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GLOBAL OVERVIEW ON FUEL EFFICIENCY AND MOTOR VEHICLE EMISSION STANDARDS: POLICY OPTIONS AND PERSPECTIVES FOR INTERNATIONAL COOPERATION

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Global Overview on Fuel Efficiency and Motor Vehicle Emission Standards: Policy Options and Perspective for International Cooperation

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I. INTRODUCTION

1. In spite of the recent financial crisis, global oil demand has steadily increased, largely due to rapid motorisation taking place in developing countries, in particular in countries with rapidly growing economies, such as Brazil, China, India and others. Oil demand growth is primarily driven by growth in the vehicle population, especially private passenger vehicles, as well as total vehicle distance traveled.

2. Controlling the energy demand and greenhouse gas (GHG) emissions from personal vehicles has become a major challenge. Curbing vehicle population growth, reducing travel demand and improving vehicle fuel efficiency are three key elements to reducing overall oil demand. A wide variety of approaches to address these three areas have been introduced in different parts of the world.

3. Most industrialized countries have established programmes to address transportation-related GHG emissions. Fuel economy programmes and GHG emission targets, either mandatory or voluntary, have proven to be among the most cost-effective tools in controlling oil demand and GHG emissions from motor vehicles (An and Sauer, 2004).

4. The United States was the first country to establish fuel economy standards for passenger vehicles after the 1970's oil crisis. However, standards have remained unchanged for nearly a quarter century from the early 80s to late 2000s, while other countries - especially European countries, Japan, and recently China and the State of California of the US - have moved forward, establishing or tightening GHG or fuel economy standards. In recent years, recognising the threat of climate change and potential oil shortages, efforts to further strengthen vehicle standards have been intensified globally, including a series of efforts by the Unites States.

5. Fuel economy programmes include both numeric standards and fiscal incentives to improve the energy efficiency of individual vehicles per unit of distance traveled. In today's technology-driven world, new technologies offer great promise to drastically improve vehicle fuel economy. Realizing such technological promise is contingent on strong policy. Technology development also responds to price. Relatively high oil prices, for example, have provided an incentive for manufactures and consumers to build and buy smaller and more fuel efficient cars.

Disclaimer: *The views expressed in the background paper are those of the authors and do not necessarily reflect those of the United Nations.*

6. Fiscal incentive programmes have improved fuel economy or reduced fuel use, especially when implemented in combination with standards. Incentives can be directed at improving the efficiency of the vehicle fleet, through variable registration fees or taxes, or by limiting vehicle use, through fuel taxes and road use fees. Table 1 summarizes major approaches to reducing automobile fuel consumption and GHG emissions from light-duty vehicles.

7. Vehicles and the automotive industry are changing at an extremely fast pace from all perspectives, including technology innovation and deployment, the development and implementation of governmental standards and regulations, industry structural shifts and consumer choice. Many technological innovations require new thinking regarding how to measure and rate vehicle energy efficiencies and GHG emissions.

Table 1
Measures to promote fuel-efficient vehicles

Approach		Measures/forms	Country/region
Standards	Fuel economy	Numeric standard averaged over fleets or based on vehicle weight-bins or sub-classes	US, Japan, Canada, Australia, China, Republic of Korea
	GHG emissions	Grams/km or grams/mile	European Union (EU), California (US)
Consumer Awareness	Fuel Economy/GHG emission labels	mpg, km/L, L/100 km, gCO_2/km	Brazil, Chile, Repubic of Korea, US and others
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, China
	Economic penalties	Gas guzzler tax	US
Support for new technologies	R&D programmes	Funding for advanced technology research	US, Japan, EU, China
	Technology mandates and targets	Sales requirement for Zero Emission Vehicles (ZEVs), PHEVs and EVs	California (US), China
Traffic control measures	Incentives	Allowing hybrids to use high occupancy vehicle (HOV) lanes	California, Virginia and others states in the US
	Disincentives	Banning SUVs on City Streets Inner city congestion charges	Paris, London

Source: Adapted from Table 1 of Feng An and Amanda Sauer (2004) (updated). Comparison of Passenger Vehicle Fuel Economy Standards and GHG Emission Standards around the World.

8. Innovative technologies such as Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) pose new challenges when it comes to the quantification of fuel economy and fuel consumption. Some BEV manufactures have claimed that their vehicle

achieve a fuel economies of up to 230 mpg (Valdes-Dapena, 2009), a claim that caused controversy across the automotive industry. Researchers everywhere are struggling to derive a method to evaluate the fuel consumption of vehicles that will both store energy from the electric grid on board, as well as use liquid fuel from time to time. As the number of countries that manufacture electronic vehicle increases, there will be a growing need for international sharing of experience and best practices, including methodologies to measure and enforce the energy efficiency initiatives.

9. Adding to the uncertainties posed by new technologies are the GHG emissions related to the sources of electricity for electrified transportation, where coal generation results in greater GHG emissions than hydro, wind, solar or nuclear power. This diversity imposes tremendous challenges on the assessment of upstream GHG emissions associated with power generation, resulting in great variations associated with life-cycle vehicular emissions assessment.

10. Another issue at hand is how to categorise and assess so-called "low-carbon fuels" which are different from traditional gasoline and diesel fuels. The present forms of commercial grade low-carbon fuels include bio-ethanol and bio-diesel. However, not all bio-fuels are created equally. They range from relatively high-carbon intensity corn-based ethanol, mostly manufactured and consumed in the US, to super low-carbon sugar-cane based ethanol in Brazil, or rapeseed-based biodiesel in Germany to grease-based biodiesel in Japan and China. Each biofuel has very different levels of life-cycle carbon emissions and other characteristics, and as such must be carefully analysed using standardised methodologies and modeling tools.

11. In order to address the emerging challenges of new technology vehicles that shift emissions from vehicle tailpipes upstream to the actual sources of energy production, we suggest that future vehicle emission regulations should focus on a complete life-cycle based GHG emission assessment.

12. The objective of this background paper is to provide an updated analysis on recent worldwide trends in vehicle fuel economy and GHG standards, identify best practices, and make recommendations for future policy making to ensure realistic, enforceable and agreeable mitigation strategies to reduce transportation energy use and associated GHG emissions in a cost-effective way.

II. MOTOR VEHICLE FUEL ECONOMY STANDARDS

13. Global vehicle standards are in the midst of dramatic changes now, as China, the EU, Japan and the US have just announced or are about to announce some major overhauls on their vehicle fuel economy regulations. At the time of writing of this report, nine countries and regions around the world have already established their own motor vehicle fuel economy or GHG emission standards as shown below in Table 2. More countries, including Brazil, India, Mexico and South Africa, are expected to initiate similar measures in the near future.

14. 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 in terms of their implementation requirements, such as mandatory versus voluntary approaches.

15. Vehicle 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 (gCO_2/km) or grams per mile (gCO_2/mile). Testing methods also differ and include the US city and highway cycles, the new European drive cycle (NEDC) and newly established JC08 cycle tests in Japan.

16. The four largest automobile markets, the US, the EU, China and Japan, each approach the regulation of fuel economy quite differently. The US is in the midst of a dramatic change regarding the way it will regulate vehicular emissions. The US used to regulate vehicles based on corporate average fuel economy (CAFE) standards, which required each manufacturer to meet two specified fleet average fuel economy levels for cars and light trucks respectively. However policy makers are now shifting to a "footprint-based" approach and looking for a way to regulate GHG emissions instead of fuel economy. In the new approach, individual vehicle fuel economy or GHG targets would be based on the size of the vehicles. As such, each automaker now has his/her own fuel economy target based on the average size of his/her own vehicle fleet.

Table 2
Fuel economy and GHG emission standards for vehicles around the world

Country/region	*Type*	*Measure*	*Structure*	*Test Method*	**Implementation**
United States	Fuel	mpg	Footprint-based value curve	US CAFE	Mandatory
California	GHG	g/mile	Car/LDT1	US CAFE	Mandatory
European Union	CO_2	g/km	Weight-based limit value curve	EU NEDC	Voluntary for now, Mandatory by 2012
Japan	Fuel	Km/L	Weight-bin based	Japan 10-15/JC08	Mandatory
China	Fuel	L/100-km	Weight-bin based	EU NEDC	Mandatory
Canada	Fuel	L/100-km	Cars and light trucks	US CAFE	Voluntary
Australia	Fuel	L/100-km	Overall light-duty fleet	EU NEDC	Voluntary
Republic of Korea	Fuel	Km/L	Engine size	US CAFE	Mandatory

Source: Adapted and updated from Table 2 of Feng An and Amanda Sauer (2004). Comparison of Passenger Vehicle Fuel Economy Standards and GHG Emission Standards around the World.

17. 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. Fuel economy standards in the Republic of Korea are based on an engine size classification system. China is following the New European Driving Cycle (NEDC) testing procedures developed by the

EU. The Republic of Korea is following testing methods that are similar to US CAFE procedures. Japan maintains its own test procedures.

18. EU is also in the midst of dramatic changes in its fuel economy policies. Until 2009, the EU promoted a voluntary standard. However, as it became increasingly evident that automakers were not going to achieve the voluntary standard, it was made mandatory and is now based on a weight-based limit value curve.

A. Detailed country profiles

1. The United States of America

a) Federal standards

19. In the wake of the 1973 oil crisis, the US Congress passed the "Energy Policy and Conservation Act of 1975" with the goal of reducing the country's dependence on foreign oil. The act established the world's first fuel economy standard, the CAFE programme. The CAFE programme maintained an important distinction between passenger cars and light trucks - each had its own standard. Under the regulation, passenger cars were classified as any four-wheeled vehicle not designed for off-road use that transports 10 people or fewer. Light trucks, on the other hand, included 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.

20. 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 trucks being pickups, used primarily for business and agricultural purposes. Since that time, however, the distinction between passenger cars and light trucks has become increasingly fuzzy, 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, and have become very popular.

21. The CAFE standard for passenger cars remained unchanged from 1985 to 2007 at 27.5 mpg, The standard for light trucks was recently increased from 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). In April 2006, the National Highway Traffic and Safety Administration (NHTSA) of the Department of Transportation (DOT) adopted a reformed CAFE scheme that is based on vehicle size defined by light-truck footprints (area between four wheels). A complicated formula correlating fuel economy targets with vehicle sizes was applied. An example of the new scheme is shown in Table 3 (Federal Register, 2006). For the first three years, from 2008 through 2010, manufacturers could choose between size-based targets and truck-fleet average targets of 22.5, 23.1, and 23.5 mpg, respectively.

Table 3
Examples of proposed size-based fuel economy targets

	Fuel Economy Target (mpg)			
Footprint (Sq Ft)	**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: Federal Register, 49 CER Part 523, 533, 537. Average Fuel Economy for Light Trucks; Model Years 2008-2011; National Highway Traffic Safety Administration, April, 2006

22. An analysis by the NHTSA shows that, as a result of different size compositions of the truck fleet, each manufacturer should have its own fuel economy targets, as shown in Table 4.

23. Future policies are set to change again under the 2010 announcement made by the US President Barack Obama, which stated that the EPA and NHTSA would harmonise their standards with the Californian approach described below.

b) The Californian approach

24. The state of California has long been a world leader in imposing stringent vehicle emission standards. California enacted legislation in 2002 directing the California Air Resources Board (CARB) to achieve the maximum feasible and cost-effective reduction of GHGs from California's motor vehicles. The standards were supposed to take effect with 2009 model year (MY) passenger vehicles. The states of New York, Massachusetts, New Jersey, Maine, Connecticut, Rhode Island, Vermont, Oregon, Arizona, New Mexico, Pennsylvania, Maryland, Florida and Washington have also approved the adoption of the California regulation for their own constituencies (Bernton, 2004).

25. CARB has proposed new near-term standards to be phased in from 2009 through 2012, and mid-term standards to be phased in from 2013 through 2016. The GHG emission standards will be incorporated directly into the current low emission vehicle (LEV) programme, along with other light- and medium-duty automotive emission standards. The LEV programme 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).

Table 4

Required fuel economy levels and estimated gains based on the proposed target levels and current information for light trucks

	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

26. The legislation will be phased in for both the near-term and medium-term standards. Table 5 outlines the GHG emission standards approved by CARB.

Table 5

California Air Resources Board (CARB) approved standards

		GHG emission standard (g/mi)		CAFE-equivalent standard (mpg)	
Timeframe	**Year**	**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 (LDT = Light Duty Trucks).

27. The California legislation also authorised the granting of emission reduction credits for any reductions in GHG emissions achieved in model 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 were compared to the near-term standard on a cumulative basis. Manufacturers that had cumulative emissions below the near-term standards earned 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 year after the end of the phase-in.

28. CARB estimates that the proposed GHG emission standards will reduce projected GHG emissions from the light-duty vehicle fleet by 17 per cent in 2020 and by 25 per cent 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 stabilise at today's GHG emission level by 2030.

29. In late 2009, after years of legal battles between the state of California, the automakers and the administration of former US President George W. Bush, the EPA granted a waiver to California to implement its GHG standard for model years 2009-2016 vehicles

c) Merger of Federal Standards with California Standards (the Obama Plan)

30. In September 2009, the US Environmental Protection Agency and US Department of Transportation (DOT) proposed a new joint regulation for greenhouse gas (GHG) emissions and fuel economy for light duty vehicles. The proposed fleet-average targets are 250 gCO_2e/mile or 34.1 miles per gallon under the US CAFE combined driving test cycle (equivalent to172 gCO_2/km under NEDC cycle) with allowance for the improvement of vehicle A/C system and use of flex-fuel vehicles. The proposed standards are based on vehicle footprint. Separate car and light-truck targets have been established.

31. In 2010, the administration of US President Obama announced the merge of Federal Standards with the California standards. To this end, the EPA and the NHTSA cooperated to develop harmonised light-duty fuel economy and GHG emission standards for vehicles built in model years 2012-2016 (released 1 April 2010), and then for model year 2017 and beyond (announced on 1 October 2010). The national programme will seek to develop joint federal standards that are harmonised with applicable state standards, with the goal of ensuring that automakers will be able to build a single light-duty fleet that satisfies all requirements.

32. On 1 October 2010, the Environmental Protection Agency and the Department of Transportation announced progress in developing standards that will dramatically reduce the fuel consumption and greenhouse gas emissions of cars, SUVs, and pickup trucks for model years 2017 to 2025. As a preliminary ruling, the departments have targeted a 2025 fuel economy standard ranging from 46 to 60 mpg, which is an equivalent of 102 - 133 gCO_2/km (in terms of the EU reporting standard[1]) and means potential savings of up to 5 million barrels of oil per day by 2030. The range is established based on annual fuel economy improvement by 3% to 6% from 2017 to 2025. At the time of writing, EPA, NHSTA and CARB are working together to formulate the final target based on feasibility analysis, industry consultation and political negotiations. The final target will be announced by the end of 2011, and it's expected that the final target would be around 53-58 mpg based on 4-5% annual improvement rates.

33. In order to achieve this major change in fuel economy policy, vehicle categorisations need to be seriously modified, bringing light duty trucks and passenger vehicles into a unified category. The light-duty vehicle class will now collectively include smaller vehicles ranging from subcompact cars and sedans to minivans, SUVs, smaller (1/2 ton) pickup trucks, and similar vehicles with a gross vehicle weight rating (GVWR) of less than 8,500 pounds.

[1] NHTSA. October 1, 2010. *DOT and EPA Announce Next Steps toward Tighter Tailpipe and Fuel Economy Standards for Passenger Cars and Trucks*. Available from http://www.nhtsa.gov/About+NHTSA/Press+Releases/2010/DOT+and+EPA+ Announce+Next+Steps+toward+ Tighter+Tailpipe+and+Fuel+Economy+Standards+for+Passenger+Cars+and+Trucks Accessed on October 1, 2010.

Medium-duty passenger vehicles are those between 8,500 and 10,000 lbs GVWR if they are designed and used primarily for personal transportation.

34. Heavy-duty trucks are defined as those that are not for personal transport. The lightest class of heavy-duty trucks is "class 2b", which includes heavy pickup trucks and vans used primarily for commercial purposes, weighing between 8,500 and 10,000 lbs GVWR. The EPA would regulate these under the Clean Air Act as heavy-duty vehicles. Other classes covered by the national heavy-duty programme would include vocational work trucks, such as new concrete mixers, refuse trucks, urban buses, and utility trucks, as well as combination tractor-trailers, commonly known as "18-wheelers".

35. EPA and NHTSA estimate that over the lifetime of the vehicles sold during 2012-2016, the light-duty standards would reduce CO_2 emissions by 950 million metric tons and save 1.8 billion barrels of oil. Overall, the finalised standards would reduce CO_2 emission from the light-duty fleet by approximately 21 per cent in 2030 versus the level that would occur in the absence of the national programme.[2]

2. The European Union

36. The European Union first considered fuel consumption from the perspective of fuel, but later on changed its strategy - in light of its commitments under the Kyoto Protocol of the UNFCCC - to regulate carbon dioxide emissions from vehicles. This style of regulation worked because there is a relatively consistent relationship between the combustion of fuels such as gasoline and diesel, and carbon dioxide emissions. When labelling vehicles on the market, individual member states still have varying reporting units, including gCO_2/km and L fuel/100 km.

37. Initially, the EU attempted voluntary emission reduction target policies. However, as the International Energy Agency (IEA) noted in its 2008 review of energy efficiency in the EU[3], significant improvements in vehicle fuel efficiency had not been sufficient to neutralise the effect of increased traffic and car size, and the previous voluntary approach to achieving energy efficiency had not reached its target.

38. A large part of the early success in increasing fleet-average vehicle fuel economy is due to vehicle dieselisation. This trend occurred in Europe due to the inherent efficiencies of diesel engines and higher energy content of diesel. However, it has been argued that dieselisation of the passenger vehicle fleet did not result in overall decrease in vehicular GHG emissions. Schipper and Fulton (2008)[4] noted that there have only been marginal energy and CO_2 emission savings as a result of this large shift to diesel engines, particularly because the vehicles tend to be heavier, and they tend to be driven more than gasoline vehicles because of lower diesel prices and better fuel economy. This research found that fuel taxes must act in harmony with fuel economy policies in order to ensure the overall increase in efficiency and reduction in fuel consumption.

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[2] EPA Regulation EPA-420-F-10-014, April 2010. Available from http://www.epa.gov/oms/climate/regulations/420f10014.htm Accessed October 1, 2010.

[3] International Energy Agency (2008). *IEA Energy Policies Review – The European Union*.

[4] Schipper, Lee and Lew Fulton (2008). *Disappointed by Diesel? The Impact of the Shift to Diesels in Europe through 2006*. http://metrostudies.berkeley.edu/pubs/reports/004_trb_diesel.pdf. Accessed on October 1, 2010.

39. To further strengthen its regulation to automakers, the EU adopted on 23 April 2009 Regulation [EC] No. 443/2009 of the European Parliament and of the Council stipulating that by 2012, the fleet average to be achieved by all cars registered in the EU shall be 130 gCO_2/km. Furthermore, 10 gCO_2/km in savings had to be achieved through the implementation of: i) use of biofuels; ii) gear shifting reminders; iii) efficient air conditioners; iv) low rolling resistance tires; v) tire pressure monitoring; and vi) a limit curve for light commercial vehicles.

40. The EU has also developed other beneficial policies to reduce the carbon dioxide intensity of driving cars. The EU is presently developing a test procedure for quantifying emissions of vehicles that use electricity, and the methodology should be ready to be applied by 2014. In the meantime, manufacturers are granted up to 7 gCO_2/km of emission credits for their fleet if they equip their vehicles with these technologies, as long as the emission reductions can be verified by independent data.

41. For vehicles that emit less than 50 gCO_2/km (popularly known as “supercars”), there are further incentives for car manufacturers.

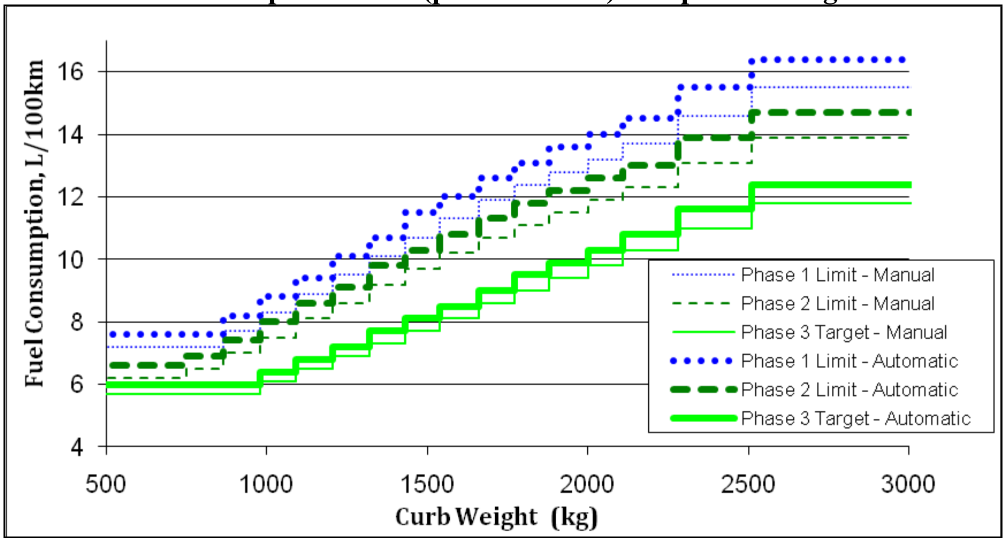
3. China

42. China began its passenger vehicle fuel consumption regulation in 2004, when it issued the National Standard GB 19578-2004 Limits of Fuel Consumption for Passenger Cars. This standard has been implemented in two phases, and is about to enter its third phase, which is now in the design phase. The two phases of the standard introduced in 2005 and 2008 have been remarkably successful in reducing fuel consumption, but more work is still needed.

43. Phase 1 took effect in July 2005 for new vehicle models, and in July 2006 for continued vehicle models. In the Chinese regulations, continued vehicle models refer to existing vehicle models that continue to be produced at the effective date of the regulation. Phase 2 took effect in January 2008 for new models and in January 2009 for all vehicle models. China is about to announce Phase 3 standards, which will be fully effective by 2015.

44. Motor vehicle fuel economy standards in China are based on 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 multi-purpose vans (MPVs), collectively defined as M1-type vehicles under the EU definition, with separate standards for passenger cars with manual and automatic transmissions. SUVs and MPVs, regardless of their transmission types, share the same standards as passenger cars with automatic transmissions. Commercial vehicles and pickup trucks are not regulated under the standards.

Figure 1
Chinese fuel consumption limits (phase 1 and 2) and phase 3 targets



45. As mentioned, the Chinese standard is a weight-based standard that every domestically made vehicle in China must achieve. Vehicles that do not meet the standard are not permitted to be sold. The testing protocol is based on the European NEDC testing standard system, using a test vehicle to measure carbon dioxide emissions over a test cycle, then converting the value into fuel consumption in L/100 km.

46. In 2002, average fuel consumption in China was 9.11 L/100 km. Through the implementation of phase 1 and 2 of the standard, average fuel consumption decreased to 8.06 L/100km, which translates into a reduction of 11.5 per cent.[5]

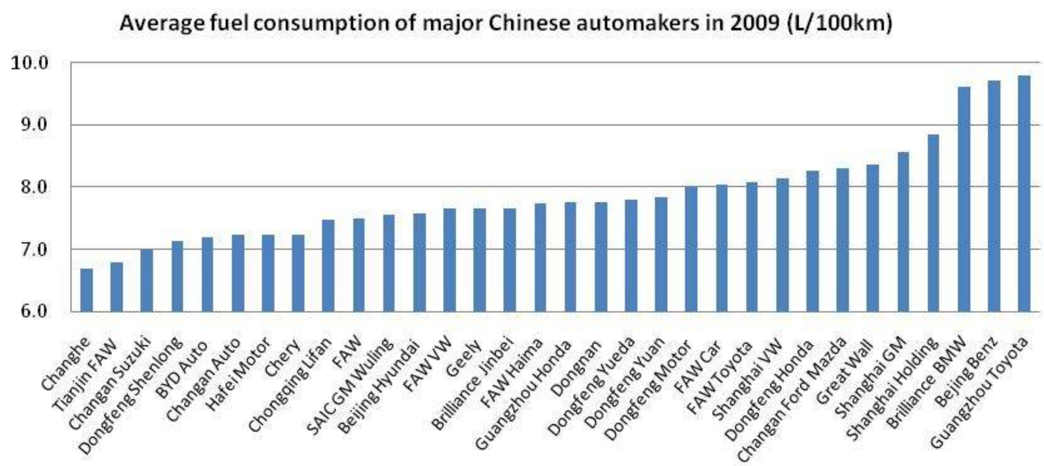
47. A key deficiency is that due to insufficient management capacity, imported vehicles are currently not subject to fuel economy regulation. Many imported cars and vehicles produced by joint-venture companies tend to be medium and high-end products with high fuel consumption. This is an area requiring the attention of policy makers.

48. According to calculations by China Automotive Technology and Research Center (CATARC), through the implementation of Phase 3 of the fuel consumption targets for passenger vehicles, 26.6 billion liters (about 19.55 million tons) of gasoline will be saved between 2008 and 2016, and CO_2 emissions amounting to 63.31 million tons will be avoided.

49. The Innovation Center for Energy and Transportation (iCET) has calculated the major Chinese domestic and multinational car manufacturers' fleet average fuel consumption rates from model year (MY) 2006-2009. Figure 2 shows the MY 2009 average fuel consumption level by individual automakers. The overall fleet average value is about 7.77L/100km. In terms of greenhouse gas emissions, this level of fuel consumption is approximately equivalent to 180 gCO_2e/km.

[5] Jin, Yuefu and Zhao Wang (2010). *Research and Formulation of Standards for Fuel Consumption of Passenger Cars in the Next Stage.* China Automotive Technology and Research Center.p.4.

Figure 2
Estimated Corporate Average Fuel Consumption of major Chinese car manufacturers

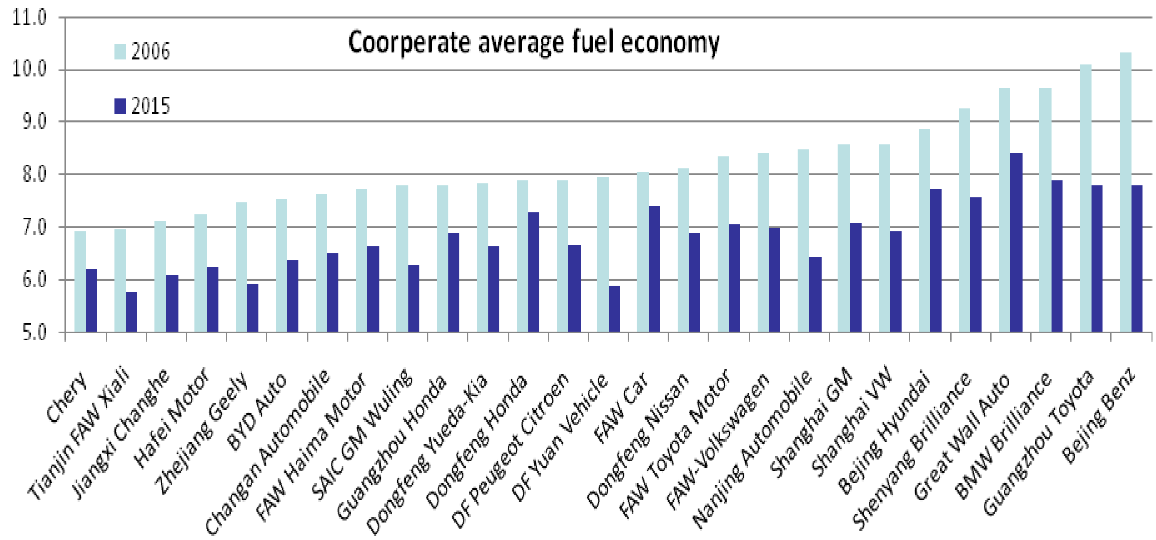


Source: iCET (2010).

50. iCET has also estimated corporate average fuel consumption in 2015 when the phase 3 Fuel Economy Standard is scheduled to take effect (Figure 3). The figure shows that each automaker would have its own fuel consumption target, due to differing vehicle weight-mixes and corresponding sales. This would result in different improvement rates for individual automakers to reach their targets. The predicted result shows that China's future fleet average fuel consumption will be around 6.67L/100km, a target lower than the US's corresponding 2016 automobile fuel consumption plan.

51. At the time of writing, the Chinese government was considering a new fuel economy target for 2020, which would require the fleet average fuel economy to reach 5.0 L/100 km. This target would translate into about 53 mpg US-equivalent, or about 116 CO_2-g/km EU-equivalent.

Figure 3
Estimated Corporate Average Fuel Consumption (L/100km) for major Chinese car manufacturers in 2006 and 2015



Source: iCET (2010).

4. Japan

52. Introduced in 2007, the current fuel efficiency regulation sets weight-based corporate average standards for model year 2015. When the 2015 targets are met, the fleet average fuel economy is expected to be 16.8 km/L under the new Japanese JC08 driving test cycle (equivalent to 125 gCO_2/km under NEDC cycle), a 23.5 per cent increase over the 2004 performance of 13.6 km/L. Under Japan's "Front Runner" programme, the most efficient vehicles of one year become the standard of the next year, thus ensuring that vehicles become increasingly efficient over time.

5. Republic of Korea

53. In July 2009, the Republic of Korea announced a proposal of a combined fuel economy and GHG emissions target of 17 km/L or 140 gCO_2e/km (equivalent to 150 gCO_2/km under NEDC cycle) respectively for model year 2015. The new standards will be weight-based and will use US CAFE combined cycle for testing purposes.

6. Canada

54. In April 2010, Canada issued a draft regulation to limit GHG emissions from passenger cars and light trucks from model year 2011 to 2016. The standards will adopt the footprint-based structure proposed in the US' latest rule making. While a more detailed analysis is being conducted, the Canadian government anticipates that the average GHG emission performance of the 2016 Canadian fleet of new cars and light trucks would match the average level of 153 gCO_2/km (169 gCO_2/km under NEDC cycle). This would represent

an approximate 20 per cent reduction compared to the new vehicle fleet that was sold in Canada in 2007. However, with a much smaller average fleet size than the one in the US, by adopting the same footprint based standard structure, Canada should be able to achieve a lower average emissions level than what the government has anticipated. If it is assumed that Canada will achieve a similar annual fuel economy improvement rate, a more realistic target for Canada would be a fleet-average of 141 gCO_2/km (154 gCO_2/km under NEDC cycle) by 2016. The official estimate of 153 gCO_2/km therefore could be considered as a low-end target.

7. India

55. Under the "Integrated Energy Policy" of 2008, minimum fuel efficiency standards were to be established for all vehicles. By the end of 2010, such a legal standard is expected to be put in place.[6] A focus on more efficient and low GHG-emission air conditioning systems for vehicles is also under consideration. The outcome of the standard should be a labelling system, based on Automotive Research Association of India test data released by manufacturers, and based on vehicle weight.

8. Latin American developing countries

56. The path for development of fuel economy or fuel consumption standards in developing economies is far from clear. In countries where automotive industry data is not collected and reported, voluntary labelling policies have been established, including standardised evaluation cycles, with the aim to inform consumers about the fuel economy of the vehicles they are considering. However, to date no mandatory fuel economy targets have been established in the Latin American region.

57. Chile was the first country in the region to announce a light duty vehicle fuel economy labelling system. The system, based in consumer legislation, requires GHG emission and fuel efficiency data to be placed on all vehicles with a gross weight under 2,700 kg.

58. In Brazil, the National Institute of Metrology, Standardisation and Industrial Quality (Inmetro) fuel economy labelling programme requests that cars be labelled with a fuel consumption label, standardised by the Brazilian National System of Metrology, Standardization and Quality Certification, and based on the Federal Test Procedure 75 (FTP-75). However, it is the responsibility of manufacturers to report the fuel economy of their vehicles, and if they display a fuel economy label, their vehicles are subject to spot checks. It is hoped that these labels will become a de facto standard for fuel economy reporting, and that they will inform consumers about better vehicle purchase decision-making.

B. Global Fuel Economy Initiative

59. The "Global Fuel Economy Initiative" (GFEI)[7], a partnership of the FIA Foundation, the IEA, the International Transport Forum (ITF), and the United Nations Environment Programme (UNEP), has estimated that a 50 per cent improvement in fuel economy - achievable using technologies that have already been or will be commercialised within the

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[6] ICCT (2010). Available from http://www.theicct.org/2010/08/pv-fuelecostandards-india/.

[7] Global Fuel Economy Initiative. 2009. *50 by 50: Global Fuel Economy Initiative*. Available from http://www.50by50campaign.org/Documents/Publications/50BY50_report.pdf. Accessed on October 1, 2010.

decade - would save over 6 billion barrels of oil per year by 2050 and cut CO_2 emissions from cars nearly in half. This is known as the "50 by 50 Initiative". In order to realise these benefits, strong vehicle fuel economy and/or greenhouse gas standards will be necessary.

60. The GFEI has realised that there are many technical and policy-related obstacles to the implementation of fuel efficient vehicle policies, particularly in developing countries, and as a result, has identified its core issues as:

- data collection and analysis of fuel economy potentials by country and region
- support for national and regional policy-making efforts
- outreach to stakeholders (e.g. vehicle manufacturers)
- information campaigns around the world to educate consumers and stakeholders

61. The "50 by 50 Initiative" has already undertaken work in Mexico, with the hope to lead Latin America in establishing science-based, CAFE-Type standards in order to improve the fuel economy of its fleet. This is likely to result in legally-binding standards by late 2010 in Mexico.

III. COMPARING INTERNATIONAL STANDARDS: ISSUES AND METHODOLOGIES

62. Comparing vehicle standards among different regions and countries is challenging. 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 not easy to compare them directly with one another. This section identifies key issues involved and proposes a generic methodology with which to compare them.

A. Differences in test driving cycles

63. Several countries have developed their own testing protocols to measure vehicle emissions and fuel economy. 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.

64. Countries and regions use essentially three different test cycles to determine fuel economy and GHG emission levels: The New European Dive Cycle (NEDC), the Japan JC08 cycle, and the US-based EPA Highway/City cycles. The original US EPA cycle has two test cycle components, city driving and highway driving. The combined test cycle is composed of 55 per cent city driving and 45 per cent highway driving. It's now been expanded further into five individual test cycles that also include A/C operation, high-speed and cold start driving cycles.[8] The new US regulatory test cycle will be based on these 5 cycles and become effective by 2012.

65. Obviously, these test cycles are very different in terms of average speed, duration, distance, acceleration and deceleration characteristics, and frequencies of starts and stops. All

[8] Available from http://www.fueleconomy.gov/feg/fe_test_schedules.shtml.

these factors significantly affect fuel economy ratings. In general, average speeds of the test cycles and associated fuel economy ratings are positively correlated.

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

66. The relationship between GHG emissions and fuel consumption is important because CO_2 is the dominant source of GHG emissions from an automobile. 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. As the vast majority of automobiles consume petroleum-based fuels such as gasoline and diesel, the conversion factors from CO_2 to gasoline and diesel fuels were treated in this analysis as constants among most countries and regions, even though small variations exist due to differences in fuel quality and additives. However, these differences are likely to remain relatively minor unless the use of alternative fuels that are not petroleum-based becomes widespread.

67. Table 6 provides conversion factors for measures associated with different regions to US 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 if compared to gasoline fuel, a gasoline-equivalent fuel economy (MPGge) measure was developed to convert diesel fuel into a comparable gasoline equivalent.

C. Corporate fleet averages vs. minimum requirements

68. Of all the standards, only the Chinese standards are based on maximum fuel consumption limits that are applicable to individual vehicle models. All other existing or proposed standards 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.

Table 6

Conversion factors to CAFE-equivalent mpg, EU-equivalent CO_2 (in g/km), and California-equivalent CO_2 emission rates (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	US CAFE	Fuel	Mpg	Y *	1.00	1/(Y) *	6,180	1/(Y) *	8,900
California	US CAFE	CO_2	g/mi	1/(Y) *	8,900	Y *	0.69	Y *	1.00
Canada	US CAFE	Fuel	L/100-km	1/(Y) *	235.2	Y *	26.2	Y *	37.8
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 of Feng An and Amanda Sauer (2004). *Comparison of Passenger Vehicle Fuel Economy Standards and GHG Emission Standards around the World.*

69. The maximum limit simply provides a ceiling for all vehicle models. The fleet average fuel consumption level should be below the limit. This analysis assumes that all vehicle models will at least meet the ceiling limits. For vehicle models that are already performing better than the standards, this analysis assumes that they will maintain their current fuel consumption levels in future years.

D. Vehicle categories and weight classes

70. Standards use varying 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 detailed information and vehicle database. Data were available for all the countries and regions studied with the exception of the Republic of Korea.

71. Another challenge is to project future fleet average fuel economy 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 US and Japan have shown significant shifts in sales from one category to another, mostly from lighter vehicle groups to heavier ones.

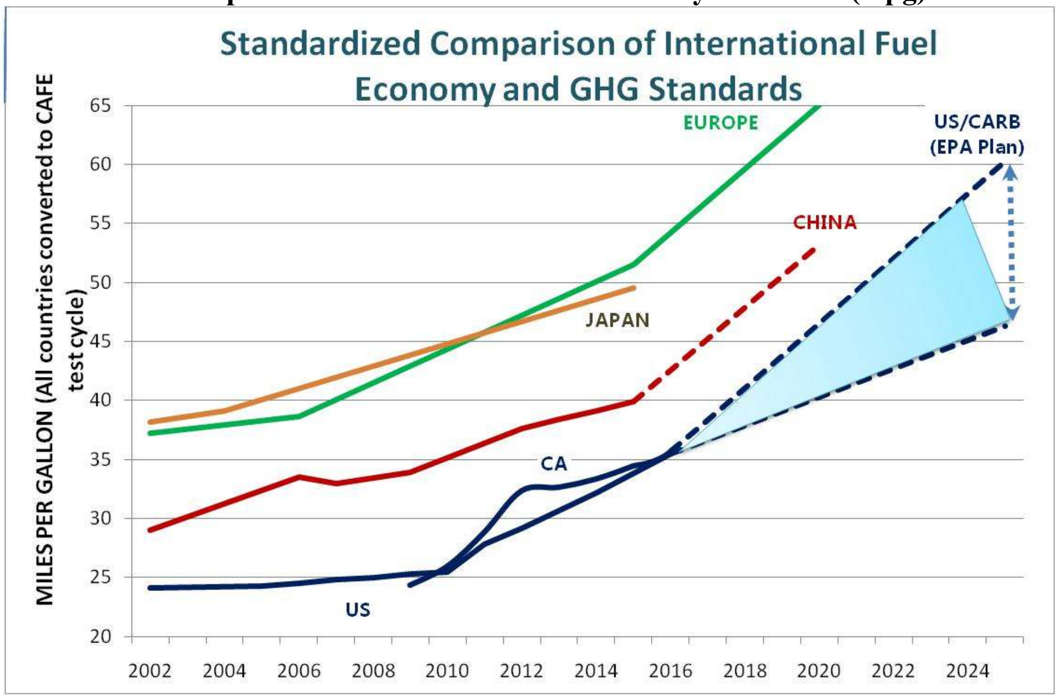
E. Comparison of global fuel economy standards

72. In the report, "Comparison of Passenger Fuel Economy and GHG Emissions Standards around the World", An and Sauer (2004)[9] proposed a methodology to directly compare fleet average fuel economy of passenger vehicle fleets in different regions and countries. Vehicle fuel economy or GHG emission limits were first converted into fleet averages. Then, for regions with standards based on vehicle categories - such as vehicle type, weight or engine size - the vehicle fleet mixes in each country were assumed to stay constant from 2002 throughout the time period analysed. Next, the US CAFE equivalent mpg and EU NEDC equivalent standard measuring grams of CO_2 per kilometer were selected as the reference standards. Finally, conversion factors to convert standards in countries to the reference standards were developed and applied where necessary.

73. Figures 4 and 5 show updated comparisons of fuel economy and GHG emission standards between the US, EU, Japan and China, normalised around metrics and vehicle test cycles as described in the above procedure. Dashed lines represent proposed standards under development. The US/CARB proposed fuel economy target range, with annual fuel economy improvement by 6% for upper boundary and 3% for lower boundary, from 2017 to 2025. These figures clearly show that the EU and Japan still have the most stringent standards, and that the US has the weakest standards in terms of fleet-average fuel economy rating. However, the developmental trends for dramatically improving vehicle fuel economy among major nations are very clear, even though each country's timeframe is different. .

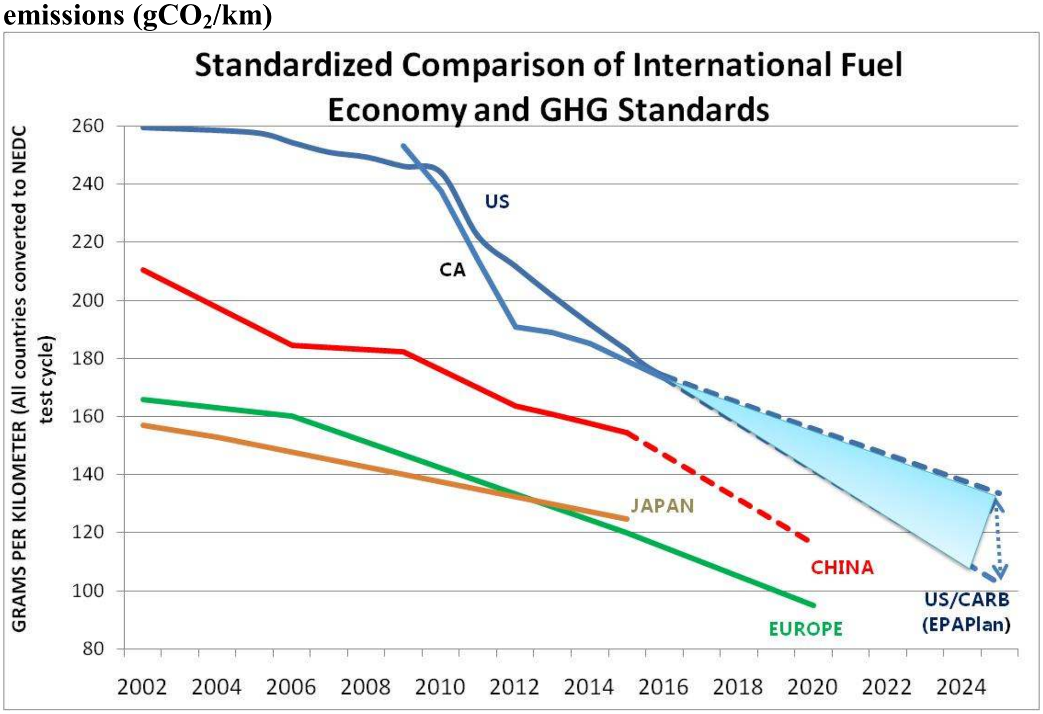
[9] Feng An and Amanda Sauer (2004). *Comparison of Passenger Vehicle Fuel Economy Standards and GHG Emission Standards Around the World.* Prepared for the Pew Center on Global Climate Change.

Figure 4
Standardised comparison of international fuel economy standards (mpg)



Source: An and Sauer (2004), Feng An et al (2007) and authors' analysis.

Figure 5
Standardised comparison of international fuel consumption standards based on GHG emissions (gCO_2/km)



Source: An and Sauer (2004), Feng An et al (2007) and authors' analysis.

74. The comparison shows that Europe has historically made the most pro-active efforts to reduce GHG emission (and fuel consumption), closely followed by Japan. Canada, China and the US have the highest CO_2 emission levels based on EU testing procedures. As the US EPA-NHTSA GHG standards go into effect, it becomes clear that the EU and US are driving toward a similar target of around 60 MPG (or 100 CO_2g/km target) in the 2020-2025 timeframe. Another trend is that both the US and the EU are shifting toward mandatory, attribute-based (either a weight-based or size-based) approaches, and moving away from fleet-average or corporate average approaches.

IV. ASSESSING FUEL ECONOMY OF ELECTRIC VEHICLES

75. While research has been underway on test cycles and fuel consumption of electric vehicle and PHEV technologies for several years, automotive companies are nonetheless keen to promote their new vehicles as super low-emitting, low fuel-consuming vehicles, despite lack of consistent and universally acceptable measurement methodology. [10]

76. The EU has attempted to address this policy gap by giving credits on the fleet average where manufacturers are able to prove that their ecological friendly technologies can save on carbon emissions, up to 7 per cent according to independently verified data presented to the regulator. Vehicles that emit less than 50 gCO_2/km qualify for a "supervehicle" credit. US EPA is considering to give "zero" emission credits for electricity use portion of BEVs and PHEVs for the first quarter-million vehicle sales, omitting the upstream emissions associated with electricity power generation.

77. Both EU and US approaches, while attempting to encourage electrification and the "zero emissions vehicle" concept, neglects one important aspect when regulating carbon dioxide emissions from the transport sector: essentially, in electric vehicles, all or a major portion of the GHG emissions related to the motive energy are transferred from the tailpipe of the vehicle to the electric grid which, depending on the proportion of fossil fuel feedstock on the grid, has an upstream emission which is not accounted for in the standard. This upstream emission is impossible to quantify on the vehicle side, but from a carbon dioxide perspective could dramatically change depending on the source of electricity. It will be a significant challenge in the future to address GHG emissions from grid-enabled transportation, and may require significant changes to the emissions regulatory system, particularly if these emissions are taken into account by other sectors and regulated under other GHG emission reduction schemes.

V. CONCLUSIONS AND RECOMMENDATIONS

78. The EU has legislated a 95gCO_2/km mandate by 2020 for the EU light duty automotive fleet. Plans to achieve this target will be formally announced by 2013. The US has recently released its own targets in a range of 46 to 60 mpg by 2025. Other countries, including Canada, China, and Japan have attempted to make their own commitments. DeCicco (2010) suggests that by optimising engines in the vehicle fleet, and making use of non-grid enabled hybrid technology, the fuel economy of the fleet could be tripled by 2035.[11]

[10] Available from http://www.nrel.gov/news/press/2009/728.html.

[11] DeCicco, John (2010). *A Fuel Efficiency Horizon for US Automobiles*. Prepared for the Energy Foundation. Available from http://energy.umich.edu/info/pdfs/Fuel%20Efficiency%20Horizon%20FINAL.pdf. Accessed on October 2, 2010.

This should give confidence to any policy maker that ambitious targets for fuel efficiency are not only desirable but in fact achievable. It is imperative that countries make long-term plans to take advantage of every technology available to reduce the consumption of fossil fuel in transportation.

79. Some manufacturers have complained that meeting differing standards around the world is increasingly difficult, given their globalised operations. As the auto industry becomes further globalised, it may eventually be in the interests of governments everywhere to achieve harmonised vehicle standards that aim for the best with regard to fuel economy targets. It would also serve the purpose of preventing the transfer of obsolete technologies to developing economies.

80. While advanced economies with sophisticated data reporting systems about vehicle sales are moving ahead with attribute-based fuel economy/fuel consumption/GHG standards, developing countries do not have sufficient capability of formulating targets for individual manufacturers, or for monitoring the compliance of individual manufacturers to a sales-weighted fleet average standard.

81. Until such economies can accurately measure and report on sales of all vehicles in their relevant markets, implementation of sales-weighted average standards, either attribute-based or fleet average-based, remains difficult. It will be necessary for the foreseeable future to support developing countries to develop regulatory systems in phases, first limiting the emissions or consumption of individual vehicles, then once an adequate measurement and reporting system is in place, developing corporate average fuel economy/emission standards which allow for more diversity in automotive products in the longer term.

82. The state-of-the-art in vehicle efficiency standards seems to be in mandatory, attribute-based, fleet-average regulations, along with classification of vehicles by likely use, rather than merely on weight. These types of standards allow for manufacturers to offer a broad range of products, while at the same time decreasing energy consumption and GHG emission.

83. However, developing countries, such as China and India, often have a dearth of data and reporting systems that do not allow these state-of-the-art standards to be implemented. As a result, minimum-requirement standards based on categories of vehicles are most likely to be successful in these regions.

84. Other developing countries, such as those in Latin America, have not yet been able to legislate motor vehicle standards, relying instead on voluntary, standardized labelling to educate consumers and convince them to make more energy-efficient, low-carbon choices when purchasing their vehicles.

85. Regulation is trending toward limiting CO_2 emissions rather than fuel consumption, but there is a need for direct reporting of upstream fuel emissions in order to accurately account for such emissions. Integration of fuel consumption and upstream GHG emissions would be essential for accurate and complete accounting, requiring a high degree of energy system integration, reporting and regulation.

86. The whole fuel-cycle approach applied in the Low Carbon Fuel Standard, which would include electricity as a form of low-carbon fuel, is one approach to regulating

upstream carbon emissions from transport energy. However, in order to help define life-cycle fuel consumption or GHG emissions of a vehicle, more would have to be known regarding each component of the fuel-chain and vehicle usage, both with fuel and with electricity would be necessary in order to properly define any type of rating for a vehicle.

87. The advent of new technologies - particularly electricity, alternative fuels, and dual-energy source PHEV vehicles - pose new problems for all these policies, which decision-makers will need to face in order to ensure that their regulations remain meaningful. After all, an electric vehicle with no tailpipe emissions is not necessarily an efficient user of energy or a low-carbon emitting technology. Addressing this issue requires a much broader understanding of the lifecycle emissions of transportation energies, and implementation of this understanding at the local level.

88. As vehicles become increasingly electrified, their emissions may begin to be regulated by other policies, such as those focusing on the electrical power sector. In this case, new methods and standards for evaluating and regulating the energy efficiency of vehicles will be necessary.

89. The number of private motor vehicles is growing at a pace never seen throughout history, in many cases in jurisdictions that do not have the know-how to measure, report and regulate on the efficiency of new or old technologies. It is essential that researchers and policy-makers cooperate to share and implement best practices, in order to promote the "greenest" technologies worldwide, and provide more assurance for a more energy and carbon-constrained world.

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