 2003, light trucks outsold cars (Automotive News, 2005).

As part of Canada's plan to meet its CO_2 obligations under the Kyoto Protocol, the Canadian government recently reached a voluntary agreement with industry for a reduction of GHG emissions from light-duty vehicles through 2010. Nineteen automakers signed the agreement to collectively reduce GHG emissions in 2010, plus interim targets. The Canadian government estimates that this target is consistent with the reduction of the average fuel consumption of the new vehicle fleet by 25 percent in 2010.

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 and its members to reduce voluntarily the CO_2 emission rates of vehicles sold in the EU. The ACEA agreement covers all vehicles produced or imported into the EU by member companies—including BMW, DaimlerChrysler, Fiat, Ford, GM, Porsche, PSA Peugeot Citroën, Renault, and the 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. Altogether, vehicles sold by companies under the ACEA voluntary agreement, including the Korean and Japanese components, make up nearly 90 percent of total EU vehicle sales.

Specifically, the ACEA agreement establishes industry-wide targets for average vehicle emissions from new vehicles sold in Europe of 140 grams of CO_2 per kilometer (gCO_2/km) by 2008, with the possibility of tightening the target to 120 gCO_2/km by 2012. Furthermore, there is an intermediate target range in 2003 of between 165 and 170 gCO_2/km. A recent estimate by an EU source predicted that European automakers' CO_2 emissions would be in the range of 145 g/km to 148 g/km in 2008, missing the 140 g/km target. 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 (Commission of the European Communities, 2004).

JAMA and KAMA agreed to similar commitments to those of ACEA, with the following modifications. KAMA has until 2004 to achieve the 2003 intermediate target. At 165 to 175 gCO_2/km, JAMA's 2003 intermediate target range is wider. Both JAMA and KAMA have an extra year to achieve the final 140 gCO_2/km target.

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 showed an average emission rate of 172 g/km. Diesel-fueled cars had a lower average emission rate of 155 g/km. Emissions from alternative-fueled cars were highest of all, at 177 g/km. These emissions are in line with the 2003 intermediate target range. Compared with 2001, the 2002 levels represent a reduction of 1.2 percent in new vehicle emissions. Despite the progress, companies will need to accelerate their efforts in the years ahead. Figure 9-5 charts 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 toward 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 that lowered taxes on diesel fuel and imported diesel cars in some EU countries, high fuel prices that encourage purchase of lower-cost diesel, and the superior driving capabilities of diesel engines.

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

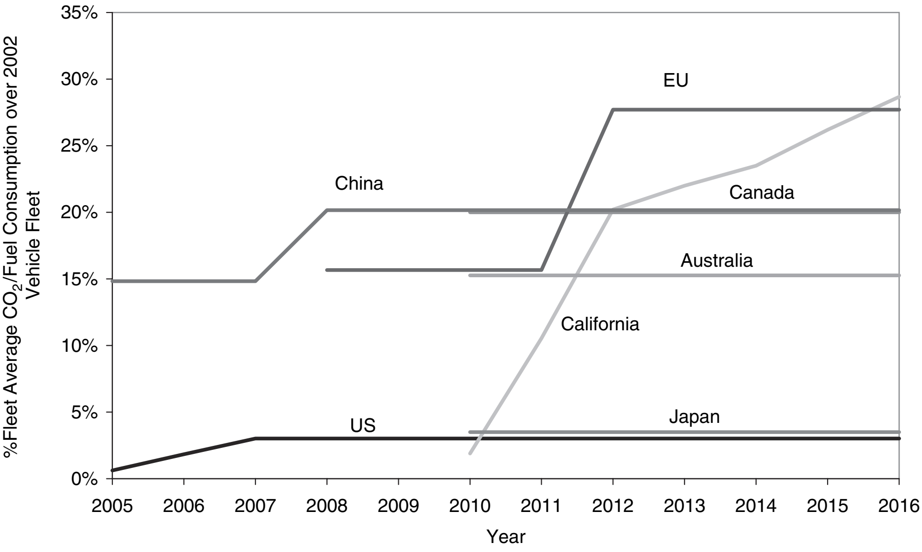

FIGURE 9-5. Progress and targets under the ACEA agreement. *Source:* European Commission.

reaffirmed its objective to reduce average per-car CO_2 emissions to this goal (Thisdell and Weernimk, 2004). The 2012 commitment is likely to be based on a broader set of incentives, including tax incentives, greener driving initiatives, and alternative fuels. Natural gas-based fuels and biofuels are the likely candidates for alternative fuels, given their beneficial well-to-wheels lifecycle CO_2 emission characteristics.

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 was 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, with some limitations. Table 9-6 illustrates the improvements required by fuel economy standards for gasoline vehicles.

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

TABLE 9-6. 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*
<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

Source: Ministry of Transportation, Japan.

improvement will result in an average fleet fuel economy of Japanese vehicles of 35.5 mpg 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.

China

Mindful of its rapidly growing passenger vehicle fleet and increasing oil demand, China recently approved regulations for new fuel economy standards for its passenger vehicle fleet. 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 took effect on July 1, 2005, for new vehicle models and will take effect on July 1, 2006, for continued vehicle models. In the Chinese regulations, "continued vehicle models" refers to existing vehicle models that continue to be produced at the effective date of the regulation. Phase 2 will take effect on January 1, 2008, for new models and on January 1, 2009, for all vehicle models.

The standards will be classified into 16 weight classes, ranging from vehicles weighing less than 750 kg, or approximately 1,500 pounds, to vehicles weighing more than 2,500 kg, or approximately 5,500 pounds. The standards cover passenger cars, SUVs, and multipurpose vans (MPVs), collectively defined as M1-type vehicles under the EU definition, with separate standards for passenger cars with manual and automatic

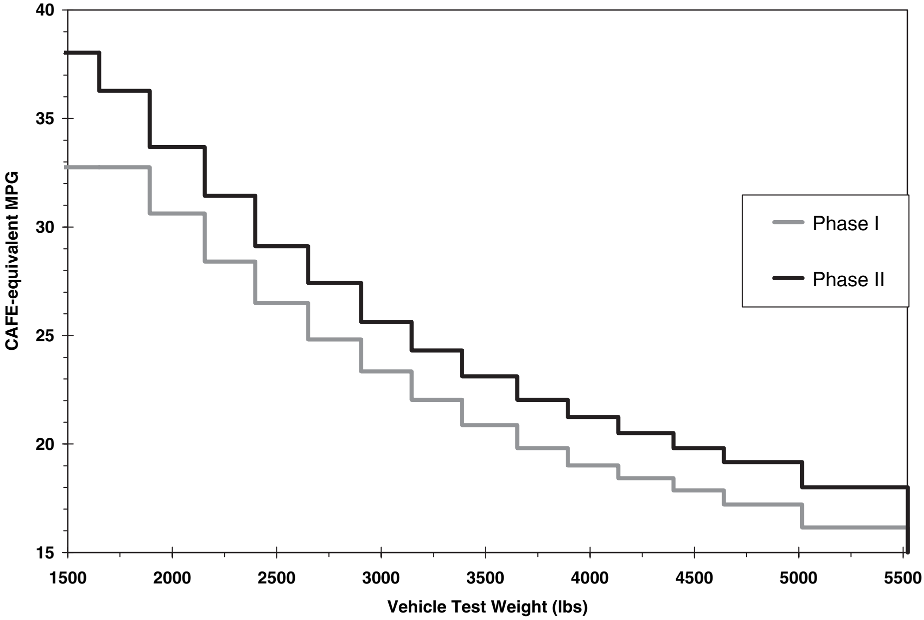

FIGURE 9-6. China's automotive fuel economy standards for passenger vehicles with automatic transmissions and for SUVs/MPVs (CAFE-equivalent mpg). *Source:* An and Sauer, 2004.

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.

Table 9-7 summarizes the new Chinese standards, with maximum limits for fuel consumption (L/100-km) or minimum CAFE-equivalent mpg limits. Figure 9-6 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 they set up maximum allowable fuel consumption limits by weight category, rather than being based on fleet averages. 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

TABLE 9-7. Maximum Limits for Fuel Consumption (L/100-km) and Minimum CAFE-Equivalent mpg Limits, for Passenger Vehicles in China (Excluding Taiwan)

Weight (lbs)	*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]*	
	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
≤4,689	13.2	14.0	11.9	12.6	20.1	19.0	22.3	21.1
≤5,066	13.7	14.5	12.3	13.0	19.4	18.3	21.6	20.4
≤5,578	14.6	15.5	13.1	13.9	18.2	17.1	20.3	19.1
>5,578	15.5	16.4	13.9	14.7	17.1	16.2	19.1	18.1

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

in the lighter weight classes. For example, a World Resources Institute analysis shows that 66 percent of cars currently sold in the United States would meet the Chinese standards, while only 4 percent of light trucks would comply (Sauer and Wellington, 2004). This will help to create incentives for manufacturers to produce lighter vehicles for the Chinese market.

Issues and Methodologies Involved with Comparing Vehicle Standards Around the World

The previous sections described 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 diverse standards, and it proposes a generic methodology with which to compare them.

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. However, in reality, these driving cycles could be far different from how the vehicles are actually driven, resulting in gaps or shortfalls between certified fuel economy levels and real-world fuel economy levels. This poses a special challenge when comparing vehicle standards and performance around the world.

Countries and regions use essentially three different test cycles to determine fuel economy and GHG emission levels: The NEDC, the Japan 10-15 cycle, and the U.S.-based CAFE cycle. 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. 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.

The U.S. combined CAFE cycle has a highest average speed of close to 30 mph and a highest fuel economy rating of about 31 mpg for the sample vehicle. The average speed of the NEDC is about 21 mph, with the fuel economy rating of the same vehicle about 27 mpg. 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, analysts at the U.S. Argonne National Laboratory 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. 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.

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 EU, China, and Australia use NEDC. Japan's fuel economy ratings are based on Japan 10-15 cycle.

Fuel Economy Versus Fuel Consumption Versus 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 EU regulates CO_2 emissions only. Because the vast majority of automobiles consumes 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 9-8 provides 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). Because diesel fuel has a different heat content and density from gasoline fuel, a gasoline-equivalent fuel economy (MPGge) measure was developed to convert diesel fuel into a comparable gasoline equivalent.

Regulatory Versus 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 noncompliance can be more or less guaranteed in the future, a voluntary target is less certain. However, this analysis compares both regulatory and voluntary targets, assuming that voluntary targets will be met in future years.

TABLE 9-8. 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. CAFE	Fuel	Km/L	Y * 2.78	1/(Y) * 2,226	1/(Y) * 3,206
Canada	U.S. CAFE	Fuel	L/100-km	1/(Y) * 235.2	Y * 26.2	Y * 37.8
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
China, Australia	NEDC	Fuel	L/100-km	1/(Y) * 265.8	Y * 23.2	Y * 33.5

Source: Table 11, An and Sauer, 2004.

Corporate Fleet Averages Versus Minimum Requirements

Among all the standards, only the Chinese standards are based on minimum fuel economy requirements that are applicable to individual vehicle models. All other existing or proposed standards throughout the world are based on sales-weighted averages either by whole vehicle fleet or by vehicle class/weight categories. The Chinese standards pose a special challenge to cross-country comparisons, because a number of assumptions must 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.

Vehicle Categories and Weight Classes

Different standards around the world 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 by these countries and regions that provide sales figures and fuel economy ratings for individual vehicle models, which are difficult to obtain for some countries. Data were available for all the countries and regions studied with the exception of the Taiwan and South Korea markets.

Another challenge is to project future fleet average fuel economy figures for different regions. 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's beyond the scope of this analysis to make such projections. The analysis assumes that the current sales composition of vehicle categories will be maintained, and future fleet average fuel economy was projected under such assumptions.

Conclusions

Fuel economy programs or GHG targets, either mandatory or voluntary, have proven to be among the most effective tools in controlling oil demand and GHG emissions from the transportation sector. Nine major regions around the world have implemented or proposed various fuel economy and GHG emission standards. Yet, these standards are not easily comparable, due to differences in policy approaches, test drive cycles, and units of measurement. This chapter discusses a methodology to compare these programs to better understand their relative stringency. Key findings include the following:

- The EU and Japan have the most stringent standards in the world.
- In the next ten years or so, the EU, China, Canada, and California all will have fleet average GHG reduction greater than 20 percent compared to a 2002 baseline case.
- The fuel economy and GHG emission performance of the U.S. automobile fleet—both historically and projected based on current policies—lag 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 GHG 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 EU 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.

References

An, F., and A. Sauer. *Comparison of Passenger Fuel Economy and GHG Emissions Standards around the World.* Washington, D.C.: Pew Center on Global Climate Change, 2004.

An, F., and J. DeCicco. "Indices of Technical Efficiency." A draft working paper. 2005.

Automotive News' Data Center. www.autonews.com/datacenter.cms.

Bernton, Hal. "Tighter Vehicle Emission Standards Proposed for State." *Seattle Times*, December 2, 2004.

California Air Resources Board (CARB). "Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles." Sacramento, CA: CARB, August 2004.

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).* Brussels, Belgium, 2004.

Federal Register, 29 CER Part 533: Light Trucks, Average Fuel Economy; Model Years 2008–2011; Proposed Rules. Washington, D.C., August 2005.

Federal Register. Docket Number 68 FR 16867. Washington, D.C., April 7, 2003.

Sauer, A., and F. Wellington. "Taking the High (Fuel Economy) Road." Washington, D.C.: World Resources Institute, November 2004.

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

Union of Concerned Scientists. *Life in the Slow Lane.* Washington, D.C., 2003.

U.S. Environmental Protection Agency. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2004.* Washington, D.C., 2004.

Ward's Vehicle Facts & Figures, 2003. Southfield, MI.