INTERNATIONAL ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE

REVIEW OF INTERNATIONAL POLICIES FOR VEHICLE FUEL EFFICIENCY

IEA Information paper

In Support of the G8 Plan of Action

Takao ONODA
International Energy Agency

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-eight of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.

International Energy Agency (IEA),
Head of Communication and Information Office,
9 rue de la Fédération, 75739 Paris Cedex 15, France.

REVIEW OF INTERNATIONAL POLICIES FOR VEHICLE FUEL EFFICIENCY

Abstract

At Gleneagles, United Kingdom in 2005, the G8 leaders signed a communiqué that included an initiative called the Gleneagles Plan of Action (GPOA), which addresses climate change, clean energy and sustainable development. This paper is one element of a comprehensive response to the GPOA in which G8 leaders pledged to encourage the development of cleaner, more efficient and lower-emitting vehicles, and to promote their deployment, by, among other means, asking the IEA to review existing standards and codes for vehicle efficiency and to identify best practices. Representative samples of fuel efficiency standards as well as voluntary programs are compiled. In addition, since standards are only one of the means by which governments can reduce fuel consumption and carbon dioxide emissions from motor vehicles, this paper assesses a broader set of governmental initiatives aimed at promoting the deployment of fuel efficient vehicles such as labelling and financial incentives. Eight recommendations regarding the nature of measures, attributes of an effective standard, standard stringency and standard related policies are made in this paper.

Since 2005, the IEA has been engaged in a programme of work for the G8 addressing the challenges of climate change, clean energy and sustainable development. Aiming at a "clean, clever and competitive energy future", this programme has produced wide-ranging analysis and policy recommendations including, *inter alia*, the IEA's 25 recommendations, which the G8 leaders agreed to implement at the G8 Hokkaido Toyako Summit. Detailed information is available on the IEA's website at www.iea.org.

Acknowledgements

The author of this paper is Mr. Takao Onoda, Policy Analyst with the Energy Efficiency and Environment Division of the IEA.

The author would like to thank Paul Waide, Ingrid Barnsley, Richard Bradley, Pieter Boot, Nigel Jollands, Rebecca Gaghen, Lew Fulton, Pierpaolo Cazzola and Emi Mizuno (IEA) for the information, comments and ideas they have provided throughout my research. Alan Meier (Lawrence Berkeley National Laboratory), Steven Plotkin (Argonne National Laboratory), Giacomo Mattinò (DG Enterprise, European Commission), Andreas Veispak (DG Enterprise, European Commission), Nobuyuki Konuma (Ministry of Land, Infrastructure and Transport, Japan), Shuji Okuda (Ministry of Economy, Trade and Industry, Japan), Akio Tamano (Toyota Motor Co.), Drew Kodjak (International Council on Clean Transport), Akihiko Hoshi (Misson of Japan to the European Union) and EEWP delegates also provided very useful suggestions and advice. Charlotte Forbes and Janet Pape (IEA) helped edit this document.

List of Acronyms and Abbreviations

ACEA	European Automobile Manufacturers' Association
AIAMC	Association of International Automobile Manufacturers of Canada
APS	Alternative Policy Scenario
CADA	Canadian Automobile Dealers Association
CAFE	Corporate Average Fuel Economy
CVMA	Canadian Vehicle Manufacturers' Association
DOT	Department of Transport
EPA	Environment Protection Agency
ETP	Energy Technology Perspective
FCAI	Federal Chamber of Automotive Industry
G8	Group of Eight
GHG	Green House Gas
GPOA	Gleneagles Plan of Action
GVWR	Gross Vehicle Weight Rating
HDV	Heavy Duty Vehicle
JAMA	Japan Automobile Manufacturers' Association
KAMA	Korean Automobile Manufacturers' Association
LDV	Light Duty Vehicle
LPG	Liquefied petroleum gas
MOU	Memorandum of Understanding
MVMA	Motor Vehicle Manufacturers' Association
MY	Model Year
NHTSA	National Highway Traffic Safety Administration
NOx	Nitrogen Oxide
NRCan	Natural Resource Canada
PM	Particulate Matter
SUV	Sport Utility Vehicle
UNECE/WP29	United Nations Economic Commission for Europe/Working Party 29
UNFCCC/ COP3	United Nations Framework Convention on Climate Change/ Conference of the Parties
UPI	Uniform Percentage Improvement
WEO	World Energy Outlook
4WD	Four-wheel-drive vehicles

Table of Contents

List of Figures

List of Tables

List of Boxes

Executive Summary

In response to threats posed to the future supply of energy and to the environment, the G8 leaders agreed to an initiative called the Gleneagles Plan of Action (GPOA)[1] which addresses climate change, clean energy and sustainable development. In the GPOA, G8 leaders pledged to encourage the development of cleaner, more efficient and lower-emitting vehicles, and to promote their deployment by, among other means, asking the IEA to review existing standards and codes for vehicle efficiency and to identify best practices. Since then, the IEA has been engaged in a programme of work for the G8 including a study on existing standards and best practices in reducing vehicle fuel use, and submitted, at the G8 Hokkaido Toyako Summit meeting in July 2008, 25 recommendations as a comprehensive response to the GPOA. The G8 leaders, in the summit document, have declared that they "will maximize implementation of the IEA's 25 recommendations on energy efficiency." This paper has been written to provide one aspect of the IEA response.

There are significant potentials for saving energy in the transport sector. The IEA's *Energy Technology Perspectives* (ETP) 2008 projects that the fuel economy of new light-duty vehicles could be improved by 50% by 2030 using cost effective technologies, including but not limited to hybridization. This would result in close to a half million tonne (oil equivalent) reduction in fuel use and close to 1 Gt annual reduction in CO_2, nearly doubling by 2050 as improved vehicles fully penetrate the stock. However, in order to achieve these energy savings, appropriate and effective policies and measures should be introduced.

This paper, in response to the above-mentioned G8 request, reviews past and current voluntary and regulatory fuel efficiency programs and then assesses the effectiveness of these policies from the viewpoints of enforcement, standard design, standard stringency and standard related policies. The results of this review are as follows:

Findings

Finding 1: Voluntary vs. Regulatory Measures

While both voluntary and regulatory measures have been widely introduced to improve vehicle fuel efficiency, the results have been mixed. On the one hand, voluntary programs have generally fallen short of their targets. On the other hand, mandatory programs produced decent results, although their effectiveness seems to depend on the ways in which the policies were designed. In most cases, mandatory targets achieved their goals, although in one case, overall fleet average fuel efficiency deteriorated partly because of perverse effects in the standard design.

As a result of the general ineffectiveness of voluntary programs to constrain vehicle energy efficiency, there is a general trend away from them. Japan switched from a voluntary program

[1] This agreement was developed at the G8 Summit meeting in Gleneagles, the United Kingdom in 2005.

to a regulatory one in 1999, as did Korea in 2005. The European Union and Canada are also considering such a change.

Regulatory measures could have played a role in deterring the ever-increasing trend of fleet-average vehicle weight that can be seen worldwide. In some cases, a regulatory measure prompted manufacturers to apply innovative technologies to vehicles to make them more efficient, rather than bigger and more powerful, and thus heavier.

Finding 2: Attributes of an Effective Standard

Scope

Both the range of vehicles to which a standard applies in a vehicle category, such as the passenger car category, and the coverage of vehicle categories are closely related to the effectiveness of the standard. In general, standards with a broader scope (e.g. covering a greater range of vehicle types) tend to lead to greater fuel savings. However, broadening the scope of a standard may increase the administrative cost of testing vehicles. Some manufacturers – especially those of light duty vehicles – can reduce such costs by producing large amounts of the same type of vehicles. Others (e.g. some small-volume truck manufacturers) need to find ways to decrease the costs of the testing, by utilizing new methods, such as computer simulation, for example.

With the exception of Japan, standards for heavy duty vehicles have not yet been introduced. Based on the Japanese experience, it appears that such standards could result in fuel savings world wide although some further in-depth analysis is needed to confirm this.

Testing procedures

What makes a good testing procedure? Consumers expect the tested fuel efficiency values to be similar to the fuel efficiency values they experience on road. In order to move in that direction, test procedures should reflect as many factors affecting the value of the fuel efficiency as possible. These requirements must be balanced against the increased cost of testing.

Fuel efficiency values are generally tested with the same or similar test procedures used to test local pollutant emissions of vehicles. This is done in part because it is an effective way to reduce the cost of testing and because some technologies for improving fuel efficiency can adversely affect the amount of local pollutant emissions.

There have also been some efforts to harmonize at least some aspects of testing procedures. This would be another effective way of reducing costs although it would be very difficult to achieve, especially in the short term. Eventually there could be large benefits from an internationally harmonized test procedure, allowing countries around the world to use similar libelling systems and adopt similar regulatory systems (or at least systems based on similar measurements).

Technology neutrality

Fuel efficiency standards are usually set to require the same level of efficiency regardless of the technologies that vehicles adopt. There are, however, cases where requirements are established on the basis of the technology used. In general, setting requirements that favour one kind of energy efficiency technology over another will distort technology development.

Regulatory flexibility

Regulatory policies can suffer from being inflexible. Existing regulatory measures generally try to use a range of mechanisms such as manufacturer fleet averaging, attribute based targets, weighted average criteria and credit trading systems to increase policy flexibility. In general, high degrees of regulatory flexibility allow more stringent targets to be met at lower cost (compared to less flexible approaches). Lead time would also be an important factor for lowering the cost.

Attribute based standards can offer the possibility that standards can get much closer to economic efficiency and may be more likely to ensure greater fairness among all automakers. Although they would not necessarily ensure the achievement of an overall improvement for vehicle fuel efficiency (as such standards are subject to weight or size shifts), a standard design in which relatively stringent requirements are imposed on heavier and bigger vehicles could solve at least part of this concern.

Flexible measures can bring some regulatory costs. In order to properly implement a credit trading system, for example, credits must be tracked and all related data such as registration data should be available within a short period of time.

Finding 3: Standard Stringency

There are several approaches to setting the level of stringency of a policy. The approach that guides part of the European Commission and NHTSA's policy is to set the level of ambition at the point where the increased retail cost of the vehicle is offset by savings from reduced fuel consumption. This cost effectiveness analysis depends largely on expectations of existing and emerging technologies (cost and effectiveness), and financial considerations such as discount rates and payback period. An alternative approach is the Japanese Top-Runner programme, in which stringency is based on the performance of the best in each weight class on the market. Under this program, the value of the mass produced vehicle with the highest fuel efficiency is used as a base value and factors such as fuel saving potential of future technologies are taken into consideration afterward.

Given that vehicle manufacturers are global entities and fuel efficiency technologies spread around the globe rapidly, governments could also look to the situation in other countries and regions for additional guidance. Although detailed country-by-country analysis is crucial and direct comparison of standard stringency would be a considerable challenge in light of different test procedures and other factors, governments could nonetheless refer to fuel efficiency improvement rates achieved and targeted in other countries or regions as a starting point.

Finding 4: Standard-related policies

Labelling

Governments have been asking manufacturers to introduce labelling schemes with the hope that they will lead to fuel savings and various labelling schemes have been introduced, though in isolation these appear unlikely to lead to significant fuel efficiency improvements. However, fuel efficiency labels do help consumers compare vehicle choices, and might particularly influence choices between otherwise similar vehicles that have different fuel efficiency ratings.

Financial incentives

Differentiated financial incentives based on tested fuel efficiency or CO2 emissions would be effective tools to stimulate demand for fuel efficient vehicles, particularly when coupled with good labelling programs. It can provide additional stimulus to producers and consumers to go beyond simply the attainment of designated targets. Such incentives could take the form of a tax deduction based on the fuel efficient performance, a fee for less fuel efficient cards or a "feebate" which is a combination of rebates for fuel efficient cars and the fees. Given the fact that some technologies for improving fuel efficiency have a negative impact on local pollutant emissions, performance in reducing local pollutant emissions could also be taken into consideration when certifying vehicles for financial incentives.

Recommendations

Recommendation 1: Voluntary vs. Regulatory Measures

In order to achieve significant energy savings in the transport sector, governments should introduce regulatory fuel efficiency standards.

Recommendation 2: Attributes of an Effective Standard

Scope

The scope of the policy framework should be broad enough to at least cover all light duty vehicles and should not allow "leakage" into categories not covered by standards. Broadening the scope to include other vehicles, such as heavy duty vehicles, should also be considered.

Test procedure

Test procedures should reflect as many factors that affect the "on-road" value of fuel efficiency as possible. At the same time, in order to lower the cost of testing vehicles, test procedures for fuel efficiency standards should be the same as, or as similar as possible to, the procedures for local pollutant emission regulation. In addition, governments should consider the harmonization of test procedures and participate in related international harmonization activities in UNECE/WP29 (World Forum for Harmonization of Vehicle Regulations).

Technology neutrality

Unless there are clear reasons for not doing so, requirements should be based on reaching a targeted fuel efficiency performance level and not based on promoting particular technologies.

Regulatory flexibility

Policy mechanisms for increasing regulatory flexibility, such as attribute-based targets, weighted average criteria, credit trading systems and appropriate lead times, should be considered in order to improve fuel efficiency with less cost. The best type/types of flexibility and optimal form of a regulatory system may vary depending on the particular concerns and other national circumstances within a country (e.g. concerns about equity among manufacturers).

Recommendation 3: Standard stringency

Governments should consider as high a fuel efficiency improvement rate as is currently set in any country or region, while taking into account, among other factors, costs and other (possibly conflicting) policy objectives such as emission regulations and compliance methods.[2] Optimally, the standard should be set at a level that maximizes net social benefit, though it is acknowledged that this may not be easy to identify.

Recommendation 4: Standard related policies

Labelling

Governments should continue to explore effective ways of labelling. If possible, the labels themselves should be consistent across countries that adopt similar labelling schemes.

Financial incentives

Governments should note that differentiated financial incentives such as a tax deduction and/or a fee or a "feebate" based on fuel efficient performance can be useful to complement fuel efficiency standards. Moreover, fiscal incentives can also be designed in a multi-attribute approach, taking into consideration local pollutant emissions and other factors that have a trade-off relationship with fuel efficiency performance, when rating and certifying vehicles for financial incentives.

[2] It should be noted that what this paper recommends is different from Uniform Percentage Improvement (UPI), which requires each manufacturer to achieve the same percentage increase in fuel efficiency. UPI could have the advantage of keeping a fleet averaging approach while allowing different manufacturers to face a target relevant to their position in the market. But it could also place a heavier burden on smaller vehicle manufacturers or discourage manufacturers from deploying more fuel efficient technologies, out of fear that they may face more stringent requirements in the future. This paper recommends that the stringency level of standards be set while taking the annual improvement rate of other regions and other factors into consideration, and that the same standards be applied nationwide to all manufacturers once they are set.

I. Introduction

Background

Road vehicles dominate global oil consumption and are one of the fastest growing energy end-uses. The transport sector is responsible for nearly 60% of world oil demand and road transport accounts for nearly 80% of the total transport energy demand. (*World Energy Outlook 2007*, page 222) Transport accounts for around 25% of energy-related carbon dioxide (CO_2) emissions. Reducing the fuel used for transportation is therefore among the highest priorities in all IEA member countries.

However, reducing fuel consumption in the transport sector has proven to be a difficult task. Furthermore, current policies are insufficient to stop road vehicle energy use rising above current levels. Even if governments were to actually implement all the measures that are currently being considered, road vehicle energy use and CO_2 emissions would still rise through to 2030 at 1.4% and 1.3% per annum, respectively, under scenarios developed in the *World Energy Outlook 2006*, (page 223). Potential fuel shortages and international commitments to reduce CO_2 emissions are now prompting countries to reconsider their policies to improve vehicle fuel economy.

At their 2005 Summit in Gleneagles, the United Kingdom, G8 leaders recognized that energy use in the transport sector is a crucial element of any sustainable development policy. They agreed to the G8 Gleneagles Plan of Action (GPOA), which covers key actions necessary to achieve sustainable development by mitigating climate change and promoting the use of clean energy sources. In the GPOA, they pledged, *inter alia*, to encourage the development of cleaner, more efficient vehicles. To this end, the G8 leaders asked the International Energy Agency (IEA) to review existing standards and codes for road vehicle efficiency and to identify practices that effectively reduce energy use.

Since 2005, the IEA has been engaged in a programme of work for the G8 addressing the challenges of climate change, clean energy and sustainable development in which, among other studies, analysis on existing standards and best practices in reducing vehicle fuel use has been carried out. The IEA, based on the result of the programme of work, submitted 25 recommendations on energy efficiency at the G8 Hokkaido Toyako Summit meeting in July 2008 as a comprehensive response to the GPOA. The G8 leaders, in the summit document, have declared that they “will maximize implementation of the IEA's 25 recommendations on energy efficiency.”

World Energy Outlook Energy Savings Potential

According to the Alternative Policy Scenario (APS) of the *World Energy Outlook 2006* (WEO) , which assumes that the policies and measures that governments are currently considering to enhance energy security and mitigate CO_2 emissions would be fully implemented, the average on-road fuel efficiency for new light duty vehicles (LDVs)would be improved from 10.7 km/l in 2004 to 16.1 km/L in OECD countries, 10.0 km/l to 14.3 km/l in transition economics, and 9.7 km/l to 14.1 km/l in developing countries.

Table 1: Average LDV on-road fuel efficiency in 2004 and 2030

	2004 (km/l)	2030 (km/l)
OECD	10.7	16.1
North America	8.6	12.8
Europe	13.0	19.6
Pacific	11.6	17.5
Transition economies	10.0	14.3
Developing countries	9.7	14.1
China	8.8	13.3
India	9.9	14.1
Brazil	11.0	16.1

Based on these figures, worldwide fuel use for LDVs could be lowered by 15% or CO2 emissions decreased by 590 Mt by 2030 if the policies and measures were to be fully implemented.[3]

The WEO APS 2006 did not take into account the latest policy announcements, including the following: Japan's new fuel efficiency standards for LDVs issued in July 2007, the European Commission's proposed legislation to reduce average CO2 emissions of new passenger cars to 120 g/km by 2012, the Energy Independence and Security Act of 2007 of the United States that requires fuel economy standard of 35 miles per gallon (mpg) by 2020, the European Commission's proposed research and development (R&D) support program, which aims to reduce CO2 emissions to 95g CO2/km (25.3-28.1km/l) by 2020, and so forth. These additional policies can be expected to further drive fuel efficiency improvements.

The IEA *Energy Technology Perspectives 2008* takes matters a step further: it estimates a cost-effective technical potential for fuel economy improvement of 50% (50% reduction in new vehicle fuel use per kilometre) by 2030. This would be challenging to achieve, but its accomplishment would result in close to a half million tonne (oil equivalent) reduction in fuel use and close to 1 Gt annual reduction in CO2, increasing thereafter as older stock is phased out. Achieving such a target should be possible, but it will require strong policies that maximize technology uptake and minimize fuel economy losses due to increases in vehicle size, weight and power. In the ETP "Blue Map" scenario, improvement in fuel economy is clearly one of the most important and cost effective measures available for transport, and plays an important role in achieving an overall CO2 reduction target of 50% below 2005 levels by 2050 across energy sectors.

The purpose of this paper

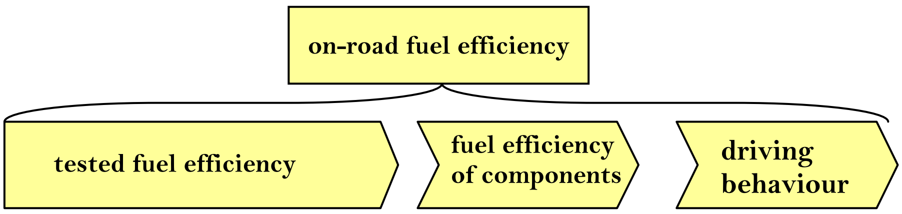
The purpose of this paper is to provide a solid foundation for a comprehensive response to the above-mentioned G8 request. Therefore, the paper reviews the effectiveness of voluntary target and regulatory standard programs aimed at accelerating the deployment of more fuel efficient vehicle technologies. The paper also seeks to quantitatively compare vehicle efficiency programs, where possible. In the course of conducting the review, it is also necessary to explore the attributes of effective standards, their stringency, and related policies, including financial incentives in individual countries.

[3] It is assumed that the improvement rate of on-road fuel efficiency in each region is constant.

This paper naturally focuses on G8 countries, but also includes information about programs in China, Korea and Australia.. Some of the selected countries have over 30 years of experience with policies to improve vehicle fuel efficiency. The range of policies is dramatic, ranging from hands-off approaches (doing nothing is a kind of policy), to voluntary programs to strict mandatory regulations. It is therefore reasonable to consider which past and present policies have resulted in outstanding outcomes and which have not. The answer to this question will help IEA member countries – indeed, all countries – formulate more effective programs to improve the energy efficiency of their vehicles.

Improving the technical efficiency of vehicles or the tested fuel efficiency is only one element of a comprehensive program to reduce fuel use and CO_2 emissions from motor vehicles. For example, as Figure 1 shows, real "on-road" fuel efficiency is also strongly affected by driving behaviour and the fuel efficiency of vehicle non-engine components not considered in the fuel efficiency test. To be most effective, technical efficiency improvements need to be combined with other policies such as those to increase on-road fuel efficiency, reduce the distances travelled by private vehicles, change the mix of vehicles providing trips, promote conversion to fuels with lower carbon content, and shift trips to public transport. More specifically, additional policies, including promotion of eco-driving, fuel taxes, creation of public transit, and regional planning, will be needed to encourage greater reliance on high quality communication in place of physical trips. These aspects are not addressed in this paper since this was not requested by the G8 at this time. It is anticipated that future IEA papers will investigate energy policies beyond those affecting vehicles themselves.

Figure 1: Relationship between on-road fuel efficiency, tested fuel efficiency, etc.



The focus on efficiency also means that the relative merits of specific future vehicle technologies such as hybrids/batteries, bio-fuels, and future fuel cells, etc., which may each play a major role in road transport in the future, are not addressed in this paper. In general it is recognized that there is an urgent need to implement new measures that will empower a more secure, environmentally acceptable energy system. Developing and reducing the cost of innovative technologies will involve time; improving vehicle fuel efficiency ought to be a first step in this campaign. These policies make economic sense, produce energy savings and provide time to develop and reduce the costs of the above-mentioned, innovative technologies.

Organisation of this paper

The paper first reviews the recent history of voluntary and mandatory fuel efficiency programs. It then assesses the effectiveness of policies to improve fuel efficiency with respect to the nature of measures, standard design, standard stringency and standard related policies. Based on these assessments, it offers conclusions and recommendations.

II. Current Policies to Improve vehicle fuel efficiency

Introduction

Several countries have some sort of policy to improve the technical fuel efficiency of their vehicle fleets. However, the particular measures employed to fulfil such policies differ markedly from country to country.

The most common measures to improve technical fuel efficiency are:
- Regulatory standards;[4]
- Voluntary targets;
- Financial incentives; and
- Consumer information.

Most countries rely on a combination of the above in seeking to fulfil their policy aims. Table 2 presents the policy measures used in the European Union, Japan, the United States, Canada, China, Korea and Australia. Each economy's approaches will now be discussed.

Table 2: Implementation of policy measures for technical fuel efficiency improvement

	Regulatory standards	Voluntary targets	Vehicle tax differentiation	Consumer information
EU	pl*	im*	pl**	im
Japan	im		im	im
United States	im		im	im
Canada	pl	im*		im
China	im		im	im
Korea	im	im		im
Australia		im		im

im = implemented
pl = planned or under consideration
* Voluntary and Regulatory measures in EU are on CO_2, not directly on fuel efficiency. Similarly, Voluntary target in Canada is on GHG.
** Several EU member states have already implemented the tax systems and the European Commission is currently calling for harmonization of the systems.

The European Union

While there was a clear trend toward fuel efficiency improvements up to the mid-1980s, average fuel efficiency remained the same from then until the mid-1990s. These trends occurred during relatively low fuel prices and in the absence of a fuel efficiency standard. In

[4] This paper distinguishes between voluntary targets on the one hand and regulated, mandatory targets on the other.

December 1995, in light of concerns regarding the lack of progress in further improving the fuel efficiency of cars, the European Commission proposed a strategy to reduce CO_2 emissions from passenger cars towards the average fuel-efficiency target of 120g CO_2/km with a time horizon beyond 2005 for the attainment.

In the late 1990s, the European Commission agreed with the European Automobile Manufacturers' Association (ACEA), the Japan Automobile Manufacturers' Association (JAMA) and the Korean Automobile Manufacturers' Association (KAMA) that each association would commit to the same quantified CO_2 emission objective for the average new passenger car sold in the EU. The content of the commitments was that the members of each of these associations should collectively achieve a CO_2 emission target of 140g CO_2/km by 2008 (ACEA) or by 2009 (JAMA and KAMA). The matter of how to share the burden of the objective between the different manufacturers within an association was left to each association itself to decide.

EU directive 1999/94/EC adopted in 1999 gives EU countries the authority to require mandatory labels indicating information on the fuel economy and CO_2 emissions of light duty vehicles to be displayed on LDVs sold within their borders and therefore enables vehicle purchasers to make an informed choice. According to the directive, the information must be provided to consumers in the following ways:

- A fuel economy and CO_2 emissions label for all new cars must be displayed at the point of sale.
- A poster (or a display) showing the official fuel consumption and CO_2 emission data of all new passenger car models must be displayed at the respective point of sale.
- A guide on fuel economy and CO_2 emissions must be produced on at least an annual basis.
- All promotional literature must contain the official fuel consumption and specific CO_2 emission data for the passenger car model to which it refers.

In addition, thanks to the directive, a number of organisations in EU member states maintain Internet sites which display the official fuel consumption and CO_2 emissions of new passenger car models offered on their regional markets. In spite of this, there is no harmonized format for labels so that different labels can be seen in different member states. Furthermore, there are currently no common energy or CO_2 performance thresholds in place across the EU.

Additional measures, notably financial incentives, have been introduced in several member states and recognized by the European Commission as necessary to reduce CO_2 emissions from new passenger cars and to meet the Community target of 120 grams CO_2/km. In 2005, the European Commission made a proposal for a Council Directive on passenger car related taxes that aims, *inter alia*, at introducing a CO_2 element in the calculation of car taxes for those member states that have such taxes. (To-date, it has not yet been adopted.)

Japan

The Japanese government has twice introduced non-binding fuel efficiency targets. The first target was set in 1978, with the target year of 1985, and the second one in 1990, with the target year of 2002.

In 1998, the Law concerning the rational use of energy (Energy Conservation Law) was amended. The amended law provided for the introduction of regulatory "Top Runner" standards and the mandatory display of energy efficiency values, and so forth, for various machineries, including passenger vehicles and freight vehicles. According to this law, standards are determined based on the performance of the vehicles whose performance is the best ("Top Runner") in the national market and on a range of other factors.

Fuel efficiency standards using the "Top Runner" method were first introduced in 1999 for light duty vehicles (gasoline vehicles and diesel vehicles). They were followed by a series of fuel efficiency standards: standards for LPG vehicles were introduced in 2003, and in 2006 standards for heavy duty vehicles (diesel vehicles) were introduced for the first time in the world. Currently, all light duty vehicles (passenger cars and light freight vehicles [vans]) and heavy duty diesel vehicles are covered by the legislative framework. In 2005, the government set up a committee to establish new fuel efficiency standards for light duty vehicles and in 2007, the new standards were made public. Now, there are two groups of targets ("incumbent" 2010 standards and new 2015 standards) for light duty vehicles. Table 3 shows the 2015 standards for passenger vehicles.

Table 3: 2015 Standards for Passenger Vehicles

Class	vehicle weight (kg)	target standard value (km/l)
1	0 - 600	22.5
2	601 - 740	21.8
3	741 - 855	21.0
4	856 - 970	20.8
5	971 – 1 080	20.5
6	1 081 – 1 195	18.7
7	1 196 – 1 310	17.2
8	1 311 – 1 420	15.8
9	1 421 – 1 530	14.4
10	1 531 – 1 650	13.2
11	1 651 – 1 760	12.2
12	1 761 – 1 870	11.1
13	1 871 – 1 990	10.2
14	1 991 – 2 100	9.4
15	2 101 – 2 270	8.7
16	2 271 -	7.4

The law also requires manufacturers to provide information on the fuel efficiency of vehicles through labelling. Fuel efficiency values are accompanied by CO_2 emission values converted from the fuel efficiency values, although people are generally more accustomed to fuel efficiency values provided in the unit of kilometre per litre (km/l).

In addition, in order to further stimulate consumer interest in fuel efficiency performance and to encourage the wide deployment of fuel efficient vehicles, the vehicle fuel efficiency certification program was implemented in April 2004. Under the program, vehicles are ranked according to their fuel efficiency performance and certified in four levels (initially vehicles were certified in two levels, and it was expanded to four levels in 2006) - the level meeting the target and the levels exceeding the target by 5%, 10% and 20%. Manufacturers can attach the certified stickers showing the vehicle's fuel efficiency performance level to the rear windows of the vehicles.

Furthermore, in an effort to tackle global and local environmental issues, a tax reduction incentive for both fuel efficient *and* less polluting vehicles was introduced in 2001 to accelerate wider deployment of more fuel efficient and cleaner vehicles.

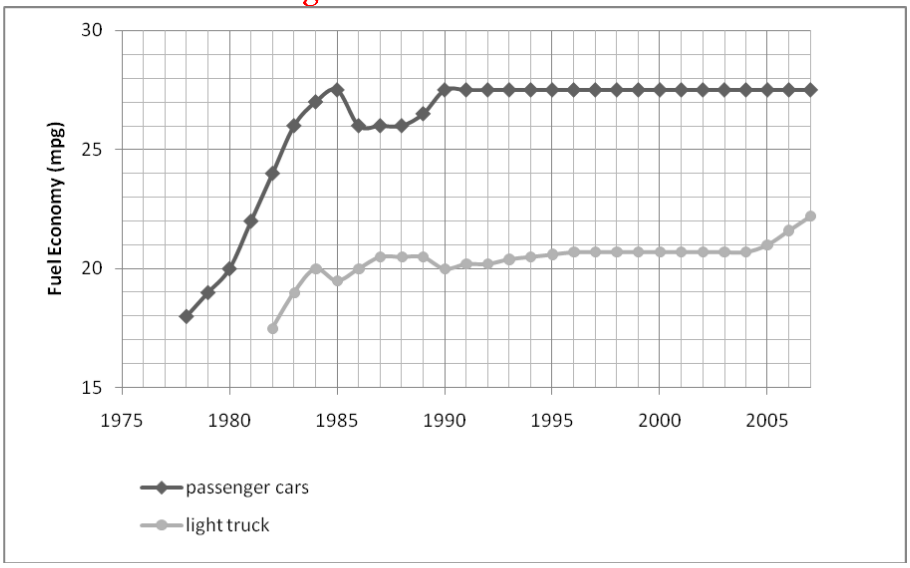
The United States

In 1975, the Energy Policy and Conservation Act was enacted into law by Congress, and the CAFE program, under which mandatory fuel economy standards are set for passenger car and light truck fleets, was established.

CAFE is "the sales weighted average fuel economy, expressed in miles per gallon (mpg), of a manufacturer's fleet of either 1) passenger or 2) light trucks up to 8 000 pounds (3 632 kg)[5] gross vehicle weight rating (GVWR) produced in the United States over any particular model year (MY)." The values are determined by computing the weighted fuel economy average of the various model types of a manufacturer in a model year.

The short-term goal of the Act was to double new car fuel economy by model year 1985 (to 27.5 mpg.[6] Congress set fuel economy standards for some of the intervening years. For the post-1985 period, Congress provided for the continued application of the 27.5 mpg standard for passenger cars, but gave the Department of Transportation (DOT) the authority to set higher or lower standards. For light trucks, Congress did not specify a target for the improvement of their fuel economy. Instead, it provided that light truck standards should be set at the maximum feasible level for MY 1979 and each model year thereafter. Consequently, light truck fuel economy standards have been established by the National Highway Traffic Safety Administration (NHTSA) of DOT for MY 1979 through MY 2007. CAFE standards up to MY 2007 are shown in Figure 2.

Figure 2: CAFE standards

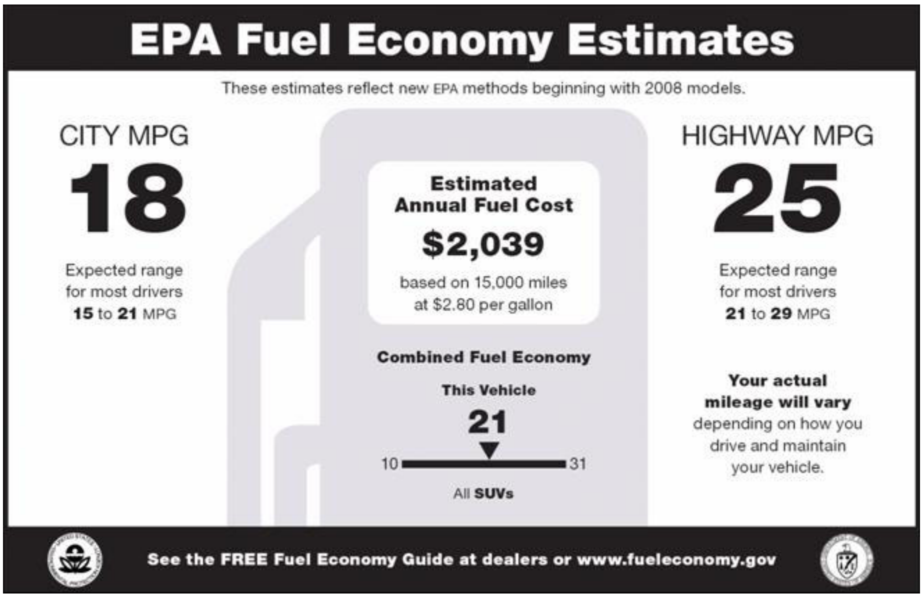


Source of data: NHTSA

[5] from 2011, 10 000 pounds (4 540 kg)
[6] Equivalent to 11.7 km/l (1 mpg = 0.425 km/l)

In the United States, fuel economy estimates have been provided for more than 30 years to consumers as a tool to help shoppers compare different vehicles. The labelling includes information comparing the fuel efficiency of different vehicles, expected on-road fuel efficiency and estimating annual fuel cost. Figure 3 shows the revised fuel economy label that will appear on vehicle window stickers beginning with 2008 models.

Figure 3: Revised fuel economy label



The Gas Guzzler Tax was established by the Energy Tax Act of 1978. The purpose of this tax is to discourage the production and purchase of fuel inefficient vehicles. The tax applies only to passenger cars – trucks, minivans, and SUVs are not covered. Table 4 shows vehicle fuel efficiencies and amount of taxes.

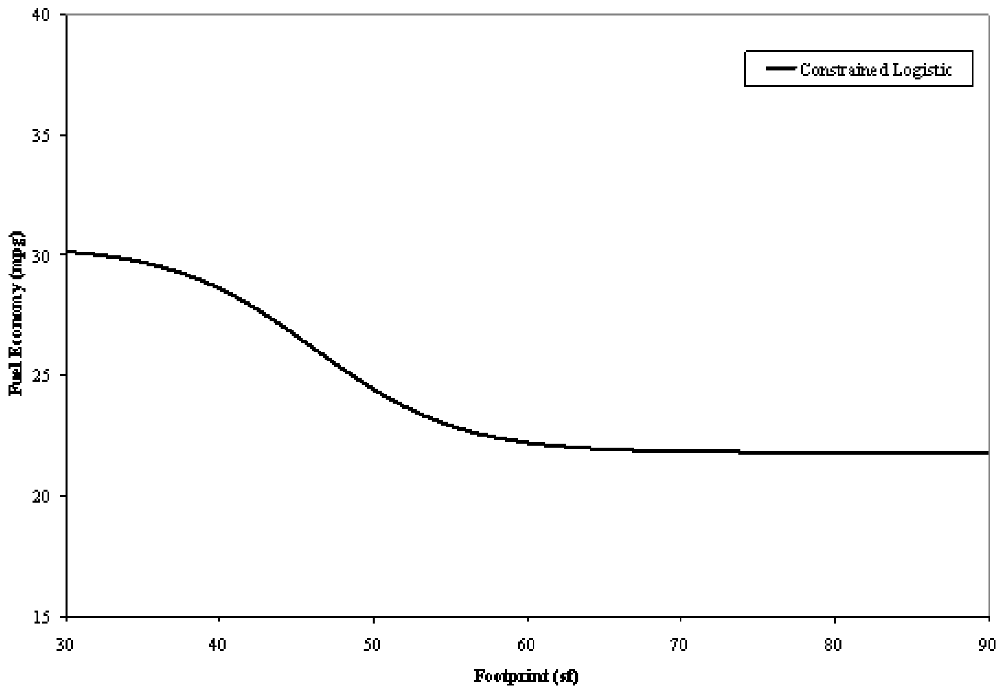
Table 4: Gas Guzzler Tax

Fuel efficiency (mpg)	Tax
at least 22.5	No tax
at least 21.5, but less than 22.5	$1000
at least 20.5, but less than 21.5	$1300
at least 19.5, but less than 20.5	$1700
at least 18.5, but less than 19.5	$2100
at least 17.5, but less than 18.5	$2600
at least 16.5, but less than 17.5	$3000
at least 15.5, but less than 16.5	$3700
at least 14.5, but less than 15.5	$4500
at least 13.5, but less than 14.5	$5400
at least 12.5, but less than 13.5	$6400
less than 12.5	$7700

In April 2006, the NHTSA published a rule making for a reform of the structure of the CAFE program for light trucks (the Reformed CAFE), as well as standards for model year 2008-2011.

Under the Reformed CAFE system, each light truck manufacturer is required to achieve the level of CAFE which is based on each vehicle's target level, set according to vehicle size. The targets are assigned according to the vehicle's "footprint" (the product of the average track width multiplied by the wheelbase). Each vehicle is assigned to a target specific to the footprint value shown in Figure 4.

Figure 4: The Reformed CAFE targets



Source: NHTSA

Canada

As the Canadian automobile markets are highly inter-linked with the US markets, fuel efficiency of the Canadian vehicle fleet could have been affected by US policy development.

In Canada, a number of voluntary agreements on vehicle fuel efficiency have been implemented since the late 1970s. These include three Memoranda of Understanding (MOUs) signed between Natural Resources Canada (NRCan), and manufacturers associations and a dealers association in late 1995 to early 1996, and an MOU signed between NRCan and domestic and international vehicle manufacturers in 2005.

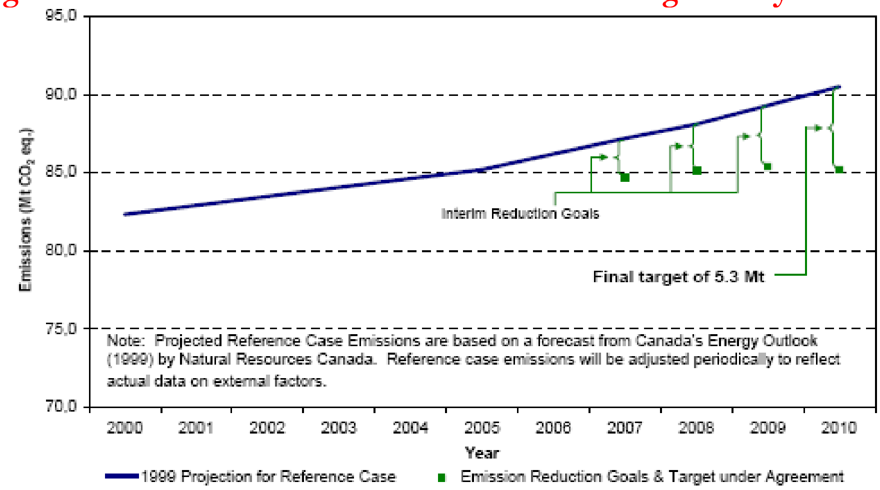
The Transport Canada Voluntary Motor Vehicle Fuel Consumption Program, originally established in 1975, sets minimum levels of fuel efficiency performance for the auto industry. Separate levels are set annually for new passenger cars and for new light duty trucks. A company's performance is measured by averaging fuel efficiency across its fleet. Although the targets are voluntary ones, the levels of the targets have been harmonized with US fuel economy standards.

An MOU between the Motor Vehicle Manufacturers' Association (MVMA) and NRCan concerning motor vehicle fuel efficiency was designed to support and enhance the important role that fuel efficiency improvements can play in reducing greenhouse gas (GHG) emissions across the transportation sector. According to NRCan, the most cost-effective method of realizing such improvement is through a balanced approach aimed at vehicle owners and operators, as well as vehicle technology. Similar MOUs were signed between NRCan, and the Association of International Automobile Manufacturers of Canada (AIAMC) and the Canadian Automobile Dealers Association (CADA).

Additionally, an MOU between the NRCan, and the Canadian Vehicle Manufacturers' Association (CVMA) and AIAMC was made in 2005 to further reduce GHG emissions. It calls on the automotive industry to reduce GHG emissions from light duty vehicles, so that annual reductions of 5.3 Mt will be achieved in 2010. Figure 5 illustrates GHG emission from LDVs which is expected to be stabilized at the 2005 level.

In November 2007, the Motor Vehicle Fuel Consumption Standards Act was proclaimed to enhance the Government of Canada's authority to regulate GHGs from vehicles after the expiry of the MOU between the NRCan, and CVMA and AIAMC. Regulations would take effect for the 2011 model year.

Figure 5: Illustration of GHG Emissions from Light Duty Vehicles



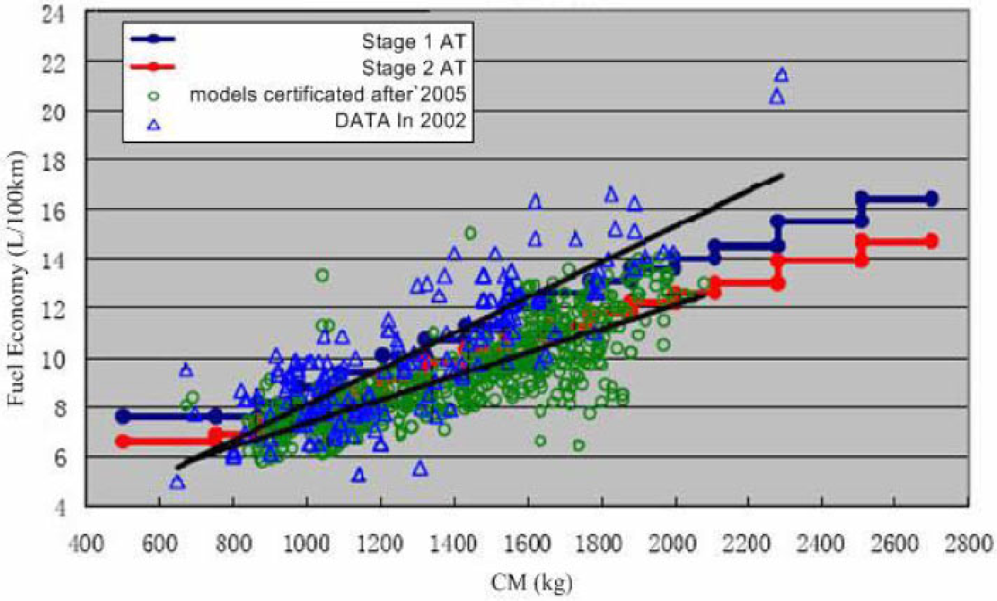
Source: Joint Government-Industry GHG MOU Committee, Canada

The National Development and Reform Commission announced in 2004 that it would introduce mandatory fuel efficiency standards for passenger cars. One of the objectives of these standards is to mitigate China's increasing dependence on foreign oil. The standards have two implementation phases: Phase 1 took effect in 2005 and Phase 2 will take effect in 2008.

The standards are classified into 16 categories based on vehicle weight. Standard values are set for each category. In addition, there are different standard values for manual transmissions and automatic transmissions. Compared with the Japanese regulation, which also has weight based categories, the Chinese standards tend to be harder on heavier vehicles than lighter ones. The figure below shows the phase 1 and phase 2 standard values for vehicles with automatic transmissions and fuel efficiency performances of vehicles sold in 2002 and those certified after 2005.

In order to be able to market a certain type of vehicle, manufacturers have to get the vehicle type certified to comply with the standards. The standard values are maximum allowable limits for each vehicle type, not the limits for the fleet average of the categories.

Figure 6: Chinese standards and vehicles' fuel efficiency performances



Source: IEA workshop presentation (2007) presented by Energy Foundation

Korea

Fuel efficiency targets have been in place in Korea since the 1990s. In addition, based on the Energy Utilization Rationalization Act, the Average Fuel Economy program and fuel economy rating identification of motor vehicles were introduced in 2005.

Current fuel efficiency targets are as follows with the target year of 2009:

25.1 km/l for displacement equal to 800cc or less,
22.3 km/l for displacement exceeding 800cc, and equal to 1 100cc or less,
19.4 km/l for displacement exceeding 1 100 cc, and equal to 1 400 cc or less,
18.2 km/l for displacement exceeding 1 400 cc, and equal to 1 700 cc or less,
13.5 km/l for displacement exceeding 1 700 cc, and equal to 2 000 cc or less,
12.4 km/l for displacement exceeding 2 000 cc, and equal to 2 500 cc or less,
10.8 km/l for displacement exceeding 2 500 cc, and equal to 3 000 cc or less, and
9.9 km/l for displacement exceeding 3 000 cc.

In 2005, this policy was strengthened so that the minister in charge may now make public the instances in which a manufacturer does not meet the designated target.

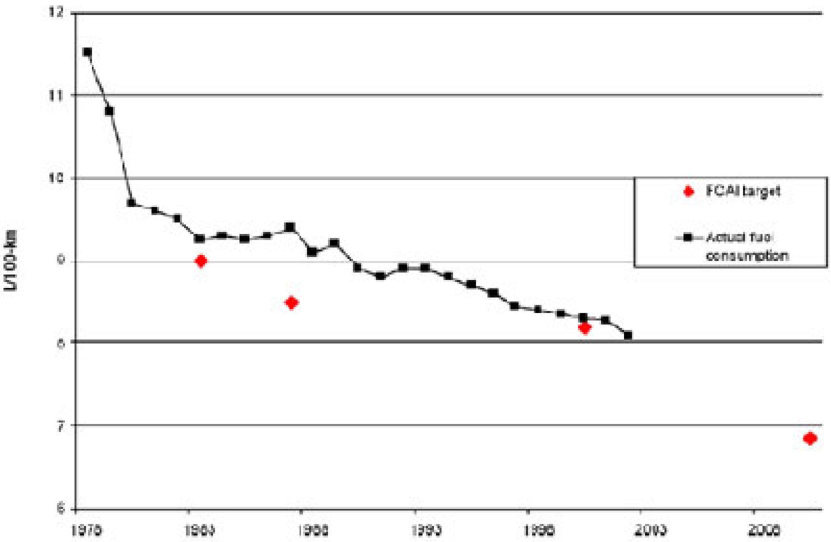
Furthermore, in order to strengthen the above-mentioned policies, the Average Fuel Economy program – similar to the US CAFE program – was also introduced in 2005 and applies to domestic vehicle manufacturers who have sold more than 1000 passenger cars annually. It is also likely to be applied to imported car manufacturers from 2010. The reference average fuel economy standards are 12.4 km/l for vehicles with engine displacement of 1 500cc or less, and 9.6 km/l for displacement exceeding 1 500cc. A credit calculated by specific formula may be granted. Vehicles are tested using the FTP 75 cycle (a test procedure used for US City mode). If a manufacturer falls short of the referenced average fuel economy, the minister in charge may issue an order of improvement. And if the order is not respected, he or she may announce,

among other things, the name of the manufacturer and a detailed model list, along with the degree of non-compliance against the referenced fuel economy.
Finally, a labelling scheme with fuel economy rating identification was also introduced in 2005. By virtue of this scheme, all passenger cars are required to display a “fuel economy label”, which indicates the car’s fuel economy rank (1-5) and its fuel economy (km/l).

Australia

The Federal Chamber of Automotive Industry (FCAI), which is an organisation representing the automotive industry in Australia, has developed a voluntary Code of Practice for reducing the fuel consumption of new passenger cars. The code commits FCAI members to a voluntary target of 6.8L/100km for petrol passenger cars by 2010. This represents an 18% improvement in the fuel efficiency of new vehicles between 2002 and 2010. The government reached agreement with the FCAI in 2003 on this voluntary target. The FCAI had previously adopted two voluntary codes of a similar nature, which included voluntary targets (Figures 7).

Figure 7: Australian Average Fuel Consumption and FCAI Targets



Source: Pew Centre

On a related issue, a mandatory fuel consumption labelling scheme was introduced in 2001. The scheme applies to:

- new passenger cars up to 2.7 tons gross vehicle mass - from 1 January 2001 and
- all new vehicles up to 3.5 tons gross vehicle mass - from 1 January 2004.

Under this scheme, a fuel consumption label is required to be placed on the windscreen of all new cars sold in Australia. These model-specific labels show the car’s fuel consumption in litres per 100 km, and its CO2 emissions per kilometre.

The Fuel Consumption Guide provides information based on tests conducted in accordance with Australian standards. Information for most models up to 2.7 tons, manufactured between 1986 and 2003, is available in an online database operated by the government and is publicly accessible.

Summary

Japan, China, Korea and the United States regulate the fuel efficiency of light duty vehicles by way of standards. The United States has the longest history of mandatory fuel efficiency standards, having introduced them in the mid-1970s. Japan followed in 1998 by adopting the "Top Runner" standards, under which next generation vehicles must meet the level of fuel efficiency of the current "top runner", in other words, the most efficient vehicles. China introduced regulatory standards for passenger cars in 2004, while Korea followed the next year.

The EU, Canada and Australia currently have voluntary programs for the promotion of vehicle fuel efficiency and two of these are moving toward regulatory programs. The EU first agreed on voluntary targets with industry associations in 1998. In December 2007, the European Commission announced a proposed registration to reduce CO_2 emissions from cars to 120g/km by 2012. A similar shift can be seen in Canada, which has an even longer history of voluntary agreements with the auto industry, having initiated such processes in the late 1970s. In November 2007, an act was passed to enhance the Canadian federal government's authority to regulate vehicle fuel efficiency. Regulations would take effect for the 2011 model year. Australia introduced several voluntary agreements. The Australian government reached agreement with industry in 2003 enact on the current voluntary targets; however, previous agreements were not complied with.

Additionally, both the United States and Japan have tax incentive (or disincentive) programs. Under the Japanese program, buyers of fuel efficient and less polluting vehicles are eligible to receive a tax deduction, while in the United States, customers of gas guzzler vehicles pay an additional tax levy.

Unlike many other regions, the EU regulates CO_2 emissions, not fuel efficiency. From 2011, Canada will regulate GHGs.

As mentioned above, each region has different policies to improve the technical fuel efficiency of vehicles. The following section assesses the effectiveness of the various policy approaches by analysing their binding power, standard design, standard stringency and standard-related policies.

III. Looking forward: identifying effective policies

As mentioned in Section I, the worldwide fuel consumption of LDVs could be lowered by as much as 15% and CO_2 emissions decreased by 590 Mt in 2030 if the policies and measures currently being considered were to be fully implemented. Section II reviewed vehicle fuel efficiency policies and measures, highlighting that selected countries tend to rely on a mix of measures to encourage greater fuel efficiency. But, how effective are those policies? Are some measures more effective than others, and/or have some countries been more successful in implementing them than others? This section assesses the effectiveness of policies to improve fuel efficiency with respect to nature of measures, standard design, standard stringency and standard-related policies.

Voluntary programs

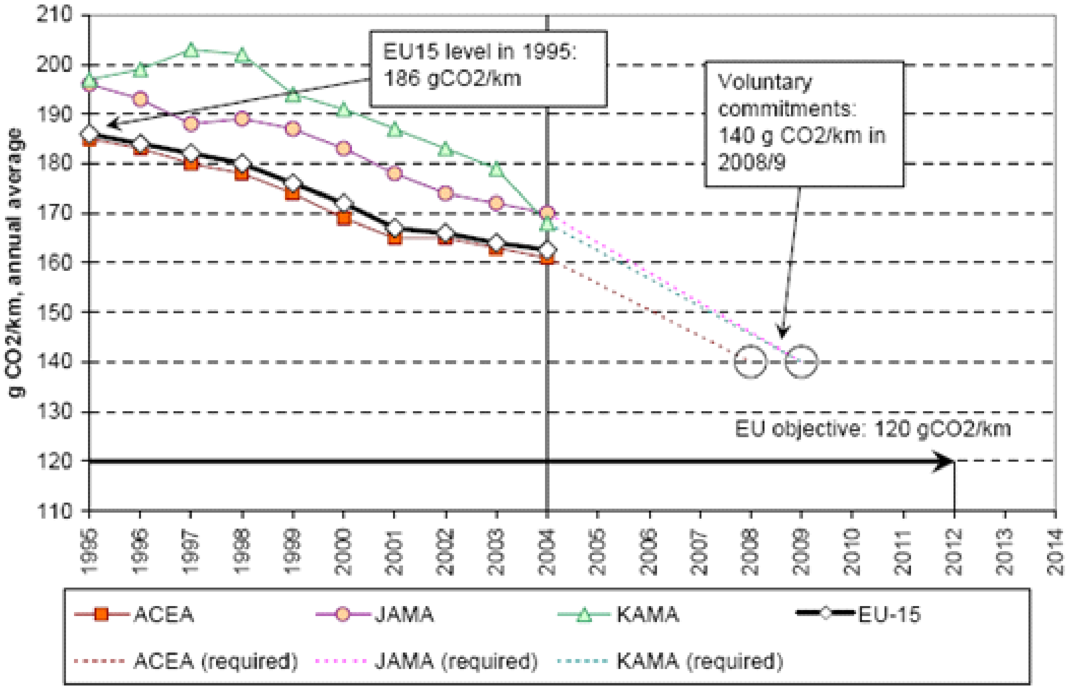
Voluntary programs were most popular during the 1980s and 1990s when it was generally thought that less government intervention would be appropriate to accomplish the greatest improvements in fuel efficiency, and the need to save fuel and reduce CO_2 emission seemed less urgent.

The European Union

Voluntary agreements were made by ACEA in 1999 and by JAMA and KAMA in 2000. In February 2007, the Commission issued a communiqué called "Results of the review of the Community Strategy to reduce emissions from passenger cars and light-commercial vehicles." In the communiqué, the Commission used, among other things, Figure 8, which illustrates CO_2 emissions from cars in Europe and concluded as follows:

> Emissions from the average new car sold reached 163 g CO_2/km in 2004, 12.4% below the 1995 starting point of 186 g CO_2/km. Over the same period, new cars sold in the EU became significantly bigger and more powerful, while prices increased less than the rate of inflation.
>
> Investigations into the impact of the limited demand side measures adopted thus far by member states indicate that improvements in car technology have delivered the bulk of reductions.
>
> The progress achieved so far goes some way towards the 140 g CO_2/km target by 2008/2009, but in the absence of additional measures, the EU objective of 120 g CO_2/km will not be met by 2012. As the voluntary agreement did not succeed, the Commission considers it necessary to resort to a legislative approach and has underlined that in addition to the proposed legislation, urgent action should also be taken by the public authorities to keep the emission reductions on track, also towards 2008/2009, for instance through fiscal incentives and green public procurement.

Figure 8: CO2 Emissions



Source: European Commission

Japan

Japan introduced two sets of non-binding targets to raise vehicle fuel efficiency, one with its target year of 1985 and the other with that of 2002,. These were voluntary in the sense that they were not provided for by law and attainment of the targets was optional, rather than mandatory. The average fuel efficiency in 1985 was below the first target. And before the second target was replaced by the regulatory standards in 1999, the average fuel efficiency had basically stagnated. This could have been caused by a change in consumer preferences, with the average mass of passenger vehicles increasing until the late 1990s. Some industry experts also claim that these trends were due to, among other factors, rapid growth in amenities such as automated transmissions and a moderate increase of heavier four-wheel-drive vehicles (4WD).

Canada

Canada currently has two voluntary programs that involve targets. One was introduced in 1976 and the other agreed with industry in 2005. The former has generally been achieving expected results. However, critics say that this is because the levels of the targets have been the same as the US CAFE standards that are mandatory ones and the Canadian automobile markets are highly inter-linked with the US market.

Australia

Australian automotive industries introduced two sets of voluntary targets in the past. Both programs seem to have contributed to fuel efficiency improvement but both failed to meet the target, partly because of changes in consumer preference (e.g. more and more people have bought bigger cars). Currently a third voluntary program is in force, with the target of 6.8 L/100 km for petrol passenger cars by 2010. An interim report will be available shortly.

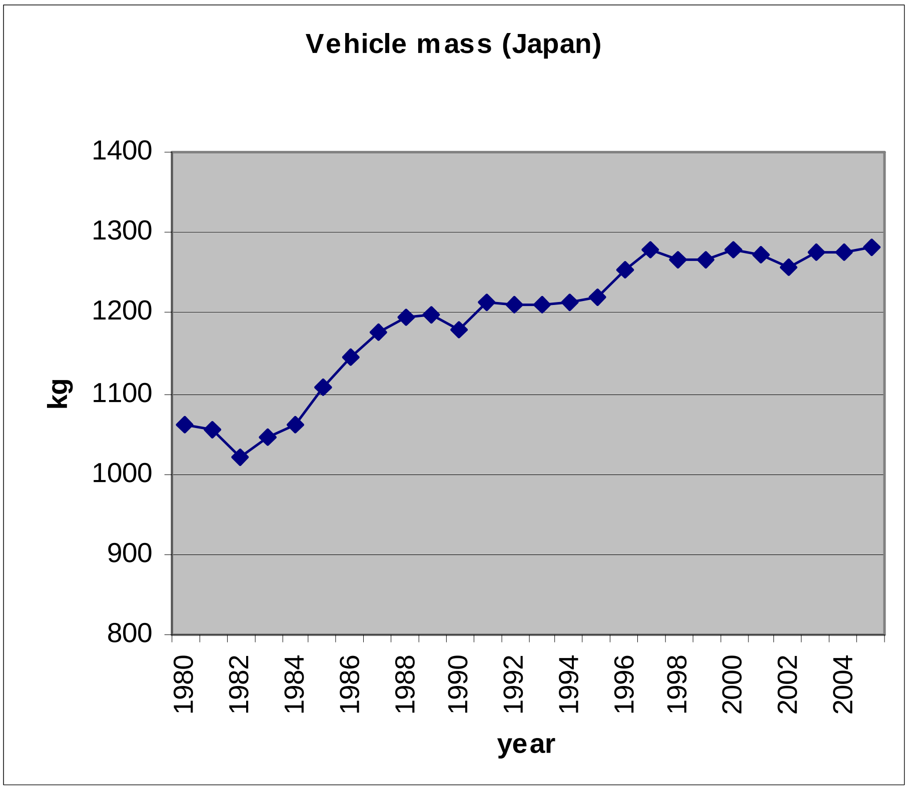
Regulatory programs

Until recently, only the United States and Japan had regulatory fuel economy requirements for LDVs. China and Korea have introduced regulatory standards more recently.

Japan

In 1999, binding standards set under the "Top Runner" program were introduced which required an average 23.5% in LDV fuel economy to be reached by the target year of 2010. Passenger car fuel efficiency has increased progressively since the late 1990s and about 80% of vehicles met the standards in 2004. Meanwhile, fleet average vehicle weight has not increased since the standards were introduced (Figure 9).

Figure 9: Average Vehicle Mass of Japanese Fleet



Some industry experts contend that the following social circumstances could have affected the observed fuel efficiency and vehicle mass trends:

- increase of ownership of small vehicles as a second car
- increased public concern for environmental issues
- economic depression during the 1990s
- space and parking constraints

However, none of these factors seems strong enough to explain this unique phenomenon of stable vehicle mass only seen in Japan after the late 1990s - it appears likely that binding standards played a substantial role. In addition, since the standards do not generally induce early compliance, other incentives, such as tax incentives, must have also significantly contributed to the fact that about 80% of vehicles reached compliance with the standards six years before the target year.

China

Phase 1 of the Chinese fuel efficiency standards took effect in 2004 and all new vehicle type introduced in 2006 or after has complied with the standards.

The United States

The CAFE program established in 1975 comprises two sets of standards: one for passenger cars and the other for light trucks such as SUVs. The average fuel economy of each group increased very rapidly from 1975 to the mid 1980s. This increase of more than 60% in a decade realized the short-term goal of the Energy Policy Conservation Act to double new car fuel economy by 1985 and fleet average fuel economy has always been above the standards. Having said that, it should also be noted the average fuel economy of each group has been almost constant or slightly decreasing since the late 1980s partly because no new standards with more stringent targets has been introduced. Worse, when the two groups are combined, the average fuel economy has been deteriorating for quite some time due to the fact that the ratio of light trucks that are less fuel efficient has been increasing.

Summary

Four countries and the EU have (or had) voluntary programs, whereas four countries have regulatory with binding standards. The outcome of voluntary and regulatory programs is shown in Table 5.

Table 5: Outcome of Voluntary and Regulatory Programs

	Regulatory standards			Voluntary targets		
	Year established	Target year	Outcome	Year established	Target year	Outcome
Japan	1999 2007	2010 2015	A*	1978 1993	1985 2002	F** F
European Union				1995 1999	2012 2008	F
United States	1975 2006	each MY	A			
Canada				1976 2005	Each MY 2010	A
China	2004 2004	2005 2008	A			
Australia				1978 1987 2005	1987 2000 2009	F F
Korea	2005	2006		2005	1996 2000 2009	

***A = achieved   **F = failed**

Design of Standards

A poorly designed standard may be worse than no standard at all because it could encourage the adoption of inappropriate technologies, unnecessarily raise the cost of compliance, and/or possibly result in unsafe vehicles, among other unintended outcomes. For these (and other) reasons, the broader design of a standard needs to be carefully considered. The discussion below outlines the most important considerations in the design of fuel efficiency standards.

Scope

The scope of a fuel efficiency standard is often determined by legislation. However, a narrow scope may limit the potential fuel savings. It is therefore important to establish as broad a scope as possible in the original mandate for fuel efficiency standards. One limitation on the scope of a standard may be the range of vehicles to which it applies. Consumer preferences may change and cause an increase in the number of vehicles manufactured outside the range originally considered (and therefore exempt from the standards). Such "leakage" was one of the major issues in the United States' fuel economy program as consumers switched from regulated automobiles to unregulated huge light trucks and sport utility vehicles. The program was reformed in 2006, extending its scope. At this time, the US Secretary of Transportation claimed that the reformed standards for light trucks would save more than 250 million gallons of fuel a year by including the largest sport utility vehicles on the market, which today weigh between 8 500 and 10 000 pounds.

A second consideration in relation to standard scope is the extent of coverage of types of vehicles. So far, most fuel efficiency programs have focused on passenger vehicles, to the exclusion of freight vehicles, partly because freight vehicle owners have traditionally been considered to be conscious of fuel efficiency and, thus, government intervention was less necessary. However, the general perception on this issue seems to be changing rapidly. Japan started regulating trucks and buses in 2006, while the European Commission proposed to set standards for light-commercial vehicles (vans) in February 2007.

A third consideration concerns the aspects of fuel consumption covered by a standard. All present fuel efficiency standards are based on dynamometer tests in which certain components are either switched off or not fully exercised. As a result, the fuel consumption caused by air conditioners and lights, for example, is not reflected in test values. It is therefore possible that manufacturers have devoted less effort to improving the efficiency of such components. The European Commission is proposing to broaden the scope of standards to include technological improvements other than vehicle engine technology that can be measured, monitored and accounted for and that will not involve double-counting, such as tyres and air-conditioning systems.

It should be noted that the IEA has been working on studying policies and measures to raise on-road fuel efficiency as well. Although this paper focuses on measures to improve tested fuel efficiency, the IEA recognizes the importance of measures to improve fuel efficiency of components that are not covered by fuel efficiency tests, and those to promote environmentally friendly driving behaviour. The IEA published a separate paper in 2007 that specifically focused on the fuel efficiency of road vehicle non-engine components (Onoda and Gueret, 2007).

In general, the wider the scope, the more robust and cost-effective the policy is. However, there may be cases where the cost to broaden the scope is relatively high.

Box 1: Is fuel efficiency standard necessary for freight vehicles?

As noted above, it is now recognised that market forces alone may not be sufficient to bring all cost-effective fuel efficiency technologies onto the market. Fluctuating fuel prices and lack of information on individual models facing private and smaller operators may be barriers for some segment of the commercial trucking HDV market. Manufacturers may also be affected by the risk of investing in such innovative technologies.

In Japan, fuel efficiency standards for heavy duty vehicles came into effect in April 2006, representing the first time in the world that this had occurred. Introducing these standards involved addressing the challenge not only of the above-mentioned conventional wisdom, but also the challenge of measuring a wide variety of heavy duty vehicles without placing too great a burden on manufacturers. The latter issue has been addressed through the introduction of a new test procedure, which utilizes state of the art computer simulation methods. The standards require an average fuel efficiency improvement of about 12% from the 2002 level.

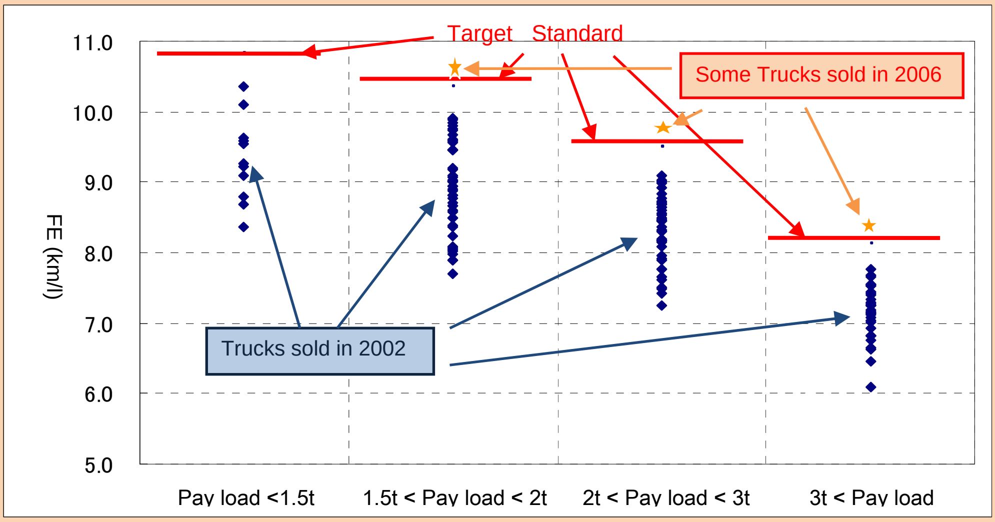
Some trucks and tractors have already met such stringent standards. It should be noted that trucks and tractors sold after 2005 should meet ten times more stringent particular matter (PM) regulation and twice as stringent nitrogen oxide (NOx) regulation, which, according to one estimate quoted by the Japanese government, generally lowers fuel efficiency by around 5 % (National Transport Safety and Environment Laboratory, 2007).

Vehicles which have met the standards at this early stage have been equipped with many of the world's most innovative technologies including Selective Catalytic Reduction and HDV Hybrid Systems.

Japan will introduce very stringent emission regulations in 2009 that, according to a report to Japanese government (Automobile Evaluation Standards Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy and the Automobile Fuel Efficiency Standards Subcommittee, Automobile Transport Section, Land Transport Division of the Council for Transport Policy, 2007), would have a negative effect on fuel efficiency of 7 to 10 percent.

Therefore, it is still not perfectly clear whether vehicles complying with the regulations can meet the fuel efficiency standards. However, early results from Japan imply that fuel economy standards for HDVs are technically feasible and result in fuel savings, although some further in-depth analysis will be needed (Figure 10).

Figure 10: Fuel efficiency performance of HDVs in Japan



Source: MLIT Japan

Test procedures

There is growing pressure from the public to make tested fuel efficiency values close to on-road fuel efficiency values. Accordingly, governments are trying to make their test procedures accurately represent actual driving patterns. At the same time, the goal of increased realism must be balanced with the higher costs of these tests. Some of the trends in test procedures are described below.

In the United States, the Environmental Protection Agency (EPA) announced a final rule in 2006 on new testing methods for calculating the fuel economy estimates. By using the data obtained from the local pollutant emission tests, the new testing methods are designed to replicate three real-world conditions which can significantly affect fuel economy: high speed/rapid acceleration driving, use of air conditioning, and cold temperature operation. Japan will also introduce new test procedures for the 2015 standards that were announced in 2007. It is the same method as for the soon-to-be-introduced local pollutant emission tests, and designed to take into consideration high speed/rapid acceleration driving condition and the effect of a cold start.

The more a government tries to make test procedures simulate real traffic conditions well, the more it costs to test vehicles. One efficient way is to use the same test procedures for fuel efficiency policy and local pollutant emissions regulation. Another merit in using the same test procedures for both fuel efficiency standards and local pollutant emission regulations is that it could be a precondition to require the high fuel efficiency and low pollutant emissions at the same time. Given the fact that sometimes there is a trade-off between efficiency and lower emissions, testing these under the same conditions would be very important. Currently countries are generally using the same or similar test procedures for measuring both fuel efficiency and local pollutant emissions.

International harmonization could be another way of decreasing the cost of complex test procedures, although this would be very difficult to achieve at least in the short term. There are several other efforts worth noting.

- Chinese standards, as well as new Japanese 2015 standards have target values in each class, divided by vehicle mass. The classes are the same as those used in internationally harmonized regulations for emissions established in the United Nations Economic Commission for Europe/Working Party 29(UNECE/WP29).
- UNECE/WP29 has established globally harmonized test procedures for motor cycle and heavy duty vehicle emission regulations and is considering starting an activity to establish a similar test procedure for light duty vehicles.

Technology neutrality

Giving certain technologies good treatment in fuel economy standards may end up hindering overall fuel efficiency improvement.

In the United States, there is special treatment of vehicle fuel economy calculations for dedicated alternative fuel vehicles and dual-fuel vehicles which can get much higher fuel economy figure than the actual ones in order to promote these vehicles from an energy security perspective. As for dual-fuel vehicles, however, a report by the National Academy of Science (citation) argues that they should be treated equally with gasoline vehicles, since they are hardly contributing to energy security in reality as they are nevertheless fuelled by gasoline.

Generally speaking, requirements based on technologies (not based on fuel efficiency performance) could favour certain kinds of technologies (in the above-mentioned case, dual fuelled vehicles), which may result in unhealthy circumstances for technology development.

But there are some exceptions. For example, different local pollutant emission regulations and fuel quality regulations could result in different fuel efficiency requirements. In Japan, current 2010 standards treat gasoline vehicles and diesel vehicles differently, partly because current pollution regulations for diesel vehicles are not stringent, compared to those for gasoline vehicles. In such a case, a different treatment would be desired in terms of preventing local pollution. New 2015 standards will treat gasoline vehicles and diesel vehicles equally because local pollutant emissions from diesel vehicles after 2009 will have to be as clean as those of gasoline vehicles due to 2009 local pollutant emission regulations.

Regulatory flexibility

Governments have made several efforts to make their programs flexible by introducing weighted average targets, including manufacturer fleet average targets, attribute-based targets and credit trading systems. Weighted average criteria allow the average fuel efficiency of vehicles to meet targets. In the case of manufacturer fleet average targets, manufacturers are required to achieve their weighted average fuel efficiency of their fleet to meet the targets. Attribute-based targets separate vehicles into classes by vehicle attributes, such as weight or size, and set different targets for each class. While weighted average criteria allow fuel efficiency "surplus" of vehicles within a group to offset "deficits" of other vehicles within the same group, credit trading systems allow the "surplus" of a group to offset "deficits" of other groups, and can be applied between manufacturers or between attribute-based classes.

In Japan, standards for each category based on vehicle weight and weighted average criteria have been adopted. A credit trading system will be introduced in the new 2015 standards. The Japanese standards generally have a lead time of around ten years.

In the European Union, the Commission in the 2007 communiqué proposed the legislative framework designed to ensure competitively neutral targets, implying that the introduction of more flexible attribute-based standards could ease heavy burdens on specific manufacturers.

In the United States, targets defined by a continuous function relating to vehicle size or "footprint" (see figure 4) were introduced in 2006 when the CAFE standard for light trucks was reformed. Average weighted criteria and a credit system have been adopted. As for the above-mentioned reformed CAFE standard, a transitional period of five years was introduced, during which time manufacturers can choose to use the original CAFE framework. Partly in order to shorten the lead time for enforcement, NHTSA, in the process of reforming the standards, requested manufacturers to submit their confidential future business plans in order to assess manufacturers' individual abilities to comply with the standards in the short term.

Perhaps the simplest and most robust regulatory design is to require all vehicles to meet a single fuel efficiency target. Manufacturer fleet average targets and tradable credits can be used to allow manufacturers to over- or under-comply in a manner that maximizes cost-effectiveness. They could not only reduce the total cost of compliance but also induce incentives for manufacturers to produce more efficient vehicles than their standards, since the more a manufacturer produces vehicles well above the standards, the more choice the manufacturer can have.

However, there are often concerns with such an approach, including:

1) difficulties in managing trading systems efficiently (without centralized vehicle registration data systems, for example, it would be costly to collect the data necessary to run the trading systems);

2) equity concerns between manufacturers (likely to impose burdens to comply with the requirement to specific manufacturers such as the ones making mostly luxury – and usually less fuel efficient – vehicles);

3) possible safety and social welfare impacts, by encouraging excessive down-sizing of vehicles (likely to exist only when the average fuel efficiency target is very ambitious with respect to the technological potential); and

4) difficulties in estimating costs of compliance (although possible consumers' unwillingness to buy too expensive vehicles could motivate manufacturers to reduce the average size of their vehicles, guaranteeing that the costs would not skyrocket -smaller vehicles are cheaper and consume less fuel- and assuring that all manufacturers have the potential to achieve the standard).

Approaches using other flexibility mechanisms have been employed in a number of countries (e.g. weight-based standards in Japan and China and size-based standards in the United States) and they may address some of these concerns. They would foster an environment that is equally competitive for all vehicle manufacturers and would make it easier for governments to set a more stringent level of targets. It should be noted, however, that attribute-based standards would not assure the achievement of an overall improvement for vehicle fuel efficiency, as they are subject to weight or size shifts. (Even if manufacturers met all the standards set for each class, for example, if the number of vehicles in the less stringent class increased, overall average fuel efficiency would worsen and vice-versa). Therefore, thorough consideration should be given to preventing any increase of average vehicle weight or size. In this regard, the development of the average vehicle weight in China and Europe, where relatively stringent standards are or will be imposed on heavier vehicles, should be carefully monitored.

Critics may claim that the flexibility would lower the level of achievement by the standards. This could happen if the flexibility is introduced after the level of standard stringency is set. However, if the forms of flexibility have already been introduced when level of stringency is considered, as is often the case with most of the economic tools, a higher level of stringency could be set by providing ways to level the marginal costs of compliance and consequently lower the overall compliance costs.

Lead time would also be an important factor for lowering the cost of compliance, by providing manufacturers with time to work on improving the fuel efficiency of their fleet. An appropriate lead time would contribute to both lowering the cost of compliance and equity among all manufacturers. According to industry experts, the development of a new car model is a lengthy process and in order to lower the cost of introducing fuel efficient technologies, the technologies must be included in the developing process. Therefore, if the lead time is shorter than the general duration of model life, the measure could require manufacturers to introduce such technologies to some existing models, which could be very costly. In addition, since different manufacturers have different points in the manufacturing cycle at which they replace models; a shorter lead time would be a burden to some manufacturers but not to others.

Box 2: Comparison of Weight-based Standards and Size-based Standards

Choosing an appropriate attribute is crucial to realizing an overall improvement in fuel efficiency. In the United States, a light truck class was introduced in the late 1970s, making the CAFE program the first one to have two classes. Vehicles are divided by vehicle type (passenger car or light truck) which, unlike vehicle weight, is only partially proportionate to fuel efficiency. Because of the shift from a class with a more stringent standard to the one with a less stringent standard, overall vehicle fuel efficiency has been declining since the mid-1980s.

Currently Japan and China are using weight-based standards, while the United States has introduced a size (footprint: wheel base times track width)-based standard for light trucks. A frequently asked question is which approach would be better.

As previously mentioned, history has shown that in Japan, fleet average vehicle weight has not increased while overall fuel efficiency has increased since the regulatory "Top Runner" weight-based standards were introduced. As noted above, there may be other social factors that explain this. Nevertheless, it appears likely that the weight-based standards played a substantial role in fuel efficiency and vehicle mass trends.

Since size-based standards have not been used before, it is not possible to evaluate any quantitative results. It will be important to monitor the new initiatives by the US government so that the relative value of the two approaches can be assessed.

The following are some possible arguments for weight-based and size based-standards. In these arguments, effectiveness of vehicle weight reduction could be one of the issues. Concerning this, it should be noted that although vehicle weight reduction could be achieved through down sizing or through material substitution, the latter, namely, vehicle weight reduction through material substitution is argued here. It is true that down sizing is one of the most important options for better fuel efficiency. However, as mentioned above, whether down sizing could be promoted depends on the design of the standard. Attribute-based standards, whether they are weight-based or size-based, could promote down sizing if the standards impose relatively stringent requirements on heavier and larger vehicles. Therefore, down sizing is not argued here.

Weight-based standards:

There is a clear reason to differentiate standards on the basis of weight. According to the law of physics, energy is in direct proportion to mass. Because of this, heavier vehicles with the same technologies, in theory, could not achieve the same fuel efficiency as lighter ones. Therefore, if the primary objective of introducing attribute based standards is to cope with equity concerns between manufacturers, standards should be defined based on vehicle weight.

There could be a technology neutrality concern, however, that weight-based standards might reduce the attractiveness of, for example, material substitution over engine technologies because under weight-based standards, introducing lighter material tends to play a lesser role in contributing to standard compliance and thus such standards could provide less incentive for manufacturers to do so. This concern is particularly evident if it is considered that government intervention would be necessary to promote the introduction of whole range of innovative technologies for fuel efficiency.

However, as will be explained later in further detail, the market could be effective enough at ensuring the deployment of the wide variety of technologies but less effective at ensuring that such technologies are used to improve fuel efficiency. Since material substitution, if introduced, would raise both fuel efficiency and "acceleration", while engine technologies in general could be used to improve "acceleration" at the expense of fuel efficiency, if governments left the market to promote deployment of innovative technologies and intervened only to make sure that technologies are used to improve fuel efficiency, focusing on the latter technologies may not raise the issue of technology neutrality much.

With the combination of market forces and government intervention, materials substitution and engine technologies could contribute to improving fuel efficiency in this case.

Size-based standards:

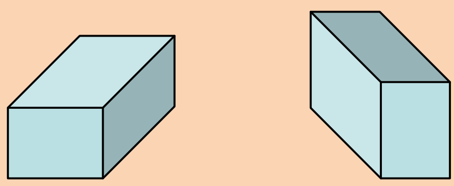
Size-based standards are consumer-friendly. People tend to buy their cars on the basis of size, not weight. They would be more interested in comparing the fuel efficiency of vehicles with similar size than comparing the fuel efficiency of, for example, sports cars and vans with similar weights.

This approach is technology neutral. It is up to manufacturers to determine which measures should be used to increase fuel efficiency, material substitution or engine technologies, for example.

However, there could be a weakness of reasoning in the differentiation since, unlike weight, size is only indirectly proportionate to energy required. One of the primary reasons for introducing attribute-based standards is to lessen the inequality among manufacturers of the burden of complying with such standards, with the hope of making it politically easier to set more stringent standards. In order to lessen inequality, the attribute should be proportionate to energy required. In addition, classes divided by an attribute that is not proportionate to energy required could provide a loophole in the entire system. There is no reason why a large footprint which does not necessarily have to require large energy by the laws of motion, for example, should have a less stringent requirement. An example of vehicle shapes with similar fuel efficiencies and different footprints is shown in Figure 11. The two different shaped vehicles have different footprints but could have similar weights, aero dynamic drag and technologies – and therefore have similar fuel efficiencies. Distinguishing between them without clear technical reasons for doing so might hinder the achievement of overall fuel efficiency improvements by inducing vehicle shifts to classes with less stringent requirements (in this case, manufacturers could increase production of flat shaped and less fuel efficient vehicles). In the US, the standard for the light truck class has been less stringent than that for the passenger car, which could have contributed to the increase of less fuel efficient light trucks, resulting in the decrease of average fuel efficiency of overall fleet (passenger cars plus light trucks).

It could be argued that size-based standards contribute to vehicle safety by inducing an increase in vehicle footprint. Others, however, could argue that large vehicles *are* threats to road safety. Regarding road safety, the following two factors at least should be considered: passenger safety and whole road traffic safety (including aggressiveness of a vehicle toward other vehicles). Passenger safety could or should be assured by vehicle safety regulations and various vehicle safety programs, including NCAPs (new car assessment programs, which are available in many countries). Safety regulations or the safety programs may not be effective in reducing the aggressiveness of large, and therefore heavy, vehicles (a collision of vehicles with different vehicle weights or sizes tends to have more severe consequences). However, this could be solved by, among other factors, down-sizing of the overall vehicle fleet. Such down-sizing could be achieved by setting appropriate slope of the attribute-based standards (whether they are size-based or weight-based) so that they could be relatively stringent on heavier and bigger vehicles.

Figure 11: Example of vehicle shapes with similar fuel efficiencies and different footprints



Standard stringency

When a standard is considered for its introduction, setting the level of stringency of the standard is one of the most difficult parts of the process, not only from a political, but also a technical point of view. Different approaches exist for setting energy efficiency targets. One approach is to set targets so that life-cycle costs can be minimized, which is used to set appliance efficiency standards in several countries and regions, and which is used as part of the approach to set CAFE standards and the European Commission's proposed regulation on CO_2 emission from cars. In some cases, this approach includes estimates of related externalities, such as oil security.

One of the difficulties with this approach is to properly estimate the cost of future technologies. A report commissioned by the European Commission concludes that in many cases, the ex-ante estimates were about twice as large as the ex-post results, but in some cases the differences were either much larger or there was hardly any difference at all. This is partly because information necessary for the estimates is crucial for competence of each manufacturer and thus in many cases not publicly available, and therefore the estimates must be done with limited information. In addition, the cost of many technologies generally changes dramatically over time from relatively expensive when first introduced to market to almost negligible when widely deployed.

Japan uses a different approach, known as the "Top Runner" programme, whereby the standard levels are defined based on the performance of the most fuel efficient vehicle on the market. Under this program, the value of the mass produced vehicle with the highest fuel efficiency is used as a base value. Positive impacts on fuel efficiency, including those by future widely available technologies, as well as negative impacts, such as effects of future safety and pollutant emission regulations, are also taken into consideration to determine the level of standards.

When the level of standards is considered, governments could also take into account the standard stringency of other countries to complement the above-mentioned approaches. This would increase the transformative market effects upon the global automobile market. In fact, there are several studies to compare the stringency of different standards, but this kind of comparison is difficult because of the existence of: different policy objectives, different test procedures, different emission regulations, different compliance methods, different size mixes and power levels, etc. Some governments set standards to save oil consumption while others try to curb CO_2 or GHG emissions (including emissions other than CO_2). Although there have been some trials which have attempted to do so, test procedures in different regions could be difficult to compare, partly because some vehicles may be fuel efficient under one test procedure while others might be fuel efficient under another test procedure due to the optimisation of vehicles in each market and so on. Diesel vehicles, which are more fuel efficient by roughly 30% than gasoline vehicles, are not available in some regions because of their local pollutant emission. One government requires all vehicles to meet the standards while others require the average of fleets to meet the standard. Under these circumstances, even the standards with the same standard values under the same test procedures would have different impacts on vehicle manufacturers.

However, within each region, the improvement of fuel efficiency as measured by each region's test procedure is a good measure of the relative improvement that a standard requires. Therefore the improvement rate required by fuel efficiency standards in selected regions is reviewed and analysed.

The goal of this comparison is to review each government's level of policy ambition to improve fuel efficiency or to reduce CO_2 emissions at the time that a regulatory or legislative action is developed. It should be noted that analysis of appropriate levels of absolute standard values that require additional application of cost-effective, innovative technologies in a specific region is, nonetheless, essential, but not carried out here, partly because of limited access of the necessary data.

Methodology

In order to compare overall and annual outcomes of current policy initiatives, it is important to clearly identify the starting year. The guiding principle for this analysis is the starting year as determined by the year in which data are used as the baseline performance that guided the regulatory agency or legislative body when the initiatives are developed.

Magnitudes of improvements required by both the Japanese 2015 standards and the European Commission's proposed standards are shown in Figure 12. In both cases, the year 2004 is treated as the base year because both the government report recommending Japanese 2015 standards published in February 2007 and the accompanying document to the European Commission's communiqué proposing 130 g CO2/km issued in February, 2007 use data in 2004 as baseline performance. (In December, 2007, the European Commission issued another document assessing the impact of different regulatory designs in which 2006 data were used, but the impact of introducing 130 g CO2/km assessed in the earlier document is still relevant here.) The new Japanese standards require the average fuel efficiency of passenger cars to increase from 13.6 km/l in 2004 to 16.8 km/l in 2015. Therefore, fuel efficiency improvement required by the standards is 24% in 11 years. In the EU, the European Commission proposed a standard of 130g CO2/km in 2012 for passenger vehicles. Since the average CO2 emission from passenger cars in 2004 was 161 g CO2/km, the fuel efficiency improvement rate required by the standard would be 24% in 8 years.[7] It should be noted that the EU uses CO2 (emissions produced), whereas Japan uses km/l (fuel efficiency), and that for an accurate comparison of percent improvement, these terms must be translated into the same type of unit.

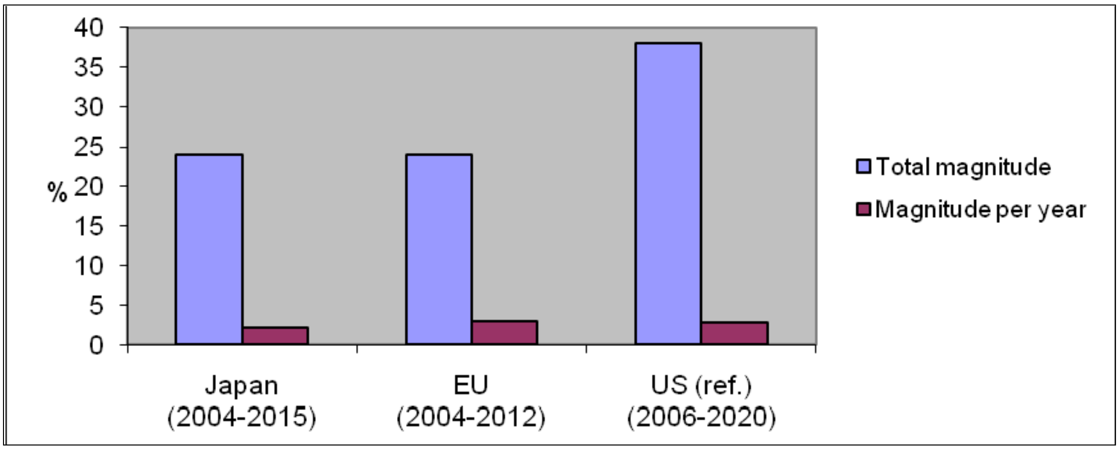
There are several mathematical reasons for comparing equivalent or identical units: (1) fuel efficiency is the inverse of emissions-based metrics, and (2) percent improvement will vary depending on the magnitude of the numbers chosen. Since this paper discusses efficiency, the fuel efficiency target has been chosen as the metric for such comparisons. Specifically, we used the reciprocals of the EU data to calculate its percentage progress. For Japan, as well as the United States, the original data were used for such calculation. In the United States, the new law[8] stipulates that the standards must be set at levels of stringency that achieve a fleet-wide industry combined passenger car – light truck fuel economy level of 35 mpg by 2020. However, standards have not been finalized yet, and therefore stringency of the standards is still unknown. Having said that, if the figure in the law is used to set values for reference, since the latest official figure of the combined fleet average fuel economy is 25.3 mpg in 2006, the magnitude of improvement would be 38.3% in 14 years.

Using the United States government's current practices as far as degree of improvement is concerned, the difference between existing standards (not current actual fuel efficiency) and the new standards could be presented. The new US law would require a 40% increase in ten years if this calculation method were applied (25 mpg in 2010 and 35 mpg in 2020). In the case of the

[7] It is assumed that the percentage of gasoline and diesel to fuel is the same.
[8] The Energy Independence and Security Act was signed into law in 2007.

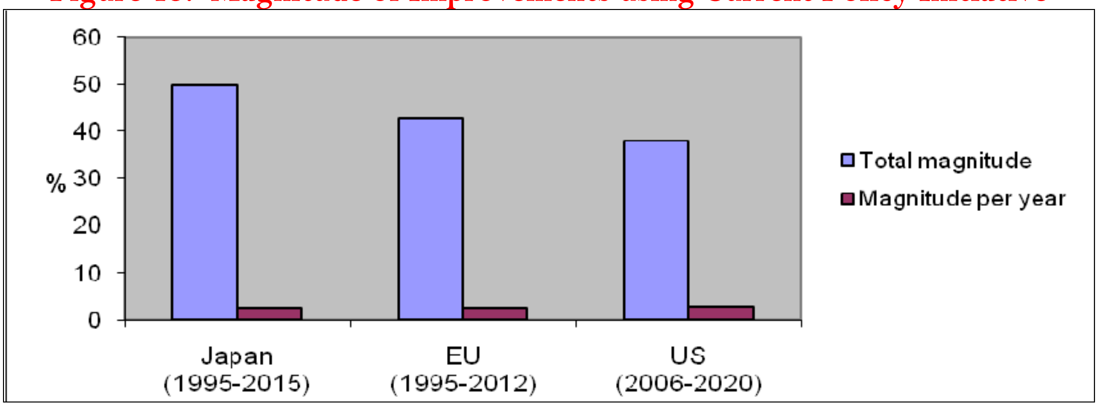
new Japanese standards, if the similar method were applied, the degree of improvement would be about 29% in 5 years (13.0 km/l in 2010 and 16.8 km/l in 2015). However, in both cases, current actual fleet average fuel efficiencies are above the standards well before the target year of existing standards. Therefore, the real impacts of the new targets on manufacturers would not necessarily be as big as the figures imply.

Figure 12: Magnitude of Improvements using Current and Proposed Standards



Using instead the magnitude of improvement of the current policy initiatives instead of-- the standards -- produces different results. Incidentally both the current Japanese "Top Runner" program and the EU strategy to reduce CO_2 emissions were introduced in 1995. As mentioned above, in the United States, Energy Independence and Security Act was signed into law in 2007.[9] Magnitudes of improvement of each policy initiative are shown in Figure 13. Passenger car average fuel efficiency in Japan in 1995 was 12.3 km/l and the average CO_2 emission from passenger cars in Europe was 186g CO_2/km. Therefore, it can be said that the "Top Runner" program requires a 50% fuel efficiency increase[10] in 20 years and the proposal from the Commission calls for a 43% increase in 17 years.[11] The new US law, as mentioned above, requires a 38.3% improvement in 14 years.

Figure 13: Magnitude of Improvements using Current Policy Initiative



From Figures 12 and 13, it can be said that from 1995 to-date, the Japanese vehicle fleet has improved its average fuel efficiency more rapidly than the European fleet, partly because of the

[9] The latest available data are those from 2006.

[10] The fact that using the new test procedure introduced in 2007 decreases fuel efficiency by about 10% is taken into account.

[11] It is assumed that the percentage of gasoline and diesel to fuel is the same.

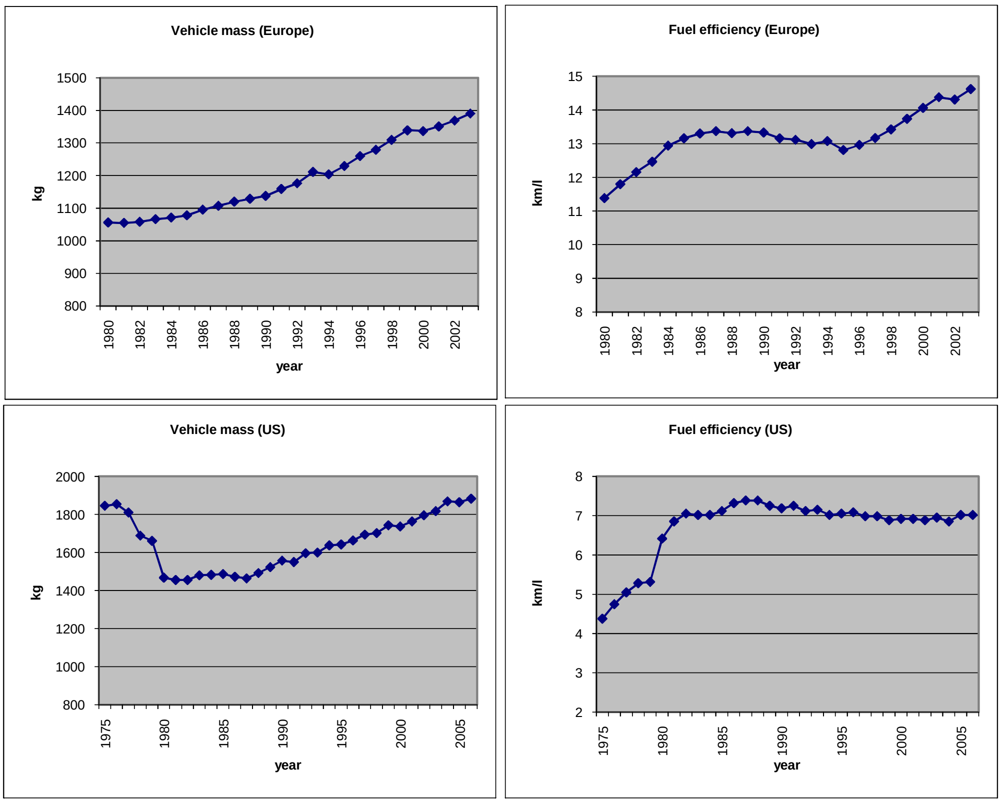
increase in European vehicle weight. As a result, the European Commission's proposed new standard is more ambitious than the new Japanese standards.
In any event, it could be said that these three policy initiatives have the ambition of achieving an annual improvement rate of more than 2.5%. Although these figures only show the combination of past trends and ambitions of various policy initiatives and different figures could be drawn by, for example, treating a different year as the base year, this kind of analysis, if combined with detailed country-by-country analysis, could complement the well-established approaches like the least life cycle cost analysis and the "Top Runner" program.

Governments' role in improving technical fuel efficiency of vehicles

One might argue that a 50% improvement in 20 years in Japan or a 43% increase in 17 years proposed by the European Commission might be too stringent to be cost-effective. What follows is an analysis of whether such stringent targets would be costly to society.

ACEA, the European car industry association, claims in its statement on its website, "the car industry supports reducing CO2 emissions", that the European car industry invests as much as EUR 20 billion (4% of turnover) per year in R&D and that over the last decade, the industry has incorporated more than 50 new CO2-cutting technologies into their vehicles. Meanwhile, when we see trends of vehicle mass and engine power, vehicles continue to grow and become more powerful, while fuel efficiency has not developed in such a constant way. Trends of fleet average vehicle mass and fuel efficiency in Europe and the United States are shown in Figure 14. In both regions, innovative technologies continue to be applied to vehicles to make them bigger and more powerful, but not necessarily more efficient.

Figure 14: Trend of fleet average vehicle masses and fuel efficiencies



Note: In Europe, the share of diesel vehicles began to increase in the mid-1990s.

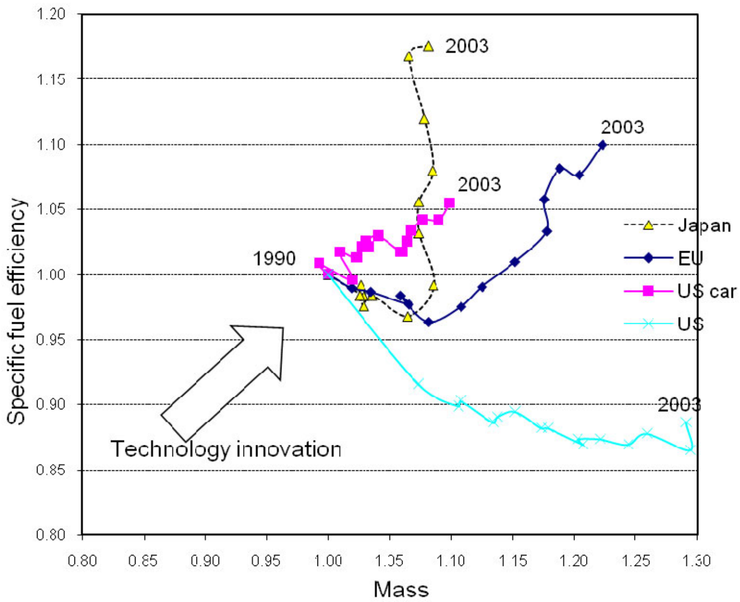
Figure 15 shows trends of average fuel efficiency and average vehicle mass after 1990. The yellow line shows data for Japan, navy for the EU, pink for US passenger cars and light blue for US passenger cars plus light trucks. The yellow line shows upward trends after the Japanese government introduced regulatory standards in the late 1990s, while other lines move towards the right. If the level of standards is set in a way that it could prompt manufacturers to shift application of technology innovations from making bigger and heavier vehicles to making them more fuel efficient (i.e. making the line move upward), manufacturers could significantly reduce the compliance cost, and drivers could enjoy improved fuel efficiency without a substantial increase of cost. Japan had a 24% increase in fuel efficiency (annual improvement rate of 3%) from 1996 to 2004.[12] It seems to be have been realized more by making the line upright (keeping the average vehicle mass constant) than by additional technology forcing (similar vehicles with similar technologies made by global manufacturers can be seen widely). Taking these numbers into consideration, it could be said that a 50% increase in 20 years or a 43% increase in 17 years, both of which correspond to an annual increase rate of 2.5%, could be achieved with minimal additional cost to manufacturers and consumers. Even higher rates may be justified, depending on the situation in each country.

A standard with substantial, steady annual improvement rates would help force additional technologies to be introduced, which might raise prices of new cars, but the increased cost could be covered by fuel savings from improvements in fuel efficiency.

It should also be noted that regulatory mechanisms may impose additional costs (monitoring/compliance/inefficiencies in the market etc). Although these additional costs appear to be more than outweighed by the benefits of certainty that regulatory mechanisms can deliver, these costs also vary, depending on the situation in each country.

Therefore, ddetailed, country-by-country analysis is needed to determine the optimal annual increase rate in each country.

Figure 15: Fuel efficiency and mass trends (1990=1)



[12] Average fuel efficiency measured in 10/15 mode was 12.1 km/L in 1996 and 15.0 in 2004.

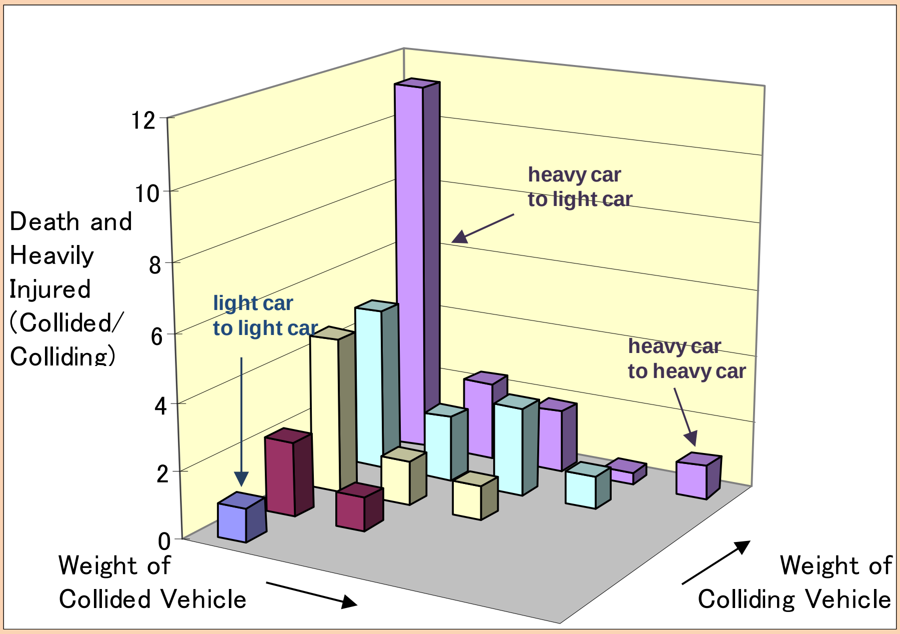
Box 3: Policies for Average Fleet Mass Management

If a standard which seeks to realize a very rapid increase in average fleet fuel efficiency is introduced, vehicle downsizing could occur. There is little experience with vehicle downsizing. Trends have always been for vehicles to get bigger and heavier, except during the aftermath of the 1970s oil crises in all three regions and after the late 1990s in Japan. In the United States from 1975 to 1982, the LDV average fleet fuel efficiency increased more than 60%. During that period, the LDV average fleet vehicle mass fell more than 20%.

Trade-offs between vehicle fuel efficiency and vehicle safety have long been a concern among the public. The majority of members of a sub-committee of the National Research Council of the United States concluded that the weight reduction and down-sizing affected by CAFE standards might have contributed to more than 1000 additional traffic fatalities in 1993. The same conclusion, however, may not be reached in the future, partly because new cars now have to comply with crash worthiness regulations and manufacturers are under heavy pressure to make vehicles safer as a result of new car assessment programs that give consumers information on the level of occupant protection provided by vehicles in serious crashes. Recent peer-reviewed research has concluded that most technologies to increase fuel economy do not affect safety and vice-versa (ICCT 2007).

Having said that, if a standard which is so stringent and could result in steep down-sizing is to be introduced, thorough consideration should be made regarding the safety of the overall vehicle fleet – the steep down-sizing and down-weighting of new vehicles while much heavier vehicles such as large SUVs are still on the road could be said to pose safety concerns, not because smaller vehicles are less safe *per se*, but because of their size and weight differential. Figure 16 shows the rates of mortality and serious injury from car accidents in Japan. Note that the rate of heavy car to light car accidents is very high compared to the death rate of light car to light car collisions or that of heavy car to heavy car collisions.

Figure 16: Death Rate and Serious Injury Rate of Car-to-car Collisions



Source: Japanese Ministry of Land, Infrastructure and Transport

Therefore, from the safety point of view, vehicle fleet down-sizing and down-weighting should occur at a moderate rate and should tend to minimize the differentials in vehicle weight. It should therefore first address the "outliers", i.e. the vehicle whose weight and size differs significantly from the average vehicle. Large and heavy SUVs are often in this situation. The most important message is that improving fuel efficiency should and could be pursued while maintaining safety. The safety argument should not be abused to convince governments not to raise fuel efficiency standards.

Standard-related policy

Regulatory standards only affect manufacturers. In order to achieve significant fuel savings and reduction of CO_2 emissions, both policy measures to push manufacturers to produce fuel efficient cars and policy measures to attract customers to buy such cars may be necessary. In the following sections, major policies aimed at consumers, namely labelling and financial incentives in selected regions are reviewed and assessed.

Labelling

Labelling could play an important role in consumers' vehicle purchasing decisions. However, they have not seemed to have had a big impact thus far.

The EU Commission (EU, 2007) introduced the results of a recent study[13] on the effectiveness of the car labelling directive, pointing to a disappointing impact of the labelling scheme so far, and proposed to improve its labelling scheme by eliminating nationally specific schemes and applying a common EU-wide scheme which includes extending the scope, introducing energy efficiency classes, and possible indication of annual running costs.

The United States' comprehensive information has been provided, yet the average fuel efficiency of LDVs has been decreasing, suggesting that labelling alone will not lead to decreased average fuel consumption.

Labelling accompanied by standards of an appropriate type and level of stringency may yield synergistic results, as these work together to influence consumer choice. Such information should include the expected fuel efficiency range for most drivers, estimated annual fuel cost and a performance comparison with similar vehicles. If attribute-based standards are in force, the relative competence of the cars to the standards in terms of fuel efficiency performance should also be included.

Financial incentives

As noted above, in Japan, 80% of passenger cars cleared the 2010 fuel efficiency standards in 2004. This is not attributable simply to the introduction of standards but largely because of the package of measures to stimulate customers to buy fuel efficient vehicles. In Japan, tax reduction incentives for fuel efficient vehicles were introduced in 2001 and revised in 2003, 2004 and 2006. Currently, clean vehicles emitting one-forth of local pollutant emission regulations or less and with a fuel efficiency of 10% and 20% above the standard qualify for tax deductions.

In the European Union, member states are responsible for implementing taxes. However, the Commission made a proposal in 2005 that member states with car taxes introduce a CO_2 element in the calculation of such taxes. The Commission reiterated the importance of the proposal in a communiqué in 2007. The accompanying document to the communiqué concludes that vehicle taxation is a powerful instrument to stimulate demand for fuel efficient vehicles. It argues that although it is difficult to isolate the contribution of fiscal measures, since taxation is a policy instrument rather than a CO_2 reduction measure in its own right, tax systems designed to gradually induce a switch towards relatively lower emitting cars would be an

[13] Source: the accompanying document to the 2007 communiqué.

efficient way to reduce compliance costs for manufacturers. It assumes that the costs for reaching the 2012 target of 120g CO_2/km would be 19% lower if taxation were appropriately imposed.

In the United States as well, state governments are responsible for most vehicle fuel taxes. However, the federal government also has a financial incentive program (or more precisely, disincentive program, to discourage fuel inefficient vehicles) known as the Gas Guzzler Tax.

As the impact assessment conducted by the Commission in 2007 shows, financial incentives would be very cost-effective. In a framework where the more fuel efficient a car is, the greater the financial incentive offered to the buyer of the car, demands for more fuel efficient vehicles would be stimulated. This would, in return, push the supply-side to produce more fuel efficient vehicles.

Summary

Standards would be more effective if they were accompanied by policies and measures to stimulate demand for fuel efficient vehicles. On their own, standards would neither generally push manufacturers to comply well before the target year, nor provide incentives to make vehicles much more fuel efficient than the standards. If a framework exists whereby the more fuel efficient a car is, the more attractive in terms of financial incentives to the customer, for example, demand for fuel efficient vehicles would be stimulated. This would, in return, push the supply side to produce vehicles that meet targets well before it is required by any regulatory or voluntary measure and to produce vehicles with a fuel efficiency performance well above designated standards. Furthermore, information on the relative performance of cars in relation to the attribute-based standards or even financial disincentives to sub-standard vehicles could induce disincentives to manufacturers to produce less fuel efficient vehicles.

IV. Conclusions

This study has examined fuel efficient vehicles from the points of view of fuel saving potentials, current and past policies and measures, and their effectiveness of realizing these potentials. Existing technologies have huge opportunity to improve fuel efficiency. However, these technologies are not always applied in a way that takes advantage of their energy efficiency capabilities.

Various policies and measures to improve vehicle fuel efficiency have been used in most major countries. As shown in Section III, some existing policies and measures were more effective than others because of their binding power, standard design, standard stringency and standard-related policies. A review of the history and current status of those policies and measures leads to a number of conclusions regarding effective strategies for increasing the fuel efficiency of motor vehicles.

Voluntary vs. Regulatory Measures

While both voluntary and regulatory measures have been widely introduced to improve vehicle fuel efficiency, the results have been mixed. On the one hand, voluntary programs have generally fallen short of their targets. On the other hand, mandatory programs produced decent results, although their effectiveness seems to depend on the ways in which the policies were designed. In most cases, mandatory targets achieved their goals, although in one case, overall fleet average fuel efficiency deteriorated partly because of perverse effects in the standard design.

As a result of the general ineffectiveness of voluntary programs to constrain vehicle energy efficiency, there is a general trend away from them. Japan switched from a voluntary program to a regulatory one in 1999 as did Korea in 2005. The European Union and Canada are also considering such a change.

Regulatory measures could have played a role in deterring the ever-increasing trend of fleet average vehicle weight that can be seen worldwide. In some cases, a regulatory measure prompted manufacturers to apply innovative technologies to vehicles to make them more efficient rather than bigger and more powerful, and thus heavier.

Attributes of an Effective Standard

The saying, "The devil hides in the details", applies to designing an effective standard. Several key attributes of effective standards are outlined below.

Scope

Both the range of vehicles to which a standard applies in a vehicle category, such as the passenger car category, and the coverage of vehicle categories are closely related to the effectiveness of the standard. In general, standards with a broader scope (e.g. covering a greater range of vehicle types) tend to lead to greater fuel savings. However, broadening the scope of a standard may increase the administrative cost of testing vehicles. Some manufacturers – especially those of light duty vehicles – can reduce such costs by producing large amounts of the same type of vehicles. Others (e.g. some small-volume truck manufacturers) need to find ways to decrease the costs of the testing, by utilizing new methods, such as computer simulation, for example.

With the exception of Japan, standards for heavy duty vehicles have not yet been introduced. Based on the Japanese experience, it appears that such standards could result in fuel savings world wide although some further in-depth analysis is needed to confirm this.

Testing procedures

What makes a good testing procedure? Consumers expect the tested fuel efficiency values to be similar to the fuel efficiency values they experience on road. In order to move in that direction, test procedures should reflect as many factors affecting the value of the fuel efficiency as possible. These requirements must be balanced against the increased cost of testing.

Fuel efficiency values are generally tested with the same or similar test procedures used to test local pollutant emissions of vehicles. This is done in part because it is an effective way to reduce the cost of testing and because some technologies for improving fuel efficiency can adversely affect the amount of local pollutant emissions.

There have also been some efforts to harmonize at least some aspects of testing procedures. This would be another effective way of reducing costs although it would be very difficult to achieve, especially in the short term. Eventually there could be large benefits from an internationally harmonized test procedure, allowing countries around the world to use similar libelling systems and adopt similar regulatory systems (or at least systems based on similar measurements).

Technology neutrality

Fuel efficiency standards are usually set to require the same level of efficiency regardless of the technologies that vehicles adopt. There are, however, cases where requirements are established on the basis of the technology used. In general, setting requirements that favour one kind of energy efficiency technology over another will distort technology development.

Regulatory flexibility

Regulatory policies can suffer from being inflexible. Existing regulatory measures generally try to use a range of mechanisms such as manufacturer fleet averaging, attribute based targets, weighted average criteria and credit trading systems to increase policy flexibility. In general, high degrees of regulatory flexibility allow more stringent targets to be met at lower cost (compared to less flexible approaches). Lead time would also be an important factor for lowering the cost.

Attribute based standards can offer the possibility that standards can get much closer to economic efficiency and may be more likely to ensure greater fairness among all automakers. Although they would not necessarily ensure the achievement of an overall improvement for vehicle fuel efficiency (as such standards are subject to weight or size shifts), a standard design in which relatively stringent requirements are imposed on heavier and bigger vehicles could solve at least part of this concern.

Flexible measures can bring some regulatory costs. In order to properly implement a credit trading system, for example, credits must be tracked and all related data such as registration data should be available within a short period of time.

Standard Stringency

The effectiveness of a vehicle fuel efficiency standard also varies depending on the stringency of the standard.

There are several approaches to setting the level of stringency of a policy. The approach that guides part of the European Commission and NHTSA's policy is to set the level of ambition at the point where the increased retail cost of the vehicle is offset by savings from reduced fuel consumption. This cost effectiveness analysis depends largely on expectations of existing and emerging technologies (cost and effectiveness), and financial considerations such as discount rates and payback period. An alternative approach is the Japanese Top-Runner programme, in which stringency is based on the performance of the best in each weight class on the market. Under this program, the value of the mass produced vehicle with the highest fuel efficiency is used as a base value and factors such as fuel saving potential of future technologies are taken into consideration afterward.

Given that vehicle manufacturers are global entities and fuel efficiency technologies spread around the globe rapidly, governments could also look to the situation in other countries and regions for additional guidance. Although detailed country-by-country analysis is crucial and direct comparison of standard stringency would be a considerable challenge in light of different test procedures and other factors, governments could nonetheless refer to fuel efficiency improvement rates achieved and targeted in other countries or regions as a starting point.

Standard-related policies

Finally, the outcome of vehicle fuel efficiency standards may also vary depending on the existence of standard-related policies aimed at stimulating demand for fuel efficient vehicles. Such policies would push manufacturers to produce vehicles that meet standards well before they are required and could act as a disincentive to manufacturers to produce less fuel efficient vehicles than standards.

Labelling

Governments have been asking manufacturers to introduce labelling schemes with the hope that they will lead to fuel savings and various labelling schemes have been introduced, though in isolation these appear unlikely to lead to significant fuel efficiency improvements. However, fuel efficiency labels do help consumers compare vehicle choices, and might particularly influence choices between otherwise similar vehicles that have different fuel efficiency ratings.

Financial incentives

Differentiated financial incentives based on tested fuel efficiency or CO_2 emissions would be effective tools to stimulate demand for fuel efficient vehicles, particularly when coupled with good labelling programs. It can provide additional stimulus to producers and consumers to go beyond simply the attainment of designated targets. Such incentives could take the form of a tax deduction based on the fuel efficient performance, a fee for less fuel efficient cards or a "feebate" which is a combination of rebates for fuel efficient cars and the fees. Given the fact that some technologies for improving fuel efficiency have a negative impact on local pollutant emissions, performance in reducing local pollutant emissions could also be taken into consideration when certifying vehicles for financial incentives.

V. Recommendations

Voluntary vs. Regulatory Measures

In order to achieve significant energy savings in this sector, governments should introduce regulatory fuel efficiency standards.

Attributes of an Effective Standard

Scope

The scope of the policy framework should be broad enough to at least cover all light duty vehicles and should not allow "leakage" into categories not covered by standards. Broadening the scope to include other vehicles, such as heavy duty vehicles, should also be considered.

Test procedures

Test procedures should reflect as many factors that affect the "on-road" value of fuel efficiency as possible. At the same time, in order to lower the cost of testing vehicles, test procedures for fuel efficiency standards should be the same as, or as similar as possible to, the procedures for local pollutant emission regulation. In addition, governments should consider the harmonization of test procedures, and participate in related international harmonization activities in UNECE/WP29 (World Forum for Harmonization of Vehicle Regulations).

Technology neutrality

Unless there are clear reasons for not doing so, requirements should be based on reaching a targeted fuel efficiency performance level and not based on promoting particular technologies.

Regulatory flexibility

Policy mechanisms for increasing regulatory flexibility, such as attribute-based targets, weighted average criteria, credit trading systems and appropriate lead times should be considered in order to improve fuel efficiency with less cost. The best type/types of flexibility and optimal form of a regulatory system may vary depending on the particular concerns and other national circumstances within a country (e.g. concerns about equity among manufacturers).

Standard stringency

Governments should consider as high a fuel efficiency improvement rate as in any country or region, while taking into account, among other factors, costs and other (possibly conflicting) policy objectives such as emission regulations, and compliance methods. Optimally, the standard should be set at a level that maximizes net social benefit, though it is acknowledged that this may not be easy to identify.

It should be noted that what this paper recommends is different from Uniform Percentage Improvement (UPI), which requires each manufacturer to achieve the same percentage increase in fuel efficiency. UPI could place a heavier burden on smaller vehicle manufacturers or discourage manufacturers from deploying more fuel efficient technologies, out of fear that they may face more stringent requirements in the future. This paper recommends that the stringency level of standards be set while taking the annual improvement rate of other regions and other factors into consideration, and that the same standards be applied nationwide to all manufacturers once they are set.

Standard-related policies

Labelling

Governments should continue to explore effective ways of labelling. If possible, the labels themselves should be consistent across countries that adopt similar labelling schemes.

Financial incentives

Governments should note that differentiated financial incentives such as a tax deduction and a fee or a "feebate" based on fuel efficient performance can be a useful complement to fuel efficiency standards. Moreover, fiscal incentives can also be designed in a multi-attribute approach, taking into consideration local pollutant emissions and other factors that have a trade-off relationship with fuel efficiency performance when rating and certifying vehicles for financial incentives.

VI. Closing remarks

There is significant potential for saving energy in the transportation sector. The ETP 2008 projects that the fuel economy of new light-duty vehicles could result in close to a half million tonne (oil equivalent) reduction in fuel use and close to 1 Gt annual reduction in CO2. However, in order to achieve these energy savings, appropriate and effective policies and measures should be introduced.

As for policies and measures to improve vehicle fuel efficiency, experience shows implementation of appropriate mandatory fuel efficiency standards for light duty vehicles in all countries would be a necessary condition for achieving significant energy savings in this sector. When a government implements mandatory standards, it should consider lessons learned from current and past efforts in other regions in terms of standard design, standard stringency and standard-related, demand-oriented measures. For example, although it is desirable to implement measures as early as possible to achieve maximum social benefit, manufacturers should be provided with adequate notice so as to be able to cost effectively respond to the new requirements. In addition, because vehicle manufacturers operate in a global market, harmonization of vehicle fuel efficiency standards would reduce compliance costs for manufacturers by providing consistent regulatory conditions across countries. This will result in benefits for drivers; with lower compliance costs manufacturers will be able to direct more resources towards the development and distribution of fuel efficient vehicles at affordable prices.

Just as vehicle manufacturers are continually learning from best practices in order to compete in the global market, governments should similarly drawn on best practices to appropriately regulate such global entities.

References

ACEA (2007) Car industry supports reducing CO2 emissions, http://www.acea.be/index.php/news/news_detail/reducing_co2_emissions_working_together_to_achieve_better_results/.

Automobile Evaluation Standards Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy and the Automobile Fuel Efficiency Standards Subcommittee, Automobile Transport Section, Land Transport Division of the Council for Transport Policy (2007), *Final Report concerning revisions of evaluation standards for Manufacturers with regard to improvement of automobile energy consumption efficiency*, http://www.eccj.or.jp/top_runner/pdf/vehicles_gasdiesel_feb2007.pdf.

CE (2006), Cost Effectiveness of CO2 Mitigation in Transport, CE, Delft.

Central Environment Council (2005), *Future Policy for Motor Vehicle Emission Reduction (Eighth Report)*, Ministry of Environment, Tokyo.

Directive 1999/94/EC of the European Parliament and of the Council (1999), *the Availability of Consumer Information on Fuel Economy and CO2 Emissions in respect of the Marketing of New Passenger Cars*, Official Journal of the European Communities, Brussels.

European Commission: Commission of the European Communities (1995), Communication from the Commission to the Council and the European Parliament, A Community Strategy to Reduce CO2 Emission from Passenger Cars and Improve Fuel Economy, Commission of the European Communities, Brussels.

European Commission (2002), Communication from the Commission to the Council and the European Parliament, Taxation of Passengers Cars in the European Union – options for action at national and Community levels, Commission of the European Communities, Brussels.

European Commission (2005), *Proposal for Council Directive on passenger Car Related Taxes*, Commission of the European Communities, Brussels.

European Commission (2007a), Communication from the Commission to the Council and the European Parliament, Result of the review of the Community Strategy to reduce CO2 emissions from passenger cars and light-commercial vehicles, Commission of the European Communities, Brussels.

European Commission (2007b), Commission Staff Working Document, Accompanying document to the Communication from the Commission to the Council and the European Parliament, Result of the review of the Community Strategy to reduce CO2 emissions from passenger cars and light-commercial vehicles, Commission of the European Communities, Brussels.

European Commission (2007c), Proposal for a regulation of the European Parliament and of the Council, Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles, Commission of the European Communities, Brussels.

ECMT: European Conference of Ministers of Transport (2007), *Cutting Transport CO2 Emissions*, OECD, Paris.

ECMT/IEA: International Energy Agency (2005), *Making cars more fuel efficient*, OECD, Paris.

EPA (2006a), Regulatory Announcement, EPA Issues New Test Methods for Fuel Economy Window Stickers, EPA, Washington, D.C..

EPA (2006b), Final Rule, Fuel Economy Labelling of Motor Vehicles: Revisions to Improve Calculation of Fuel Economy Estimates, Federal Register / Vol. 71, No. 248, Washington, D.C.

EPA (2006c), Final Technical Support Document, Fuel Economy Labelling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates, EPA, Washington, D.C..

EPA (2006d), Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2006, EPA, Washington, D.C..

Federal Chamber of Automotive Industries (2003), Voluntary Code of Practice - Reducing the Fuel Consumption of New Light Vehicles, http://www.fcai.com.au/media/2003/04/00000012.html.

Greene, D. L. (2005), *"Improving the Nation's Energy Security: Can Cars and Trucks be Made More Fuel Efficient?"* Testimony to the U.S. House of Representatives Committee on Science, February 9, 2005, http://cta.ornl.gov/cta/Publications/Reports/US%20Science%20Committee_DavidGreene.p df.

Greene, D.L. (2007), "*Policies to Increase Passenger Car and Light Truck Fuel Economy*," Testimony to the U.S. Senate Committee on Energy and Natural Resources January 30, 2007, http://cta.ornl.gov/cta/Publications/Reports/Policies_to_Increase_Passenger_Car.pdf.

ICCT: International Council on Clean Transportation (2007), Sipping Fuel and Saving Lives: Increasing Fuel Economy Without Sacrificing Safety, http://www.theicct.org/documents/ICCT_SippingFuelFull_2007.pdf.

ICCT (2007), Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update, http://www.theicct.org/documents/ICCT_GlobalStandards_2007.pdf.

IEA (2008) *Energy Technology Perspectives 2008*, OECD Publications, Paris.

IEA Workshop (2007) *Scaling-up Energy Efficiency: Bridging the Action Gap* http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=298

IEA: International Energy Agency (2006), *World Energy Outlook 2006*, OECD Publications, Paris.

IEA (2006), *CO2 Emissions from Fuel Combustion*, 2006 edition, OECD Publications, Paris.

Joint Government – Industry Greenhouse Gas (GHG) Memorandum of Understanding (MOU) Committee (2006), *First Progress Update*, http://oee.nrcan.gc.ca/transportation/ghg-memorandum/documents/First-Progress-e-(July-4).pdf.

Oosterhuis, Frans (2006), *Ex-post estimates of costs to business of EU environmental legislation*, IVM, Institute for Environmental Studies, Amsterdam.

Ministry of Economy, Trade and Industry (2006) *Top Runner Program*, www.eccj.or.jp/top_runner/index.html.

Ministry of Land, Infrastructure and Transport (2007), *zidousha nenpi ichiran (fuel efficiency list)*, www.mlit.go.jp/jidosha/nenpi/nenpilist/nenpilist0703.pdf.

National Academy of Science (2002), Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Academy Press, Washington, D.C..

NHTSA (2006a) Report to Congress, Study of Feasibility and Effects of Reducing Use of Fuel for Automobiles, http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Vehicle%20Safety/Studies%20&%20Reports/Associated%20Files/StudyOfFeasibility-Report-to-Congress.pdf.

NHTSA (2006b) Final Rule, Average Fuel Economy Standards for Light Trucks Model Years 2008-2011, http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/2006FinalRule.pdf.

NHTSA (2006c), Corporate Average Fuel Economy and CAFE Reform for MY 2008-2011, http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/2006_FRIAPublic.pdf

NHTSA (2007), Summary of Fuel Economy Performance, http://dmses.dot.gov/docimages/pdf102/480389_web.pdf.

NTSEL (2007), Ex-post Evaluation in Japan, http://www.iea.org/Textbase/work/2007/vehicle/Goto.pdf

Pew Center on Global Climate Change (2004) *Comparison of passenger vehicle fuel economy and greenhouse gas emission standards around the world* http://www.pewclimate.org/docUploads/Fuel%20Economy%20and%20GHG%20Standards_010605_110719.pdf

Schipper, L.(2007), Vehicle Efficiency and CO2 Emissions: Troubling Trends, http://embarq.wri.org/documents/Schipper-VehicEfficiency.pdf.

The White House (2008), Fact Sheet: Increasing Our Energy Security and Confronting Climate Change Through Investment in Renewable Technologies, http://www.whitehouse.gov/news/releases/2008/03/20080305-2.html emissions from passenger cars and light-commercial vehicles, Commission of the European Communities, Brussels.

European Commission (2007c), Proposal for a regulation of the European Parliament and of the Council, Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles, Commission of the European Communities, Brussels.

ECMT: European Conference of Ministers of Transport (2007), *Cutting Transport CO2 Emissions*, OECD, Paris.

ECMT/IEA: International Energy Agency (2005), *Making cars more fuel efficient*, OECD, Paris.

EPA (2006a), Regulatory Announcement, EPA Issues New Test Methods for Fuel Economy Window Stickers, EPA, Washington, D.C..

EPA (2006b), Final Rule, Fuel Economy Labelling of Motor Vehicles: Revisions to Improve Calculation of Fuel Economy Estimates, Federal Register / Vol. 71, No. 248, Washington, D.C.

EPA (2006c), Final Technical Support Document, Fuel Economy Labelling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates, EPA, Washington, D.C..

EPA (2006d), Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2006, EPA, Washington, D.C..

Federal Chamber of Automotive Industries (2003), Voluntary Code of Practice - Reducing the Fuel Consumption of New Light Vehicles, http://www.fcai.com.au/media/2003/04/00000012.html.

Greene, D. L. (2005), *"Improving the Nation's Energy Security: Can Cars and Trucks be Made More Fuel Efficient?"* Testimony to the U.S. House of Representatives Committee on Science, February 9, 2005, http://cta.ornl.gov/cta/Publications/Reports/US%20Science%20Committee_DavidGreene.p df.

Greene, D.L. (2007), "*Policies to Increase Passenger Car and Light Truck Fuel Economy*," Testimony to the U.S. Senate Committee on Energy and Natural Resources January 30, 2007, http://cta.ornl.gov/cta/Publications/Reports/Policies_to_Increase_Passenger_Car.pdf.

ICCT: International Council on Clean Transportation (2007), Sipping Fuel and Saving Lives: Increasing Fuel Economy Without Sacrificing Safety, http://www.theicct.org/documents/ICCT_SippingFuelFull_2007.pdf.

ICCT (2007), Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update, http://www.theicct.org/documents/ICCT_GlobalStandards_2007.pdf.

IEA (2008) *Energy Technology Perspectives 2008*, OECD Publications, Paris.

IEA Workshop (2007) *Scaling-up Energy Efficiency: Bridging the Action Gap* http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=298

The Online Bookshop

International Energy Agency