

CO2 EMISSIONS FROM ROAD VEHICLES

**Annex I Expert Group on the United Nations Framework Convention on Climate Change
Working Paper No. 1**

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

This Working Paper is one of a series of eighteen studies carried out under the project: "Policies and Measures for Possible Common Action". The project was carried out by the OECD, together with the International Energy Agency, in 1996 and 1997 for the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The goal of the project was to assess a range of cost-effective greenhouse gas mitigation policies and measures for countries and Parties listed in Annex I to the UNFCCC. The eighteen working papers have been made widely available as analytical input to negotiations under the UNFCCC Ad hoc Group on the Berlin Mandate. The working papers may also provide input to national decision-making processes on greenhouse gas mitigation policies. The measures analysed do not necessarily represent policy preferences of Annex I Parties.

The project benefited greatly from substantial input from delegates. Three successive chairmen of the Annex I Expert Group provided outstanding leadership for the project: Doug Russell (Canada); Ross Glasgow (Canada); and Ian Pickard (United Kingdom). The work was supervised by Jan Corfee Morlot (OECD). Fiona Mullins (OECD) drafted the initial framework which was used to structure the eighteen working papers.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czechoslovakia (now Czech Republic and Slovakia), Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States. Where this document refers to "countries" or "governments", it is also intended to include "regional economic organisations," if appropriate.

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EXECUTIVE SUMMARY

Context

The transport sector is responsible for 25 per cent of global CO₂ emissions from fossil fuel use, and this share is growing. Of all energy-using activities, transport is generally the area where governments find it hardest to find politically feasible policies that can mitigate greenhouse gas emissions. Projections for Annex I countries indicate that, without new CO₂ mitigation measures, road transport CO₂ emissions might grow from 2 500 million tonnes in 1990 to 3 500 to 5 100 million tonnes in 2020.

Annex I countries already have in place a wide range of measures that affect vehicle energy use and CO₂ emissions. These include vehicle purchase taxes, annual charges, fuel taxes and other fees, fuel economy standards, targets for fuel economy improvement in national vehicle markets, and voluntary agreements with manufacturers to take a range of initiatives to improve fuel economy. National and local governments are also working hard to develop strategies to address the environmental and social problems associated with urban transport, and these strategies can contribute to mitigating CO₂ from vehicles. Many countries have announced new initiatives to reduce vehicle CO₂ emissions since 1990, including the introduction of all of the types of measures considered in this study.

Description of Measures and their Policy Objectives

The current draft of this study provides an in-depth analysis of several types of measure, which might be considered for implementation in a common action to mitigate road vehicle CO₂ emissions:

Measures whose primary objective is to reduce the energy intensity of cars and “light trucks”¹:

- “feebates”, where purchasers of the most efficient vehicles receive a tax rebate while purchasers of less efficient vehicles pay a tax;
- “corporate average fuel economy standards” (CAFE);
- voluntary agreements between governments and car manufacturers to achieve fuel efficiency improvements.

Taxes on fuels purchased for use in road vehicles. Three options are considered:

- “vehicle tax reform”, where existing charges on cars and light trucks are reduced, and fuel taxes are increased to keep total tax revenue constant;

¹ “Light trucks” are mentioned here, but the coverage might include a variety of vehicle types, including “vans” or “minibuses”, “sports utility vehicles” and four-wheel drive vehicles.

- “full budgetary cost pricing”, where fuel taxes are modified to improve the extent to which car and truck drivers pay the full costs to the public budget of their driving;
- “externality adders”, where fuel taxes are modified to include externality adders, so that the full social costs of driving are reflected to car and truck drivers.

As well as contributing to CO₂ mitigation, these measures might contribute to broader objectives, including reducing the negative social and environmental impacts of road use. Any of these measures might be combined with others, or with additional actions aimed at enhancing their effectiveness by overcoming market imperfections.

The measures have been the subject of a considerable amount of experience, debate and analysis. Much of the debate about their effects and costs centres around two key issues: the preferences and behaviour of consumers on the one hand, and the potential for technological developments on the other. The current report attempts to elucidate the range of uncertainty in the costs and effects of these types of measure.

The study suggests that further work could address other types of measure, focusing on transport innovation. It also provides a brief consideration of measures that could be addressed in such further work, including:

- local initiatives and packages of measures to reduce the broader environmental and social impacts of transport and, with these, greenhouse gas emissions
- research, development, and measures to encourage technological innovation in vehicles, fuels, transport systems and transport and urban infrastructure

Approach and Methodology

For each type of measure, the study aims to evaluate: the potential impact of the measure on vehicle CO₂ emissions; the direct and wider economic costs associated with the measure; the other policy issues associated with the measure, including trade, employment, social and environmental issues; issues that need to be considered in the implementation of the measure; the potential advantages and disadvantages of common action to implement the measure; and the possible approaches that Annex I countries might take to implement the measure in common².

The analysis of vehicle fuel economy measures and fuel taxes is based on existing literature on the effects of these measures in individual countries, along with additional analysis and modelling to examine the effects on greenhouse gas emissions, vehicle ownership and traffic levels in a more general Annex I country context. The study estimates fuel tax increments that might be introduced on a “no-regrets” basis, drawing, *inter alia* on a set of three OECD country case studies. The costs of vehicle fuel economy measures are estimated based on technology cost-effectiveness studies in the literature. Economic effects of fuel economy measures and fuel taxes are discussed based on reviews of the relevant literature.

Analysis of common action on transport innovation is at a much earlier stage than that of the other measures. The study suggests that further work on this subject might follow an approach based on case studies contributed by countries.

² These are the elements identified for consideration in the Framework for Analysis of the Common Actions project.

The three types differ considerably in the way they are likely to be implemented, the level of government at which they are likely to be implemented, in their potential effects on CO₂ emissions, and in the scope for, and advantages and disadvantages from common action.

Greenhouse gas reduction potential, costs and timing, advantages from common action

Light duty passenger vehicle fuel economy standards, feebates and targets.

Where there are information or other barriers to the uptake of energy efficient technology in the new car market, the energy savings from this group of measures may be cost-effective for users: some energy-efficiency improvements could be incorporated into cars without damaging other car attributes valued by consumers, and would pay for themselves in fuel savings. The potential for energy savings through such improvements probably lies in the range 5-20 per cent in North America and 10-25 per cent in Europe for new vehicles, if efficient designs are introduced at a rate in line with the normal retooling cycle of the industry³. The assessment of the “cost-effective” energy savings level for any standard or other measure is likely to vary among countries, and this type of measure may only be relevant for some groups of countries within the Annex I group.

Energy intensity changes in new cars typically take about ten years to penetrate most of the on-road fleet in OECD countries, but somewhat longer in countries with a high rate of used car imports. In the longer term, the cost-effective reduction relative to trends may be much larger, depending on the adaptability of consumer preferences to new types of car. Measures leading to the uptake of cost-effective technology could have positive effects on consumer surplus and manufacturing employment, although they might also lead to small increases in traffic and its attendant environmental and social impacts. Governments might wish to combine such measures with fuel or vehicle-kilometre taxes to avoid these impacts.

Common action could offer significant advantages for this type of measure, except for countries with very large domestic car markets, as the cost of deploying new technology depends heavily on the size of the market for that technology. Emission reductions that would be cost-effective for vehicle users, from a common action over the Annex I region, could amount to at least 100 million tonnes of CO₂, and perhaps several hundred million tonnes. Meanwhile, unilateral actions in this area would be liable to have distorting effects on trade which could be reduced if countries adopted similar measures. The long-run effect would probably be to reduce emissions in non-participating countries, as an increasing proportion of new vehicles would be designed for improved fuel economy. However, there is the possibility of a short-run effect where less efficient vehicles and, more importantly, designs and production lines, are exported to countries that do not impose the tighter standards.

The majority of new vehicles are subject to one of three types of fuel economy test cycles: that of the European Union and UNECE; that of the United States; and that of Japan. International differences in vehicle markets and driving conditions are often mentioned as an argument against standardisation of fuel economy test cycles. Some types of common action on fuel economy standards might depend on agreement either to use the same cycle or on conversion factors among the cycles. However, agreement

³ Fuel savings are calculated over 4 years, discounted at an 8 per cent discount rate. In North America, the fuel price is taken to be 30 US¢ per litre of gasoline and the typical car is assumed to be driven 16 400 km per year. In Europe, the fuel price is assumed to be 85 US¢ per litre of gasoline and the average car is assumed to be driven 13 800 km per year.

on test cycles is probably not necessary for some types of common action on fuel economy, for example, voluntary agreements with manufacturers to achieve fuel economy improvement targets.

Fuel taxation

This section focuses mainly on fuel taxation options which can be considered “no regrets” — that is, their rationale does not depend on climate change policy. The options considered include: “tax reform” — shifting the weight of taxation on road-users away from vehicles and towards fuel; “full budgetary cost pricing” — ensuring that the costs to governments of road provision are recovered from road users through fuel taxes or other types of charges that reflect the costs associated with particular users; and the augmentation of fuel tax by “externality adders” that reflect externalities associated with traffic congestion, accidents, air pollution, noise and other issues.

In a very broad-brush analysis, this study estimates that

- “tax reform” from 2000 might reduce light duty vehicle greenhouse gas emissions in 2010 by around 10 per cent or more in several OECD countries;
- “full budgetary cost pricing” from 2000 would reduce emissions from light duty vehicles in 2010 by about 5 per cent and emissions from heavy duty vehicles by over 10 per cent in some countries, but in others, no increase in fuel taxes would be justified;
- “externality adders”, introduced in 2000, based on externality estimates in France, Japan and the United States, would reduce emissions from all vehicle types in 2010 by 15 per cent or more.

These results have an uncertainty of at least ± 50 per cent. In general, most of the effects of tax increases on greenhouse gas are nearly immediate, although effects on new vehicle technology can take a decade or more to be fully reflected in the on-road fleet. There is likely to be limited potential to increase the strength of taxes justified on a “no regrets” basis over time, with the exception of “externality adders”, where the unit valuation of social and environmental impacts may increase in the future.

The size of the fuel tax increase that might be justified in these three ways is likely to vary considerably among countries, and would have to be decided at a national or perhaps regional level. In view of the variations among countries, it would be hard to justify a harmonised tax level throughout the Annex I group of countries. A harmonised tax at regional level might still be worthy of consideration, given that differences among countries within regions, though substantial, are smaller than those among regions.

Increased fuel taxation is an efficient means to internalise externalities associated with CO₂ emissions and fossil fuel resource depletion. Such a tax increase, or a minimum level, might be decided as a common action on an Annex I-wide basis, but would be most efficiently adopted as part of a cross-sectoral carbon tax.

The impact on Gross Domestic Product (GDP) of any net increase in road-user taxation could be positive or negative, and is likely to depend heavily on the way tax revenues are recycled into the economy. This issue would also have to be studied on a national basis to determine the best use for any revenues.

The economic and mitigation advantages of harmonised taxes are uncertain, but are probably relatively small, especially where the taxes are justified by costs and externalities that vary among countries. One

possible advantage is the reduction in fuel “tourism”. Some small countries or countries with long borders do suffer from “gasoline tourism”, where car drivers cross the border to seek cheaper fuel, although price adjustments near the border can help avoid this effect. Fuel tankering by trucks is a more serious problem, as trucks can carry enough fuel to drive thousands of kilometres. Where truck drivers carry large amounts of fuel to avoid filling up in countries with high taxes, the result can be an increase in greenhouse gas emissions due to the energy needed to carry the fuel.

Fuel tax increases in Annex I countries might affect non-participating countries in various ways. It is not clear whether higher freight costs in participating countries would affect competition, stimulating production (and greenhouse gas emissions) in non-participating countries. This effect is not at all well understood, as the role of freight transport in the economy in general is poorly understood. This issue would have to be studied in depth to obtain a clear understanding of possible advantages from tax harmonisation. Higher fuel taxes in Annex I countries might tend to reduce the world oil price which, again, would tend to stimulate activity and greenhouse gas emissions in non-participating countries. This effect is not specific to the tax instrument.

Transport innovation

This study does not report in quantitative terms the possible greenhouse gas mitigation effects of “transport innovation” measures — these are evaluated in Working Paper 13. This report identifies a range of measures that might be considered to encourage innovation in transport behaviour, technology and infrastructure.

Measures can be implemented at a local level to change transport behaviour, including, for example: reductions in access to roads and parking spaces, and the introduction of fees; reductions in speed limits; “traffic-calming” measures; education and information to change driving behaviour, mode and vehicle choice; and encouragement for community-based initiatives. National measures can include legislative provision to allow road pricing by local authorities; introduction of advertising codes of practice for vehicles; media, education, training and information programmes; and support (information, funding, analytical support, etc.) to encourage innovative local initiatives.

Technology and infrastructure innovation might include the development of energy-efficient alternative fuel or electric vehicles; innovative transport systems; information technology to allow for road pricing and transport control/management systems; new infrastructure designs to encourage non-motorised transport; or low-energy or low-transport intensity goods distribution systems. Innovation might be encouraged through funding of research and development, technology trials, market incentives, information sharing, and other measures.

The effects of innovation are likely to be long-term and are very uncertain. Technology and behaviour changes have the theoretical potential to achieve a near-elimination of greenhouse gas emissions from the transport sector. International co-operation in the area of innovation is important to share risk, reduce costs and increase the effectiveness of initiatives. Such co-operation is already occurring to some extent. Common actions in this area might further help to share the costs, risks and benefits associated with experimentation, and provide opportunities for additional exchanges of ideas and experience, which would facilitate governments and others in identifying and evaluating new opportunities.

Potential for common action

Replication of successful measures

The political feasibility of the measures discussed in this study varies strikingly among Annex I regions. Some governments have been able to introduce fuel tax increases at quite substantial rates. Others face strong opposition to fuel taxes from lobbies, including oil companies and consumer groups, but have been successful in implementing mandatory vehicle fuel economy standards. In the short term, measures in many countries are likely to be feasible only if they are truly “no-regrets” options from the greenhouse gas mitigation perspective, although their role in greenhouse gas mitigation may add weight to arguments for their introduction. Some of the most obvious “no-regrets” options are: voluntary agreements with car manufacturers for fuel economy improvements at “cost-effective” rates; reforming vehicle and fuel taxation; and encouraging local initiatives to improve transport systems. Attempts to implement even these measures can face substantial barriers, as they may depend on interactions between national, international and local government organisations, as well as industry.

Replication might be aided by increased sharing of information about successes and failures, especially regarding different approaches to implementation and working with stakeholders.

Agreement to take action in the transport sector toward an aim or target

Most Annex I countries might agree that the transport sector represents a priority area for developing new policies to address multiple externalities. However, so far, few countries have made commitments to reduce transport sector emissions separate from those of other sectors. Indeed, many governments would prefer not to adopt such a commitment, considering it more efficient to design mitigation strategies on an economy-wide basis. Nevertheless, Member countries of the European Conference of Ministers of Transport have issued a declaration stating the objective of reducing vehicle CO₂ emissions. It is possible that a stronger commitment might be made in the future, among this or another group of countries.

Many countries have established targets for improving the average fuel economy of new vehicles, and several of these targets have been agreed with vehicle manufacturers. This type of target may be more feasible than sector targets, as an area for common action, and indeed, manufacturers in the European Union have agreed to such a target on a regional scale.

Co-ordination to implement the same or similar measures

Experience so far in Europe and North America indicates that it might be very difficult to negotiate common fuel economy standards or harmonised taxes. However, many countries within regions do use similar types of measures — for example, Canada uses US CAFE standards as a voluntary approach, and most European countries have similar levels of fuel tax. Countries have also been able to agree to minimum levels for some types of policy — for example, fuel taxes in the European Union. Some increase in co-ordination is possible, taking into account national circumstances, perhaps guided by principles such as full cost pricing, the internalisation of externalities, or addressing information barriers in the new car market.

Specific policies and measures implemented together

Many of the measures considered here would be inappropriate for harmonised action, as their design depends on local circumstances. To reflect the global costs of climate change, the rationale for common action in the form of a fuel tax “externality adder” may be greater. Such a measure seems some way from implementation, and might depend on agreement to a cross-sectoral carbon tax.

Possible approaches to common action, participants, and vehicles for action

This study identifies some examples of possible approaches to common action, which might involve some combination of the various types of measure that have been discussed, and might involve various levels of commonality:

1. **An agreement to take action in the transport sector/replication of successful measures.** Such an agreement might be analogous to existing UNFCCC commitments with a focus on the transport sector. The monitoring, evaluation and review process associated with the agreement might also be established by analogy with the Convention, or might build on work elsewhere. Parties would not necessarily commit to implement specific measures under this agreement, but would be free to determine their own most cost-effective approaches. Parties might build on existing efforts in international organisations, such as the European Conference of Ministers of Transport, to establish databases that can be used to monitor the effects of policies and progress in greenhouse gas mitigation policy implementation. They might also share information on and develop methodologies for the estimation of transport subsidies and externalities.
2. **An agreement to adopt a particular kind of measure.** This might entail agreement to a principle, such as the need to bridge an information gap in the car market, the need for full cost pricing and internalisation of externalities in the transport sector, the need to encourage local initiatives, or the need to accelerate technology development and deployment. Such an agreement could be adopted in conjunction with, or subsequent to, the monitoring, reporting and review option described above. The agreement might also entail a commitment to some specific type of response following from the principles — for example, to introduce a particular type of measure by a given date. This latter type of agreement would probably be most easily implemented on a regional scale, but some types of measure might be agreed throughout Annex I.
3. **An agreement to implement a specific measure in common.** Examples of possible measures include: a minimum CAFE standard or feebate system or an international voluntary agreement with manufacturers; a system of recognition and funding for local mitigation initiatives; or agreed national contributions to a common R & D fund. A common action in this area could build on one or more of the many existing agreements among groups of countries. It would need to be based soundly on expert advice and discussion as well as consultation on policy.

Any of these three types of common action might be established by all Annex I countries or by some subset. For individual measures (approach 3), harmonisation may only be feasible on a regional level.

INTRODUCTION

Parts 1 and 2 of this study provide an analysis of two types of measure, which might be considered for implementation in a common action to mitigate road vehicle CO₂ emissions:

- measures such as vehicle fuel economy standards, feebates, voluntary agreements with manufacturers
- increases in fuel taxation

These two types of measure are treated separately in this study, although they might best be adopted in combination.

This focus in this study on fuel taxes and measures targeting vehicle fuel economy is not intended to indicate that these are necessarily the most promising measures for common action. However, these measures are easily defined, and have been the subject of a considerable amount of experience, debate and analysis. Much of the debate about the effects and costs of these measures centres on two key issues: the preferences and behaviour of consumers, on the one hand, and the potential for technological developments, on the other. These are both areas where considerable uncertainty remains, and this uncertainty means that it is, at present, impossible to say whether fuel economy standards or fuel taxes are cost-effective, or whether one is more or less cost-effective than the other. However, this study does attempt to elucidate the range of uncertainty in the costs and effects of these measures.

This paper also provides a brief consideration of:

- local initiatives and packages of measures to reduce the broader environmental and social impacts of transport and, with these, greenhouse gas emissions
- research, development, and measures to encourage technological innovation in vehicles, fuels, transport systems and transport and urban infrastructure

Policy Objectives

The two groups of measures addressed in depth in this study aim to reduce greenhouse gas emissions associated with road transport, through measures that reduce vehicle energy use. Additional policy objectives may be served by the two types of measure:

- Measures targeted on vehicle fuel economy may also reduce the overall costs to consumers of driving, stimulate technological developments in the automotive industry, and shift consumer spending from imported oil to manufactured goods (vehicles). It should be noted that measures that improve fuel economy tend to reduce the variable cost of driving, leading to the “rebound” effect, where traffic levels increase. Thus, fuel economy-targeted measures may have unwanted side-effects, working against policy objectives such as reducing traffic

accidents, congestion, noise and air pollution. Nevertheless, some of the technology adopted in more efficient vehicles may also result in lower emissions of air pollutants or noise. The economic rationale for this type of measure might be to address market imperfections, if they are thought to exist⁴, associated with the manufacture and sale of vehicles.

- Fuel taxes might contribute to the policy objectives of: reducing vehicle energy intensity; reducing traffic and associated economic, social and environmental costs; paying for the economic, social and environmental costs of road transport; or increasing general government revenue allowing for tax reductions or additional expenditure elsewhere in the economy. Economic rationales for fuel taxation might include internalising externalities associated with fuel use, including those associated with climate change from CO₂ emissions, air pollution directly linked to fuel use, the public costs of ensuring security of fuel supply, and any external costs associated with resource depletion. Fuel taxation may also be, and is, used as a “second-best” means of recovering or internalising other costs of vehicle use, which are difficult to price directly, such as costs of road provision, the effects of road congestion, uninsured accident costs, or pollution not directly linked to fuel use.

Full description of measures

Definition of measures for common action

The measures addressed in this study are defined as follows:

- Measures whose primary objective is to reduce the energy intensity of cars and other personal light duty vehicles:
 - “feebates”, where purchasers of the most efficient vehicles receive a tax rebate, while purchasers of less efficient vehicles pay a tax. The design of feebates addressed in this study is one that does not aim to increase the total tax burden of motorists, and where the feebate scale increases linearly with vehicle fuel consumption (in litres per 100 kilometres); this means that the zero point of the scale is set as close as possible to the average new vehicle fuel economy at any time.
 - “corporate average fuel economy standards” (CAFE). CAFE standards are defined here as statutory minimum levels of average fuel economy (litres/100 kilometres), of vehicles of a given class (cars, other light passenger vehicles), sold by each manufacturer into a national or regional market. CAFE levels can be made tradable between manufacturers or scaled according to vehicle weight, emission levels, or other factors.
 - voluntary agreements between governments and car manufacturers to achieve fuel efficiency improvements (e.g. a certain percentage improvement in the new-car fleet over a certain period).
- Taxes on fuels purchased for use in road vehicles. Three options are considered:

⁴ This question is a subject of debate. Market imperfections might include lack of information, “bounded rationality” on the part of vehicle purchasers, barriers to entry for new manufacturers or other factors contributing to a lack of choice for purchasers.

- “vehicle tax reform”, where existing charges such as vehicle sales tax, registration fees, or road taxes, are reduced, and fuel taxes are increased to keep total revenue from road users constant
- “full budgetary cost pricing”, where fuel taxes are modified to improve the extent to which motorists pay the full costs of their driving in the public budget
- “externality adders”, where fuel taxes are modified to include externality adders, so that the full social costs of driving are reflected to motorists.

Any of these measures might be combined with others, or with additional actions aimed at enhancing their effectiveness by overcoming market imperfections. Such actions might include the introduction of vehicle fuel economy labelling, education and media-based information programmes, or incentives for corporate research and development.

Various types of common action are possible for each type of measure. These include:

1. An agreement to develop transport sector policies with the aim of mitigating greenhouse gas emissions. These would not necessarily have to lead to stabilisation or reductions in emissions in the near term: for most countries, a reduction in the rate of growth would be a positive step. Such an agreement might be modelled on, or might be an extension of, the recent declaration by ECMT ministers and the vehicle manufacturing industry. It could include the development of an international database on transport statistics relevant to energy use and greenhouse gas emissions, perhaps with a compilation of analysis and case studies on the effects of national strategies. The agreement might involve Annex I Parties sharing information and analysis of measures, perhaps through their communications to the Conference of the Parties to the UNFCCC.
2. An agreement to adopt a particular kind of measure — for example, one of the group of measures that encourages improvements in vehicle fuel economy, or strategies to ensure that drivers pay their full budgetary and social costs. This agreement might involve targets, for example to achieve a 0.75 per cent, 1.5 per cent or 3 per cent per annum reduction in car fuel economy (L/100 kilometres), or to eliminate budgetary subsidies to road transport for specific road users by a certain date.
3. An agreement to adopt a measure in common, for example a common fuel economy standard or fuel tax, at levels negotiated by co-operating countries.

Context

Current emissions

Greenhouse-gas emissions from transport derive mainly from the use of fossil fuels, and the main greenhouse gas produced is CO₂. The transport sector, including travel and freight movement by road, rail, air, and water, was responsible for about 25 per cent of 1990 world primary energy use and 22 per cent of CO₂ emissions from energy use (including energy use in fuel production) (Michaelis, 1996). These shares are growing in almost all countries. Total transport energy use and CO₂ emissions per capita have grown steadily in most countries in the last 20 years, one exception being the United States (see

Figure 1). A variety of factors have contributed to this growth, including: rising incomes; steady or declining fuel costs; technological advances; changes in culture and life-style. Government policies may also have contributed to the growth, for example, through subsidies for infrastructure, policies intended to improve mobility and access, and policies aimed at keeping oil prices low.

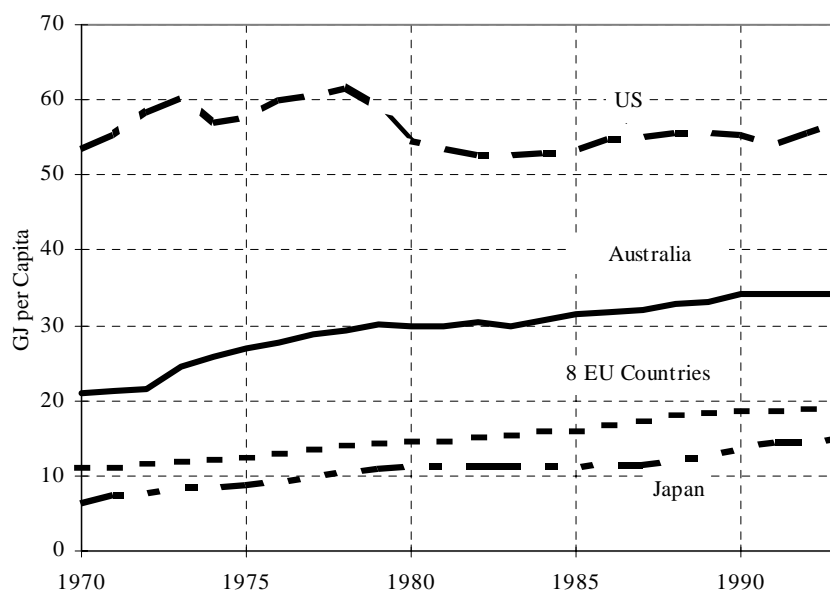


Figure 1. Transport Energy Use per Capita in OECD Countries, 1970 to 1993

Figure 2 shows the breakdown of transport energy use between road, rail, air and inland water for the 20 countries with the highest reported⁵ transport energy consumption in 1990 (IEA, 1993c and 1993d). In these countries, road traffic used roughly 80 per cent of total transport final energy consumption, air traffic 13 per cent, rail 4.4 per cent, and inland water transport 2.6 per cent. For road, air and water transport, almost all of the energy use is in the form of oil products, with CO₂ emissions proportional to the amount of energy used, apart from slight differences between oil products. Rail transport uses mostly diesel fuel and electricity, and energy use in Figure 2 is shown as final energy: conversion losses in power generation are excluded.

⁵ The figure only shows countries for which transport sector energy use is reported in IEA statistics. The countries shown are not necessarily the 20 largest consumers of transport energy.

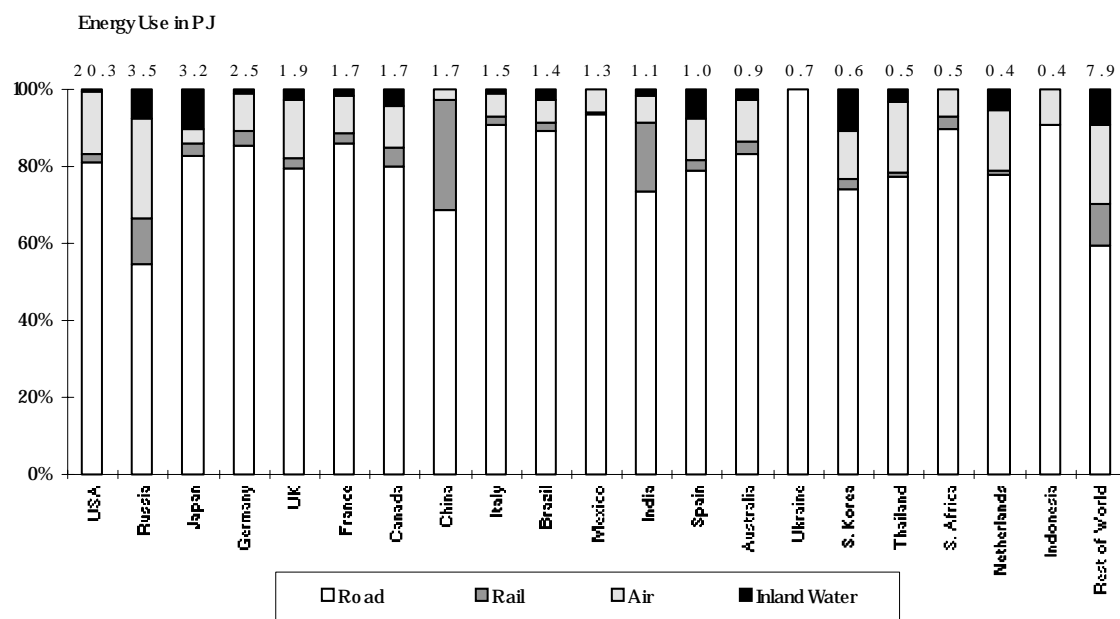


Figure 2. Transport Sector Energy Use in 1990 by Mode in the Highest Consuming Countries
Source: IEA, 1993c; 1993d

Most of the radiative forcing caused by the transport sector is a result of CO₂ emitted directly by vehicles. However, emissions of non-CO₂ greenhouse gases and CO₂ emissions caused indirectly by road vehicle use contribute an additional radiative forcing equivalent to 50-90 per cent of the radiative forcing of vehicle tailpipe CO₂ emissions⁶ (based on CEC, 1992; IEA, 1993a; DeLuchi, 1991). Electricity accounts for about a quarter of final energy use by railways (783 PJ: Pischinger and Hausberger, 1993); most of the life-cycle greenhouse gas emissions from electric trains are from power stations. Emissions by aircraft of NO_x at high altitude may contribute as much radiative forcing as their CO₂ emissions, although this is highly uncertain (IPCC, 1995).

Projected Emissions

Most Annex I countries expect their transport sectors to be the fastest growing sources of greenhouse gas emissions to 2000, and the IPCC Second Assessment Report (IPCC, 1995b) identifies transport as the fastest growing sector of energy use to 2025. Scenarios based on trend projection with no new policies introduced indicate that CO₂ emissions might increase by 40-150 per cent between 1990 and 2025 (Grubler, 1993; IPCC, 1995a; WEC, 1995; Walsh, 1993a). Among these, the WEC scenarios, illustrated in Figure 3, are the most recently developed and have the clearest documentation, and are used in this study as a basis for considering the effects of greenhouse gas mitigation measures in the transport sector. The WEC scenario assumptions are described in detail and contrasted with those in other sources in Appendix D. In all of the scenarios reviewed, road transport retains the dominant share of transport energy use, well into the next century, and in this context, this study focuses on road transport mitigation options.

⁶ The figures given here include emissions of CFCs and HFCs, mainly due to leakage and venting from car air conditioning units.

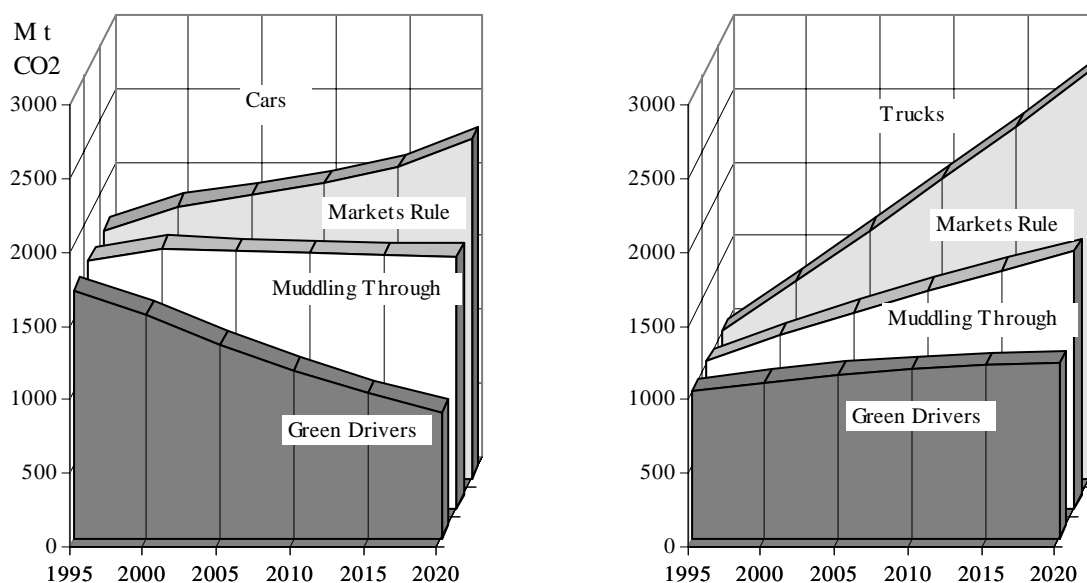


Figure 3. WEC Transport Scenarios: CO₂ Emissions from Road Transport in Annex I Countries

The WEC scenarios are developed from scenarios of GDP growth in different world regions, along with a set of assumptions about the links between GDP growth and car ownership, freight and air transport. Additional assumptions are made about the distance cars are driven, the energy intensity of various vehicle types, and the way these develop over time.

- In the “muddling through” scenario, WEC assumes moderate economic growth (2.2 per cent per year in OECD, 4.2 per cent elsewhere), with sustained large income differentials between different parts of the world. Technical progress (in vehicle energy efficiency) is moderate, with 0.5 per cent reduction in car energy intensity per year. As a result, total road transport CO₂ emissions increase from 2 500 Mt in 1990 to 3 500 Mt in 2020.
- In the “markets rule” scenario, a general lifting of trade barriers and move towards free market economies results in rapid economic growth (2.8 per cent in OECD, 5.2 per cent elsewhere). Technical progress is faster than in “muddling through”, with 1 per cent reduction in car energy intensity per year. Road transport CO₂ emissions increase to 5 100 Mt in 2020.
- In the “green drivers” scenario, growing evidence for the need for action to reduce pollution, in particular greenhouse gas emissions, leads to concerted action, including the implementation of a carbon tax. Economic growth is slower than in either of the other two scenarios, and technical progress is much more rapid. Meanwhile, a general shift away from energy-intensive transport modes results in less motorised travel and freight transport, leading to a net reduction in transport energy use in Annex I countries.

While this report does not endorse any of these scenarios as probable, or even necessarily fully internally consistent, the “muddling through” and “markets rule” scenarios constitute reasonable starting points for considering the effects of transport sector greenhouse gas mitigation measures. The “green drivers” scenario is not relevant as a reference scenario for the current paper, as it already incorporates the effects of new government policies.

Assuming that there is little shift in the mix of fuels used for each transport mode, CO₂ emissions are proportional to the energy used by that mode.

Although the study starts from this set of scenarios, it should be noted that they do not illustrate the full set of possible futures. In particular, in all of these scenarios, road freight transport energy use grows much more rapidly than passenger road transport energy use. This has some grounding in historical growth rates (see Figure 4), but it is also possible that passenger transport energy use might remain much higher than freight energy use in Annex I countries for the foreseeable future.

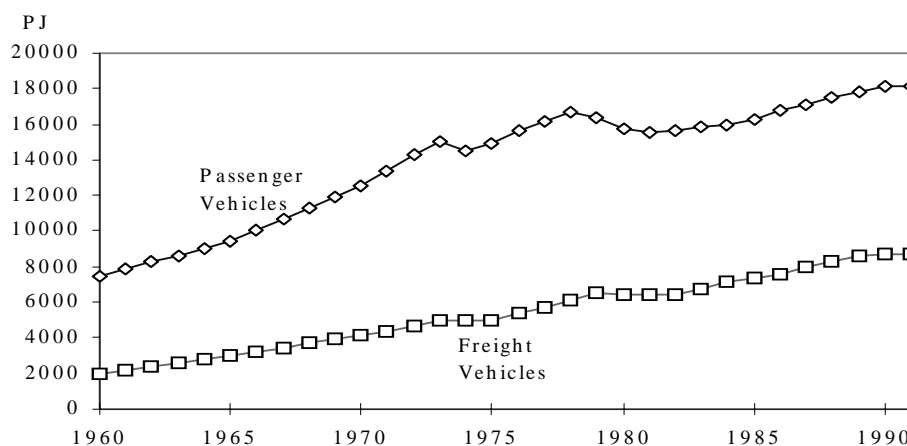


Figure 4. Historical Road Transport Energy Use, Six Major Annex I Countries
(United States, Japan, Germany, France, Italy, United Kingdom)

Energy Intensity Trends

Transport energy projections typically incorporate a reduction in fleet energy intensity in the range 0.5 per cent to 2 per cent per year (Grübler *et al.*, 1993, IEA, 1991, 1993a, Walsh, 1993a), but even the lower end of this range may be optimistic for the future. On-road energy intensity (fuel consumption per kilometre driven) of light-duty passenger vehicles in North America fell by nearly 2 per cent per year between 1970 and 1990, to about 13 to 14 litres per 100 kilometres (L/100 kilometres), but is now stationary or rising. The current average on-road energy intensity in North America is 25-30 per cent higher than that in Europe (Schipper, 1996). In other industrialised countries, changes in on-road fuel consumption from 1970 to the present were quite small (see Figure 5).

Whereas on-road average energy intensity fell only slightly in Europe and Japan during the last 20 years, new car fuel consumption according to official tests fell by about 20 per cent as shown in Figure 6 (IEA, 1993a, Schipper, 1996). The divergence between these two measures has been widely reported and is growing in many countries (IEA, 1993a; Martin and Shock, 1989; Schipper and Tax, 1994). Differences arise because, *inter alia*, the tests do not adequately reflect changing traffic conditions; cars are not usually tested with auxiliary equipment, such as air conditioning, in operation; and some tests do not include cold starts, which can result in excess fuel consumption as high as 50 per cent for short trips in cold weather (Hausberger *et al.*, 1994).

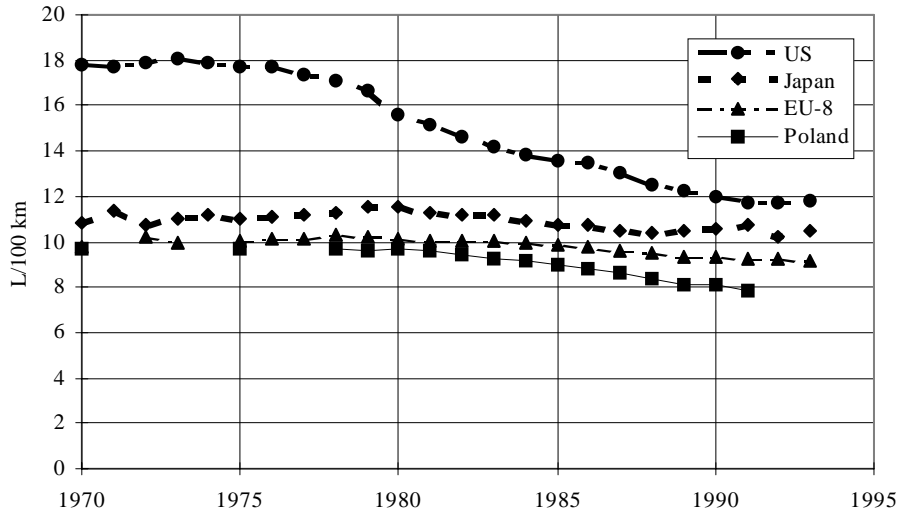


Figure 5. Light-Duty Passenger-Vehicle Energy Intensity (L/100 km)
Source: Schipper, 1996

Even in some countries, such as Italy and France, where fleet average energy intensity has fallen during the past 20 years, the energy intensity of car travel (MJ/passenger-kilometres) has increased as a result of declining car occupancy (Schipper et al., 1993). Meanwhile, the more recent trend is towards higher energy intensity in new cars, in countries including the United States, Germany, and Japan (IEA, 1991; 1993a). The implication is that, without changes in government policy, light duty vehicle energy intensity cannot be expected to fall in the near future, although a reduction of up to 0.5 per cent per year is possible.

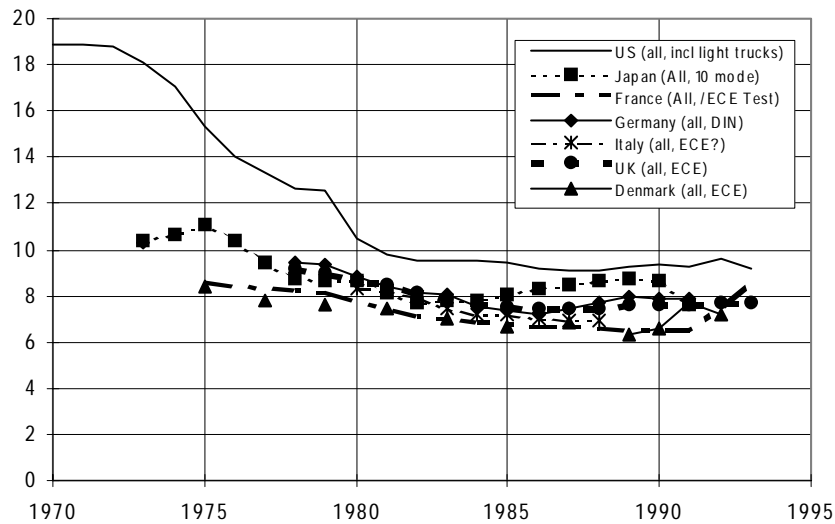


Figure 6. New Light-Duty Vehicle Fuel Economy, L/100 km
Source: Schipper, 1996

Factors in the recent increases in energy intensity include the trend towards larger cars, increasing engine size, and the use of increasingly power-hungry accessories (IEA, 1991, 1993a; Martin and Shock, 1989; DiFiglio et al., 1990; Greene and Duleep, 1993). The range of vehicle types used for personal transport has also expanded, with a growing market for "light trucks" (small pickup trucks and minibuses) and in particular, towards the new classes of sport utility vehicles and the growing use of four- and all-wheel drive options.

The impressive reduction in energy intensity in American light duty vehicles is of particular interest for the current report. Part of the current discussion of the effectiveness of fuel economy standards and fuel taxes revolves around the question of the role played by standards in the United States since they were introduced in the late 1970s, versus that played by increasing real fuel prices during the period 1973 to 1980.

As Figure 7 shows, average truck energy use per tonne-kilometre of freight moved has shown little sign of reduction during the past 20 years in countries where data is available (Schipper *et al.*, 1993). This type of data are difficult to obtain and interpret in most countries, partly because of the wide variety of vehicle types that carry freight by road, and differences among countries in the way in which goods transported by these vehicles are included in national statistics.

Energy use is typically in the region of 0.7 to 1.4 MJ/tonne-kilometres for the heaviest trucks, but can be in excess of 5 MJ/tonne-kilometres for smaller trucks. In countries where services and light industry are growing faster than heavy industry, the share of small trucks or vans in road freight is increasing. Along with the increasing power-to-weight ratios of goods vehicles, these trends offset, and in some cases outweigh, the benefits of improving engine and vehicle technology (Delsey, 1991a). Energy intensity tends to be lower in countries with large heavy-industry sectors, because a high proportion of goods traffic is made up of bulk materials or primary commodities.

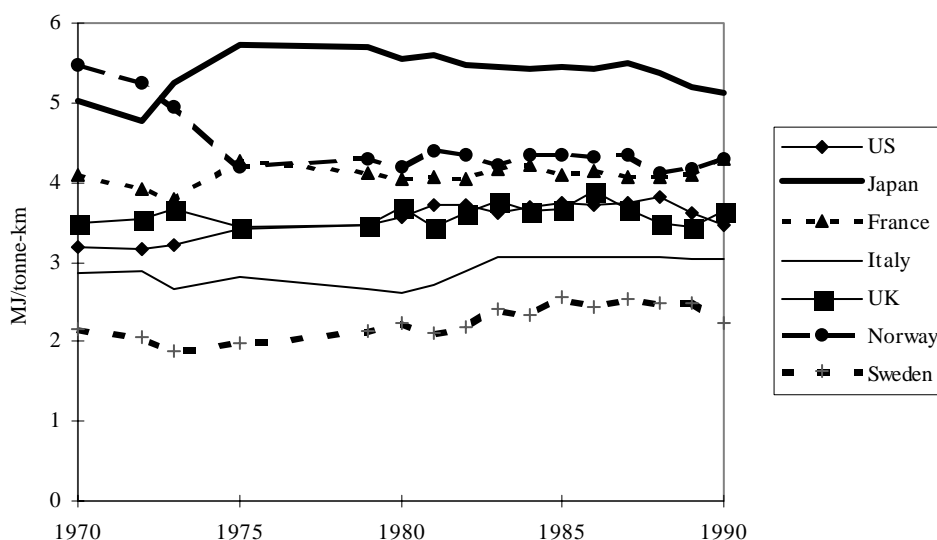


Figure 7. Energy Intensity in Freight Transport, MJ/tonne-km

Source: Schipper *et al.*, 1993

Measures currently in place

A wide range of measures can influence vehicle energy intensity and distance travelled, including vehicle standards, taxes and licence fees, as well as fuel taxes. Table 1 briefly reviews some of the relevant measures in a few Annex 1 countries. Existing measures may affect the potential for new measures in this sector — for example, value-based car taxes can be converted to fuel-consumption taxes without changing the average tax paid, and without even having much effect on the tax rates for existing vehicle models.

Nearly all governments impose excise taxes on sales of gasoline, in addition to normal sales taxes. Most governments also impose excise taxes on diesel fuel. Road transport fuel taxes may have been introduced primarily as revenue-raising measures or as luxury taxes, but are increasingly being justified on the grounds that they reflect the social and environmental costs of road use, and tend to reduce these costs.

Car sales tax is, again, often imposed as a luxury tax. These taxes tend to lead to fewer and smaller cars being purchased than would otherwise be the case, and hence to less driving and lower greenhouse gas emissions. They may also lead to slower fleet turnover, so that the fleet may be more polluting per kilometre driven than would otherwise be the case. Commercial vehicle sales are generally untaxed. In many cases, governments allow accelerated depreciation of commercial vehicles of certain types for tax purposes.

Registration fees and annual road taxes may be used for general revenue raising, or to provide funds for roads and other infrastructure. Registration fees have much the same effect as car taxes, but are more often designed to influence car choice, for example, through higher fees for larger engines. Annual road taxes are designed in some countries to encourage scrapping of old, polluting cars and can also be designed to influence car choice in the used car market — for example the annual “vignette” fee in France is designed to encourage the use of energy-efficient cars. Effects of these measures on greenhouse gas emissions depend on the way they are designed.

Governments impose both safety and emission standards on all types of vehicles. Safety standards can affect energy use because they influence the mass of the vehicle and the rolling resistance of its tyres. Emission standards have led to the requirement to install catalytic converters on most gasoline vehicles now produced in Annex 1 countries, possibly leading to slightly increased energy use, although the effect on total greenhouse gas emissions is probably neutral. Standards for noise and other emissions from diesel vehicles may also have resulted in slight increases in energy use. Only the United States has compulsory vehicle energy efficiency standards.

Several federal countries are listed in Table 1. In many instances, transport policies vary among states within a federation. This is an important consideration in the development of common actions, which usually depend on international negotiations in which only the federal government is represented. Federal governments are likely to find it harder than governments of non-federal countries to agree to any measure, where this might be opposed by individual states within their federation.

Two measures are in place in the European Union (EU), which are of particular relevance to this study because of their international nature. The first is a voluntary agreement by car manufacturers to achieve a 10 per cent reduction in average new vehicle CO₂ emissions per kilometre, on a sales-weighted basis for each manufacturer, between 1993 and 2005. A previous target, to achieve a 10 per cent reduction in fuel consumption per kilometre of new cars between 1978 and 1985, was achieved in 1983. The second is an EU-wide minimum fuel tax: European Council Directive 92/82/EEC sets minimum rates for excise duties on mineral oil for road transport and other fuels. These are 0.245 ECU/litre for diesel, 0.337 ECU/litre for leaded gasoline and 0.287 ECU/litre for unleaded gasoline⁷.

⁷ 1 ECU = US\$1.25

Table 1. Vehicle and Fuel Taxes and Fuel Economy Standards in Annex 1 Countries

| Country | Fuel Tax % of Fuel Price in 1994 | | Vehicle Sales Tax New vehicle registration fees | Annual Road Tax and Other | Fuel Economy Standards, Voluntary Agreements |
|-----------|----------------------------------|----------|---|---|---|
| | Unleaded Gasoline | Diesel | | | |
| Australia | 53-56 | 58 | 22 % general rate for cars and trucks; luxury cars at 45% for wholesale value in excess of A\$52,000 | Annual road tax in some states varies with mass. Registration charges on trucks vary with mass and configuration. | Voluntary target of 8.2 L/100 km by 2000 for cars |
| Austria | 63.6-63.9 | 49.1 | Vehicle sales tax based on vehicle price and fuel economy. | | |
| Canada | 47.8-50 | 41.6 | Vehicle sales tax based on fuel economy in Ontario | | Voluntary CAFE standards for cars and other light duty vehicles |
| Denmark | 66.5 | 41.5 | VAT at normal rate of 25 %, recoverable for commercial goods vehicles Registration charge 105 % of retail price (with tax) for cars to 34 400 DKr. 180 % above; 95 % of price for small commercial vehicles (below 4t) | Road tax is weight related 50 % of insurance premium cost is tax | |
| France | 78.7 | 65.1 | VAT at normal rate of 20.6 %, recoverable on commercial vehicles where owner is VAT registered Registration tax FF550 average, depends on "fiscal horsepower" which is a function of engine size, power rating, and fuel (gasoline/diesel) | Road tax varies by département based on fiscal horsepower, 224 - 10,688 FF 18 % of insurance premium cost is tax | |
| Germany | 76.0-78.1 | 62.5 | VAT at normal rate of 15 %, deductible for vehicles for professional and commercial use Registration charge of DM30 plus DM3 stamp duty | Road tax for cars depends on fuel (gasoline/diesel) and catalyst. Range from DM13.20 to DM45.5 per 100cc of engine size. Commercial vehicles charged according to weight. | |
| Hungary | 63.6-63.9 | 67.4 | VAT at 25 % in general, but 12 % for catalyst-equipped cars | Annual road tax is related to weight: 400 to 1000 HUF/100 kg | |
| Italy | 73.7 | 65.1 | VAT at normal rate of 19 % Luxury tax of Lit 5 million to 12 million according to engine size. Transfer taxes at flat rate in addition to VAT. Flat rate registration charge. | Ownership tax is related to fiscal HP. Ranges from L26 065 to 1 544 485 for 5 to 45 HP, then add L55 395 per HP. Additional charges apply to diesel, LPG and CNG vehicles. 13.5 % tax on insurance. Vehicle radios are taxed at L32 400 to 59 700 per year | |
| Latvia | about 23 | about 13 | New and used cars: tax 20 % of value plus tax related to engine capacity (around US\$50 for 1.5 litre engine) Trucks, 1 % of value | Private cars & buses, road tax varies with weight above 1.5t. Below 1.5t, about \$12, above 12t, about \$160. Trucks, varies with weight. Maximum (over 30t) about \$500. | |

continued on next page

Table 1 continued

| Country | Fuel Tax % of Fuel Price | | Vehicle Sales Tax New vehicle registration fees | Annual Road Tax and Other | Fuel Economy Standards |
|----------------|--|--|--|---|--|
| | Unleaded Gasoline | Diesel | | | |
| Japan | 48.3 | 43.7 | <p>Cars State tax: VAT at normal rate of 3 % Local tax: 5 % of price</p> <p>Private Trucks State tax: 3 % of price Local tax: 5 % of price</p> <p>Company Vehicles State tax: 3 % Local tax: 3 %</p> | <p>Cars Tonnage tax (national) 6 300¥ Vehicle tax (local) 34 500 ¥ (@1 500cc) Light motor vehicle tax (loc) 7 200¥ (4 wheel)</p> <p>Private Trucks Tonnage tax: 8 800¥ per 2 tonnes Vehicle tax: 22 500 ¥ (@ 4 tonnes) Light motor vehicle tax 4 000¥</p> <p>Company Vehicles Tonnage tax, as private vehicles Vehicle tax: 8 500 ¥ (1 500cc) Light motor vehicle tax: 5 500¥ for cars 4 000¥ for trucks</p> | Voluntary car and truck standards by size class |
| Netherlands | 74.1 | 59.7 | <p>Sales tax: VAT at normal rate of 17.5 % Registration fee 45.2 % of net list price for cars, less DfI 3 395 for gasoline cars and DfI 1 287 for diesel cars.</p> | Annual road tax is related to weight and fuel type. | |
| New Zealand | 47.7 | 11.9 | | Road user charge for heavy vehicles | |
| Poland | 57.6 | 36.3 | <p>Cars Import duty, 35 %, but 30 % for EU, 0 % below import quota from EU. Border tax, 6 % on CIF price + import duty. Excise tax, 15 % of CIF price +43%. if CIF price exceeds 7000 Ecu. VAT, 22 % on CIF price + all other taxes.</p> <p>Vans and trucks Import duty 35 % of CIF but 0% up to quota Border tax, 6 % on CIF + import duty VAT, 22 % on CIF + other taxes</p> | <p>Ownership tax on cars, 48 to 990 zł Tax on buses, capacity-related, 180 to 726 zł Tax on trucks, weight related, 114 to 828 zł (US\$1=2.57zł)</p> | <p>Ban on importing 2-stroke vehicles; Ban on importing cars older than 10y; trucks older than 3y; Ban on importing damaged vehicles; Efficiency of imported cars is being addressed by Ministry of Industry and Trade</p> |
| Russia | 23.0 ^a | 20.0 | | | |
| Spain | 66.8 | 56.9 | <p>VAT at 16 % (normal rate is 15 %). Special tax of 12 % for private vehicles with various exceptions. A reduced rate for 4WD vehicles is being increased to the normal rate. 8 650 ptas for all vehicles.</p> | <p>Ownership tax on cars related to fiscal horsepower. Ranges from 2 652 to 18 820 ptas. Tax on commercial vehicles relates to weight. Ranges from 8 878 to 31 148 ptas. 5% tax on insurance.</p> | |
| United Kingdom | 70.2 | 67.0 | <p>VAT at normal rate of 17.5 %. No special car tax or registration tax.</p> | Annual road tax of £135 for light duty vehicles. | |
| United States | 25 to 38 part State tax, varies by State | 31 to 42 part State tax, varies by State | <p>Sales tax varies by State "Gas-guzzler" tax, \$1000-7700 increasing with fuel consumption for cars below 22.5 mpg. Luxury tax, 10 % of cost over \$30 000.</p> | Varies by State: \$14-138 | CAFE Standards for cars and other light duty vehicles |

a) Leaded gasoline

Study Organisation and Approach

The remainder of this report is divided into three main parts: Part 1 addresses measures that target vehicle fuel economy; Part 2 addresses increases in fuel tax; and Part 3 addresses transport innovation. Each section discusses the greenhouse gas and economic effects of the measures it addresses, and considers the potential for common action in relation to those measures.

The evaluation of measures is based on a review of the available literature, with additional analysis and inference to apply experience and analysis from individual countries to relevant regions within the Annex I group.

In each case, the study aims to evaluate: the potential impact of the measure on vehicle CO₂ emissions; the direct and wider economic costs associated with the measure; the other policy issues associated with the measure, including trade, employment, social and environmental issues; issues that need to be considered in the implementation of the measure; the potential advantages and disadvantages of common action to implement the measure; and the possible approaches that Annex I countries might take to implement the measure in common⁸.

Finally, the study includes a section that briefly examines options for the implementation of common actions, noting in particular the opportunities to combine measures of the various types covered in the study.

⁸ These are the elements identified for consideration in the Framework for Analysis of the Common Actions project.

PART 1. MEASURES TARGETING FUEL ECONOMY

This section will evaluate the potential of a range of measures targeting light duty vehicle (cars and other personal passenger vehicles) to improve fuel economy. The measures to be evaluated are feebates, fuel economy standards and voluntary commitments by manufacturers. In each case, the study will examine the strength of measures to achieve 0.75 per cent, 1.5 per cent and 3 per cent per annum fuel economy improvements over the period 2000 to 2020. Estimates will be made of the effect of such improvement rates on CO₂ emissions and on the economy.

Existing and planned measures

Standards, targets and voluntary agreements

The best-known, and most discussed and analysed case of a fuel economy standard is the United States' Corporate Average Fuel Economy (CAFE) standard. Legislation was introduced in 1975, placing a lower limit on the sales-weighted average fuel economy (in mpg) of light duty vehicles sold by manufacturers into the US market. Separate standards were set for cars and light trucks. The standard has tightened, from 18 mpg on cars in 1978 to 27.5 mpg in 1985, and has never exceeded this level. In some years, the standard has fallen, and subsequently risen again (see Figure 8). On trucks, the standard was tightened from 17.2 mpg in 1979 to 20.5 mpg, and is 20.7 mpg for model year 1996.

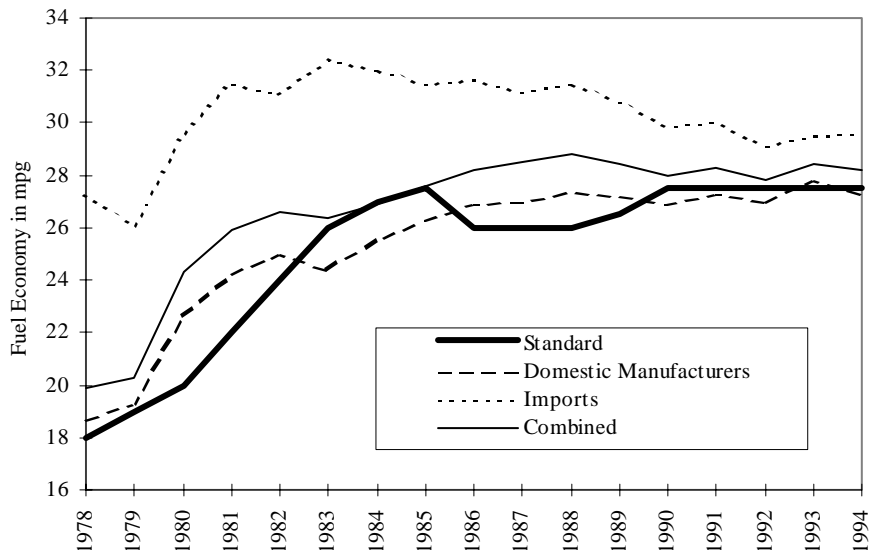


Figure 8. The CAFE Standard for Cars in the United States, and CAFE Levels Achieved by Manufacturers

Source: Davis, 1995

In addition to the basic standard, the CAFE legislation includes a system of charges and fines, which provides additional incentives for manufacturers to sell energy-efficient cars. A “Gas Guzzler” tax was introduced from 1980, starting at \$200 for cars below 15 mpg, and increasing to \$550 below 13 mpg. By 1991, the tax had increased to \$1 000 for cars under 22 mpg, rising to \$7 700 for cars under 12.5 mpg. At the same time, manufacturers have to pay fines if they fail to achieve the standard in their sales. A total of \$322 million (1990 prices) has been paid in fines since CAFE was introduced (Davis, 1995).

There are many possible designs for fuel economy standards, targets and voluntary agreements. Proposals for a strengthening of the US CAFE standard, or for implementation of a standard elsewhere, mostly differ from the existing US approach, in which a single CAFE level is defined for cars, and another for other light duty passenger vehicles. This approach is criticised, on the one hand, because the single car standard is thought to have imposed greater costs on US domestic manufacturers than on certain foreign manufacturers⁹, and on the other hand, because having a separate light truck standard fails to address the effect on fuel consumption of the rapidly expanding market for “light trucks” used as cars.

Alternative options include setting a single standard for all vehicles used for personal private transport, or the opposite extreme, setting a standard that varies according to the weight, interior volume, engine power-to-weight ratio, or vehicle class. Recent proposals for standards both in the United States and the European Union, as well as the legislation in place in Japan, have all involved some allowance for higher fuel consumption in larger and/or heavier vehicles. This is essentially to avoid imposing high costs on the manufacturers of such vehicles, and the opposition that those manufacturers would present to any attempt to implement a single standard. There are many difficulties with any attempt to apply CAFE-type standards according to some fixed formula, and there are particular complexities associated with standards for trucks, which vary in configuration. Despite much discussion and analysis in the United States, these problems have not been resolved.

Many Annex I country governments have, at some time, negotiated voluntary agreements with vehicle manufacturers to improve fuel economy according to some target level or improvement rate. Some governments have also imposed compulsory targets on manufacturers. Some recent targets and agreements include the following:

- Canada has recently signed an agreement with domestic and import manufacturers in order to develop a strategy for further fuel efficiency improvements through a balanced approach aimed at vehicle owners and operators as well as vehicle technology.
- The Japanese government has set targets for car fuel economy improvements within different size classes. While there is no constraint on the shift between sales of different size classes, the targets are expected to increase average fuel efficiency¹⁰ from 12.5 to 13.5 km/L¹¹ between 1990 and 2000 — an increase of 8.5 per cent (Minato, 1996).

⁹ CAFE in the United States has historically favoured Japanese manufacturers, because their vehicles are generally smaller than domestic manufacturers’ products, but disadvantaged European manufacturers, because most of their exports to the United States are luxury models.

¹⁰ Based on Japanese 10 · 15 mode test

¹¹ The fuel consumption change is from 8.0 to 7.4 litres per 100 km, implying a reduction rate of 0.8 per cent per year

- Germany has introduced a target of 25 per cent reduction in average fuel consumption by cars between 1990 and 2005 — a rate of 1.9 per cent per year.
- Switzerland recently declared a target for cars imported to the country (almost all cars are imported) of a reduction by 15 per cent in average fuel consumption between 1996 and 2001 — a rate of 3.2 per cent per year (Swiss Federal Council, 1995).
- European car manufacturers have agreed to a target of 10 per cent reduction in average new vehicle CO₂ emissions per kilometre, on a sales-weighted basis for each manufacturer, between 1993 and 2005.
- Austria is planning to implement binding agreements with car manufacturers requiring improvements in vehicle energy efficiency (Austria, 1995).
- France is exploring the possibility of a Europe-wide limit on truck engine power, with the aim of reducing energy intensity by 20 per cent in 2015 (France, 1995).

ECMT¹² Member-country transport ministers and European and world automotive industry associations have issued a “Joint Declaration,” in which they commit to work together “to substantially and continuously reduce the fuel consumption of new cars sold in ECMT countries” and “to manage vehicle use so as to achieve tangible and steady reductions in their total CO₂ emissions”. In the declaration, they undertake jointly: to examine the possibilities for a car labelling system; to develop criteria for information technology in vehicles; to improve co-ordination of research and development; to develop information/education campaigns aimed at vehicle users, dealers and importers; and to study the environmental value and economic feasibility of a variety of measures aimed at reducing vehicle CO₂ emissions. They have established an “Informal Industry-Government Working Group” to collect and share information and data that would help to establish a common understanding of the trends and influences on transport CO₂ emissions, and to monitor progress towards achieving the objectives of the Declaration. The declaration includes no quantitative energy intensity reduction target, but might form the basis for a future target.

The European Commission, in a communication to the European Union Council and European Parliament, recently proposed a strategy to achieve a substantial reduction in CO₂ emissions from cars, responding to an Environment Council request to the Commission to look at the possibility of substantially lowering the fuel consumption of new cars by 2005. Twelve of the EU Member states and the European Parliament have mentioned a target of achieving fuel consumption reductions to 5 litres/100 kilometres for gasoline cars and 4.5 litres/100 kilometres for diesel cars (EC, 1995). Achieving this target by 2005 would represent a reduction rate of 2-3 per cent per year. The Commission also proposed a strategy for moving towards this target, while recognising that 2005 was a rather ambitious target date, and a longer time horizon would allow the target to be reached through renewal of the vehicle model range and without substantial downsizing of the fleet. The Commission’s proposed strategy consists of a combination of

¹² The European Conference of Ministers of Transport. This organisation provides a forum on transport policy issues in which almost all Annex I countries participate. Members are: Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Moldova, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. Associate Members are Australia, Canada, Japan, New Zealand, the Russian Federation and the United States. Albania and Morocco are Observer countries.

measures, including voluntary agreement with industry, fiscal measures such as feebates, and fuel economy labelling (EC, 1995).

Feebates

Recently, several governments have considered the possibility of using “feebates”: taxes for vehicles with high fuel consumption along with rebates for vehicles with low fuel consumption. Such a scheme is in operation in Ontario, Canada, with a tax ranging from Can\$75 to 4 400 (about US\$55 to 3 300) on new cars with fuel consumption over 6 L/100 kilometres sold in the province; purchasers of cars with fuel consumption under 6 L/100 kilometres receive a Can\$100 (about US\$75) rebate (Canada, 1994).

Austria has also implemented a tax system known as “NOVA” (*Normverbrauchsabgabe*).¹³ NOVA was introduced in 1992, prior to which the tax rate on new vehicles was 32 per cent. The tax on a gasoline vehicle with fuel economy of 8 L/100 kilometres is unchanged. New vehicles with lower fuel economy pay less tax than before the change, while vehicles with higher fuel economy pay more tax up to 10 L/100 kilometres for gasoline cars, 9 L/100 kilometres for diesel. The maximum level of the tax is 37 per cent of the vehicle pre-tax price. This tax provides an incentive to improve fuel economy only in the range where the tax rate varies with fuel economy (i.e. below 10 L/100 kilometres for gasoline cars, 9 L/100 kilometres for diesel cars).

While these are the most significant applications of the feebate concept identified for this study, many countries apply vehicle sales taxes that are related to the price of the vehicle. As Figure 9 shows for German cars, there is a strong correlation between car price and fuel economy. However, there is a very significant difference between the type of incentive offered by a feebate and that offered by a sales tax. The sales tax encourages consumers to “downsize” — that is, to purchase cheaper, and hence lower-performance, less comfortable cars. Sales taxes provide a disincentive to adding more expensive, energy-efficient technology to a car of a given level of performance and comfort. A similar argument applies to vehicle purchase taxes and registration fees that are linked to engine size: they provide an incentive to reduce engine size, which may lead to some reduction in fuel consumption, but they do not provide a direct incentive to improve energy efficiency. A feebate, while providing an incentive to downsize, also provides an incentive to use more efficient but more expensive technology.

For countries with existing vehicle sales taxes, the implementation of feebates offers a revenue-neutral way of reforming existing taxes to introduce an incentive for improved fuel economy. Similar reforms are possible for other vehicle charges, such as registration and licence fees.

¹³ The sales tax T on a new vehicle is calculated based on the pre-tax price P and the vehicle’s rated fuel economy FE in L/100 km:

$$P+T = 1.2 \times P \times (1 + 0.02(FE-3)) \text{ for gasoline vehicles up to } FE = 10 \text{ and}$$

$$P+T = 1.2 \times P \times (1 + 0.02(FE-2)) \text{ for diesel vehicles up to } FE = 9.$$

NOVA is described in more detail in Appendix C

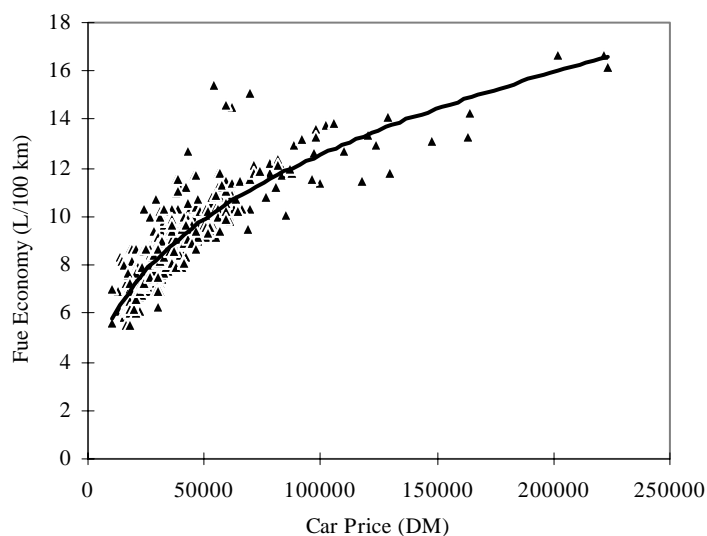


Figure 9. Car Fuel Economy vs. List Price in the German Market

Source: DRI, 1995

Approach to analysis of measures

There is a close relationship among analyses of feebates, standards, targets and voluntary agreements, because all of these measures stimulate the same basic mechanisms. They have effects on manufacturers' research and development of new technology, incorporation of new technology into vehicles, consumer vehicle choices, the number of vehicles sold, and the extent to which the vehicles are driven. However, there are major uncertainties, differences among these classes of measures in the way they are implemented, and hence the way their costs and effects are determined. The effects are summarised here, but their magnitudes and uncertainties are discussed in more depth later in the report and in Appendices A to C.

1. The various measures encourage manufacturers to develop new technology for incorporation into vehicles and to re-channel some of their research efforts which are currently focused on improving performance, comfort and safety¹⁴ into research to improve fuel economy. This long term effect is, in fact, the most uncertain aspect in the effects of the measures. When a measure is introduced that requires the introduction of technology that is not yet available, it is very likely to stimulate additional research by manufacturers, but it is not possible to predict how successful this research will be. An important disadvantage of compulsory standards, relative to feebates or voluntary approaches, is that they do not allow for this uncertainty and may impose excessive costs on manufacturers attempting to comply.
2. The measures encourage manufacturers to incorporate more energy-efficient technology in vehicles. This is likely to be a short-term effect in addition to underlying technical progress, but one that may only be maintained as long as the measures are sustained so as to encourage technical change faster than the underlying rate. In estimating the costs and effects of standards, feebates and targets in this study, manufacturers are assumed to respond in a way that equalises the marginal cost of fuel economy improvement for each vehicle sold. Results are thus critically dependent on assumptions about the cost curves for energy efficiency

¹⁴ This may conflict with the policy objective of reducing accidents and the associated injuries and fatalities.

improvements in different types of vehicles. This study explores the effect of using a range of different cost curves discussed in Appendix A.

3. The measures encourage manufacturers to market, and/or consumers to purchase both more energy efficient, and smaller vehicles. These are effects that will only be maintained as long as the measures are sustained, so as to encourage technical change faster than the underlying rate. Existing studies have used a wide range of estimates, based on econometric and stated preference studies, for the responsiveness of consumers to feebates in choosing less energy-intensive vehicles. The current study tests this full range of estimates which are discussed in Appendix C.
4. Increases in vehicle technology costs tend to increase average vehicle prices, but the tendency towards smaller vehicles pushes average prices down. The overall effect could be either an increase or a decrease in vehicle prices, resulting in a decrease or an increase respectively in the number of vehicles purchased. This affects the vehicle stock and hence the amount of traffic. Estimates of these effects in the current report are based on econometric studies discussed in Appendix B.
5. As the measures result in improved energy efficiency, the overall costs of driving fall. This tends to result in increased mileage — the so called “rebound” or “take-back” effect. A range of values for the rebound effect are tested in this study, based on the econometric studies discussed in Appendix B.
6. Reduced driving costs also tend to result in increased vehicle purchases, as the consumer utility of owning a vehicle increases, and as a smaller proportion of household expenditure is used for fuel. The sizes of these effects are estimated based on the econometric studies discussed in Appendix B.

The relative size of the various effects is subject to considerable uncertainty, and has been debated at length and without resolution in the context of the United States. Consumer and manufacturer responses depend strongly on the cost and availability of energy-efficient technology, and on the extent to which consumers change their behaviour in response to changes in price and technology. However, certain stakeholders in the United States debate argue that the costs of technology to manufacturers, and the tendency of consumers to increase their mileage in response to reduced driving costs, are both so large that tighter standards would be costly and environmentally counterproductive. Manufacturers in North America and Europe have consistently emphasised their preference for voluntary approaches, which would not impose these costs on them and society.

In general, technical changes are likely to dominate for relatively weak measures, but become less important for stronger measures, as the marginal cost of adding more fuel-efficient technology increases. Meanwhile, although many economic analyses of these measures assume that consumers will respond with a constant elasticity to changes in vehicle costs, it is possible that they would not respond to small cost changes.¹⁵ Thus, the consumer demand response is only likely to become important for much stronger measures.

¹⁵ In a market where retail discounts of 10 per cent or more are common, feebate charges of 2 or 3 per cent may not be noticed by consumers — they could be lost in the general uncertainty about prices (“lost in the noise”) when choosing among vehicles.

The relative importance of the various mechanisms also depends to some extent on how the measure is implemented. For example, DRI (1991) suggests a feebate which is levied from, or paid to, the consumer directly and cannot form part of a car loan. As fees for high-consuming vehicles would be a constraint for consumers with little capital — and, indeed, the rebate for low-consuming vehicles would be very attractive — it would be likely to have more effect on them than feebates that were incorporated into vehicle list prices.

Each of these mechanisms, or groups of mechanisms, has been analysed in considerable depth, to a large extent because of experience in the United States with CAFE standards. This report draws on this body of analysis, as well as literature on the effects of the individual measures. A more detailed discussion of the literature can be found in Appendices B and C.

Different approaches have been used in the literature for the assessment of these measures. Most studies, but not all, employ a model that takes account of both consumer responses and technology (manufacturer) responses. Consumer responses are generally estimated from stated-preference surveys or econometric (revealed-preference) studies. These studies evaluate consumer demand for vehicles of different types as a function of income, vehicle price, fuel price, vehicle fuel economy and other variables. Manufacturer responses are generally estimated from detailed, bottom-up engineering studies, which analyse the cost and energy efficiency changes associated with individual changes in vehicle technology.

The measures are considered only for cars and other light duty vehicles. This is partly because there is little literature evaluating their use for other types of vehicles, but also because the measures are thought to be less appropriate for commercial vehicles. Fuel economy standards and feebates are likely to be hard to define for many types of commercial vehicles, and the effects are hard to predict. Meanwhile, commercial vehicle purchasers are likely to be more responsive than car purchasers to measures targeted more directly at their CO₂ emissions, such as a fuel tax, or other alternatives, which are addressed in the Working Paper 13.

Results presented in this report for the effects of standards are based on the assumption that they are enforced, and that the new car fuel economy achieved is equal to, or better than, the standard. Other effects of standards — on the cost and number of vehicles purchased, the characteristics of vehicles, and the amount they are driven — are explored largely in the light of the United States' experience and based on theoretical expectations from engineering and econometric studies reviewed in Appendix B.

Feebates and related measures have been analysed in some detail recently for both the United States Government (DOE, 1995; DRI, 1991) and the European Commission (DRI, 1995). Independent analyses (DeCicco *et al.*, 1993; Koopman, 1995) were also reviewed for this study. Table 2 summarises the definitions of feebates analysed by these studies, and the approaches taken. This report carries out additional analysis based on the range of assumptions and findings in these studies.

In each case, the measure involves a feebate that increases as vehicle energy intensity increases. In most, but not all cases, the zero-point is chosen to achieve a balance between aggregate taxes and aggregate rebates. No new government revenue is generated and administrative costs are expected to be small compared with the overall transfer between vehicles. The zero-point is reduced as average energy intensity falls. In some instances, separate zero-points are chosen for different vehicle types (generally cars and light trucks in the United States) so that the measure is revenue-neutral within those vehicle types.

Table 2. Methodology in Feebate Studies

| Measure Definition | Vehicle Group | Approach |
|---|--|---|
| DOE (1995) for United States | | |
| Linear, \$210 per L/100 km | Cars and Light Trucks (separate zero-points) | Uses: detailed technology model to determine manufacturing costs of individual car technology options, a consumer utility |
| Linear, \$420 per L/100 km | Cars and Light Trucks (separate zero-points) | model to determine the utility for a household associated with owning a particular vehicle and hence the probability that |
| Linear, \$210 per L/100 km | Cars and Light Trucks (one zero-point) | the household will own that vehicle; travel is determined by a sub- model based on household size, income, car(s) |
| Non-linear with respect to energy intensity, \$210 per L/100 km at average fuel economy Average \$420 per L/100 km | Cars and Light Trucks (separate zero-points) Cars and Light Trucks (separate zero-points) | owned, number of workers, location, etc. |
| Cars: \$450 per L/100 km per cubic metre of interior volume Trucks: Linear, \$210 per L/100 km | Cars and Light Trucks (separate scale) | |
| DRI (1995), for Denmark, France, Germany, Italy, Spain, United Kingdom | | |
| \$2000 per L/100 km | Cars | Methodology is not specified in detail. Principally appears |
| \$1500 per L/100 km; 1040 Ecu net tax. | Cars | to use a single-equation car demand model to estimate the effect of feebates on consumer demand for cars of different sizes. |
| Koopman (1995) for European Union | | |
| \$375-625 per L/100 km | Cars | Methodology is intermediate in sophistication between that of DOE(1995) and DRI (1995). Uses an economic model of car technology supply, consumer demand for cars and distance travelled, and consumer utility (as a function of spending on transport) |
| DeCicco et al., 1993 | Cars and light trucks | Does not analyse effects of feebates on fuel economy and emissions, but looks at effects of a variety of feebate structures on competition between vehicle manufacturers. |

The effects of targets and voluntary agreements for improvements in fuel economy are evaluated using the WEC (1995) transport scenarios, which include varying assumptions about the rate of improvement in light duty vehicle fuel economy in different world regions.

The effects of achieving given rates of improvement (0.75 per cent, 1.5 per cent and 3 per cent per year) are modelled for the five Annex I regions (the first five in Table 3) by changing the rate of change of fuel economy in the “Muddling Through” and “Markets Rule” scenarios. The model includes a “rebound” effect where reduced driving costs lead to additional traffic relative to the reference scenarios. Vehicle sales are also assumed to increase.

Table 3. Annual Percent Reduction in Car Energy Intensity, WEC Scenarios, 1995-2020

| | OECD EUROPE | NORTH AMERICA | OECD PACIFIC | CIS | CENTRAL AND EASTERN EUROPE | ASIA | AFRICA | LATIN AMERICA |
|------------------|-------------|---------------|--------------|--------|----------------------------|--------|---------|---------------|
| Green Drivers | 2.32 % | 2.45 % | 2.40 % | 2.73 % | 2.40 % | 2.45 % | 1.23 % | 2.73 % |
| Muddling Through | 0.47 % | 0.67 % | 0.38 % | 0.35 % | 0.38 % | 0.67 % | -0.73 % | 0.35 % |
| Markets Rule | 1.00 % | 1.04 % | 0.80 % | 1.14 % | 0.80 % | 1.04 % | -0.26 % | 1.14 % |

Costs of Energy Intensity Improvements

The costs of fuel economy improvements in cars have been extensively analysed, and the literature on this subject is reviewed in Appendix A. Figure 10 summarises this information, showing a range of possible future costs of energy intensity reductions based on the literature.¹⁶

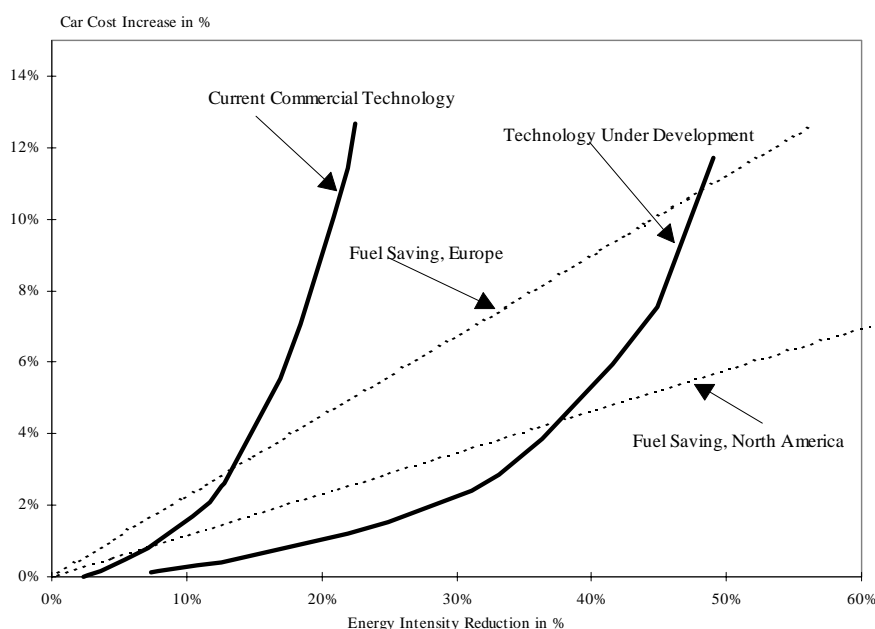


Figure 10. Synthesis of Studies: The Uncertainty in Future Costs of Energy Intensity Reduction

Understanding the level of these costs, and the shape of the curves, is crucial for evaluating the potential effects of policies aimed at improving vehicle fuel economy. The high cost curve is based on industry estimates of the costs in 2001 of introducing vehicle technologies which are already in mass production somewhere in the world (NRC, 1992). The curve is similar to that generated from high cost estimates for the United Kingdom (DTp, 1996). The lower curve is based on low cost estimates for the United Kingdom (DTp), including technologies which are not yet in mass production, some of which probably could not be commercialised before about 2010, and which might affect consumer acceptance of vehicles.

¹⁶ Estimates of cost have been identified only for North America and Europe. The costs here are percentage increases in car cost relative to a base price of US\$16,000 which is approximately the average car price in the United States (Davis, 1995) and is a fairly typical cost for European countries (DRI, 1995). Fuel economy improvements are relative to a base of approximately 10.5 litres per 100 km in North America, and 8.5 litres per 100 km in Europe. The range of cost curves is further discussed in Appendix A.

Some of the technologies considered in the construction of both curves are likely to substantially increase their market penetration in the coming years with or without government intervention — indeed, some will have done so since the studies on which the curves are based were carried out. They are used in this report as being indicative of the possible range of costs of introducing new technology to light duty vehicles.

Costs are likely to depend heavily on timing and the extent of notice given to the industry for any new standards. In many cases, new technology will not add to costs, provided it is introduced in the normal retooling cycle of the industry, which is of the order of five years. Some technology based on new materials and joining techniques may offer cost reductions.

Both the high cost estimate and the low cost estimate in Figure 10 would be disputed by one set of stakeholders or another. This dispute arises from disagreements about a) the cost and effectiveness of various technological developments and b) the extent to which consumers would be prepared to buy vehicles including those developments, especially where cost, performance, comfort and safety might be affected. There appears to be little hope of resolving this dispute in the near-term future, and the current report simply takes the two extremes as a range of possible values for technology costs. Working Paper 13 addresses some of these questions of technological and behavioural uncertainty in more depth, and will explore options for governments to design measures to deal with these uncertainties.

Some technology improvements may pay for themselves in fuel savings. The dotted lines in Figure 10 show the discounted value of fuel saving for energy intensity reductions in typical cars in North America and Europe. Below these dotted lines, fuel economy improvements pay for themselves in reduced, discounted fuel cost. Because of the uncertainty in technology costs, and consumer acceptance of new technology, there is a considerable range of uncertainty in the fuel economy improvements that would be cost-effective in the long term. By 2020, the cost-effective reduction in new vehicle energy intensity, relative to the trend, could be 5 to 30 per cent in North America, and 10 to 45 per cent in Europe¹⁷. In the shorter term, cost-effective energy savings probably lie in the range 5-20 per cent in North America and 10-25 per cent in Europe and OECD Pacific region for new vehicles if efficient designs are introduced at a rate in line with the normal retooling cycle of the industry (over 5-10 years).

Greenhouse Gas Effects

CAFE

The United States introduced a Corporate Average Fuel Economy (CAFE) standard in 1975. The effects of CAFE on fuel economy in the United States have been much debated, with some observers suggesting that the car fuel consumption reductions of the 1970s and 1980s were caused by high oil prices or by increasing car imports from Japan. These arguments are reviewed by OTA (1994), which finds that there is little real doubt that CAFE has been effective in reducing new vehicle fuel consumption.

Provided CAFE standards are set and enforced at a technically achievable fuel consumption level that is lower than would otherwise be achieved, they are likely to result in average new vehicle fuel economy levels at, or slightly below the standard. This makes CO₂ emissions per vehicle-kilometre very easy to

¹⁷ Fuel savings are calculated over 4 years, discounted at an 8 per cent discount rate. In North America, the fuel price is taken to be 30 US¢ per litre of gasoline and the typical car is assumed to be driven 16 400 km per year. In Europe, the fuel price is assumed to be 85 US¢ per litre of gasoline and the average car is assumed to be driven 13 800 km per year.

calculate. However, CAFE standards are likely to affect the number of new vehicles bought, and the amount those vehicles are driven.

Effects on car model mix and technology

If there were only one car manufacturer, or if all manufacturers produced a similar mix of vehicles, CAFE standards would be expected to have the same type of effect as a feebate, assuming they could be designed to achieve exactly the same fuel economy change. Economically rational manufacturers would do so in such a way that they would equalise the marginal opportunity cost per unit of energy efficiency improvement in each vehicle sold. The opportunity cost for manufacturers of introducing the technology includes its effects on the price consumers will pay for the vehicle, and on the number of vehicles they are able to sell. Assuming that manufacturers were economically rational and had full information, they would respond in the same way, whether subject to a corporate average fuel economy standard, a feebate or a target, provided each was designed to achieve the same average fuel economy improvement from that manufacturer. The extent to which they did so would depend on the gradient of the feebate schedule or the stringency of the standard. Improvements of this type would be just as important for small, low-fuel-consuming vehicles as for large, high-fuel-consuming vehicles.

Car manufacturers differ in the type of vehicles they produce, and so they would incur different costs in achieving a given CAFE standard. Thus, the measure would operate in a similar fashion, but would have different effects on different manufacturers. Some manufacturers, who produced small or very energy-efficient cars, would have no incentive to improve the efficiency of their products, while others, who produced only luxury cars, might be unable to achieve the standard or would incur very high costs in doing so. This situation has been the case in the United States market, where the big three domestic manufacturers have a product mix that allows them to just meet the standard, while some foreign manufacturers (mostly Japanese) have consistently sold cars that were more efficient than the standard, and other foreign manufacturers (mostly European) have been unable to meet the standard and have had to pay fines.

It might be argued that feebates are fairer and more economically efficient because they apply equal marginal opportunity costs to all manufacturers, without the need to predict the cost-effectiveness of new technology. Many alternative formulations of CAFE have been proposed which reduce differences in the effects on manufacturers. These could include:

- the use of tradable CAFE permits
- a national new vehicle average fuel economy standard to be met by manufacturers collectively, with individual manufacturers' targets determined through negotiation
- CAFE combined with feebates, or with "gas guzzler" taxes
- CAFE that depended on the type of cars sold — for example, allowing higher average fuel consumption for the product mix of manufacturers that produced larger or heavier cars, or cars with more seats.

Of these options, tradable CAFE permits would have an effect closest to that of feebates, and would be the most economically efficient approach to imposing fuel economy improvements on manufacturers. A collective national standard could have the same effect, provided negotiations between manufacturers were fair. However, the other options might be easier to implement.

Combining CAFE with feebates or with gas guzzler taxes allows governments to ensure that a minimum level of average fuel economy with reasonably well-known costs is achieved, at the same time as providing an incentive for improvements beyond that minimum level.

CAFE that depends on the type of cars sold avoids excessive costs to producers of luxury cars, and allows an incentive to be provided to producers of small cars, but its efficiency as a measure depends on the skill of those designing the legislation, who must determine the relationship in the standard between vehicle characteristics and fuel economy. It is hard to justify any particular formulation of such a standard (e.g. relating it to interior volume, engine power, list price, or mass) without creating incentives for “gaming” where manufacturers redesign their product mix to take advantage of the formulation. Meanwhile, separate scales would probably be needed for different types of vehicles.

For ease of analysis in discussing the effects of CAFE, targets and voluntary agreements, we make the assumption that governments specify the national new vehicle average fuel economy improvement to be achieved, and that manufacturers find the least cost approach to achieving it. This essentially amounts to the situation that would arise under a system of tradable CAFE permits, or CAFE levels negotiated between manufacturers. The effects are also (assuming completely rational and cost-minimising manufacturers) equivalent to those that would occur under a feebate system.

Effects on car technology

To improve fuel economy, car manufacturers have to sell more fuel-efficient vehicles. They can do so either by introducing new technology in existing vehicle types, often at a slightly higher price, or by adjusting their marketing to sell more of the relatively low fuel-consuming vehicles in their existing range of models. As the vehicles that consume less fuel are usually the smaller, cheaper ones, this amounts to encouragement for downsizing.

Analysis of the history of CAFE and its effects in the United States indicates that some slight downsizing did, indeed, occur at the times when CAFE standards were increasing most rapidly. However, as Figure 11 shows, there has been no long term reduction in car interior volume. On the other hand, the graph does show that car weight and engine size fell sharply, especially during the period when US domestic manufacturers were improving the CAFE of their sales most rapidly, but these have increased since the mid-1980s, when CAFE standards stopped being increased.

Throughout the period that CAFE standards have been applied, engine power-to-size ratios have been increasing. Thus, engine sizes fell in the early days of CAFE without much penalty in performance. More recently, engine size has been stationary or increasing, giving substantial increases in performance.

Nivola and Crandall (1995) suggest that CAFE standards can be given little, if any, of the credit for the drop in US new car energy intensity during the period 1978 to 1984 — they perform an econometric analysis to show that fuel price was the main influence. Other influences may have included increased penetration in the car market by foreign manufacturers with smaller vehicles, and other factors, such as inflation and economic cycles — indeed, these factors are all inter-linked. The energy intensity of new

American cars had already started to fall in 1974, presumably as a result of downsizing after the oil price 1973-74, and there was a further sharp drop in 1980 following the second oil price rise (see Figure 6 on page 23).

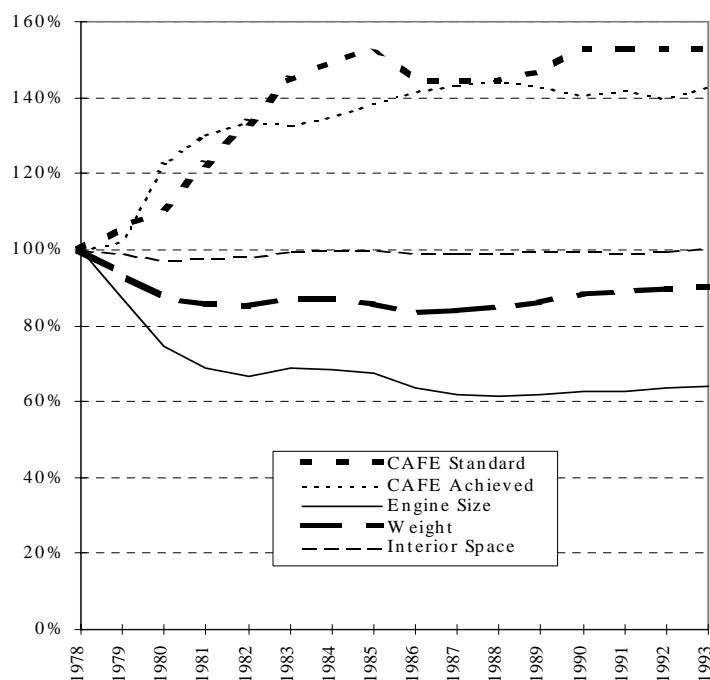


Figure 11. Annual Percentage Changes in US Car Fleet CAFE, Engine Size, Weight and Interior Space

Source: Davis, 1995

Effects on fleet size and traffic — the “rebound” effect

The size of the CAFE “rebound” effect — induced additional traffic resulting from the reduced cost of driving — is an essential determinant of whether CAFE standards, feebates or other related measures will be cost-effective. The issue has mainly been discussed with reference to analysis of the elasticity of travel (vehicle-kilometres) with respect to the fuel cost per kilometre (or mile). Greene (1992), finds that the short term elasticity is about -0.13 and that there is no evidence for any difference in the long-run elasticity. He concludes that the rebound effect must lie in the range 5-15 per cent — that is, a 10 per cent reduction in the fuel cost of driving will lead to a 0.5-1.5 per cent increase in driving. Other studies, reviewed in Appendix B, indicate that the long-run elasticity of travel with respect to fuel costs might be higher than that found by Greene (1992). Typical values using are in the region of -0.3 to -0.5. About half of this is due to changes in the distance driven per vehicle, and half due to changes in vehicle ownership. None of the studies reviewed in this report appears to have investigated whether consumers respond to reductions in driving cost that arise from improvements in fuel economy in the same way that they respond to reductions in fuel price.

The rebound effect is not only a response to changes in the fuel cost of driving, as has already been outlined above on page 33. In addition to the effects of CAFE on fuel economy, and hence fuel costs, it is necessary to consider its effects on vehicle prices and the number of vehicles purchased. Lower fuel costs might increase consumers’ utility from car ownership and hence increase the number of cars they buy (DOE, 1995); alternatively, if consumers are assumed to operate within a budget, lower fuel costs mean that they have more money to spend on cars (DRI, 1991; Goodwin, 1992). Both this effect, and changes in vehicle fuel economy, are likely to influence the rate of turnover of the fleet — i.e. the rate at which vehicles are scrapped, and perhaps the extent to which vehicles of different ages are driven.

If new technology is expected to be the major part of the response to CAFE, average vehicle prices are likely to increase as they become more efficient. Vehicle sales will be pushed down by the increase in price, but the improvement in fuel economy will tend to increase sales — the relative size of the two effects is uncertain. Improved fuel economy in the fleet will tend to result in more driving, and changes in vehicle sales may add to or subtract from this effect.

If downsizing is expected to be a large part of the response of manufacturers and consumers to CAFE, average vehicle prices are likely to fall, and new purchases are likely to grow. The total number of vehicles, and the distance they are driven, are likely to increase. There may be mitigating effects: a shift to smaller, lighter, cheaper vehicles may mean a shift to less durable vehicles, so that fleet turnover increases without much increase in car numbers. Also, as the size of the fleet grows, the distance driven per vehicle is likely to decrease.

While various studies have examined all of these links, the results remain uncertain. The various modelling studies of feebates (DOE, 1995; Koopman, 1995; DRI, 1995) reviewed in Appendix C are relevant to this issue, given that the effects of feebates are likely to be similar to those of CAFE. As discussed in Appendix C, these studies imply that the rebound effect might amount to somewhere in the range 8 per cent to 40 per cent. As a result, a 10 per cent fuel economy improvement corresponds to only 6-9 per cent reduction in fuel consumption. Higher estimates of the rebound effect (based on the DRI study) derive from the assumption that little low-cost technical change is possible, and that most of the response to CAFE comes from downsizing. Lower rebound estimates derive from the assumption that low-cost technology is available to meet CAFE requirements, so that little downsizing occurs. None of these studies can be taken as a reliable prediction of what might happen if a government were to introduce feebates, as they all depend on simplifying assumptions of one kind or another — for example, they are unable to account for the way policy affects underlying technical change and consumer preferences.

This rebound effect is an important disadvantage of CAFE. Increased vehicle purchases imply greater energy use and pollution in vehicle manufacturing, while increased fleet sizes and traffic imply greater use of urban space for cars, and increases in the other environmental and social impacts of car use. Thus, CAFE standards may be able to contribute to energy and climate change policy objectives, and may also contribute to economic objectives (stimulating vehicle sales, employment in the manufacturing industry, and increasing consumer surplus), but are likely to work against other environmental and social objectives. These issues are further discussed later in the paper.

Voluntary agreements

Voluntary agreements with manufacturers are assumed to have the same effects on greenhouse gas and technology costs as equivalent CAFE standards. One major difference is that manufacturers choose to make the changes in their product and sales mixes, rather than having them imposed by government. In practice, voluntary agreements have also tended to differ from CAFE standards in that manufacturers agree as a group to aim to achieve percentage reductions in new-vehicle energy intensity by some target date. This means that there is no obligation on any particular manufacturer to achieve reductions. Indeed, some manufacturers may consider it a considerable advantage to them to market vehicles with lower fuel consumption, while others believe they have relatively little to gain by doing so. As with any type of voluntary agreement, where there is no sanction for failing to meet the target, it is unlikely to be possible to demonstrate that any change has occurred which would not have happened anyway. Nevertheless, some incremental improvement in fuel economy may be achieved as a result of voluntary agreements, if they encourage manufacturers to pay a little more attention to this issue in their product development process, and if they think that their competitors are doing so.

No additional in-depth analysis is offered here, but modelling has been carried out of the effects of voluntary targets on CO₂ emissions from cars in Annex I countries, based on the WEC (1995) scenarios. The methodology is described briefly in Appendix D; the model takes account of the “rebound” effect, in the range 8 per cent to 40 per cent, and the implications for traffic are discussed later. The results for emission reductions with a 40 per cent rebound effect are shown in Figure 12, in which the effects of 0.75 per cent, 1.5 per cent and 3 per cent per year improvement targets are evaluated in the “Muddling Through” (MT) and “Markets Rule” (MR). Targets are assumed to begin to have an effect on new cars immediately, feeding into the fleet as a whole over ten years in OECD countries, and over fifteen years in other Annex I regions.

One interesting point to note from these graphs is that targets will not always result in an improvement relative to business-as-usual, especially in the near-term. Although technical progress is assumed to be relatively slow in the Muddling Through scenario, in the Markets Rule scenario car fuel economy improves more rapidly. This means that the 0.75 per cent per year target represents a slower improvement than that which would have occurred anyway.

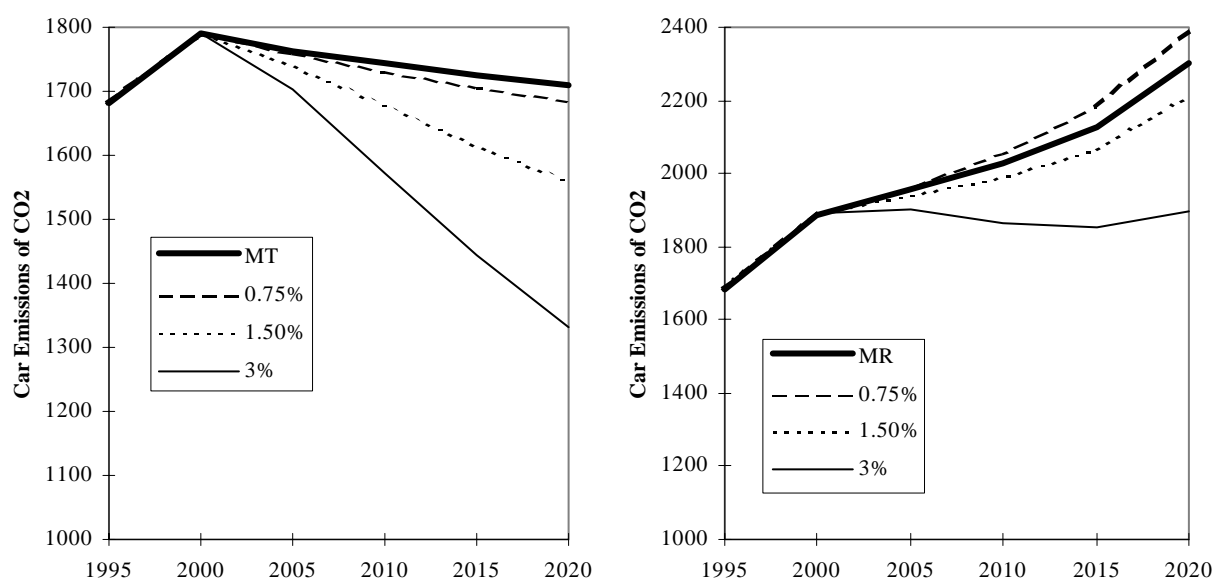


Figure 12. Effects of Fuel Economy Targets on CO₂ Emissions from Annex I Countries

As countries differ in their underlying rates of energy intensity reduction in the WEC scenarios, in the rate of vehicle turnover in the fleet, and in the extent to which they import used vehicles, the effects of introducing targets differ among them. Figure 13 gives an indication of the possible variation among regions in the percentage CO₂ emission reductions as a result of a 1.5 per cent target, based on the Muddling Through scenario and allowing for a 40 per cent rebound effect.

In calculating CO₂ effects of targets for fuel economy, the size of the associated traffic increase has also been estimated. These are shown in Table 4, relative to the WEC (1995) “Muddling Through” and “Markets Rule” scenarios assuming an 8 per cent and 40 per cent rebound effect.

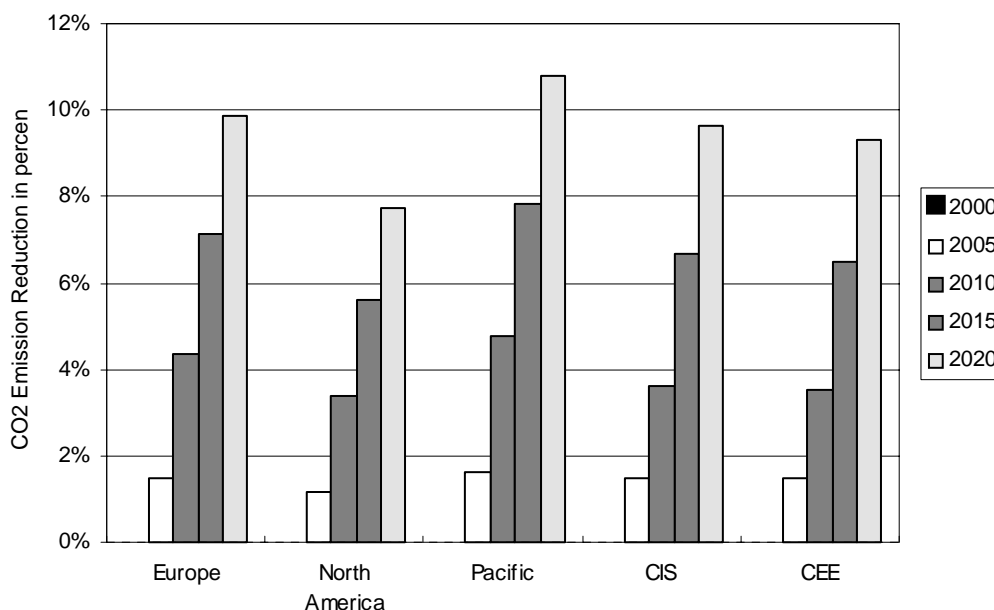


Figure 13. Regional Effects on CO₂ Emissions of a 1.5 per cent per Year Fuel Economy Improvement Target from 2000.

Compared with Muddling Through Scenario. 40 per cent Traffic Rebound Effect.

Feebates

It has already been mentioned that feebates operate in a similar manner to CAFE for individual manufacturers. However, whereas the size of the incentive to improve fuel economy differs among manufacturers for a CAFE standard, in the case of feebates, all manufacturers face the same incentive, at least in terms of the marginal value per vehicle model of reducing fuel consumption. This is a major argument in favour of feebates.

Table 4 Increase in Traffic in Annex I Countries as a Result of the Rebound Effect from Fuel Economy Improvements to Meet Targets

| | Trillion veh-km | 40 % Rebound (Increase in Billion veh-km) | | | 8 % Rebound (Increase in Billion veh-km) | | |
|--------|-----------------|--|--------|------|---|--------|-----|
| | | 0.75 % | 1.50 % | 3 % | 0.75 % | 1.50 % | 3 % |
| Target | Base MT | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 6.85 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 6.94 | 12 | 63 | 166 | 2 | 12 | 33 |
| 2010 | 7.06 | 32 | 187 | 511 | 6 | 37 | 99 |
| 2015 | 7.19 | 55 | 326 | 906 | 11 | 64 | 173 |
| 2020 | 7.34 | 81 | 475 | 1337 | 16 | 93 | 250 |
| Target | Base MR | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 7.34 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 8.02 | -19 | 39 | 157 | -4 | 8 | 31 |
| 2010 | 8.79 | -81 | 107 | 502 | -16 | 21 | 98 |
| 2015 | 9.76 | -164 | 191 | 950 | -33 | 38 | 183 |
| 2020 | 11.19 | -279 | 292 | 1541 | -56 | 58 | 292 |

Results from various studies of the costs and fuel economy effects of feebates are summarised in Table 5. These studies use very different models to assess the way feebates affect manufacturers and consumers, and produce results that are qualitatively different. In particular, DOE (1995) finds that manufacturers' vehicle design changes account for most of the response to feebates, whereas DRI (1995) assumes that consumers account for most of the response.

Table 5. Effects of Feebates

| Region | Feebate Design | GHG Emission Reduction | Effect on Vehicle Ownership | Effect on New Vehicle Energy Intensity (l/100km) | Effect on Traffic | Effect on Value of Vehicle Sales | Effect on economy ^b |
|---------------------------|--|--------------------------|--|--|---------------------------|----------------------------------|---|
| United States (DOE, 1995) | \$210 per L/100 km. Revenue-neutral on cars and light trucks | 7 % decrease | Short term 2 % increase in sales, by 2010 3.5 % decrease in sales Overall 0.7 % decrease in sales | 12 % reduction | 2.5 % increase | 1 % increase | \$10 billion per year benefit to households |
| United States (DOE, 1995) | \$420 per L/100 km. Revenue-neutral on cars and light trucks | 8.4 % decrease | 1.1 % increase in ownership. Sales roughly as \$210 per L/100 km feebate | 14 % reduction | | | \$11.1 billion per year benefit to households |
| Europe (DRI, 1995) | \$2000 per L/100 km Revenue-neutral on cars | NQ | 4-6 % increase | 30 % reduction | NQ | NQ | |
| Europe (Koopman, 1995) | \$500 per L/100 km. Revenue-neutral on cars | 10 % reduction ; in 2010 | 1.9 % reduction | 12 % reduction | 1-2 % increase in car use | 1 % increase | Decrease in economy-wide welfare |

NQ = not quantified

(Based on DOE, 1995; DRI, 1995; Koopman, 1995)

While DOE uses a far more sophisticated model than DRI, this sophistication does not necessarily imply more certainty. Given that many of the studies' differences in assumptions reflect real uncertainties in, for example, the way consumers make decisions about what kind of car to buy, there must be real uncertainties in the results. Nevertheless, DRI does appear to have neglected vehicle design changes and have assumed that consumers would be more prepared to buy smaller vehicles than the DOE analysis suggests.¹⁸

Based on these studies and the discussion in Appendix C, Table 6 provides an estimate of the range of possible effects of feebates on new vehicle energy intensity and travel if they were introduced in 2005 with five years notice to the manufacturers (i.e. giving manufacturers time to begin to retool their production lines). The table shows ranges of percentage reductions in vehicle energy intensity associated with implementation of: existing energy-efficient technology; vehicle downsizing; and the development of new technology (the research and development response); as well as the final energy saving after accounting for the traffic "rebound" effect. Four feebate levels are considered: \$250, \$500, \$1000 and \$2000 per L/100 kilometres. Assumptions are as follows:

¹⁸ It is possible that higher feebate levels would have a larger effect on consumer choices than models based on constant vehicle price elasticities would suggest. Feebates with a slope much below \$1,000 per L/100 km are not likely to be noticed by consumers (DeCicco and Gordon, 1993; Reilly-Roe, 1996; Hausberger, 1996)

- The effect of vehicle redesign is derived from the range of estimates of technology costs in Figure 10. New technology is assumed to be implemented in vehicles to the point where the cost of a marginal improvement is equal to its value in reducing the feebate imposed on the vehicles: that is, the energy efficiency improvement from new technology is given by the point where the gradient of the energy efficiency cost curve is equal to the feebate slope. The range of uncertainty in the extent of this effect derives from uncertainty about the cost of technical changes, and about the extent to which consumers will find these changes acceptable, without a reduction in the price of the vehicle.
- New technology is assumed to enter the product mix following a market penetration curve with 50 per cent penetration of cost-effective technologies within five years of governments giving notice of the policy.
- The downsizing response is assumed to be related by a constant elasticity to the feebate size in proportion to a base vehicle price of \$16 000. Thus, the downsizing effect on fuel economy is given by $\ln(DS) = \eta \ln(P+F)$ where DS is the factor by which the energy intensity is multiplied, F is the feebate slope, P is the base vehicle price and η is a constant, which lies in the range -0.38 to -3.3 (this is based on the downsizing effect in the various studies reviewed above and is explained further in Appendix C).
- The research and development effect is purely illustrative, with the range based on the assumption that the four feebate levels stimulate additional fuel economy achievements equivalent to the lower level effect for the deployment of existing technology. Research and development effects are assumed to be reflected in new vehicle fuel economy with a five year delay.
- Finally, the percentage reduction in energy use and CO₂ emissions by the new-vehicle fleet is calculated allowing for traffic rebound effect of 8 to 40 per cent — this was discussed above in the section on the rebound effect from CAFE.

It must be emphasised that this table is intended purely to give an impression of the possible orders of magnitude of the various effects. A full evaluation would depend on the use of a model such as those developed by DOE (1995) and Koopman (1995).

As Table 6 shows, the marginal contribution of vehicle redesign decreases with increasing feebate levels, because of the increasing marginal cost of applying new technology. DOE (1995) found that the downsizing response increased roughly in proportion to the size of the feebate. This result has been reproduced intentionally here, but it should be noted that it is largely a consequence of the assumptions about consumer preferences made in the model used by DOE. The downsizing response may well be non-linear, with small feebates having little effect.

The relative size of the role played by vehicle redesign, and that played by downsizing in the mix of vehicles sold, is important in determining the cost and effectiveness of a feebate scheme or standard to achieve a given fuel economy level. If little redesign is possible, most of the effect will have to come from downsizing. In this case, the rebound effect is likely to be relatively large because of the reduction in vehicle prices and increase in the number of vehicles purchased. To be fully effective, feebates (or equivalent fuel economy standards) would have to be applied over a large enough market to influence manufacturers' model designs. Thus the car markets in most individual European countries or in single North American states and provinces are not large enough, but regions such as the European Union, or countries with large car markets such as the United States or Japan might be large enough. Where single

small countries introduce feebates, only the downsizing response is likely to be achieved. This is consistent with experience so far in Austria and Ontario, where feebates have not achieved a measurable improvement in fuel economy (Hausberger, 1996; Reilly-Roe, 1996).

Table 6. Effects of Feebates: Reductions in New Vehicle Fleet Fuel Economy (L/100 km) and Energy Use Reduction from Feebates Introduced in 2005

| Year | Vehicle Redesign | | Additional Technology Cost (% of vehicle price) | | Downsizing | | Illustrative R&D Effect | | Total New Fleet FE Reduction | | New Fleet Traffic Increase | | New Fleet Energy Saving | |
|-----------------------------|------------------|-------------|--|-------------|------------|-------------|-------------------------|------|------------------------------|------|----------------------------|------|-------------------------|------|
| | Low Effect | High Effect | Low Effect | High Effect | Low Effect | High Effect | Low | High | Low | High | Low | High | Low | High |
| \$250 per L/100 km feebate | | | | | | | | | | | | | | |
| 2005 | 2 % | 11 % | 0 % | 0 % | 1 % | 5 % | 0 % | 0 % | 3 % | 15 % | 0.2 % | 7 % | 3 % | 10 % |
| 2010 | 4 % | 18 % | 0 % | 1 % | 1 % | 5 % | 0 % | 2 % | 4 % | 24 % | 0.3 % | 12 % | 4 % | 15 % |
| 2020 | 5 % | 24 % | 0 % | 1 % | 1 % | 5 % | 0 % | 4 % | 5 % | 31 % | 0.4 % | 16 % | 5 % | 20 % |
| \$500 per L/100 km feebate | | | | | | | | | | | | | | |
| 2005 | 3 % | 14 % | 0 % | 0 % | 1 % | 10 % | 0 % | 0 % | 5 % | 22 % | 0.4 % | 11 % | 4 % | 14 % |
| 2010 | 6 % | 23 % | 0 % | 1 % | 1 % | 10 % | 0 % | 3 % | 7 % | 33 % | 1 % | 17 % | 6 % | 21 % |
| 2020 | 7 % | 30 % | 1 % | 2 % | 1 % | 10 % | 0 % | 7 % | 8 % | 41 % | 1 % | 24 % | 8 % | 27 % |
| \$1000 per L/100 km feebate | | | | | | | | | | | | | | |
| 2005 | 5 % | 17 % | 0 % | 1 % | 2 % | 18 % | 0 % | 0 % | 7 % | 32 % | 1 % | 16 % | 7 % | 20 % |
| 2010 | 9 % | 28 % | 1 % | 2 % | 2 % | 18 % | 0 % | 5 % | 11 % | 44 % | 1 % | 26 % | 10 % | 30 % |
| 2020 | 11 % | 37 % | 2 % | 4 % | 2 % | 18 % | 0 % | 10 % | 13 % | 53 % | 1 % | 36 % | 12 % | 37 % |
| \$2000 per L/100 km feebate | | | | | | | | | | | | | | |
| 2005 | 8 % | 20 % | 1 % | 1 % | 5 % | 32 % | 0 % | 0 % | 12 % | 45 % | 1 % | 27 % | 11 % | 30 % |
| 2010 | 13 % | 33 % | 3 % | 3 % | 5 % | 32 % | 0 % | 8 % | 17 % | 58 % | 2 % | 42 % | 16 % | 41 % |
| 2020 | 17 % | 43 % | 6 % | 8 % | 5 % | 32 % | 0 % | 16 % | 21 % | 67 % | 2 % | 57 % | 19 % | 49 % |

The feebates are assumed to be applied to a base vehicle with list price \$16,000 and fuel economy 9 L/100 km

Fuel economy measures for trucks

No assessments are available of the effect of fuel economy measures on the energy efficiency of trucks or other vehicles, and it is difficult to estimate the effects of such measures in the absence of detailed cost vs. fuel economy information for heavy duty vehicles. In principle, there is every reason to expect that both manufacturers and vehicle purchasers would be responsive to incentives. However, truck purchasers already place a high priority on fuel economy. To the extent that literature exists on the cost of fuel economy improvements in trucks (e.g. ETSU, 1994) it indicates that further improvements would be, at best, only marginally justified by fuel cost savings. This means that there would be no increase in economic surplus as a result of introducing these measures for trucks. A CAFE standard or feebate scale for trucks would also be very difficult to develop, because of the wide variation in truck design.

A wider range of measures to reduce truck CO₂ emissions is considered in Working Paper 13..

Political Feasibility: Trade, Economic and Other Policy Effects

The economic rationale for incentives for improved vehicle fuel economy is a subject of debate, and this rationale will be discussed later in this section. Nevertheless there has been considerable political interest and support for the introduction of such measures in recent years, the main question often being the best form for such incentives. The ease with which standards, targets and feebates can be applied varies between countries, as shown by the differences in approach currently adopted.

Some measures might be introduced through modification of existing measures — one important example mentioned earlier is the potential to reform existing car sales taxes to reflect fuel economy instead of list price. The same changes might be made to import duties, registration fees and other existing levies. Converting taxes based on list price or engine volume to fuel economy-related taxes can in some cases result in the creation of a new incentive for improved fuel economy without having much effect on the prices of existing models.

Only one country has been identified — the United States — that imposes compulsory fuel economy standards on individual manufacturers. Others have voluntary agreements with manufacturers as a group.

Opposition to this type of measure comes mainly from motor vehicle manufacturers and, sometimes, from motorist associations. The main grounds for this opposition are the effects of standards and feebates on competition between manufacturers, and the theoretical inefficiency of this type of measure relative to fuel taxes, as a means of reducing energy use.

Manufacturers have tended to oppose tighter CAFE standards in the United States, and the introduction of any mandatory standards in Europe. Nevertheless, they have entered into numerous voluntary agreements with governments, as mentioned above. Manufacturers are likely to oppose any formulation of compulsory standards. Several proposals have been made for modified versions of CAFE, for example, linking standards to car interior volume, to take account of differences between manufacturers. However, there are likely to be effects on competitive advantage from any formulation of standards. Some “gamesmanship” might also be anticipated, where companies change their product mix to take advantage of the way the standard is formulated.

Some of the studies reviewed above indicate an increase in vehicle sales and the total value of sales as a result of the introduction of feebates or standards, which would presumably be in manufacturers’ interests. The industry has not generally accepted the results of these studies, on the grounds that they are over-optimistic about the cost of introducing new technology, and the extent to which consumers will buy that technology. It is probably not possible to know whether this view is correct without experimentation on a large scale, to find out how technical changes affect costs in mass production, and to find out whether consumers will accept the changes. Some manufacturers have experimented on a small scale, introducing individual energy-efficient models, and have found that these are not purchased in large numbers. However, this kind of experimentation is rather different from a whole-hearted effort to market energy-efficient options across the range of vehicle models. Such an effort would depend on the co-operation of manufacturers, who would clearly prefer a voluntary approach.

Trade and relative effects on firms or countries

Trade effects have been analysed mostly for CAFE standards which, as mentioned above, can impose different costs on different vehicle manufacturers. This has been a major issue in the discussion of fuel economy standards in both North America and Europe, and is perhaps part of the reason for the increase in

interest in feebates as an alternative. The existing CAFE regulations in the United States require each car manufacturer, regardless of the segment of the market that manufacturer targets, to sell vehicles with an average fuel economy above (in mpg) the CAFE standard. Manufacturers failing to meet the standard are, in principle, fined, although there is a system of bankable CAFE credits and loans to allow manufacturers who fail to meet the standard one year to avoid being fined.

Feebates can, in fact, have exactly the same differential effect between manufacturers, depending on the size of the feebate slope relative to the CAFE fine. However, manufacturers who do not meet the CAFE standard are breaking the law and being fined, whereas those who pay higher feebates are simply paying fees. Moreover, fees (such as the gas guzzler tax in the United States) may be tax-deductible, whereas fines generally are not. Manufacturers subject to CAFE may thus incur higher costs in meeting the CAFE standard than they would in paying feebates, or in meeting more flexible versions of CAFE regulation.

The fairest measures in this context are likely to be either feebates, or tradable (or negotiable) CAFE standards. These measures have the effect of setting one marginal cost of vehicle energy intensity for car manufacturers, whereas non-negotiable CAFE standards tend to result in different marginal costs for different manufacturers. This means that non-negotiable CAFE leads to greater economic inefficiencies and differential effects between manufacturers.

Where manufacturers are competing in an international market, and the manufacturers of one country find it easier to produce low energy intensity cars than the manufacturers of another country, the relative competitive advantage of the two countries will be changed by either standards or feebates. Countries wishing to export large vehicles might see such measures as a barrier to trade. Standards and feebates can be designed to change these effects, for example by allowing for vehicle size or type in the standard. The volume-based feebates discussed in DOE (1995) are one approach to this, and DeCicco *et al.* (1993) discuss a range of alternatives in some depth, evaluating their implications for US domestic versus imported vehicles. DOE (1995) demonstrates that feebates based on fuel-economy per interior volume can be designed to favour US manufacturers relative to overseas manufacturers, while achieving nearly as much greenhouse gas mitigation as simple fuel-economy-based feebates; however, this might be seen as a barrier to trade by countries wishing to export small vehicles.

An issue which is perhaps more important is the effect of measures to improve new vehicle fuel economy on the trade in second-hand vehicles. Second-hand vehicles are exported in very large numbers, within the Annex I country group from western Europe to central and eastern Europe, and from Japan to Australia and New Zealand. Meanwhile, the majority of cars used in developing countries were either manufactured in Annex I countries, or to old designs from Annex I countries, often on production lines exported from Annex I countries. Improved fuel economy in new car markets is likely, in the long run, to lead to improved fuel economy in second-hand car markets. However, there is the possibility of a short run effect where vehicles and, more importantly, designs and production lines, are exported to countries that do not impose the tighter standards. This is an issue that may need to be addressed through international discussions. Possible solutions include restrictions or voluntary agreements on the export of obsolete technology by the main car-producing countries, and the introduction of fuel economy incentives for both new and second-hand cars in importing countries. Such measures are likely to be controversial, as these obsolete technologies are available at very low cost relative to new technology.

Economic efficiency arguments

Measures directed at vehicle technology — such as CAFE or feebates — are often viewed on economic grounds as second- or third-best alternatives to fuel taxes for internalising externalities associated with

climate change. If it is thought that markets for fuels, vehicles and vehicle use function perfectly, then fuel taxes will certainly be the most efficient means of internalising these externalities. Measures focused on vehicle technology only indirectly affect energy use and greenhouse gas emissions: these depend on how much the vehicle is used, and on its manner of use. The “rebound” effect, where drivers use vehicles more because fuel costs are reduced, is a result of this indirect approach and is an aspect of the measures’ inefficiency for mitigating greenhouse gas emissions. Secondly, technology standards may impose higher-than-optimal costs on drivers and manufacturers, by encouraging or forcing drivers who will use their vehicles very little to buy more efficient technology, even where the cost of the technology is not justified by the fuel saving.

The economic rationale for measures focused on vehicle design and vehicle choice depends on the existence of some market distortion, or market barriers such as transaction costs associated with consumers’ optimisation of attributes, including fuel economy, in new vehicles. CRA (1991) states that CAFE standards will always be more expensive as a means of greenhouse gas mitigation than other measures focused on changing consumer behaviour, such as fuel and vehicle-kilometre-travelled taxes. However, this finding depends on the assumptions that the new car market is efficient in vehicle attribute pricing, and that consumers’ valuation of attributes is invariant.

Market research involving stated-preference surveys generally indicates that consumers do consider energy efficiency important and value it at roughly the level that might be expected from the fuel savings it offers them (DOE, 1995; Bunch *et al.*, 1993). This valuation in the United States is typically of the order of \$400-600 per L/100 kilometres for a new car — however, it is not clear whether this is translated into a price signal in the new car market. The evidence that it might not is largely based on technology cost curves presented in Appendix A. The steepest of these curves (from a source used by the CRA study) indicates that a 5 per cent energy intensity reduction would be cost-effective at \$400 per L/100 kilometres. This is quite a small reduction potential compared with energy savings that are thought to be cost-effective in other end-use sectors, and provides little, if any indication of market failure. The lower cost curves indicate that maybe 20-40 per cent would be cost-effective. Intermediate curves, used in much analysis of car technology by the US government, indicate a cost-effective saving of 20 per cent. A clear answer to this question would depend on a) a hedonic pricing study of the new car market, to identify to what extent fuel economy does affect car price and b) on knowing the “true” shape of the technology supply curve. The first is possible, the second probably is not.

Studies of actual prices have focused on the used car market because it is expected to be a more efficient indicator of consumer preferences, and have shown that about half to three-quarters of anticipated changes in fuel costs show up in relative car prices (Daly and Mayor, 1983; Kahn, 1986).

There are several possible features of new car purchases that might prevent the full value of fuel economy to consumers from being reflected in car prices, and some are considered in the following paragraphs.

Satisficing

Perhaps the most important deviation from the perfect market would arise if consumers were not able to simultaneously optimise a wide range of vehicle attributes. The neo-classical economic model of consumer decision-making is one where consumers have a utility function, which is a non-varying function of a wide range of attributes.

Many alternative models of decision-making are consistent with observed consumer behaviour, including “satisficing”, or decisions made on the basis of a small number of attributes (e.g. Dietz and Stern, 1993).

There are several reasons why alternative models of decision-making might reflect actual behaviour better than the simple utility function model. Some of these reasons are consistent with neo-classical economics: there may be search costs, transaction costs, or information barriers associated with trying to optimise beyond a small number of attributes. Other reasons fall outside the realm of neo-classical economics: for example, consumers may simply be unable to weigh up large numbers of attributes at the same time; consumer valuation attributes may depend on the context in which they are considered; attribute valuations may depend on the presence of other attributes.

In the Dietz and Stern model, different consumers might base their decisions on different attributes so that an aggregation of the values placed by all consumers on a wide range of attributes would show some valuation of all of those attributes. However, the valuation would be lower than would be indicated if consumers were able to optimise fully. Values may tend to occur in clusters — for example, the consumers who seek an energy-efficient car might tend also to prefer a small, low-powered car. Vehicle purchasers who seek high-powered, highly automated, luxuriously upholstered cars might place energy efficiency relatively low on their list of priorities; the price they are prepared to pay for their car will not reflect the value of energy efficiency to them. This does not mean that they do not value low fuel costs, it simply means that they place a higher priority on other attributes, and only their preferences for these high priority attributes are revealed in their purchase decisions.

If the Dietz and Stern model, or a similar model, of decision-making is correct — and this remains to be proven — manufacturers would receive attenuated signals from consumers indicating the extent to which they would value improved fuel economy (as well as other attributes) if it were offered as an “optional extra” in all vehicle models. The argument for voluntary agreements, standards or feebates in this case is to correct for the inefficiency of the market.

Budget constraints

An alternative explanation for consumers taking into account only a limited number of attributes in their decision making is that they have a constrained budget (or rising marginal costs of capital). Car purchasers may then have a limit on the price they can pay as a lump sum for a new car, although this is separate from their weekly budget for fuel.

For consumers operating within a budget constraint, feebates and CAFE standards would lead to downsizing where the vehicle they choose is above the CAFE level or the feebate zero-point, and upsizing for consumers who would have choose a vehicle below this level. This effect is captured in the DRI (1995) study but not in the DOE (1995) study.

This type of budget constraint is not a rationale for introducing standards: in this case, standards would force consumers to accept attributes that they do not value at the expense of attributes that they do value. Thus, Nivola and Crandall (1995) show that vehicle mass and acceleration had a higher price premium in the new car market in the United States in the years following 1984 than in the preceding years. They suggest that this price premium was imposed by manufacturers following the fall in oil prices to prevent consumers from choosing larger, more powerful cars which would have led firms to exceed the CAFE standard. However, they do not support this suggestion with an evaluation of a change in the price premium attached to rated fuel consumption, nor do they provide a year-by-year analysis of attribute prices which would be needed to demonstrate that falling oil prices triggered the increases in the prices of mass and acceleration.

The “principal-agent” barrier

A commonly discussed barrier to energy-efficiency investments in all sectors is the “principal-agent”, or, “tenant-landlord” barrier. This term is used for the situation where the person considering the investment in new technology is not the person who will pay the cost of operating that technology. It is a common situation in the new car market. First, cars usually have multiple successive owners, so that the first owner only expects to pay operating costs for the first three or four years of the car’s life. Second, cars are often purchased by companies for their employees (who are sometimes allowed to choose the model), or by hire-car companies. In the case of company cars, the companies may also pay part of the fuel costs. Moreover, where the type of car employees can buy depends on their position in the company, the role of the car as a status symbol is greatly enhanced, increasing the value to employees of attributes such as size and power.

Operating costs may be reflected in the used-car market, as described above, at least in part, and also by clients’ preferences in hire cars. Companies may encourage their employees to choose fuel-efficient cars or may choose the cars for them. However, the “second-hand” nature of these expenses means that they are likely to be reflected less in fuel economy valuation in the new-car market than in the used-car market.

Myopic behaviour

It is often observed that consumers make purchase choices based on what would appear to be a very high discount rate: that is, they appear to place a very low priority on future costs relative to present costs. The model used by Greene and Duleep (1993) to estimate future improvements in fuel economy in US cars assumes that consumers will buy more fuel-efficient cars if any additional cost is paid off in fuel savings within four years at an 8 per cent discount rate. The scenarios generated by this model have so far tended to over-estimate fuel economy improvements, and it is not possible to say whether this implies that new car buyers require a shorter pay-back period than four years for fuel economy improvements, that Greene and Duleep underestimated the cost of those improvements, or that manufacturers’ decided not to offer those improvements, although they would have been cost-effective.

Apparent high consumer discount rates may simply be a reflection of the transaction costs and other barriers to consumers choosing energy efficiency — lack of information, transaction and search costs, satisficing, or the principal-agent problem. These barriers may be considered to justify interventions in the form of standards, feebates or other measures.

Discount rates can be high for other reasons. Consumers may be uncertain about future fuel prices, for example; they may face constraints on capital expenditure, or high interest rates for borrowing; they may intend to sell the car after a short time and be uncertain about the extent to which improved fuel economy will be reflected in the resale price. None of these factors would necessarily provide an economic rationale for governments to intervene in vehicle markets, as they do not generally represent market distortions — rather, they reflect the way markets deal with risk and uncertainty. On the other hand, governments may consider these risks and uncertainties to be misperceived by consumers, in which case they might consider intervention justified.

Use of “revealed” preferences

A major implicit assumption in much of the analysis of vehicle choice, and in particular in the use of the concept of consumer surplus, is that consumer preferences are constant and are revealed in their behaviour (Jacobs, 1994). This implies that current consumer behaviour can be taken as an indication of their future

preferences. It also implies that vehicle marketing and other media influences cannot change preferences; they can only, as marketing professionals often suggest, inform consumers about ways in which their preferences can be met.

The idea that marketing might change preferences is a controversial one for obvious reasons — it implies essentially that firms with sufficient advertising budgets might be able to influence prices for product attributes. This would mean that firms would not be price-takers in the market. Evidence for the influence of advertising on preferences is inconclusive — although this is perhaps hard to believe for any parent. Wilk (1995) has found that exposure to television advertising appears to affect the aspirations and preferences of teenagers, but that once the same individuals reach adulthood, their aspirations are similar to those who do not watch television, probably because of budget and family constraints. However, aspirations changed by advertising might be maintained where incomes are high enough to meet them — for example in OECD countries. Meanwhile, advertising may not influence people's underlying values, but still affect the way they associate those values with particular attributes in a product. In this case, car manufacturers might be able to use advertising to influence the pricing of attributes in their products.

There is a growing body of evidence (e.g. Turrentine and Sperling, 1993; Goodwin, 1985) that consumers' behaviour has as much to do with habit and familiarity as any permanent set of values. This means that there is both inertia and flexibility in consumer choices. Consumers sometimes change their preferences quite radically, but they may not demonstrate the extent to which they appreciate a new technology until they have experienced using it. For consumers to have this experience in relation to advanced technology energy-efficient vehicles, it may be necessary to go further than putting one or two energy-efficient models on the market (which has already occurred with little success); consumers might need to be made familiar with the existence and advantages of these models through extensive marketing, and might also have to be persuaded by retailers to try them out.

In a view of the world where preferences are changeable, the economic analysis reviewed in this paper can only provide information about current or past preferences. There is so far little quantitative evidence on the extent to which consumer preferences might change as a result of changes in experience. However, the implication is that measures that encourage a change in the technology consumers use might have a role to play.

Personal behaviour versus societal values

Studies that use consumer surplus deduced from observed market behaviour as an indication of the desirability of an outcome are making implicit assumptions about the way societal decisions should be made. In some instances (e.g. DOE, 1995) the concept of consumer utility incorporates a weighting of consumer surplus, so that a consumption increase in low-income households is valued more than the same increase in high-income households. Such studies often find that reductions in polluting activities would cause a loss in consumer utility and hence would be undesirable from a societal point of view. Much of the increase in consumer utility in the DOE (1995) study is associated with increased car ownership and mileage, and hence possibly increased environmental and social costs.

Two assumptions might be questioned here:

First, it is not obvious that individual welfare or utility is equal to income-weighted consumer surplus. It is quite possible that consumers might, in fact, prefer to have their choices constrained to reduce pollution, but that they are not prepared to constrain their own choices individually. This is a reflection of the often-expressed view that there is no point in reducing one's own polluting activities if everybody else continues to pollute. Thus, individuals might look to community processes or to governments to set the reasonable

boundaries for their choices. The existence of such boundaries might not reduce their personal welfare and might even be an essential contributor to it.

Second, it is not obvious that individuals' welfare can be summed directly to obtain societal welfare. In this case, fuel economy standards and other measures should not be judged on the basis of their effect on consumer utility estimated from historical behaviour. Such measures might be better assessed using models that incorporate all externalities, if it were possible to place a value on these. The measures might alternatively be judged on the basis of active community or democratic processes.

This question of a possible difference between measures of aggregate welfare deduced from historical individual behaviour, and societal welfare including externalities and perhaps revealed in community decision-making processes, also has implications for the use of economic efficiency arguments in general. Policies that correct for market distortions may result in higher consumer surplus, as revealed by the market, and perhaps higher GDP, but this may sometimes be associated with higher external costs and reduced quality of life.

Costs of measures

Although it has been seen that standards and feebates would be likely to increase the cost of vehicles, they would reduce the cost of operating the vehicles. Provided the measures were set at a level that reduced the overall cost of driving, the costs to the consumer of using them for greenhouse gas mitigation would be negative. Costs to others, including the wider economic effects of the measures and the social and environmental externalities associated with increased driving, have not yet been analysed in detail, but it is quite possible that these costs would increase if additional measures were not introduced to internalise externalities. Some of the relevant issues will be discussed in the following paragraphs.

Employment

Employment effects of the various measures can possibly be judged from their effects on vehicle sales, although the consumer surplus and GDP effects estimated in the various studies reviewed by this paper will have effects on other sectors of the economy. The increases in consumer surplus estimated by DOE (1995) and Koopman (1995) are largely a result of reduced spending on fuel, and consumers are likely to find other goods and services to spend their money on, in addition to more-efficient vehicles. As most goods and services are more labour intensive than oil products, it seems likely that employment will be stimulated.

As shown above, the various studies reviewed in this report find that CAFE standards and feebates tend to increase the total number of vehicles sold, although it is possible that, under certain circumstances, vehicle sales could decrease, depending on the relative effects of higher vehicle costs and lower running costs. In this case, the value of sales would still be likely to increase. An increase in the number of vehicles sold is likely to result in an increase in employment in the manufacturing industry, although the relative competitiveness of firms and hence, the location of that employment might change. OTA (1994) reviews two studies on the employment effects of 40 mpg CAFE standards, with conflicting results. One study, by the Motor Vehicle Manufacturers' Association, finds that the CAFE increase would be very costly for US domestic manufacturers, and so would result in a large decline in sales of domestically produced cars relative to imports. The other, by the American Council for an Energy Efficient Economy, assumes that the standards are cost-effective, with less money spent on gasoline but more on cars, including domestically-produced cars. This implies more employment in the US car industry, as well as additional

employment elsewhere in the economy resulting from increased consumer spending on other goods. The difference between these two findings largely stems from differences in assumptions about the cost and availability of technology. If technical changes are relatively cheap and easily adopted by manufacturers and consumers, improvements in technology would be the remain response to standards; if technical changes are expensive, downsizing, and hence, an increase in small imported cars would be a more important part of the response.

Table 7. Employment Effects of 40 mpg CAFE Standard in US

| MVMA Study | ACEEE Study |
|--|---|
| 200 000 jobs lost in 1995, 210 000 in 2001, base case, sales decline 10 per cent | No decline in sales, fuel saving is \$53.8 billion per year, additional spending on cars \$17.3 billion per year. |
| 173 000 jobs lost in 2001 if sales do not decrease | 25 000 new jobs by 1995 |
| 159 000 jobs lost if American "Big 3" manufacturers get 53 % of small car market | 72 000 new jobs by 2000 |
| 315 000 jobs lost if sales decline 20 % | 244 000 new jobs by 2010 of which 47 000 in car industry |

Source: OTA, 1994

Equity

According to the DOE (1995) study, feebates result in the short term in an increase in demand for new, smaller cars and a reduction in demand for second-hand cars. This implies that a reduction in used-car prices would likely occur. In this case, low income households are likely to benefit from reduced costs in the short term. In the longer term, improved fuel economy in new cars would lead to lower costs for their second-hand owners, and the increased cost of energy efficiency would be unlikely to be fully reflected in second-hand vehicle prices. However, some measures that have been suggested as adjuncts to fuel economy measures, including vehicle scrapping incentives and increased annual licence fees for inefficient vehicles, could lead to higher costs of car ownership for low-income households, with negative effects experienced especially in rural areas where households are dependent on cars.

Transport and environment

Fuel economy standards are likely to work against some other objectives in transport and environment policy. In particular, as shown earlier, they are likely to lead to a larger number of vehicles on the road, which will be driven longer distances because of reduced fuel costs. This "rebound" effect, where a 10 per cent reduction in energy intensity could be accompanied by an increase in traffic in the range of 8-40 per cent, is a major disadvantage of this type of measure from an environmental and social perspective, although in economic terms it may amount to an increase in consumer surplus (DOE, 1995).

Internalisation of the broader social and environmental costs of vehicle use may be an important adjunct to fuel economy policies. However, even internalisation of the costs, through economically efficient measures such as congestion pricing and pollution charges, might not be sufficient to offset the increase in traffic induced by standards. The effects of internalising externalities are discussed further in Part 2 of this report.

In general, increases in traffic are likely to lead to more traffic congestion and accidents, as well as increased noise and emissions of local air pollutants, with effects on health and visual amenity. Reduced energy consumption does not necessarily imply lower emissions of pollutants produced during combustion, and some energy-efficient technologies might increase emission factors: for example, lean-burn engines can offer reduced fuel consumption, but increased emissions of NO_x.

To the extent that fuel economy improvements involve reducing vehicle mass, there are also possible effects on safety. This has been a major element in the political discussion of tighter CAFE standards in the United States, where lobbies against tighter CAFE have linked lower fuel consumption with smaller vehicles, and hence with vehicles that are likely to be particularly vulnerable in collisions. While this need not be the case, Greene and Duleep (1993) note that lighter vehicles are more prone to roll-over than heavy vehicles, and that the existing United States CAFE standards have been linked to an increase in roll-over incidents and hence deaths. On the other hand, smaller vehicles cause less damage to other vehicles in collisions.

Reducing vehicle fuel economy as part of a common action

This report has shown that there may be large opportunities for greenhouse gas mitigation through the implementation of fuel economy measures or through changes in vehicle and fuel taxation. This section considers the advantages and disadvantages of common actions to implement such measures, and some of the implementation issues that such common actions would entail. As it is possible that any common action would involve a combination of fuel economy measures and other measures such as fuel taxes, discussion of the potential role of the Annex I Expert Group and possible vehicles for action are reserved for the end of the report, following examination of some of these other measures.

Some of the measures discussed in the report would be relatively easy to implement. Car manufacturers have a strong preference for voluntary approaches rather than compulsory measures. Taxes and other fees already imposed on new and imported vehicles might be converted to fuel-economy-related taxes, with relatively little effect on the tax level for existing models.

Several issues have been raised in this report which would need to be resolved or taken into account before any common action on vehicle fuel economy could be seriously considered. These include:

1. The uncertainty in the cost of new technology to improve fuel economy;
2. The uncertainty in the extent to which consumers will value vehicles with this new technology;
3. The uncertainty in the extent to which the measures will lead to downsizing in the fleet;
4. The uncertainty in the effects of the various types of measure on competition among manufacturers and on international trade; and
5. The uncertainty in the effects of the various types of measure on a) the number of new vehicles purchased; b) the mix of new vehicles purchased; c) the used car market and the rate of scrappage; d) the amount that vehicles are driven.

Analytical findings with regard to the issues in areas 3 and 4 have depended largely on assumptions made in areas 1 and 2:

- If new technology is assumed to be cheap — or if consumer preferences are flexible — consumers accept the new technology easily, and little downsizing occurs. In this case, the findings indicate that most manufacturers will benefit from increased car sales and an increase in the value of those sales. There is likely to be a moderate increase in traffic and its environmental and social impacts.

- If new technology is expensive, but still little downsizing occurs, then sales of cars may fall or stay constant as individual cars become more expensive. In this case, the increase in traffic is likely to be quite small.
- If downsizing forms a major part of the response, sales of cars are likely to increase and the total value of sales is also likely to increase, but there is might be a significant shift in the competitive advantage of manufacturers and in trade patterns. There is also likely to be a large increase in traffic as fuel costs fall and the fleet grows.

Fuel economy measures as components of a common action

Any action taken in this area would need either to resolve the uncertainties described above, or to take account of them. There are several ways that governments might co-operate to do both and only two are suggested here:

The first approach, and that preferred by the automobile industry, would be to enter into partnership with manufacturers to clarify the issues and to achieve the technical improvements that are generally agreed to be cost-effective. Existing voluntary agreements might be taken as a model for this, with new vehicle fuel economy improvements of the order of 0.8 to 2 per cent per year. If such voluntary agreements included efforts to collect and analyse information on new technology and on vehicle markets, this might lead to more ambitious targets in the future. An international agreement on this issue might grow from the current discussion between ECMT Member and Observer governments and car manufacturers. Agreements might be most easily and effectively established at a regional level. To address the rebound effect from fuel economy improvements, it would be important for countries to consider other measures to address the wider social and environmental costs of transport. These measures might include increased fuel taxation.

A second approach, likely to be opposed by the industry but providing a greater incentive to achieve results, would be the use of feebates or CAFE standards, or perhaps a combination of these. Weak CAFE standards might be set at a level that manufacturers agreed was achievable, and might be designed to be tradable or negotiable among firms to avoid effects on competitive advantage. Feebates might also be set at a low level, for example the level that would reflect the consumer surplus (if any) from improved fuel economy. An international agreement might determine the level of the overall CAFE standard, and establish a system for trading CAFE credits, while feebates might be set at a national level. CAFE standards and feebates might be extended to imports of used vehicles although they would be harder to apply to domestic used car markets. Many other variations might be possible, with different degrees of harmonisation or formulae for differentiation among countries.

Greenhouse gas mitigation advantages of common action

Perhaps the strongest argument for common action in this area is that vehicle fuel economy measures are not likely to be cost-effective when applied in one or two small countries, but could be cost-effective if applied on a large scale. Where a small country adopts feebates, fuel economy standards or targets alone, it is unlikely to influence the design plans of the major car manufacturers. The measures might affect manufacturers' marketing strategies and consumers' choices in that country, but the effect on consumer surplus would be likely to be negative, and the rebound effect might be relatively large, as discussed above. A much larger reduction in greenhouse gas emissions, with a potential increase in consumer surplus, could be achieved if fuel economy improvements were to occur through the introduction of energy-efficient vehicle options that are not currently on the market. To obtain this type of effect, a

voluntary agreement or a set of incentives might need to be established in a region on the scale of the United States or the European Union.

Based on Table 6, the impact on greenhouse gas from a downsizing alone where a small country implements feebates would probably be less than half, and perhaps less than a fifth, of that obtained where feebates or other incentives are implemented over a wider region. It would not matter which type of incentives the various countries introduced, provided they were designed to make it cost-effective for manufacturers to market more energy-efficient vehicles. Such incentives need not be confined to feebates, standards and voluntary agreements, but could also include other measures, such as fuel taxes. However, any common action would depend either on establishing what measures were considered to be equivalent, or using a target-based approach with countries choosing their own measures. The main condition is that, regardless of their starting point, countries would have to aim for similar percentage reductions in energy intensity to bring about a fairly uniform change in the market faced by manufacturers.

National differences, trade and competition: advantages and disadvantages of common action

Differences among countries imply some disadvantages from common action, and may therefore be barriers to implementation of common action in this area. National differences may mean that cost-effective levels of fuel economy differ among countries. In this case, any measure that aims for a common standard would be economically inefficient.

Countries differ in the mix of vehicles their consumers purchase, the mix of models their manufacturers (if any) produce, the extent to which they import new and second hand vehicles, and many other factors. They also differ in driving conditions. This has implications for the standard test cycles in which fuel economy is measured. Across the Annex I group of countries, the vast majority of new vehicle models are subjected to fuel economy tests using one of three systems: that of the European Union and UNECE, that of Japan, and that of the United States. The test cycles in these three regions differ significantly and produce different results for any given vehicle model. One of the reasons for differences in cycles is that driving conditions differ among countries. By the same token, the effects of a given fuel economy measure would differ among countries because of their different driving conditions, even if the measure produced the same change for all countries in the fuel economy of vehicles based on test cycles.

Any common action that extended beyond the regions covered by these different test regimes, and that depended on measurement of absolute levels of fuel economy (e.g. for a CAFE standard or for a common feebate scale) would depend on an agreement among countries, either on conversion among the results of the tests, or on a common set of test cycles. Such agreement would not be necessary for a common action based on voluntary agreements or targets to achieve percentage changes, where governments were free to choose their own measure definition. It would also be unnecessary for any common action either in Europe or in North America. The issue of test cycles might represent a problem within regions for certain countries, such as New Zealand, which recognises test results from all three of Europe, Japan and the United States.

Car producers have to put a considerable amount of effort into monitoring and meeting emission, safety and other standards in different world regions. A single Annex I-wide test cycle would reduce the costs of licensing models for sale in different countries.

Common action would help to avoid the trade changes involved in any one country adopting standards or other measures alone. However, trade effects cannot be eliminated: mitigation of greenhouse gas will

impose different costs on different manufacturers, even if it is implemented in the most efficient way possible. Common action to improve vehicle fuel economy has been discussed for some years in the European Union, as well as in North America. The main stalling point in Europe has usually been the difficulty in finding a formula for standards or feebates that does not have effects on competition among manufacturers of different countries. Proposals considered by the European Commission's Motor Vehicle Emissions Group (MVEG, 1992) included fuel economy-related charges linked to vehicle mass. The group aimed to find a formula which would both mitigate the impact of a feebate system on heavier vehicles, and ensure that the feebate charge always increased with increasing fuel consumption. Despite the effort to develop this formula, European Union Member countries have not yet entered formal discussions on a feebate scheme. The European Commission recently issued a communication to the European Parliament and Council of Ministers (EC, 1995) suggesting various options for feebates and other measures. As has already been mentioned, it would be difficult to derive any alternative formulation of standards or feebates that did not put one manufacturer or another at a disadvantage.

The case for a common action in this area hangs very much on two possibilities — either the possibility that consumer preferences associated with improved fuel economy might not be reflected in vehicle prices, or the possibility that consumer preferences would change if the vehicles on offer were to change. If either of these is thought to be true, it would be inefficient or irrelevant to make allowances for vehicle size or weight in any standard or feebate formulation. Meanwhile, as in the case of addressing competition between manufacturers within a country, probably the fairest and most efficient way to address competition effects between countries is to find a way of equalising the marginal mitigation cost between manufacturers. This implies the use of an internationally agreed feebate schedule, negotiable/tradable CAFE standards, or a voluntary agreement set at a level that would have the same effect. Again, it would not matter which of these options individual countries chose, provided they set the measure at a level that would give an equivalent percentage reduction in fuel economy.

Various options are possible to reduce effects on competition in the short term, such as: introducing standards or feebates gradually, to allow manufacturers time to respond; introducing a minimum, fairly weak common CAFE standard and allowing countries the flexibility to apply additional feebate-type or other incentives; creating a two tier standard, one for cars in general and another for an innovative, energy efficient car whose sale might be encouraged by tax incentives. These issues would clearly need more consideration among any group of countries considering the introduction of standards as a common action.

PART 2. FUEL TAXES

This section explores the potential for common action in the area of fuel taxation. This measure is of particular importance, partly because it is often described as the most economically efficient way of encouraging reductions in energy use. Thus, fuel taxes are likely to be the most economically efficient means of internalising any externality associated with climate change. An additional advantage of fuel taxes over vehicle-focused measures is that they have an immediate effect on fuel consumption and hence on greenhouse gas emissions.

Fuel taxes have also been discussed in many countries as a means of internalising other externalities, such as the effects of traffic congestion, noise, air pollution, accidents, resource depletion and military costs associated with ensuring security of oil supply. In general, fuel taxes are not likely to be the most efficient means of internalising or reducing these externalities, with the exception of costs associated with resource depletion and security of supply. Traffic congestion and noise, for example, may be best addressed through congestion charges, access restrictions, etc. Despite this, fuel taxes are probably easier to implement at the national or federal level of government, whereas local, regional and state authorities may need to be involved in measures targeted more directly on reducing externalities. Options to encourage local initiatives are discussed in Part 3 of this report.

Whereas the last section focused on fuel economy improvement in light duty vehicles, this section pays attention to the effects of fuel taxes on both light and heavy duty vehicles. Heavy duty vehicles in most Annex I countries are predominantly diesel-engine-powered, and diesel fuel is usually taxed at lower levels than gasoline, the main fuel for light duty vehicles. Diesel taxation receives particular attention in the section on full cost pricing.

Some Annex I countries (e.g. Austria, Belgium, France, Germany, Netherlands, United Kingdom) reported increases in motor fuel taxes in their first communications to the UNFCCC Conference of the Parties, as measures to mitigate greenhouse gas emissions. The percentage and real value of tax in gasoline and diesel prices increased in nearly all of the Annex I countries between 1990 and 1995 (IEA, 1995a). Several countries have introduced tax increases in the last ten years which greatly exceed increases in consumer prices.

Fuel tax increases as part of a common action could take many forms. Different forms could be appropriate for different countries. This study explores three fuel taxation concepts, although many others are possible:

- “**vehicle tax reform**”, where existing charges such as vehicle sales tax, registration fees, or road taxes, are levied on fuel sales instead of on a one-off or annual basis
- “**full cost pricing**”, where fuel taxes are modified to improve the extent to which motorists pay the full costs of their driving to governments
- “**externality pricing**”, where fuel taxes are modified to incorporate externality adders

The first of these three options would be revenue-neutral -- that is, it would not involve any increase in government revenue from vehicles, although it might change the distribution of charges across different vehicles. The other two options would raise additional government revenue. A major issue in the analysis of fuel taxation options is the question of the use of the revenue. Within the set of studies on “Policies and Measures for Common Action”, the study on carbon taxes addresses this issue in most depth. However, the current study provides a brief review of some of the options and the issues that they raise.

Approach to Analysis

The first concept addressed is “vehicle tax reform”. In this report, this term essentially means shifting the charges imposed on drivers from fixed costs, such as registration fees and licence fees, to variable costs, such as fuel taxes. The argument for doing so is that car users pay insufficient attention to the costs of driving, and only take account of fuel costs in making comparisons with other modes. Thus, shifting more of the costs drivers pay to the fuel cost would encourage them to walk, cycle, take public transport, or refrain from travelling. The size of the fuel tax increase is determined by the reduction in other costs. The greenhouse gas effects of vehicle tax reform and other fuel tax measures are estimated using the model described in Appendix D.

One proposal that has received attention, especially in the United States, is a variation on the concept of transforming fixed costs to variable costs, known as “pay-at-the-pump insurance”. This measure raises part of the insurance premium needed to provide a minimum, statutory level of cover, as a surcharge on fuel. In addition to raising the fuel price, and potentially allowing for insurance to be obtained at lower costs, it addresses the problem of uninsured drivers. Pay-at-the-pump insurance has been analysed in the United States in two studies (Wenzel, 1995; Gruenspecht *et al.*, 1995). These reports draw on economic modelling of transport energy demand and the results of public discussions, and analyse the legal, social and other implications of the concept in addition to the effects on fuel consumption.

The second concept is “full cost pricing”; the use of fees levied on road users to recoup the full government costs of road and road services provision. Many countries already recover the full costs of road provision through vehicle and fuel taxes and other charges, but some do not. Meanwhile, in some of those that do, the distribution of charges across road users may not reflect the costs they impose. This issue has been explored in many studies, including three country case studies carried out for the OECD. These three studies are briefly reviewed in Appendix E. This paper makes use of the case study estimates of unrecovered public costs to calculate fuel tax levels that would reflect the full public costs of road use to drivers, using the model described in Appendix D.

The third concept is that of “externality adders”. The three OECD case studies also produce estimates of the full social costs of transport. This study also uses the model described in Appendix D to evaluate the effect of introducing externality adders to fuel prices to reflect these costs. It is recognised that fuel taxes are unlikely to be the most efficient or the most effective way to address the broader externalities of road use. Two of the case studies also evaluate the effects on CO₂ emissions and other externalities of packages of measures designed to address those externalities more efficiently, and these effects are reviewed here.

Greenhouse Gas Effects of Fuel Tax Increases

Road fuel taxes have an effect on fuel consumption, and hence on CO₂ emissions, through a variety of mechanisms. In general, a 10 per cent increase in fuel prices might be expected to result in the following:

1. an immediate reduction in distance driven per car by up to 3 per cent, and a reduction in freight traffic by up to 2 per cent
2. an immediate change in driving behaviour, trip patterns and vehicle management, resulting in perhaps 1-2 per cent reduction in energy intensity
3. a reduction in the energy intensity of new vehicles purchased, contributing, in the long run, a further 2-4 per cent reduction in energy intensity in the case of cars, and up to 2 per cent reduction in energy intensity in the case of trucks
4. an immediate reduction by up to 3 per cent in the number of new cars purchased

These effects are discussed in Appendix B, which provides a brief literature review.

Fuel taxes can also influence fuel choice. Where fuels differ only slightly in their properties (e.g. as in the case of leaded and unleaded gasoline), very small differences in price can have a large effect on consumer choice. Where fuels differ more significantly, as in the case of gaseous fuels as alternatives to gasoline, larger price incentives may be needed to encourage their introduction.

In most circumstances, fuels that offer a substantial greenhouse gas mitigation potential are also considerably more expensive than gasoline or diesel (Michaelis, 1996) and large tax differentials would be needed to encourage their use. This report does not address the effects of taxes on alternative fuel use, although this issue is addressed in Working Paper 13 of this series.

There are likely to be additional effects from the use of the revenue arising from fuel tax increases, which may offset reductions in CO₂ emissions. If the revenue is used to reduce taxes on vehicles, the number of vehicles purchased and their energy intensity is likely to be increased. Where the revenue is used to reduce income tax, increasing consumers' purchasing power, vehicle sales and energy intensity, as well as traffic levels, are likely to be slightly increased. Revenue might also be "earmarked" for specific uses, such as subsidising public and non-motorised transport infrastructure and operation, funding research and development into vehicles or alternative fuels, or setting up demonstration schemes for new transport systems and technologies. While "earmarking" or "hypothecation" of taxes is economically inefficient as a means of determining government spending on specific activities, it often makes tax increases more politically acceptable. Some of these options are discussed in a little more detail in Parts 3 and 4 of this report, which are preliminary and have been further explicated in Working Paper 13 of this series.

Taxes in Europe and Japan are higher on gasoline than on diesel, a cross-subsidy from car users to truck operators that has a side-effect of encouraging the use of diesel cars. The implications for CO₂ emissions are complicated: diesel cars on average have lower CO₂ emissions per kilometre than gasoline cars, but since the fuel is cheap, their owners are encouraged to drive more than gasoline car owners. An investigation of this issue in France has shown that people who switch from gasoline to diesel tend to be high-kilometrage drivers (on average 16 000 kilometres per year, whereas gasoline car drivers average 12 000 kilometres). Diesel car owners on average drive 20,000 kilometres per year. Thus, half of the

difference between diesel car drivers and gasoline car drivers is thought to derive from differences in lifestyle, and half from the differences in fuel price (Orfeuil, 1996).

Vehicle tax reform

As Table 1 on page 26 shows, vehicle users in many countries pay substantial taxes and fees to national and local authorities, upon purchasing new vehicles and on an annual basis. Some countries, such as the United Kingdom, France, and Japan have recently reduced vehicle taxes and increased fuel taxes. This can result in reduced driving, energy use and greenhouse gas emissions.

The greatest potential for this measure is probably in light duty, personal vehicles. Commercial vehicles are usually subject to lower purchase taxes as a percentage of value, although they are subject to high licence fees in some countries. To give an indication of the size of the effect of tax reform for a typical Japanese car, moving the taxation burden from purchase and annual taxes to fuel taxes would double the tax on gasoline, and increase the gasoline price by 50 per cent (50 US¢ per litre). In Europe, the effect depends on the country as taxation structures differ considerably, but based on a typical French car (IEA, 1993a; DRI, 1995) tax reform would only increase the gasoline price by 15 per cent (15 US¢ per litre). In the United States, again based on typical taxes (IEA, 1993a; Wenzel, 1995) the fuel price increase would also be about 15 per cent (5 US¢ per litre)

The fuel price increases associated with full pay-at-the-pump insurance can be substantial — fuel prices would need to be more than doubled in the United States and increased by nearly 60 per cent in France to include the insurance costs of a typical family car (based on IEA, 1993a). Lower levels would be possible, for example, to cover a basic level of third-party accident insurance, with additional insurance purchased in the normal manner.

The fuel price increase would tend to discourage driving, and encourage drivers to choose more fuel-efficient cars. However, reduced costs of vehicle ownership would tend to result in more, higher value and hence higher energy-intensity vehicles being bought. The effect of vehicle tax reform depends on the extent to which fuel prices affect demand for new vehicles, and for fuel economy in new vehicles.

Table 8. Assumptions and Results for Vehicle Tax Reform in OECD, Muddling Through Scenario

| Sample country for tax regime | France | United States | Japan |
|---|----------|---------------|----------|
| Vehicle price including taxes and first year fixed costs (license, registration, insurance) | \$19 000 | \$19 000 | \$11 000 |
| Vehicle purchase tax shifted to fuel tax | \$103 | 0 | \$450 |
| Annual tax shifted to fuel tax | \$90 | \$100 | \$471 |
| Fuel Use Reduction in 2035 | 9-11 % | 12-13 % | 12-22 % |

A first set of estimates of the CO₂ and other effects of moving light duty vehicle purchase and annual taxes to fuel taxes has been carried out. This analysis has been carried out using the model described in Appendix D to calculate vehicle ownership levels, vehicle fuel economy, and the distance travelled, based on income, fuel prices, and the various tax levels. The model calculates the fuel tax level required to maintain the level of government revenue per vehicle-kilometre, when purchase and annual taxes are removed in 2000. Table 8 lists the assumptions made for the three countries analysed — France, Japan and the United States — and the principal results. Figure 14 illustrates the effects on CO₂ emissions from light duty vehicles for the OECD if these three countries are taken as proxies for OECD Europe, North

America and Pacific regions. It must be emphasised that these are only illustrative calculations, as tax structures vary considerably within these regions. The variability shown in the effect of tax reform on fuel use and CO₂ emissions depends on the assumed elasticity of car fuel economy with respect to changes in car tax. This has been tested as an elasticity of fuel economy with respect to the car retail price index. The results shown are for an elasticity range of 0 (giving larger reductions) to -0.85 (giving smaller reductions). This value of -0.85 corresponds to the elasticity that might be expected if consumers' car purchases are constrained by a price limit or budget, so that reductions in the car price index lead directly to their buying cars with a higher real value. The correlation between car value and fuel consumption is taken to be 0.85, based on the range of models available in Germany (see Figure 9). In Figure 14, the elasticity is taken to be -0.4.

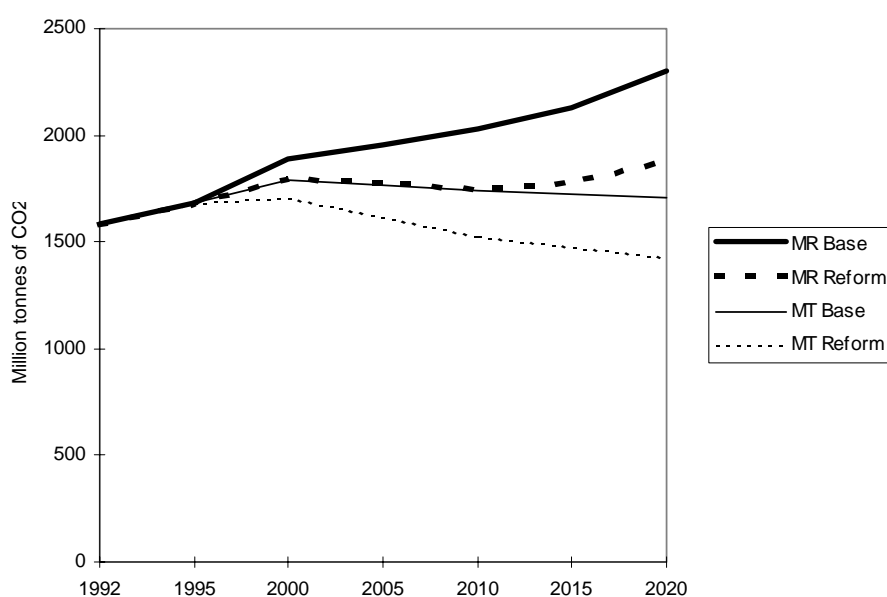


Figure 14. Effects of Moving Registration Fees and Road Taxes to Fuel Duties in OECD Countries

Full-cost pricing and externality adders

Several studies for countries, including Canada, France, Japan, the Netherlands and the United States, have evaluated the extent to which road users fall short of paying the full budgetary, environmental and social costs of driving, and the effects of internalising these costs through various measures. In general, fuel taxes may not be the most efficient means of internalising costs associated with air pollution, road damage, noise or accidents (DRI, 1996; Orfeuil, 1995). Nevertheless, pricing to reflect externalities is one of the arguments that has been brought forward in many countries in support of higher fuel taxation.

“Full-cost pricing” is defined here to mean pricing which reflects the full cost of provision of roads and other facilities. In general, road users pay for these facilities through some combination of special charges and taxes, including special vehicle purchase taxes, registration fees, licence fees, fuel excise duty, and direct fees for the use of parking spaces, and toll facilities (usually bridges, tunnels or motorways).

“Externality adders” can reflect non-monetised and external costs, such as externalities associated with climate change, oil resource depletion, military expenses and damages associated with maintaining

security of oil supply, inconvenience and risk caused to pedestrians by urban traffic congestion, the nuisance caused by noise in residential areas, the health, comfort and visual amenity effects of air pollution, and uninsured costs associated with accidents.

The following two sections briefly summarise estimates of the fuel price increases that might be justified by “full cost pricing” and “externality adders”, and the effects that these price increases might have on CO₂ emissions:

- the next section addresses government budgetary costs associated with providing roads and road-related services;
- the section following that considers the full environmental and social costs associated with road transport.
- Budgetary Transport Subsidies

Roads have public good characteristics and it is not possible at present to charge efficiently for their use. This is one of the main reasons that governments provide roads, while in many countries, aiming to recover the costs of doing so as far as possible through road user charges on fuel or vehicles. Meanwhile, transport policy-makers have had to deal with growing problems, with rising levels of traffic congestion and increasing road damage, noise, vibration and pollution. Some of these issues have traditionally been addressed through technical means — increasing road capacity, strengthening existing roads, introducing vehicle standards, and improving traffic management systems and road design (measures that are normally designed to increase the capacity of existing roads). Transport ministries have, for many years, been active in searching for ways of managing congestion other than through increasing capacity. In theory, the most economically efficient way to do this would be through road-user charges based on the long-run marginal cost associated with each additional person’s use of the roads (Newbery, 1990). This might be expected to include the cost of road maintenance and construction, but might also include other social and environmental costs. Full cost pricing in road transport has thus been seen as a mechanism for discouraging driving and reducing the congestion, accidents and environmental damage associated with car and truck use.

Measuring transport subsidies

There is little argument over the basic principle that road users should pay for the services they receive. Some observers have argued that the transport sector has positive externalities and so should be subsidised by government. However, the positive externalities claimed — such as the economic efficiency advantages from the mobility of goods and services, or pedestrian access to homes and services — can mostly be argued to be internalised through one market or another. Nevertheless, it is hard to reach consensus on the allocation of public costs among road users. It is not at all clear how costs should be divided among private motorists, public transport users, commercial goods vehicle operators, pedestrians and public services. Marginal costs are especially difficult to evaluate and justify in a way that all road users would accept.

Similarly, there is some question over which taxes and fees should be included in an evaluation of road-user payments towards government expenditures. For example, sales taxes levied at the normal rate can be viewed as part of general taxation, but lobbyists against increases in fuel and other transport taxes frequently include these taxes when they argue that road users already pay their full costs. Fuel duties are less obviously part of general taxation — in some countries, such as the United States and Japan, they are

explicitly levied to provide a road fund. In others countries, especially in Europe, fuel duties have been implemented essentially as a general revenue-raising measure. Other costs, such as special vehicle taxes, registration fees, annual road tax, etc., are more explicitly intended to raise funds for purposes associated with provision of road and road user services.

Three OECD country case studies have been carried out, examining the size of any net subsidy to private road users (cars and trucks) in France (Orfeuill, 1995), Japan (Morisugi, 1995) and the United States (DRI, 1996), and investigating possible scenarios in which these net subsidies are eliminated through a variety of measures. The case studies, which are briefly summarised in Appendix E, draw up balances of government revenues from road users (excluding sales tax at the general rate), versus the cost of roads and road-related services to government and public sector companies, including capital expenditure and charges. Measurement of both revenues and expenditure is complicated by the need to compile information on charges and costs at several levels of government, often with substantial variation among regions of a country. Items typically included in the balances include:

On the revenue side:

- special vehicle purchase taxes, vehicle registration fees and annual licence or other fees;
- fuel taxes;
- driver licence fees;
- charges for the use of public facilities, such as tolls and parking charges;

and on the cost side:

- land appropriation, infrastructure construction and maintenance funding;
- spending on policing and emergency services;
- administration of licensing and registration systems; and
- exemptions from sales taxes on fuel or vehicles for certain road users.

The items included in the balance vary among countries.

The balances are used in the case studies as the measure of net aggregate budgetary subsidies to road users. Revenues and spending are also disaggregated to obtain estimates of the net subsidies to different types of users. Disparities usually exist between: diesel and gasoline users, who pay different levels of tax in many countries; light duty and heavy duty vehicles, which impose very different costs in terms of road damage and road construction standards; and urban and rural road users, who impose different costs in terms of road provision.

In calculating the level of user payments to governments, the studies exclude normal levels of sales tax on goods and services. This component of road transport taxes is assumed to be part of general revenue-raising, rather than a fee related to the provision of infrastructure and services.

In the Japanese case study, Morisugi (1995) tests the effects of different allocations of government spending among road users. This is particularly important for Japan, which has much lower levels of car

use and higher levels of bus use than France or the United States. The shares of public spending assumed to be allocable to cars and trucks range from 64 per cent to 100 per cent. The remainder is assumed to be allocated to providing pedestrian and public transport infrastructure, utilities (electricity, gas, water, sewerage) under roads, the use of the roads by public services, etc. A fair allocation would probably lie between these two points and the figures chosen must be taken as an illustrative range.

As Table 9 shows, the OECD case studies, and others along the same lines, find that road users in European countries are, in aggregate, covering the costs of public road and service provision through the taxes and fees they pay. In France, user fees in 1991 exceeded government outlays by about US\$9 billion, although this excess is projected in the case study to fall to US\$8 billion in 2010, on the assumption that fuel taxes do not increase (in fact, fuel taxes in France have increased since the study was written). In Japan, the position is less clear. If the definition of government expenditure on behalf of car and truck users includes all aspects of road spending, these road users received a subsidy of US\$16 billion in 1991, and this is projected to increase to US\$24 billion in 2010. However, using a low estimate of the share of government expenditure that should be allocated to car and truck users, the study finds that these users paid an excess of US\$15 billion in 1991, rising to US\$18 billion in 2010. Finally, the US study finds a net subsidy to road users of US\$15.5 billion in 1991, rising to US\$25.5 billion in 2010.

Table 9. Public Sector Expenditure vs. User Fees in the Transport Sector (1991 US\$)

| | Public Sector Expenditure | | | | | User fees | Ratio |
|-----------------------------------|---------------------------|----------|----------------|------------------------------|-------------------------|---------------|---------------------------|
| | Total \$ billion | % of GDP | Per vehicle \$ | Per unit of traffic (\$/vkm) | Per unit of fuel (\$/L) | Total (bn \$) | Fees / public expenditure |
| France | 19 | 1.6 | 650 | 0.044 | 0.44 | 29 | 1.49 |
| Japan (high car/truck allocation) | 88 | 2.5 | 1500 | 0.134 | 1.05 | 51 | 0.58 |
| United States | 74 | 1.3 | 400 | 0.021 | 0.16 | 59 | 0.79 |

When the costs of provision and the user fees are disaggregated by different types of users, the picture changes somewhat. Diesel vehicles in Japan do not pay their full costs, because of low rates of diesel fuel excise duty relative to that for gasoline (Morisugi, 1995). For France, Orfeuil (1995) carries out a very detailed analysis of the net subsidy to different types of road users. Although he finds that most road users pay more in tax than they cost the government, gasoline users pay an excess of FF 51 billion (about US\$10 billion) while diesel users pay very little excess.

Other supports to car use

In addition to budgetary expenditure on road transport, the case studies also briefly consider other types of explicit and implicit support to road users. The United States and French case studies both identify the provision of parking spaces for employees at work as a major implicit support for car use, and examine the effects of introducing parking charges. The extent to which free parking provision can be considered a market distortion in favour of driving depends on the situation: where it is an untaxed benefit to employees, and a similar benefit is not offered to employees using public transport or other modes, there is a distortion in favour of car use.

Tax schedules and employment practices in many countries act as supports of one kind or another to car use, and also to the purchase of larger or more powerful cars. These include the provision of company cars, tax credits, or payment by employers, for expenses in travel to work, and many others. Many

governments impose lower taxes on company purchases of cars than on private purchases. These purchases can include company purchases for employees, and the purchase of hire cars, which together may comprise a large proportion of the national fleet and are usually sold into private use after three to four years.

Planning regulations that require developers to include a minimum number of parking spaces with new office buildings or housing can also act as an implicit support to car use. None of these possible distortions have been assessed in the OECD case studies or the current report.

Establishing fair pricing systems

The costs reviewed above are total and average costs of road provision. Economically efficient road user charges would be based on long-run marginal costs, which would need to be evaluated with a much more detailed view of the way each kilometre driven by each road user affects the current and future need for expenditure, at the margin. Such a detailed study has not been carried out here. Efficient charges would need to reflect directly the costs that each road user causes — thus, they would vary according to the type of vehicle, the location, the traffic conditions and other factors. It is technically possible to impose such charges and many governments have experimented with, or implemented, road pricing schemes of one kind or another. At their simplest, these are tolls for restricted access routes such as motorways and bridges. Some cities (notably the Norwegian cities Oslo and Trondheim) have implemented toll rings (Polak and Meland, 1994; Ramjerdi, 1994). New Zealand charges trucks for their use of roads on the basis of the distance driven. Several Annex I Parties have experimented with electronic road pricing. However, so far, no such scheme has received wide acceptance.

Of the three case studies, two, the French and the United States study, explore different approaches to pricing. The United States results are relevant here, in that they focus on pricing to address congestion and road damage. The French study addressed measures to address a wider range of social and environmental costs, and will be discussed in the next section on Externality Adders.

The United States case study (DRI, 1996), investigated two alternative “full user fee funding” scenarios, one using an increased gasoline tax from 1998, the other using a mixture of congestion pricing and parking charges for cars and axle weight charges for trucks to raise revenue, to cover a reduced level of government spending. The second scenario is called the “optimal pricing” scenario, because the fees introduced are designed to reflect the budgetary costs related to different types of road use. Fuel taxes are a second-best solution to user fee funding because fuel use is only indirectly related to the amount of road space required by cars, or the amount of road wear caused by heavy trucks.

The gasoline tax scenario obtains 15 per cent greenhouse gas emission reductions in 2010 relative to the base case scenario, where user fees are unchanged. The “optimal pricing” scenario obtains 12 per cent greenhouse gas emission reductions (see Figure 15). Traffic levels are affected in the two scenarios in different ways. Overall levels are reduced more in the gasoline tax case than the optimal pricing case, but under optimal pricing, traffic patterns are changed, with commuter traffic most reduced.

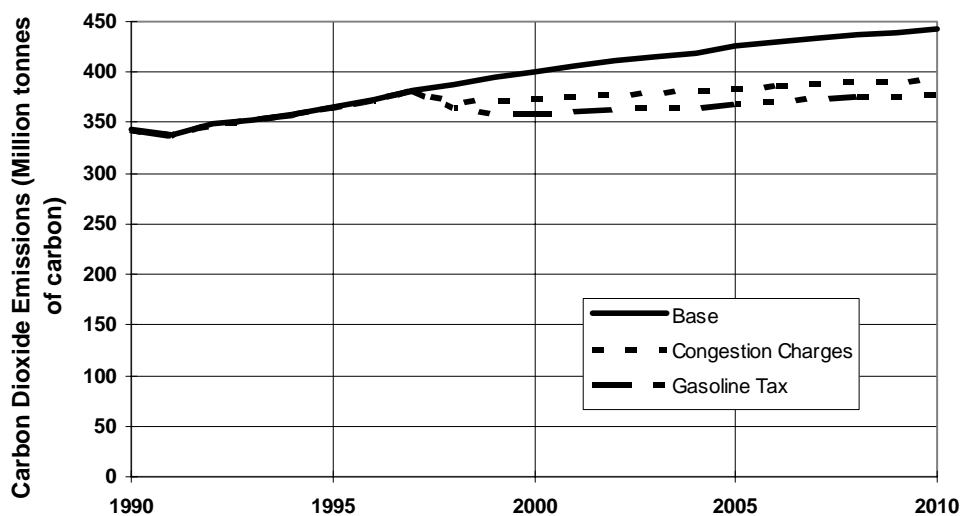


Figure 15. Effects of Road User Full Cost Pricing in the United States

Source: DRI, 1996b

The United States findings show how a strategy aimed at addressing other transport priorities may also be able to contribute to greenhouse gas mitigation.

While fuel taxes are a poor proxy for marginal road use costs, they remain the main revenue raising tool in the transport sector in many countries. This is partly because they are easy to administer. Meanwhile, fuel use is at least partly related to the distance driven by road users and to the size of the vehicle. To some extent there is a differentiation among road users in terms of the fuel they use (between gasoline and diesel), although this differentiation is decreasing, especially in Europe. However, fuel taxes cannot so easily be differentiated between urban and non-urban users to reflect the costs they impose.

For illustrative purposes, this study considers the effect of introducing the changes in fuel tax shown in Table 10 to move towards full budgetary cost pricing in the transport sector. Base prices are 1994 values taken or estimated from IEA statistics (IEA, 1995a) for all regions except the CIS, where PPP prices are derived from Golub et al. (1995). Unsubsidised prices are estimated from the three OECD case studies for the OECD regions, with prices for central and eastern Europe estimated from OECD Europe prices, and prices for the CIS estimated from the United States price.

Of the three case studies, only the one for France estimates the full budgetary costs associated with diesel and gasoline users separately for all vehicle types. It finds that diesel users impose higher costs per unit of fuel than gasoline users, whereas they are currently paying lower costs. The Japanese case study suggests equalisation of the diesel and gasoline prices as part of a move towards full cost pricing, but does not justify this in terms of the costs imposed by different road users. Nevertheless, this equalisation is tested here. In the United States, gasoline and diesel users currently pay the same prices (although diesel is more heavily taxed) in many states. This situation is assumed to continue.

The price increments are tested in the WEC Muddling Through and Markets Rule scenarios, including a decrease in the gasoline price for Europe.

Table 10 . Fuel Price Changes in 2000 for Full Budgetary Cost Pricing

| Region: | North America | | OECD Europe | | OECD Pacific | | Central/Eastern Europe | | CIS | |
|---|---------------|-----------|-------------|-----------|--------------|-----------|------------------------|-----------|-----------------------------|-----------|
| Sample country where subsidies were estimated | United States | | France† | | Japan† | | Not estimated | | Russia, fuel subsidies only | |
| | Base | Full Cost | Base | Full Cost | Base | Full Cost | Base | Full Cost | Base | Full Cost |
| Gasoline | 29 | 32 | 85 | 55 | 115 | 123 | 50 | NE | 30 | 30 |
| Diesel | 29 | 32 | 60 | 65 | 76 | 123 | 40 | NE | 7.5 | 15 |

† Subsidies estimated in these countries are used for illustrative purposes in modelling transport energy use in the regions, although the countries they are not necessarily representative of others in their regions.

Effects on greenhouse gas emissions of full budgetary cost pricing

In estimating the effects of introducing the fuel tax changes listed in Table 10, the model described in Appendix D has been used to test variations from the WEC (1995) transport energy scenarios. The model was used to investigate the effect on CO₂ emissions of introducing the price changes in 2000. The results are shown below in Figure 16. Effects are shown in comparison with two base scenarios: Muddling Through (MT) and Markets Rule (MR). Effects of mode shifts may be significant in the case of freight, so road and rail freight emissions have been included together. Mode shifts are not expected to be large in the case of cars although significant changes could occur in some countries..

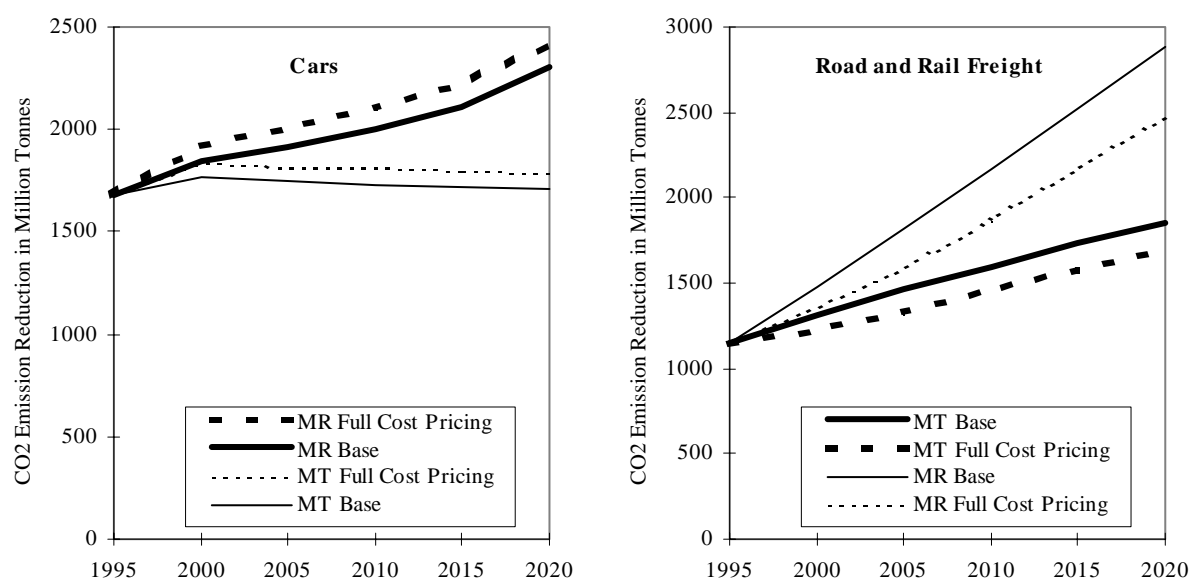


Figure 16. GHG Effects of Full Budgetary Cost Pricing Through Fuel Tax in OECD, Central and Eastern Europe and CIS (Excludes OECD Europe Effect of Gasoline Price Reduction)

For cars, moving to full budgetary cost pricing results in an increase in CO₂ emissions, because of the reduction in gasoline prices in Europe. Although the mitigation effect for freight is very large, most is due to the effect on the CIS, where the correct measure of current diesel prices and any possible subsidy is most uncertain. Meanwhile, as Appendix D notes, CIS freight energy use in the WEC scenarios is rather high, so that the mitigation potential may also be overestimated here.

A significant feature of the greenhouse gas effects of tax increases of this type, is that they are fairly rapid: much of the effect is on the distance driven although effects on the numbers of vehicles purchased and the

fuel economy of those vehicles take longer to filter through into the fleet. However, the effects do not increase after about ten years following the implementation of the tax increases. Thus, introducing such taxes might reduce greenhouse gas emissions for a while, but growth could resume later.

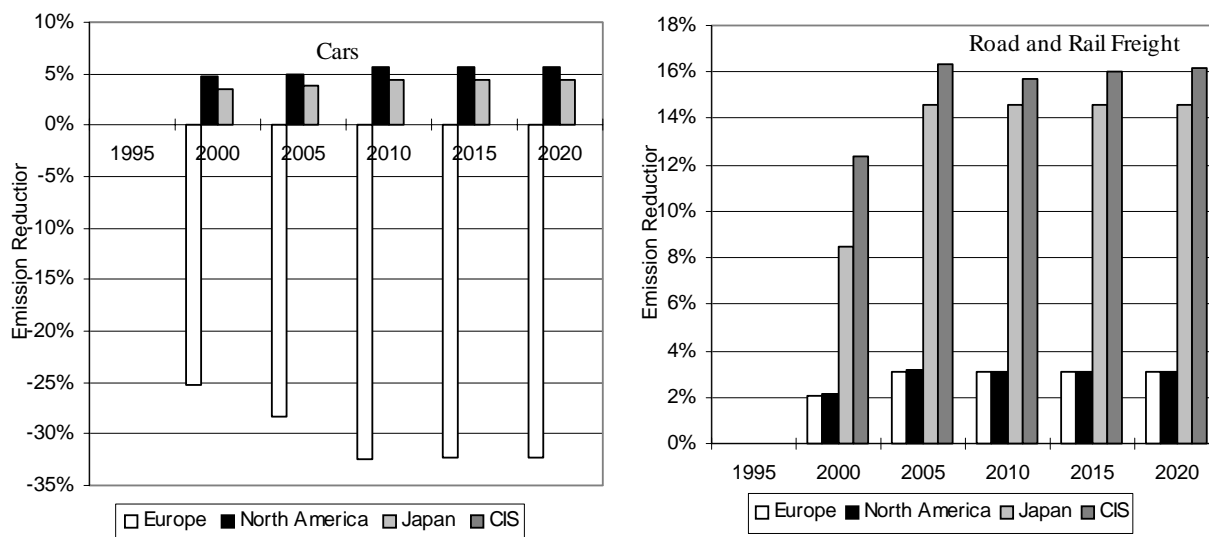


Figure 17. Regional Effects on GHG Emissions of Full Budgetary Cost Pricing

While the figures indicate a substantial mitigation potential, of the order of hundreds of millions of tonnes of CO₂, it must be emphasised that they are only illustrative: countries would need to carry out their own analysis to establish what, if any potential exists. Many countries are likely to be in a similar situation to that of France, in that their budgetary expenditure on roads is already fully covered by user fees. Meanwhile, alternative measures may be more effective in addressing the broad range of transport sector policy objectives, including greenhouse gas mitigation. Finally, it should be noted that the model used to estimate the effects of measures was crude and disaggregated, based on price elasticities with uncertainties of ± 50 per cent at least.

Transport externality adders

In addition to evaluating the budgetary subsidies to road transport, the OECD case studies evaluated road transport externalities. They included assessments of the external costs of traffic congestion, accidents, traffic noise, air pollution and greenhouse gas emissions. Externality definitions and methods for valuation differed more among case studies than methods for budgetary subsidy definition and valuation. This reflects a general difficulty in trying to achieve a consensus view among experts on what constitutes an externality and how it should be valued.

All three case studies include estimates of the level of transport externalities in 1991. Only the French and the Japanese studies evaluated the effects of reducing or internalising externalities along with budgetary subsidies.

Defining and measuring externalities

Existing studies have tended to focus on four types of externality associated with driving. These are:

1. costs imposed on other road users in the form of delay because of traffic congestion;

2. costs imposed on other road users (including pedestrians, cyclists and public transport users) because of accidents or the risk of accidents, to the extent that these are not covered efficiently by insurance;
3. costs imposed on the population in general in the form of suffering, damages, and loss of visual amenity from air pollution;
4. and costs imposed on the population in general in the form of suffering and annoyance because of noise.

Other external costs may be attached to climate change, depletion of non-renewable resources, military costs and damage from protecting security of oil supply, effects of transport on habitats and biodiversity, social dislocation, effects of urban quality of life, housing value, and other factors. Most of these are very difficult to value, and some may be very large.

Some of these externalities, those associated with climate change, depletion of resources, and security of oil supply, are of obvious relevance in the context of greenhouse gas mitigation. Internalising these externalities through fuel taxes would in principle be the most efficient way to address them. The other externalities might be more efficiently reduced or internalised through other measures, including congestion pricing, increased insurance premiums, and standards or charges for air pollution and noise. Impacts on habitats and communities might best be addressed through changes in transport system design. Nevertheless, fuel taxation is often discussed as a crude means of reflecting the externalities of road use to drivers for the same reasons (of convenience) that governments frequently collect road funds through fuel taxes. This section examines the possible effects of externality adders in fuel taxes. This question was addressed in the three OECD case studies.

One of the most important questions raised by each of the three studies, and answered in different ways, regards the definition and measurement of social and environmental externalities. Social and environmental damage depend very much on circumstances — the location of the vehicle causing the damage, the time, the characteristics of the vehicle and so on. Efficient pricing would in theory mean creating a market in the various forms of damage — so that sufferers from noise, congestion, air pollution and so on could seek direct recompense from those who cause it. In practice this is obviously impossible, but the implication is that the appropriate levels for efficient taxes to internalise the externalities would be the marginal externality caused by each individual road user. Determining this is, again, almost impossible. Damages from air pollution vary according to the location of the pollution source, the time of day, the weather, and the extent to which property and ecosystems are exposed. Thus, externality estimates tend to be based on very crude averages, or are extrapolated from a very few precise evaluations for particular circumstances.

Studies differ in the type of effects that they include in externalities. For example, some argue that it does not make sense to consider externality pricing for the effects of congestion on other drivers who are choosing to drive despite those effects, although economic efficiency arguments would lead to the inclusion of those effects in pricing. Evaluation of accident costs, and the component that is not paid by insurance, is particularly difficult. Most studies do not take account of the indirect effects of accident risk on quality of life — for example, the extra time and stress caused to non-motorists in negotiating city streets, or the time cost to parents who have to accompany children to school (and the additional externalities caused when they drive them to school).

The case study authors found it difficult to identify robust estimates, even of the damage costs associated with air pollution and noise. Thus, the French study relied on estimates of control costs rather than

damage costs in the cases of air pollution and noise, and the Japanese study used air pollution externality estimates per vehicle kilometre which had been developed for Germany. Governments wishing to introduce road user charges aimed at internalising externalities are likely to find it extremely difficult to find externality estimates that are generally accepted.

The case studies consider different ranges of externalities. All three considered externalities associated with accidents, air pollution, noise and climate change. The French case study also included congestion, while the Japanese study included loss of habitats. The United States study drew on literature sources (in particular MacKenzie *et al.*, 1992) covering a very wide range of social and environmental costs.

The country case studies use a variety of carbon emission costs as shown in Table 11.

Table 11. Social Costs Associated with CO₂ Emissions

| | France | Japan | United States |
|--|------------------|-----------------|------------------|
| \$ per tonne of CO ₂ | 5.5 to 19 | 20 ^a | 3.2 to 13 |
| Total CO ₂ external cost (billion \$) | 0.6 to 2.5 | 4 | 1.8 to 8.6 |
| CO ₂ external cost / vehicle-km (\$) | 0.0015 to 0.006 | 0.006 | 0.0008 to 0.003 |
| CO ₂ external costs / GDP | 0.05 % to 0.21 % | 0.12 % | 0.03 % to 0.15 % |

a) secretariat estimate

Other externality estimates are summarised in Appendix E. Overall externality estimates for road transport are: US\$16-24 billion in France in 1991, rising to \$18-29 billion in 2010; US\$21 billion in Japan in 1991, rising to \$24 billion in 2010; and in excess of US\$118 - 371 billion in the United States in 1991. However, these estimates are not evaluated on a comparable basis; any common action including the use of externality adders would probably depend on developing comparable externality estimates.

Based on the studies, using externality adders in fuel taxes would imply the price increases shown below in Table 12, where costs of road provision have also been included. Again, it must be emphasised that these prices are used for illustration purposes only. Countries considering raising fuel taxes to reflect the full social costs of transport would need to carry out their own detailed analysis of those costs, and of the best way to address them.

Table 12. Fuel Price Changes for Full Social Cost Pricing

| Region: | North America | | OECD Europe | | OECD Pacific | | Central/Eastern Europe | | CIS | |
|---|---------------|-----------|-------------|-----------|--------------|-----------|------------------------|-----------|--|-----------|
| Sample country where subsidies were estimated | United States | | France† | | Japan† | | Not Estimated | | Russia fuel subsidies only (as previous section) | |
| | Base | Full Cost | Base | Full Cost | Base | Full Cost | Base | Full Cost | Base | Full Cost |
| Gasoline | 29 | 53-106 | 85 | 103-121 | 115 | 148 | 50 | NE | 30 | 30 |
| Diesel | 29 | 53-106 | 60 | 103-121 | 76 | 148 | 40 | NE | 7.5 | 15 |

† Externalities estimated in these countries are used for illustrative purposes in modelling transport energy use in the regions, although the countries they are not necessarily representative of others in their regions.

Effects on greenhouse gas emissions of eliminating externalities

When the price increases in Table 12 above are incorporated in the WEC scenarios, the results obtained are as shown in Figure 18 below, which is obtained using mid-points from the ranges above. Clearly, the effects on CO₂ emissions are very substantial.

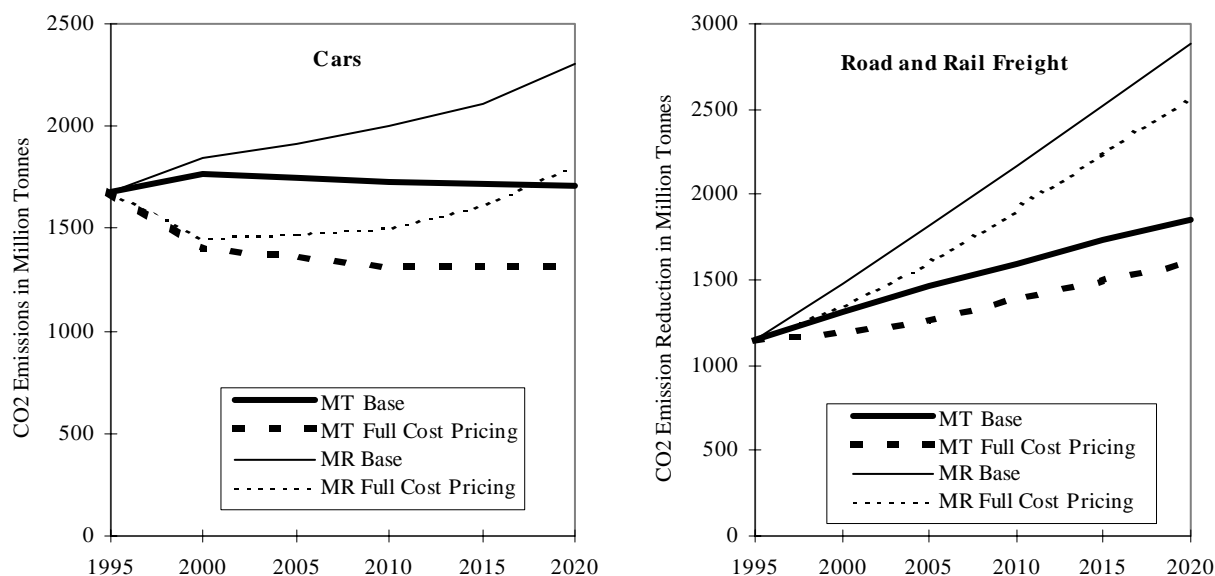


Figure 18. CO₂ Reduction Effect of Externality Adders in Fuel Taxes

Figure 19 shows the regional breakdown of the mitigation effects, with the largest reductions coming from cars in North America. Again, it is worth noting that the effect of introducing a tax is rapid, but that it is unlikely to reverse a long-term upward trend in emissions. However, in this case, unlike the case of taxes to recover government costs, the level of externalities from road user might increase more rapidly than fuel use. One reason suggested by the French case study is that the valuation of health, life, amenity, etc., is likely to increase at least as fast as per-capita income. This will tend to increase the unit valuation of the externalities associated with physical effects of transport. If externality adders increased over time, they might achieve a long-term reduction in emissions. Meanwhile, many externalities have been excluded from the estimates used here, and some externalities that have been included, such as those associated with climate change, are very uncertain.

Other means of reducing and internalising externalities

While externality adders in fuel taxes would probably be an effective means of achieving quite large greenhouse gas emission reductions from the transport sector, other measures might be more efficient in reducing the broad range of externalities.

The French case study, noting the political difficulty in raising fuel taxes sufficiently to internalise costs and their ineffectiveness in reducing externalities: the study estimates that an externality adder in fuel taxes would only reduce the externalities by about 15 per cent. The study therefore develops a “synthesis scenario” relying more on regulations and agreements. As such measures are hard to model, a number of assumptions are made regarding their effects.

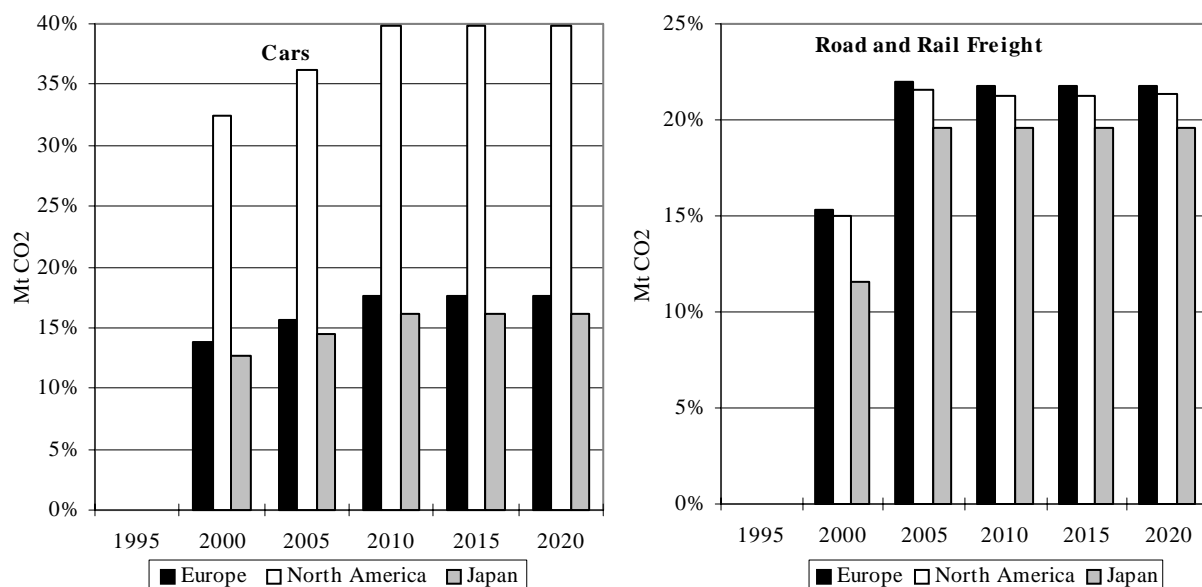


Figure 19. Regional Effects on GHG Emissions of Externality Adders in Fuel Taxes

Four new measures generate additional revenue: parking fees in towns; taxation on employer-provided parking; suppression of parking spaces in city centres; reduction of tax exemptions related to travelling to work by car. Public income increases by 8 per cent compared to the Base Case, with most of the increase coming from light vehicles in towns.

Expenditure requirements decrease relative to the Base Case because of reduced urban traffic, but this is offset by an increase in spending on measures to reduce noise and accidents. Overall, public sector outlays decrease marginally (by 0.5 per cent) relative to the Base Case.

The synthesis scenario incorporates measures to reduce noise, local pollution, greenhouse gas emissions, and accidents. The principal measures are:

- Progressive increases in investment in noise protection, resulting in a one-third reduction in noise exposure;
- Generalisation of routine vehicle emission inspections, with the obligation on owners to ensure that their vehicles meet the original emission standard under which they were licensed. This measure is assumed to reduce emissions by 15 per cent and fuel consumption by 5 per cent (through improved engine maintenance);
- Withdrawal of the 50 per cent reduction in annual licence fee applied to vehicles over five years old with the increased revenue being used to reduce taxes on low income households. This is assumed to increase the rate of car scrapping, especially for those vehicles that cannot meet emission standards and require extensive maintenance work. The result is a further 35 per cent reduction in urban pollution;
- A mix of measures to improve road safety, including restricting access to the most dangerous vehicles to very experienced and save drivers, increasing road patrols, investing in safety measures etc. These measures reduce accidents by 24 per cent;
- Additional measures, in particular parking controls and fees, reduce urban traffic by 11 per cent;

The overall effect of these measures on road transport externalities can be seen in Table 13.

**Table 13. External costs (high estimates) of road transport in France 2010
Synthesis Case vs. Base Case**

| | Base US\$ bn | Synthesi s US\$ bn | Difference |
|------------|-----------------|--------------------------|------------|
| Noise | 3.83 | 2.58 | -33 % |
| Pollution | 4.54 | 3.18 | -30 % |
| GHG | 5.59 | 4.94 | -12 % |
| Accidents | 9.77 | 6.75 | -31 % |
| Congestion | 5.37 | 4.60 | -14 % |
| Total | 29.10 | 22.05 | -24 % |

While these results are largely a matter of expert judgement, the indication is that greenhouse gas emissions might be reduced substantially, although not as much as they might be if fuel taxes were increased. The study suggests that, as the externalities are reduced but not eliminated through this package of measures, there would still be a justification for introducing a fuel tax increase close in size to that investigated in the last section.

Effects on Vehicle Ownership, Traffic and the Environment

It has already been mentioned that an advantage of fuel taxes relative to pure fuel economy measures is their anticipated effect on traffic. Whereas fuel economy measures are liable to result in increased vehicle ownership and traffic, fuel tax increases are likely to decrease them. Table 14 shows the effects on car ownership, traffic, and fleet average energy intensity that have been calculated in the three tax cases described above.

Table 14. Change in Car Fleet and Traffic in Tax Scenarios: Annex I Region

| | Tax Reform | | Full Cost Pricing | | Externality Adders | |
|---|------------|--------|-------------------|-------|--------------------|---------|
| | MT | MR | MT | MR | MT | MR |
| Percentage Change in Car Ownership | | | | | | |
| 2010 | -1.4 % | -1.6 % | 2.2 % | 2.3 % | -6.9 % | -7.1 % |
| 2020 | -2.4 % | -2.5 % | 2.1 % | 2.0 % | -6.7 % | -6.4 % |
| Percentage Change in Traffic | | | | | | |
| 2010 | -5.5 % | -6.2 % | 3.6 % | 4.2 % | -14.1 % | -14.7 % |
| 2020 | -7.2 % | -7.9 % | 3.4 % | 3.8 % | -13.5 % | -12.8 % |
| Percentage Change in Fleet Average Energy Intensity | | | | | | |
| 2010 | -2.6 % | -2.9 % | 1.0 % | 1.2 % | -11.3 % | -12.0 % |
| 2020 | -3.4 % | -4.0 % | 1.0 % | 1.1 % | -10.6 % | -10.1 % |

A few observations can be made based on this table, while noting that the validity of the results depends on the validity of the various price and other elasticities discussed in Appendix B. In all cases, percentage changes in traffic are larger than percentage changes in average energy intensity. Changes in fleet size account for around half of the changes in traffic in the pure tax cases, and for about a third of the change in traffic in the tax reform case. The remainder of the changes in traffic are due to changes in driving per vehicle.

In the tax reform case, car ownership has been found to decline, despite the reduction in taxes on vehicles. This arises because of the strong assumed influence of the increased fuel price on car ownership.

In the full cost pricing case, car ownership, traffic and energy intensity all increase. This is because of the reduction in fuel taxes assumed in Europe.

Reductions in traffic are likely to result in proportional, or more than proportional, reductions in the externalities associated with car use. The reason why the decrease could be more than proportional to the decrease in traffic is that part of the reduction in energy intensity may be associated with a reduction in the share of short trips in total mileage, implying fewer cold starts and lower emissions of local air pollution per kilometre driven.

The reduction in car ownership and any downsizing that occurs also have implications for the environment and for greenhouse gas emissions, because of reduced resource use and pollution associated with vehicle manufacture and disposal. About a tenth of the lifecycle energy use and greenhouse gas emissions (excluding CFCs) are associated with vehicle manufacture and disposal (IEA, 1993a; DeLuchi, 1991; Martin and Michaelis, 1992). Reduced car ownership may therefore contribute around 5 per cent of any greenhouse gas mitigation in the pure tax cases, somewhat less in the tax reform case.

Table 15 provides similar results for the effects of “full cost pricing” and externality adders on freight traffic. Again, it must be emphasised that the results in this table derive directly from the elasticity assumptions in Appendix B. Some of these, in particularly the elasticity of truck energy intensity with respect to fuel price, are very uncertain.

A first important comment arising from this table is that the reduction in truck traffic is much larger than the reduction in total freight traffic. In some cases rail freight traffic increases, which will slightly offset greenhouse gas mitigation due to reduced truck traffic. These effects differ among countries. A greater potential for mode shifting is thought to exist in North America, Australia and the CIS than in Japan or Europe.

Table 15. Change in Freight Traffic in Tax Scenarios: Annex I Region

| | Full Cost Pricing | | Externality Adders | |
|---|-------------------|--------|--------------------|--------|
| | MT | MR | MT | MR |
| Percentage Change in Total Freight Traffic | | | | |
| 2010 | -2.8 % | -4.1 % | -6.1 % | -6.0 % |
| 2020 | -2.7 % | -4.0 % | -6.6 % | -6.1 % |
| Percentage Change in Truck Traffic | | | | |
| 2010 | -5.1 % | -8.5 % | -10.6 % | -9.9 % |
| 2020 | -5.1 % | -9.0 % | -10.6 % | -9.3 % |
| Percentage Change in Rail Traffic | | | | |
| 2010 | -0.3 % | 1.8 % | -1.3 % | -0.9 % |
| 2020 | 0.8 % | 5.6 % | -0.9 % | 0.1 % |
| Percentage Change in Truck Average Energy Intensity | | | | |
| 2010 | -4.2 % | -6.7 % | -3.8 % | -2.7 % |
| 2020 | -4.2 % | -6.9 % | -3.9 % | -2.4 % |

Political Feasibility: Economic, Equity and Trade Effects

It has already been mentioned that fuel taxes are, in principle, the most economically efficient means of internalising the climate change externality and reducing CO₂ emissions. However, this economic rationale depends on some level of agreement about the size of that externality. Based on an economic efficiency argument, it would not make sense to separate transport fuels from other sources of CO₂ emissions in imposing a carbon tax. Indeed, the transport sector may even seem a strange place to begin carbon taxation, given the high existing levels of tax and the heavy dependence on oil in this sector, relative to others where carbon taxation might lead to fuel switching at relatively low costs.

Rather than consider transport fuel taxes as carbon taxes, this study has concentrated on other rationales. The tax reform concept and “full cost pricing”, are no-regrets measures from the climate change perspective: they are justified for reasons other than climate change. This also applies to tax adders reflecting the majority of the externalities identified in the OECD case studies.

The extent to which such “no-regrets” justification exists, and is robust against criticism, is a major determinant of the feasibility of any of these measures. As much of the justification for taxation is economic, the effects of taxes on various aspects of the economy are usually tested in economic (computer) models. However, the role of the transport sector in the economy is poorly understood. It is clear that transport of people and goods plays a key role in the functioning of local, national and international markets — for labour, land, raw materials, intermediate goods and products. This role is rarely captured in economic models: transport is usually incorporated as a cost, as a contributor to personal welfare, but rarely, if ever, as factor of production. The effect of transport efficiency on the cost and availability of the full range of traded goods and services is poorly understood, much less modelled. Similarly, the negative effects of transport on quality of life, communities, and the environment, are poorly understood and are not usually incorporated in economic models.

Economic analysis of the direct effects of gasoline taxes frequently indicates a negative impact on consumer surplus and GDP because of their effects on household consumption (e.g. Koopman, 1995; Boyd and Uri, 1994; DRI, 1996). The ability to respond to taxes by changing patterns of vehicle use varies among households, with high-income, multiple car households having the greatest flexibility (Walls et al., 1993). In the United States, gasoline taxes are expected to be regressive, although this may not be the case in countries where low-income households tend not to own cars.

The United States case study for the OECD (DRI, 1996) includes an evaluation of the effects of changes in road user pricing on the economy, using DRI’s macro-economic model of the United States economy. The full user fee funding scenarios have GNP 0.3-0.5 per cent lower in 2010 than the subsidies-continued scenarios, although these results need to be treated with caution. DRI assumed that the increase in road user charges was compensated by a decrease in all other taxes. This implies shifting taxation from income-related tax to a sales tax, with regressive effects. Conversely, DRI (1991) finds that the overall economic effect of fuel taxes can be positive, subject to the revenue being recycled through reductions in taxes on general earnings.

Some general observations can be made here. First, the studies mentioned do not compare different uses of the revenue from fuel taxes. Such comparisons are possible and have certainly been made in relation to the uses of increased revenues from carbon taxation (Baron, 1996). Nevertheless, more detailed analysis in this area would be welcome. Second, the effects of fuel taxes should be considered in comparison with other means of achieving the policy objective. If, as in the case of Boyd and Uri (1994), the taxes are to be used to reduce the budget deficit, the appropriate comparison is with other means of reducing the deficit (e.g. income or sales taxes, or reduced government spending). Third, different results may be

obtained using different methods of accounting for aggregate welfare. Specifically, where social and environmental goods are incorporated into the analysis through some form of shadow pricing, the welfare effects of increasing taxation on motor fuel are more likely to be positive, given the size of the estimated externalities of road use. The regressive effects of gasoline taxes are on road-users while the effects on non-road users are rarely discussed. Where reductions in GDP do occur, they are likely to be at least in part due to a fall in “defensive” expenditure — for example, less need for medical care expenditure for asthmatic children.

Any possible conventional economic costs of increased gasoline taxes might at least in part be counteracted. Regressive effects can be countered by using tax proceeds to increasing transfers to low income households, or to improve public and non-motorised transport facilities; broader effects on the economy might be positive for certain uses of the revenue — e.g. to reduce tax rates in lower tax brackets, stimulating employment. However, governments considering increasing fuel taxes clearly need to assess their own situation and determine the effects of different uses of the revenue.

Diesel taxes have long been kept at a low level in many countries because of their potential negative effects on users of diesel — mainly commercial transport operators and especially freight companies, and the industries that depend on them for goods transport. The doubling in diesel prices that has been considered above would result in a substantial increase — in the region of 10-20 per cent — in the costs of bulk road freight transport. The percentage cost increase for smaller goods vehicles would be much less than this, but still perhaps noticeable. Diesel fuel prices have been found to have some effect on the total volume of goods transport and the modal choice for that transport, although the effects are small and often unmeasurable (a brief review of literature is given in Appendix B). To the extent that increased diesel taxation leads to less goods transport, there is likely to be an effect on patterns of production. A doubling in diesel price could increase the cost of production in the short term by an amount in the order of 1 per cent, affecting national competitiveness where the tax increase is unilateral. In the long term shifts in transport and location patterns might largely compensate for this. Meanwhile, if diesel-users are paying less than their share of road costs and are causing a large proportion of the external costs of road use, introducing charges to address these costs would be expected to have beneficial effects for aggregate welfare.

The first of the fuel tax options considered here — vehicle tax reform — is intended to avoid increasing the tax burden on the motorist, and may be beneficial for low-income households that have difficulty with lump-sum payments. On the other hand, to the extent that tax reform is used to solve the problem of non-payment of ownership-related fees, it will have a negative impact on low-income households. Consumer and environmental groups are generally supportive of the idea, although road construction companies in the United States have opposed “pay-at-the-pump” insurance on the grounds that it might reduce the scope for fuel taxation to contribute to the road fund.

The second and third options — full cost pricing and externality adders — involve a net increase in the taxation of road users where this is justified by government spending on roads, or by the existence of externalities. Where the additional revenue is used to reduce general income taxes, the measure may have negative effects on low-income households and industrial output. On the other hand, if the revenues from full cost transport pricing are targeted on these areas, it may be possible to achieve net benefits.

None of the OECD case studies provides a macro-economic evaluation of the effects of internalising externalities, however, we can make some observations based on what might be expected in theory. Reducing and internalising externalities may lead to reductions in GDP, as consumer expenditure is diverted into emission control technologies, and as car and truck access to city centres is restricted, impeding access to jobs and shops. On the other hand, aggregate welfare should, in principle, increase,

although measuring this would depend on having metrics for “green” GDP or welfare that incorporate externalities.

It is also possible that GDP could increase as a result of internalising externalities, where the effect is to stimulate certain industries, such as those that produce pollution control equipment, or to stimulate new patterns of urban development and technical change. This seems improbable from a neo-classical economic perspective, which tends to the assumption that the free market is naturally the most efficient state for the economy. But viewed from an evolutionary economics perspective, changes in regulation and other constraints on the market may stimulate innovation and growth.

A full understanding of the economic, equity, trade and environmental effects of the range of taxation measures considered here would depend on more careful analysis. This might partly involve detailed modelling of alternative options, including measures more carefully targeted on specific road users and externalities. The effects of this type of measure might be evaluated in a general equilibrium or macro-economic simulation model with detailed input/output representation of industrial sectors, in particular the motor industry. An additional approach that might be more fruitful in the short term could involve assembling more case study information on countries that have adopted different combinations of policies, or have undertaken changes in their transport policy.

Increased Fuel Taxes as Part of a Common Action

This report has explored a variety of “no regrets” measures which might involve raising fuel taxes, and therefore reducing CO₂ emissions from the transport sector. These measures are “no regrets”, in that they either involve no change in the direct taxation of motorists, or they adjust prices to improve their relationship with costs. In many cases, the measures would result in very substantial reductions in greenhouse gas emissions, of the order of 10 per cent or more of road transport CO₂ emissions. While other measures might be more efficient means of addressing the various government, environmental and social costs that the taxes are intended to reflect, fuel taxation remains one of the most widely used measures and in many ways one of the simplest to implement. Meanwhile, fuel taxation is the most efficient means of pricing for the externalities associated with climate change, resource depletion and national security of oil supply.

Advantages of common action

A common action to develop methodologies and to monitor and report on policies would have a number of advantages. It would enable governments to consider options that they might otherwise overlook, it would help governments to design policy changes with the maximum possible information, and it might accelerate the process of policy change.

Any common action that increased taxes in common, either as a result of a monitoring and reporting process, or as a result of an agreement to increase taxes in a particular way or by a particular amount, would reduce the costs to individual countries of introducing unilateral tax increases. These costs may be quite small, although it has been emphasised above that they are poorly understood. It is not clear how a national economy, and commercial activities, in particular, are affected by increases in either gasoline or diesel taxes, and their effects on the mobility of labour and goods. Thus, to the extent that unilateral tax increases might affect a country’s competitiveness in trade, there is likely to be an advantage from co-ordination.

Fuel taxes do affect vehicle choices, and co-ordination of tax increases is likely to increase the market for energy-efficient vehicles and hence enhance the effect of the tax on greenhouse gas emissions. This enhancement is not likely to be as large as that discussed in Part 1 of this report, from the co-ordination of measures focused on vehicle fuel economy; in that case, technical change is expected to be the main impact of the measures, whereas in the case of fuel taxes, it is a relatively small and indirect effect.

The avoidance of border effects may be an advantage of tax harmonisation, especially in regions with a large number of small countries, or for countries with particularly long borders. Where large fuel price differences exist between neighbouring countries, there is a strong incentive for drivers, especially international freight hauliers, to purchase their fuel in the countries with the lower fuel tax. Gasoline tourism is certainly likely to result in an increase in greenhouse gas emissions if drivers travel further to find fuel, and if they find that fuel cheaper than buying more heavily taxed fuel at home (including the cost of driving to the neighbouring country to buy it), this will further reduce the impact of the taxes in their home country. However, no assessments are thought to have been made of the size of this effect, and the associated advantage in greenhouse gas mitigation from common action cannot be estimated. This issue is most important within the European Union, and “gasoline tourism” is thought to account for about 20 per cent of gasoline sales in Switzerland. It is also sometimes mentioned as a constraint on fuel taxation policies in North America. There is, therefore, an advantage from some regional co-ordination of fuel taxation, in that border effects can be avoided. The issue has been addressed in Canada, where taxes vary among provinces, by means of border adjustments, where the tax varies among filling stations so that there is no sudden change in price at province boundaries.

Barriers to common action: national differences, trade and competition

No-regrets opportunities are likely to differ widely among countries. This implies that any harmonised change in fuel taxation might lead to economic inefficiencies, and be more costly than independent action, perhaps co-ordinated through an agreement to principles and methodologies. The “tax reform” and “full cost pricing” approach discussed in this report are both adjustments to existing government intervention in the road transport sector. As such, the exact formulation of any adjustment will depend heavily on the existing pattern of taxes, subsidies and other interventions. Similarly, the potential for mitigation will vary among countries. Some countries may have no scope for adopting a particular measure — the tax reform approach is irrelevant for a country with no taxes on vehicles, while the full cost pricing approach is irrelevant for countries that already cover government spending on road transport through taxes.

The political potential for increasing road-transport fuel taxes may be limited in some countries. In the United States, where DRI (1996) and others have suggested that road users do not fully cover their costs to government, attempts in recent years to increase taxes have failed, while events of early 1996 suggest that there is more potential for a reduction in fuel taxes than for an increase. In the CIS, fuel prices have increased substantially in recent years but the process of removing subsidies slowed from 1994. Fuel taxes have been, and are continuing to be, increased in several European countries and in Japan.

The potential for fuel tax increases appears (perhaps rather like the potential for consumers choosing small cars) to be influenced at least in part by past experience. Countries with a history of high fuel prices generally seem to have the flexibility to increase them further, despite some lobby groups’ arguments that the taxes are too high. However, it is not clear that fuel tax levels are determined in many countries by the economic rationales discussed in this paper, although some do have policies of “full user funding” for roads. Other factors such as the need for revenue and the interests of particular groups have a strong political influence.

The arguments brought forward by stakeholders include many of those discussed above. Perhaps not surprisingly, the more vociferous are against fuel tax increases; freight operators and industry, in general, tend to argue for low diesel taxes; oil producers, not surprisingly, oppose all taxes on oil products; consumer groups argue against gasoline taxes (on the grounds that they are regressive).

The arguments for fuel taxes sometimes come from surprising quarters: for example, vehicle manufacturers generally support fuel taxation rather than vehicle standards as a means of improving fuel economy, because they argue that this is a more effective means of reducing energy use. The analysis in this paper and elsewhere (e.g. NRC, 1992) suggests that fuel taxes might suppress vehicle demand more than standards, although standards may impose larger costs on manufacturers in the short term. The road construction industry sometimes supports fuel taxation because this is seen as its main source of income. Other support not surprisingly comes from environmental groups, public transport users' associations, and public transport operators.

MVA(1995) have carried out a stated preference survey based on interviews to evaluate the possible effect of large fuel price increases in the United Kingdom. This is of some interest, as it provides some insight into consumer attitudes to tax changes. This survey indicated that consumers did not wish to see tax increases, but that they did support the concept of tax reform, as they particularly disliked the fixed costs of vehicle ownership. Similar interviews in the United States (Kempton, 1996) have revealed that even consumers who support environmental objectives are opposed to fuel tax increases because they do not believe the government would use the revenues in a manner that they would support. This implies that fuel tax increases are most likely to be acceptable to voters when they coincide directly with visible tax reductions elsewhere, or with new and widely supported spending programmes. For governments which do not support the earmarking of taxes, this can create a conflict between principle and public support.

A further barrier faced in most countries, but especially in federal countries, is the relationship among different levels of jurisdiction. The three OECD transport case studies showed that France, Japan and the United States all have substantial divisions of responsibility among various levels of government for transport service provision on the one hand, and substantial differences in their ability and willingness to raise taxes and fees on the other. Tax reform may depend on agreeing and co-ordinating changes in taxes and fees at these different levels of jurisdiction, unless it is confined to those taxes for which the national or federal government is responsible.

Large countries with strong regional differences, such as the United States, Canada, and Russia, where some regions produce substantial amounts of oil, may also face difficulties in attempting to reach consensus policies on fuel taxation. This may force national governments to depend much more on local initiatives to achieve greenhouse gas mitigation. Such initiatives are discussed in Part 3 of this report and the discussion is extended in Working Paper 13.

Even with agreement to the principles of "full cost pricing" and "externality adders", governments attempting to implement these might face barriers in the evaluation of, and agreement on, appropriate levels of taxation. Estimates of subsidies and externalities are usually disputed, with some analysts and stakeholders arguing that they do not exist or are too uncertain to include in taxes. Analysts differ in their views on what should be included in prices to road users and on the methods for measuring or estimating those prices. Calculation of externalities is complicated, involving many real uncertainties and leaving considerable room for differences of judgement.

The measures discussed in this report would need to be incorporated into any common action in ways that took national differences into account. This might mean that common action would need to be confined to co-operation on developing methodologies, monitoring and reporting on policies and their effects, and

perhaps agreeing on targets for full cost pricing or introducing externality adders. In view of the variations among countries, it would be hard to justify a harmonised tax level throughout the Annex I group of countries, although an agreement on a minimum level, or increment, to reflect externalities associated with climate change and resource depletion might be a worthwhile aim. A harmonised tax at regional level might still be worthy of consideration, given that differences among countries within regions, though substantial, are smaller than those among regions.

PART 3. INNOVATION FOR SUSTAINABLE TRANSPORT

This third set of options for common action comprises government action to encourage or implement a wide range of innovative technical and behavioural measures, which might contribute to a transition towards sustainable transport systems. Many require implementation by, and/or co-operation with, industry and local governments.

There is a robust rationale for local development and adoption of integrated transport strategies, rather than relying on a single, nationally imposed measure to reduce CO₂ emissions. Transport activity has a wide variety of social and environmental impacts, and yet it is an essential element of economic and social life. Management of the transport sector's negative impacts often depends on very carefully designed, and often quite complex strategies, if this management is to be accepted by those affected, and unintended side-effects are to be avoided. One example of an unintended side-effect is the increased traffic likely to be caused by fuel economy standards. Many other side effects have been experienced with other measures.

At a local level, especially in cities, it is often possible to implement transport management strategies that would not be economically and politically feasible at a national level. Nevertheless, there is a role for national governments in providing the legislative framework within which such local initiatives can occur, and in providing information and other support for local governments wishing to develop "sustainable transport" strategies.

Technological innovation is also likely to be part of any move towards "sustainable transport". Again, as technological innovation is essentially a creative and experimental activity, and as any innovative technology has to meet the needs of those who will use it, governments cannot plan for technical change. As in the area of local transport management, an approach based strongly in co-operation and experimentation is most likely to produce successful technologies.

There may be a strong overlap between the development of innovative local transport strategies, and that of innovative technology. New technology usually needs to be tested and demonstrated on a small scale before it can enter into general use. Thus, electric and alternative fuel vehicles have often been introduced first by local governments or companies, rather than by national governments.

Policy Objectives

The policy objective of the group of measures addressed in this part of the report is to encourage innovation that might allow large reductions in transport greenhouse gas to be achieved. Other policy objectives that might be addressed by the same initiatives could include those of reducing the negative environmental and social impacts of transport, such as congestion, accidents, noise and air pollution, as well as improving the ability of the transport system to meet the needs of its users.

Definition of Measure

The measures addressed include changes in urban and transport infrastructure, the use of alternative fuels and vehicle technology,¹⁹ and changes in production and consumption patterns related to transport. A large number of measures might be adopted to meet the policy objectives above, and an illustrative list of possible measures is given in Table 16. The measures are focused in two areas which have a strong overlap — behaviour and technology:

A first type of measure includes policy packages aimed at reducing the amount of car and truck traffic (i.e. to reduce vehicle-kilometres travelled), and at changing driving behaviour. Implementation will be considered at a local, national and international level, including the role of national and international measures to stimulate local initiatives and experimentation.

The second type of measure includes policies aimed at stimulating research and development, technological experimentation and implementation of new technology. This might include changes in infrastructure, vehicles, or fuels.

This paper addresses the two types of measure in separate sections, although in many cases there will be overlaps between the types.

Table 16. Policies to Change Behaviour and Technology

| Policies to Change Behaviour | Technology/infrastructure/system changes |
|--|--|
| Local | |
| charges and restrictions on road use and parking | urban design to reduce need for car use and reduce truck traffic |
| reductions in speed limits | infrastructure design to facilitate non-motorised transport |
| trial low-transport-intensity retail distribution systems | transport control/management systems |
| education, training and information programmes to change driving behaviour, vehicle or mode choice. | road design to reduce speed |
| community-based initiatives/processes | trials/incentives for electric and alternative-fuel vehicles, e.g. in local authority-owned/managed fleets |
| | trials of innovative transport systems , e.g. “personal rapid transport” |
| | trials of low-transport-intensity retail distribution systems |
| | trials of information technology for road pricing |
| National | |
| legislative provision for local authority road-pricing | R&D, trials or incentives for alternative fuel and other new and alternative technology vehicles |
| advertising codes of practice for vehicles | planning guidelines for local authorities |
| media, education, training and information programmes | R&D, trials and implementation of inter-modal freight technology |
| support (information, funding, analytical support, etc. for community-based and local authority initiatives) | R&D, trials and implementation of information technology for road pricing, freight transport optimisation and other types/aspects of “intelligent” transport systems |

Policies to Change Behaviour

At a national level, measures in this area would involve ensuring the existence of a policy framework in which local and stakeholder initiatives have a chance of success. This might mean: modifying urban and

¹⁹ Including electric vehicles

transport planning guidelines and regulations to allow local government to initiate policy changes; setting up fora in which local governments and others can share ideas and publicise successes and failures; and providing support in monitoring of projects and development of appraisal methods. Many aspects of this process of interaction might work in a manner analogous to international negotiations and information-sharing.

At a local level, initiatives might include: changes in transport investment, shifting the focus from roads to public transport or non-motorised transport; restricting car and truck access to city centres and residential areas; introducing parking fees, cordon tolls and other charges to motorists; restricting parking provision on streets, at work and in shopping centres, at the same time as improving public transport access; promoting alternative technology vehicles, such as ultra-light weight, alternative fuel or electric vehicles; promoting user choice of public transport and non-motorised transport.

Approach

This section addresses possible measures and mechanisms for greenhouse gas mitigation which have not been much analysed. It therefore relies on a case study approach. Case study information will be drawn from the work of Annex I Party governments and existing networks of local authorities. The European Commission supports work in this area through its Urban Environment Expert Group, as does the United States government, under the Intermodal Surface Transportation Efficiency Act (ISTEA).

Context: an OECD workshop on travel behaviour

Parts 1 and 2 of this report used fairly conventional engineering and economic analysis to estimate the possible future effects of measures to reduce transport CO₂ emissions. However, it is increasingly recognised (e.g. ECMT/OECD, 1995) that the measures that national governments are currently introducing are insufficient to bring about the substantial reduction in CO₂ emissions that many of them would like to achieve. Such emission reductions would depend on one of a) radical reductions in traffic relative to projected levels, b) radical reductions in the energy intensity of vehicles, or c) switching to fuels with a very low fossil carbon content. Conventional engineering and economic analysis tends to predict that none of these options is available, except at very high cost in reduced consumer surplus. This is based on the assumption that consumers' current revealed preferences are unlikely to change: they will continue to wish to buy larger, higher performance cars and to spend a fairly stable share of their income on travelling in those cars.

The OECD recently (18/19 March 1996) held a workshop on individual travel behaviour, inviting about twenty experts in one discipline or another, mainly from the social sciences. Many of the participants had carried out studies, including interviews or surveys on attitudes and preferences in relation to transport. There was near-consensus in the group that consumers' current travel behaviour is not a fixed expression of fundamental values and preferences, but is more likely to result from a combination of habits and circumstances. The implication is that those habits and circumstances, and the travel patterns that go with them, could change considerably, without necessarily involving a reduction in consumer surplus.

A comparison between two types of study illustrates this possibility. One study discussed during the workshop involved a survey of consumers in Southern California to find out how they would react if offered choices between alternative fuel vehicles having various attributes (Segal, 1995). This, and other studies of a similar type (e.g. Bunch *et al.*, 1993) commonly find that consumers would not be interested in purchasing electric vehicles or other alternative fuel vehicles of the types currently available, even if

they cost no more than gasoline vehicles. The studies find that consumers place a very high financial premium on the range and short refuelling time of gasoline vehicles.

Conversely, a study by Turrentine and Sperling (1992) found that consumers would, indeed be interested in purchasing electric vehicles, provided they had some experience of driving them. Turrentine carried out a series of lengthy (and expensive) interviews to explore with consumers how they used their existing vehicles and how they might use an electric vehicle, and took them for test drives in electric vehicles. At the end of this process, many of the interviewees preferred the electric vehicles to conventional vehicles

Many criticisms could be levelled at any attempt to form generalisations from this type of study. However, Turrentine demonstrated that preferences can change. Other, more conventional studies (e.g. Goodwin, 1985) show how consumer attitudes change when circumstances change. People often develop attitudes that support the choices they make, *ex post*. Thus, transport users often have a negative attitude to the transport modes that they do not use. Another aspect of this, mentioned in the OECD workshop, is that they may never have familiarised themselves with the “territory” associated with other transport modes (this applies especially to buses, which can offer a highly social environment which can appear threatening to the uninitiated).

The OECD workshop concluded that consumer preferences can change, but that this change is most likely to occur after changes in circumstances have occurred. This presents a very difficult conundrum for national governments to address, because it is very hard (some would say, unethical) for them to force changes on their unwilling constituents. However, workshop participants proposed an alternative, which is that changes do actually occur where stakeholders in the transport system make an informed, considered decision.

One example cited was a region in Scotland, where the local government was considering a choice of infrastructure options. These included the continued predominance of roads in its spending plans in one option, and a large shift to other modes in another. They contracted consultants to model the options, and look at what they might mean for families in the area. They then presented the results to constituents, through direct and personally presented information in shopping centres and other public places, and finally, they asked constituents to rank their priorities among the options. Local politicians were asked to carry out the same ranking. The two sets of ranking were very similar but radically different from existing policy, entailing a large shift in funding away from roads and towards public transport. As a result, a strategy was enacted that was based on the politicians’ and constituents’ combined preferences.

In a counter-example, the Norwegian government launched transport plans for the ten largest Norwegian cities. Transport scenarios were developed for each city, and in each case included a “growth” scenario, involving more roads, and an “environmental” scenario. The scenarios were discussed in the cities, and in all ten cities, the local constituents decided on the “environmental” scenario as the best approach. However, all ten actually opted for the “growth” scenario — a continuation of existing policy.

These two situations were different in many ways, but probably important factors in the change in the Scottish example were the involvement of local people in the process, and the origin of the process in the local government. In the Norwegian case, the national government initiated the process, and decisions were made by experts in transport planning rather than through a consultative process.

The OECD workshop drew several conclusions that are relevant to this common actions study:

- it is not possible to predict what strategies will work, but change is most likely to occur when it is initiated by stakeholders;
- in this context, the best approach to finding ways of changing transport patterns is by promoting local experimentation;
- national governments can play a role in this experimentation by helping to create the environment where it can occur, and by supporting it when it does occur;
- national governments can support experiments by providing help with monitoring, analysis and publicity, and facilitating exchange of information between local authorities interested in undertaking new experiments

Effects on greenhouse gas emissions and costs

It is obviously impossible to generalise regarding the potential effects of local initiatives on transport greenhouse gas emissions. Nevertheless, there are several instances where modelling work has been carried out to estimate the effects. One is included in the current paper. More have already been contributed by delegates and reviewers and have been included in Working Paper 13. It is also possible to provide one example — in the case of Singapore — where an integrated transport strategy has been implemented and the effects on energy use and greenhouse gas have been estimated.

The Randstad region

The Randstad region in the western Netherlands includes Rotterdam, Utrecht, Amsterdam and The Hague. Traffic congestion in the region is growing. Traffic in the Netherlands is projected to increase by 70 per cent between 1990 and 2010. The Government is seeking policy strategies to reduce the growth to about 35 per cent. Several studies of the transport system and policies' probable effects have been undertaken. The results of some of these studies have been used by NOVEM for an analysis of possible strategies for the Randstad as a contribution to the IEA publication *Cars and Climate Change* (IEA, 1993a; NOVEM, 1992).

A transport network model was used to examine the impact of policy measures on traffic and hence on CO₂ emissions in the Netherlands. The Netherlands and Belgium are represented in the model by 958 zones, each treated as a starting point and destination for trips. The Randstad region is broken down into 724 very small zones and Belgium into ten large zones.

The model estimates the number of trips starting and ending in each zone based on demographic factors. It then assigns trips to routes through the transport network, choosing between modes, and taking account of congestion delays and the waiting time for public transport sections of trips. It then calculates fuel use and CO₂ emissions for cars based on emission factors, cars, per vehicle kilometre, and per hour spent in congestion.

The model can be used to test the effects of transport policies, such as increases in costs for a given mode or constraints on road use or parking. The 14 policy measures considered in the study and their calculated effects on traffic and CO₂ emissions, are shown in Table 17. While the most effective measures considered were road pricing and fuel taxation, this is a function of the level of taxation considered. The other measures may be much easier to implement.

Table 17. Modelling Results for Transport Measures in the Netherlands: Effects in 2010.

| Case | Description | Urban Areas | Netherlands Total | | |
|------|---|---------------|-------------------|--------------|-----------------------|
| | | Traffic Index | Traffic Index | Speed Index | CO ₂ Index |
| 0 | Reference Case (2010, No Measures) | 100.0 | 100.0 | 100.0 | 100.0 ²⁰ |
| 1 | Double parking fees, extend parking fee area | 98.3 | 99.1 | 101.5 | 99.0 |
| 2 | Limit parking accommodation | 97.8 | 98.7 | 100.6 | 98.8 |
| 3 | Increase fuel price 30 per cent | 95.2 | 93.9 | 99.1 | 94.3 ²¹ |
| 4 | Road pricing (raise driving cost by 50 % in cities, 25 % elsewhere) | 92.8 | 92.6 | 99.1 | 93.3 |
| 5 | Charge Gld 5 tolls to enter city area) | 98.2 | 99.1 | 98.3 | 99.4 |
| 6 | Do not build new roads to meet increasing traffic demand | 89.0 | 98.6 | 103.4 | 98.5 |
| 7 | Provide roads to meet demand | 113.3 | 108.3 | 98.5 | 107.3 |
| 8 | Limit traffic in residential areas | | | Not modelled | |
| 9 | Improve public transport | 99.6 | 99.4 | 100.2 | 99.5 |
| 10 | Provide park and ride facilities | | | Not modelled | |
| 11 | Designate lanes for high-occupancy cars | 96.8 | 96.8 | 100.6 | 96.4 |
| 12 | Improve traffic management | | | Not modelled | |
| 13 | Lower speed limit 30 per cent | 91.8 | 88.1 | 85.4 | 96.0 |
| 14 | Lower speed limit 10 per cent | 100.2 | 98.4 | 95.7 | |

Table 18 shows the effects of the measures in the model if they are combined together in packages. It also shows the estimated costs of the packages.

Table 18. Effects of Combined Measures

| Case | Description | Urban Areas | Netherlands Total | | | |
|------|--|---------------|-------------------|-------------|-----------------------|---------------|
| | | Traffic Index | Traffic Index | Speed Index | CO ₂ Index | Cost (bn Gld) |
| 1 | Parking Control Package (higher fees, limited area plus improved public transport) | 92.7 | 94.3 | 102.4 | 94.4 | 7 |
| 2 | Price Policy Package (fuel price increase, road pricing and parking fees plus improved public transport) | 83.0 | 83.7 | 102.1 | 83.3 ²² | 7 |
| 3 | Do-Nothing Package (no investment in roads but improve public transport) | 85.0 | 94.6 | 103.9 | 94.7 | 7 |
| 4 | Meet-Demand Package (invest in roads to meet demand and improve public transport) | 109.5 | 104.6 | 97.4 | 104.3 | 14 |

²⁰ Base CO₂ emissions = 3 659 tonnes.

²¹ The Randstad model does not allow for changes in vehicle technology resulting from higher fuel prices. The actual reduction in CO₂ emissions would probably be greater than this.

²² Ibid.

In addition to the overall effects of the policies shown in these tables, NOVEM found that:

- Parking control measures can have unexpected results and have to be designed with care. People making short trips are more likely to be discouraged by parking difficulties than those making long trips. Displacing short-trip traffic, where parking capacity is a constraint, creates more parking space for long-trip traffic.
- Fuel price increases result in a greater decrease in vehicle-kilometres overall than in the urban area. Higher fuel and road use costs tend to reduce long trips, freeing road capacity in the urban centres for more short trips. Improved public transport mainly attracts long-distance commuters and so affects the system as a whole more than urban areas.
- The "do-nothing" package reduces CO₂ emissions by 15 per cent in urban areas, as increased congestion discourages car use, but only 5 per cent overall.

*Singapore: effects of integrated transport policy*²³

Singapore is a small island state with 2.8 million people in an area of 633 km² (44/ha). Since the early 1970s, it has adopted a variety of measures to control the traffic problems associated with high population density and rapid economic growth:

- Computerised traffic signal systems have been widely implemented in the central business district (CBD)
- The Area Licensing Scheme (ALS), a road pricing scheme introduced in 1975, aimed at reducing morning peak traffic in the CBD. Drivers were required to purchase windscreen stickers which were checked on entering the ALS zone. The program immediately reduced the number of vehicles entering the zone during the morning peak and shifted many people's morning commute habits. The success of the scheme led to its extension to include evening peak hours from 1989, and then to the whole day from 1994. In 1996 an electronic road pricing system will replace the ALS.
- The Weekend Car Scheme was introduced in 1991. Owners of cars registered under the scheme can normally drive only at weekends, and receive a rebate on vehicle registration fees and import duty. They can purchase day licenses to operate their cars during the week, in peak or off-peak hours.
- Fiscal measures, including high import duty, vehicle registration fees and annual road tax have been implemented to discourage car ownership. In 1994, import duty and registration fees amounted to 195 per cent of car import values.
- The Vehicle Quota System was introduced in 1990, limiting new registrations of cars and other vehicles. New vehicle buyers have to bid for quota allocations in a monthly public auction
- Road tax increases with engine capacity, encouraging the purchase of small, energy efficient cars.
- Fuel tax is approximately 40 US cents/litre.

²³ This section is reproduced from Michaelis (1996).

- Public transport is of high quality, with buses providing a 20 kilometres/ average service. There is a 67 kilometre mass rapid transit system with more than half of Singapore’s homes and work locations within 1 kilometre of the route.
- The road network has been upgraded and the capacity expanded constantly to provide more efficient transport links and maximise the effectiveness of the road system.
- Settlement planning is systematic, with co-location of homes, shops, schools, recreational facilities, factories and offices in each of 17 new towns or housing estates.

The result of this combination of measures on traffic and energy use was estimated by Ang (1992) and is summarised below:

Table 19. Estimated 1990 Fuel Consumption in Singapore Without Car Constraint Policies

| | Gasoline | Diesel |
|--|----------------|-------------|
| | million litres | |
| Actual consumption | 741 | 465 |
| Impact of not having policy: | | |
| Passenger traffic increase | +153 | |
| Modal shift | +218 | -84 |
| Shift to larger cars | +52 | |
| Traffic congestion | +122 | +77 |
| Consumption without policy | 1 286 | 458 |
| Estimated impact of policy on consumption | -42 % | +2 % |

Sources: Ang, 1992, 1993.

Other policy effects

Local initiatives could help in achieving the full range of policy objectives associated with transport, including reducing pollution, noise, accidents and traffic congestion, improving the quality of transport services, and stimulating economic activities in new areas.

Policies for Technology Innovation

Any effort to stimulate technological innovation is likely to face similar or greater uncertainties than efforts to change behaviour. In addition to the inherent uncertainty in any technological development regarding the potential to achieve objectives for performance and cost, those aiming to introduce new technology face the uncertainty about consumer acceptance for that technology.

Many radical changes in transport technology have been proposed, ranging from high-speed trains operating in evacuated tunnels (to avoid air resistance) to “personal rapid transport” systems — public car-sized vehicles on a monorail system which operate a bit like an automated taxi service. Some of these may be very good ideas, and may even succeed. However, none is likely to succeed without substantial financial backing to test the idea. Financial support for new ideas is usually hard to obtain, because of the high risk involved. New ideas in the transport sector are particularly risky, because of the clear competitive advantage of the technology currently in use. In this context, two main strands of action are suggested as the basis for common actions for technology innovation:

- development of new technology for use in existing mainstream transport concepts;
- experimentation with new or alternative transport concepts.

The first of these strands is an area where the automotive industry is already very active, in some instances with government support. A major aim of government involvement in this type of development has been to encourage industry to focus more of its own resources on research and development that will support development of energy-efficient, alternative-fuel or alternative-technology vehicles.

The second strand is one where initiatives have tended to depend more on support from governments at a national or local level. In some cases — such the French TGV (high speed train) — the initiatives have been successful and have been widely replicated. Other ideas that have been discussed for decades and that have been backed by large investments — such as supersonic air travel or magnetically levitated trains — have not yet shown signs of any great success.

Approach

This section has been further developed in Working Paper 13 of this series.. It explores the technical potential for greenhouse gas mitigation through the development and deployment of new technology based on literature sources. It reviews current national and international programmes for technology innovation in the transport sector, and will include examples of innovations that have been introduced or are being considered. It also attempts to identify areas where the costs of these programmes might be reduced or their effectiveness enhanced through additional international co-operation.

Transportation technology initiatives by local authorities and companies

This section has been developed in Working Paper 13. Contributions are invited from governments on existing demonstration schemes of new transportation technology. Obvious examples might include: electric battery, fuel cell and alternative fuel vehicles used in municipal bus and service fleets; schemes such as provision of electric hire cars; trials of road-pricing technology and other information technology; public transport systems such as guided bus-ways, the Curitiba bus interchange system, and public transport information systems.

Government-industry partnerships

This section has been developed in Working Paper 13. Contributions have been invited from governments on experience with partnerships. This includes the United States government's Partnership for a New Generation of Vehicles and Advanced Battery Consortium; the European Commission's programmes, such as DRIVE, and the transport elements of the THERMIE programme; Japanese initiatives on batteries, "intelligent transport systems" and others; and "mega-projects" such as maglev, personal rapid transit and the Swiss underground high speed train.

Research to enable technological innovation

The IPCC Second Assessment Report highlighted the following:

Important areas for fundamental research relating to transport technology include: recyclable materials for cheap, robust, lightweight vehicles; materials with special properties for high-efficiency engines, turbines, flywheels, etc.; advanced conversion technology for liquid fuels from biomass; electrochemistry for batteries and fuel cells; power electronics for electric-propulsion-system management; power-transmission technologies for vehicles powered direct from the mains; and information technology for vehicle and traffic optimization. There is also a need for social and economic research, for example, into consumer behaviour and choice, including attitudes toward new technology. (Michaelis, 1996).

In the long term, it is conceivable that a transition will occur to surface transportation technology with a greenhouse gas emission intensity near zero (Michaelis, 1996).

Market interventions

Working Paper 13 discusses the role of market intervention in stimulating technological innovation, drawing on national experiences. The section evaluates the type and strength of intervention that might be needed to encourage various existing near-market technologies, and the economic justification for such interventions. The IPCC Second Assessment Report (Michaelis, 1996) highlighted the following:

Interventions in the market may have the advantage that government does not necessarily have to attempt to “pick winners” among technologies or to bear the risk of investment in research that may not bear fruit. However, this risk does have to be borne by manufacturers that wish to remain in the market and have to respond to the government’s intervention. One example of a technology-forcing intervention is the California Air Resources Board’s strategy for encouraging the development of zero emission vehicles. Meanwhile, a strategy of announcing a timetable for gradually tightening standards or increasing fiscal incentives, aimed at reducing greenhouse-gas emissions, will encourage industry both to introduce currently available technology and to develop new technology. (Michaelis, 1996).

Encouraging Innovation as Part of Common Action

Working Paper 13 explores the scope for international co-operation in the following areas:

- sharing information on successful strategies through a database of successes and failures
- developing methods and guidelines for assessing initiatives
- developing a national and international framework that encourages local initiatives and provides recognition and publicity for successes
- developing co-operative programmes in research to enable technological innovation
- co-operating on innovative projects
- creating a fund for innovative projects
- market incentives for technological innovation

Some preliminary ideas are included in the following paragraphs.

Information sharing

The UNFCCC might have a contribution to make by liaising with existing fora for co-operation, and might be able to increase the attention given by these fora to greenhouse gas mitigation. Co-operation to share information on transport initiatives is already occurring through the ECMT and the European Commission.

Parties might agree to incorporate a section on local sustainable transport initiatives in their national communications to the COP.

There are advantages from common action in such an experimental area, in ensuring that successes and failures can be used to inform future initiatives, and also in encouraging new initiatives by giving them international recognition.

Developing methods and guidelines

Initiatives are currently assessed in a wide variety of different ways. Much of the assessment of local initiatives is in a form that does not provide information on the effects on greenhouse gas emissions. For example, local authorities will frequently report increases in the use of cycle paths or buses, but rarely report the effects on traffic or energy use. Guidelines might be drawn up for use in monitoring and appraisal of local initiatives, perhaps related to the guidelines for national communications under the UNFCCC.

Developing a framework to encourage local initiatives

Local transport strategies mostly have local benefits, although those who design them often include the global benefits in their arguments for implementation. It might be possible for the UNFCCC to encourage local initiatives to take account of such global benefits by setting up some form of best practice recognition scheme — for example by establishing a “climate friendly” logo that could be used by cities that implement mitigation strategies.

Annex I Parties might also agree to incorporate a section in national communications explaining how they are fostering and building on such local initiatives.

Developing co-operative research programmes

This is an area where many co-operative initiatives already exist, largely for reasons of cost-effectiveness. Further initiatives might build on the work of IEA Implementing Agreements, the European Commission, and others, including the Climate Technology Initiative, to share results and discuss priorities in basic research. Annex I Parties could consider setting up a fund for research and development, perhaps creating a new research centre where scientists and engineers from different countries could work on common projects. In this case it would be important to draw on the experience of joint research centres in the European Union. Some countries might wish to link their contributions to such a fund to a small levy on transport fuels.

Co-operation and funding for innovative projects

Again, this is an area where co-operation often occurs, although on a less organised basis than research and development co-operation. Within the European Union, demonstration projects are often carried out in one or two countries with European Commission funding. “Mega-projects” often depend on the formation of international consortia. Annex I Parties could consider co-operating on new projects in an organised way, perhaps setting up a fund for the purpose. Some countries might wish to link their contributions to such a fund with a small levy on transport fuels.

Market interventions to encourage innovation

Co-ordinated interventions to encourage alternative fuels or other new technology may be more effective than interventions adopted by a single country, mainly because firms aiming to supply the new technology will have a larger market for their product and can capture economies of scale and mass-production.

PART 4. OPTIONS FOR COMMON ACTION, IMPLEMENTATION AND VEHICLES FOR ACTION

This report has given some indication of the potential greenhouse gas mitigation from a range of measures to mitigate vehicle CO₂ emissions. In many cases, the “no-regrets” potential is large, with mitigation in the order of hundreds of millions of tonnes (10 per cent or more) of transport sector CO₂ emissions, but the extent to which it can be realised is highly uncertain. The report has also examined the advantages and disadvantages of common action to implement the individual measures, and some of the implementation issues that would need to be considered.

Although this report is organised into separate parts addressing different measures, in many instances it has been noted that these measures might need to be combined to enhance their effectiveness and to reduce their economic and other costs. Thus, a voluntary agreement with manufacturers to improve vehicle fuel economy might be combined with an increase in fuel taxation, along with encouragement for local initiatives, to avoid the “rebound” effect of improved fuel economy on driving. Meanwhile, car manufacturers might be supported in meeting target fuel economy improvements by government co-funding for research and development or demonstration projects.

Literature on the subject of environment policy in the transport sector has repeatedly emphasised the advantages of combining measures, and the potential pitfalls from adopting single measures.

This section returns to the three types of common action listed in the introduction. These were:

1. An agreement to develop transport sector policies with the aim of mitigating greenhouse gas emissions;
2. An agreement to adopt a particular kind of measure;
3. An agreement to adopt a measure in common.

The possible design and implementation of such common actions will be considered in this section.

Agreement to develop transport sector policies

This first option would be an extension of Annex I Parties’ existing commitments under the UNFCCC, where they agree to introduce policies to reduce greenhouse gas emissions and enhance absorption by sinks, but do not specify that these policies should relate to any particular emission source or sector. ECMT Member governments, in the joint declaration with industry summarised on page 31, have stated their objective of achieving a “tangible and steady reduction” in vehicle CO₂ emissions.

An agreement in this area need not necessarily be attached to any target, or lead to stabilisation or reductions in transport sector emissions in the near term: many countries take the position that national greenhouse gas mitigation priorities should be based on cost-effectiveness, implying that sector targets are

an inefficient approach. Meanwhile, for most countries a reduction in the rate of greenhouse gas emission growth in the transport sector would be a positive step. A first-stage agreement might be one to implement “no-regrets” or “cost-effective” measures to mitigate transport sector greenhouse gas emissions.

A major element of such a general commitment would probably be the monitoring, reporting and review process attached to it. Transport analysts often complain of poor and non-comparable data in many countries and emphasise the need for a move towards consistent definitions of vehicle and road types and fuel economy indicators, and consistent methods for measuring transport activity and energy use. The work programme initiated by the ECMT joint declaration is beginning to address some of these issues, and the IEA is working on the development of consistent energy end-use indicators.

ECMT is also compiling information on national greenhouse gas mitigation policies in Member countries, drawing on the UNFCCC national communications and a country questionnaire. This compilation is more detailed than the “compilation and synthesis” of information in the national communications being carried out by the UNFCCC secretariat, and goes beyond information in the communications. Again, there might be mutual benefits from co-operation with ECMT on this process.

The agreement might aim to go beyond collecting information on national policies to include and exchange information on local initiatives. There are already efforts to do this on a regional scale — for example, in the work of the European Commission on environment and energy, and as part of the United States Intermodal Surface Transportation Efficiency Act (ISTEA). ECMT and OECD recently reviewed policies in 132 cities (ECMT/OECD, 1995). Initiatives also exist on a wider international scale — for example, through the International Council for Local Environmental Initiatives (ICLEI), the Sustainable Cities Campaign and the Car-Free Cities Club. The Annex I Parties could work with these various bodies to compile and maintain a database on relevant initiatives, and to develop and promulgate monitoring and assessment methodologies. Such a process would require commitment from Parties to provide information, as well as funding.

There are many ways in which an agreement in this area might be initiated and implemented. One of the most obvious is through modifications to the guidelines for national communications to the COP, to incorporate more detailed reporting on transport sector indicators and policies, and on local initiatives. It might also be valuable to set up some form of working party or expert group to liaise with the various relevant organisations, and to consider assessment, monitoring and reporting methodologies. Such a group might be able to draw on experience elsewhere, for example, in ECMT and in the United States’ “Car Talk” process.

Agreement to adopt a particular kind of measure

This second option would allow Annex I Parties, or a sub-group of Parties, to make a commitment to a particular policy or type of policy, without complete harmonisation. This commitment could take various forms. Thus, it would at a minimum entail agreement to a principle, such as the need to bridge an information gap in the car market, the need for full-cost pricing in the transport sector, the need to encourage local initiatives, or the need to accelerate technology development and deployment. The agreement could be adopted in conjunction with, or subsequent to, the monitoring, reporting and review option described above.

The agreement might also entail a commitment to some specific type of response following from the principles — for example establishing voluntary agreements on fuel economy with car manufacturers,

increasing fuel taxes or other road user charges, enacting enabling legislation to encourage local initiatives, or providing government funding for research and development.

At its strongest, the agreement might entail a commitment to introduce policy changes of a certain type, by a certain date, and to determine those policy changes in a certain way. This might involve, for example, agreeing on a methodology for determining road user charges, and on a date for implementing those charges, or agreeing on an annual percentage reduction target for vehicle energy intensity.

Some international agreements of this type already exist, the main example being the European Union, where many tax and other policies have been co-ordinated in this way rather than opting for complete harmonisation. The OECD, IEA and ECMT, as well as various UN bodies, develop broad policy agreements of this type in many areas. The approach has the obvious advantage that it achieves at least some of the advantages of policy co-ordination, while allowing for differences in national circumstances.

The most obvious way to develop and implement such a common action is as an extension to the monitoring, reporting and review option. However, governments might be able to make an agreement to principles and targets more rapidly, especially in areas such as that of fuel economy targets and fuel tax increases where many already have national policies.

Agreement to adopt a measure in common

While it is unlikely that countries will wish to harmonise their transport sector mitigation policies completely, there are elements that might be harmonised or where a very specific commitment might be made. Some of these might be: a minimum CAFE standard or feebate system or an international voluntary agreement with manufacturers; a fuel tax increment to reflect externalities associated with climate change and resource depletion; a system of recognition and funding for local mitigation initiatives; or agreed national contributions to a common research and development fund. In some cases, these agreements might be established on a regional level, or involving some other subgroup of countries, in which case greater harmonisation might be possible. It might be possible to link the various harmonised measures: for example, even a low estimate of the climate change externality would raise a substantial amount of revenue throughout the Annex I region,²⁴ which might be committed to a trust fund for investment in local initiatives and research and development.

A common action in this area could build on one or more of the many existing agreements among groups of countries. Thus, the United States CAFE standard is already used as a voluntary CAFE level for vehicle sales in Canada. European Union car manufacturers have already agreed to a common target for fuel economy improvement, and European Union countries agree to minimum levels of fuel taxation, as well as sharing funds for research and development and other purposes. The IEA has established several Implementing Agreements in which countries pool both information and research and development funding. UNECE establishes vehicle emission standards which are adopted into national legislation throughout Europe and beyond. The International Standards Organisation might also be a vehicle for establishing non-compulsory vehicle standards.

An agreement in this area would need to be based soundly on expert advice and discussion, as well as consultation on policy. The Annex I Parties might initiate the process by setting up a working party for the purpose, or allow it to develop from the processes supporting the two options above.

²⁴ In round terms, a US\$5/tonne carbon tax would correspond to about 0.3 US¢ per litre on gasoline. A tax at this level throughout the Annex I region would raise about US\$3 billion per year, or 10 per cent of the world automotive industry's annual R&D budget.

APPENDIX A. THE TECHNICAL AND ECONOMIC POTENTIAL FOR VEHICLE CHANGES²⁵

The **technical potential** for reducing CO₂ emissions associated with providing a particular service depends on the definition of that service. It is quite possible today to build a motorised personal passenger vehicle with fuel economy in the region of 0.5 L/100 kilometres or less (Lovins *et al.*, 1993) but this vehicle will not provide all of the same services that a current technology large family saloon car provides. New technology cars have failed in the market in the past because they did not match conventional cars in terms of low cost, reliability, range, luggage space, comfort, speed and acceleration. Estimates of the potential for improving energy efficiency without changing the performance of the vehicle are more modest. For example, NRC (1992) estimates the potential for fuel economy improvements in the United States through the incorporation into vehicles of technologies which are already in mass production somewhere in the world at 34-37 mpg or a reduction of about 20 to 27 per cent in energy intensity. Table 21 gives a range for the year 2010 of the potential reduction in energy intensity through the incorporation of technologies many of which are not yet in mass production. This range is 35 per cent to 70 per cent for cars, and much less for other vehicle types.

The **economic potential** for reducing CO₂ emissions is usually defined as the reduction that can be achieved cost-effectively — i.e. where any increased cost for vehicle technology is repaid through fuel savings. The economic potential depends not only on the definition of the service the technology is supposed to provide, but also on the service user's definition of "cost-effective". Some might argue that the economic potential is zero — that is, vehicle purchasers already make their vehicle choices on the basis of vehicle attributes, including fuel economy, and they choose the level that is cost-effective for them.²⁶ Many analysts in the United States and Europe follow the method of K.G. Duleep (e.g. in Greene and Duleep, 1993) in defining a "cost-effective" energy efficiency improvement as one where any increase in car cost is paid back in fuel savings over four years, discounted to the time of purchase at an 8-10 per cent discount rate. This definition is reasonable for some users: for example, it may correspond to the trade-off between first cost and operating costs made by many fleet operators. Car purchasers in the aggregate choose less energy efficiency than such a model would suggest, although this is not necessarily because they are not concerned to minimise costs: different analysts do not agree on the costs of technology changes (DeCicco and Ross, 1993; OTA, 1994; IEA, 1993a). Engineering studies of vehicle technology costs are heavily dependent on assumptions about production volumes, changes in manufacturing practices, etc. In many instances, more energy efficient vehicle technology may be cheaper to produce than conventional technology: the true costs cannot be known before the technology is in full production.

²⁵ Much of the material in this Appendix derives from Michaelis (1995).

²⁶ The validity of this argument is discussed in Part 1 of this study, in the section on economic efficiency arguments.

Energy-Intensity Reduction in Road Vehicles

Reductions in energy use per vehicle-kilometre can be achieved through changes in maintenance practice, vehicle body design changes, more energy-efficient engine and drive-train designs, and changes in operating practice.

Vehicle maintenance may be inadequate, particularly in countries with economies in transition, because spare parts and servicing are too expensive or unavailable (Davidson, 1992) or because maintenance is a low priority for drivers. Regular checks on tyre pressure, engine oil, and tuning can save energy. Studies on cars have shown a 2 to 10 per cent fuel saving immediately after engine tuning (Davidson, 1992; Martin and Shock; 1989; Pischinger and Hausberger, 1993) although this can then deteriorate rapidly. The benefits of engine checks for energy efficiency are likely to decrease in future as increasing numbers of gasoline engines have self-regulating (closed-loop oxygen control) electronically controlled fuel injection, in order to meet emission standards and for compatibility with three way catalytic converters. Increases in tyre pressure can also reduce energy use, with potential energy savings of up to 3 per cent.

Vehicle mass affects energy use for acceleration and in overcoming resistance or friction in the axles, wheels, and tyres. In most types of road vehicles, acceleration and rolling resistance each typically account for about one-fourth to one-third of the useful mechanical energy from the engine, although these shares are larger for city buses and delivery vans. Vehicle mass can be reduced by using advanced materials, improved component design and joining techniques, and by reducing vehicle size or engine size. Concept cars have been demonstrated with masses 30 to 40 per cent below that of conventional cars of similar size and performance (Chinaglia, 1991; Delsey, 1991b; Lovins *et al.*, 1993) although technology used in concept cars does not necessarily translate into viable commercial technology. The technical potential in 2010 for mass reductions without compromising comfort, and performance is probably in the range of 30 to 50 per cent for most vehicle types, although this might have large effects on cost and could involve other aesthetic changes in vehicles which consumers might not accept.

The technical potential in 2010 for reducing rolling resistance is probably around 30 per cent for cars but rather less in buses and trucks (ETSU, 1994; DeCicco and Ross, 1993; EEA, 1995). For most road-vehicle types, a 10 per cent drop in rolling resistance reduces energy intensity by roughly 1 to 3 per cent provided engine size is reduced (ETSU, 1994; NRC, 1992).

Air resistance, or drag, accounts for a third to a half of the energy required to move most types of vehicles, although the share is lower for city buses and delivery vans. Changes in vehicle design can reduce it by about 50 per cent for most vehicle types, offering about 15 per cent reduction in energy intensity, provided engine size is reduced (ETSU, 1994). Again, this might involve increased costs and could carry weight penalties (e.g. for enclosing the undersides of vehicles). It could also affect vehicle aesthetics. The ultimate limit on drag reduction without reducing vehicle size is probably 70 to 80 per cent, but this would involve radical changes in vehicle shape and performance.

Improved transmission designs can reduce energy use by allowing the engine to operate closer to its optimum speed and load conditions. Complete engine load/speed optimisation can be achieved with electronically controlled, continuously variable transmissions (CVT), although these may be more expensive than conventional gearboxes and are currently only available for small cars. Energy savings in the range 3 to 10 per cent are possible, relative to automatic transmissions (DeCicco and Ross, 1993; Tanja *et al.*, 1992; NRC, 1992).

Changes in gasoline-engine technology have resulted in gradual improvements in energy efficiency. This progress is likely to continue. Energy-intensity reductions in the region of 15 to 30 per cent are thought to

be available with current technology (Bleviss, 1988; Martin and Michaelis, 1992; DeCicco and Ross, 1993; ETSU, 1994; NRC, 1992; Pischinger and Hausberger, 1993). These reductions could arise from a combination of many changes, including improvements in component design and lubrication, improvements in materials, increased use of electronic control systems, and changes in engine design, such as the use of three or four valves per cylinder.

Car manufacturers have worked intensively on advanced two-stroke engines, with the aim of reaching the noise, emission, and durability standards of existing four-stroke engines. While this has not yet been achieved, they would, if commercialised, have higher efficiency and power-to-volume and weight ratios than four-stroke engines, allowing for more flexibility in car design and potentially for improvements in fuel economy of around 10 per cent, provided the efficiencies realised were not used to raise power.

Another engine concept is the gasoline direct-injection engine, which might have fuel requirements 10 to 25 per cent lower than those for a conventional engine (Schäpertöns *et al.*, 1991), although such engines remain far from commercialisation. Lean-burn gasoline engines may also be able to offer 10 to 20 per cent energy savings, but further development will be needed in the engines: Although the combustion conditions in the engines often generate less NO_x than those in conventional engines, these NO_x emissions cannot be controlled by existing three-way-catalytic converters. Vehicles with these engines may not meet future NO_x emission standards, unless NO_x formation can be reduced or a lean-burn engine NO_x reduction catalyst can be developed.

Diesel engines in heavy-duty vehicles are already very efficient. The energy efficiency of a large truck engine can approach 40 per cent in use. The potential for further energy savings is probably no more than 10 to 20 per cent in the long term

Diesel-engine cars, taxis and vans are widespread in Europe, the Middle East, and Southeast Asia, although they cannot meet some strict U.S. particulate emission standards. Unless they can be substantially reduced, the NO_x and particulate emissions from diesel engines could pose a growing barrier to their acceptance in many parts of the world. Most of these cars have indirect-injection diesel engines and offer a 5 to 15 per cent lower fuel consumption (in energy terms) than gasoline cars. Cars with direct-injection diesel engines consume about 10 to 20 per cent less fuel than indirect-injection diesel engines.

Alternative engine designs, including gas turbines and Stirling engines, have received attention from governments and manufacturers over the decades. These engines are cleaner than Otto or Diesel engines and are also fuel-flexible, but in the 50 to 300 kW range required for road vehicles, they are currently inefficient and expensive and have poor load-following characteristics. By 2025, improved materials and precision engineering could make these engine types viable for road vehicles. Hybrid engine/electric drive-trains could be used to avoid the need for the engine to match the load on the drive-train. However, there is no reason to assume that any alternative engine concepts will improve faster than the gasoline four-stroke engines that they are designed to replace.

Cost of Energy-Intensity Improvements

Several studies estimate the potential for reducing the energy intensity of car use in the United States (DOE, 1995; OTA, 1994; DeCicco and Ross, 1993; Greene and Duleep, 1993; NRC, 1992) and the United Kingdom (DTp, 1996; ETSU, 1994). Most, but not all, of these sources use technology cost models which are directly derived from, or modified versions of, the model developed by K.G. Duleep of EEA in the

United States. This model has evolved over the years with the addition of new technology cost estimates, but the basic principles have been unchanged. Figure 20 shows that there is a very wide range

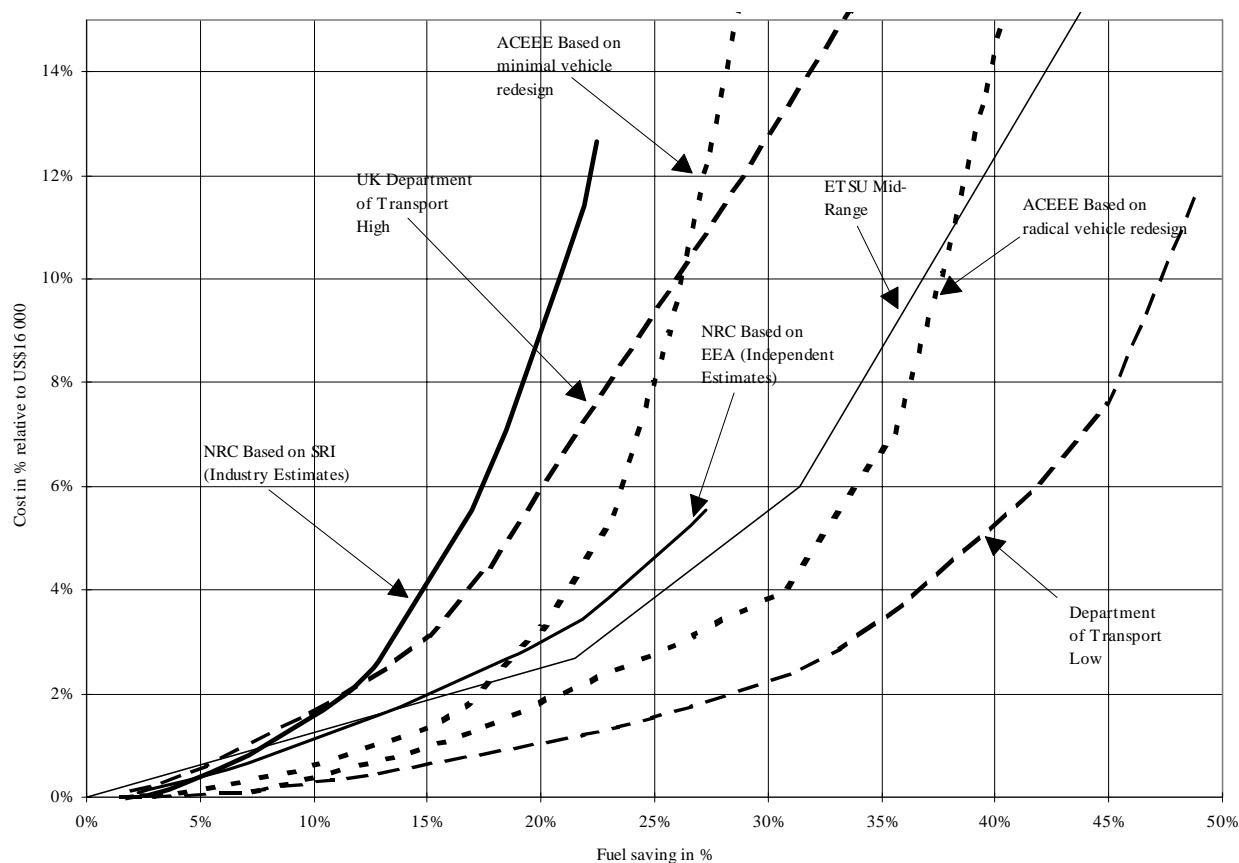


Figure 20. Supply Curves for Fuel Economy in Light Duty Vehicles

in the estimates for the cost of achieving a given fuel economy level, although some care must be taken in interpreting these results, as the curves are not calculated on an equivalent basis. The highest cost curve is based on information supplied by United States vehicle manufacturers to a consultant (SRI) which reported to a committee of the National Research Council (NRC, 1992). The EEA curve is also based on data supplied to the NRC committee. Both of these two curves are “illustrative” calculations of average costs of fuel economy improvement for subcompact cars in the United States car market in 2001. The ACEEE curves are based on a modification of the EEA data by the American Council for an Energy Efficient Economy (ACEEE). These curves are estimates of the fuel economy costs for the overall fleet in 2010. The NRC curves apply only to subcompact cars, whereas the ACEEE curves apply to the whole United States car fleet. The most significant difference between the ACEEE data and that of EEA is that ACEEE assumes much lower costs for small fuel economy improvements than EEA. Much of this difference probably results from differences in assumptions about industry retooling costs for design modifications.

There has been less open debate of energy efficiency costs in Europe. The United Kingdom Department of Transport has adapted the NRC (1992) technology cost-effectiveness estimates to the United Kingdom situation, including a slightly different range of technology options and generating a range of possible costs vs. energy savings for an “average” United Kingdom car (see Table 20). The resulting fuel economy supply curves are shown in Figure 20 as “United Kingdom Department of Transport High” and “United

Kingdom Department of Transport Low”. Whereas the United States curves are based on estimates of the potential penetration of individual technologies into each size segment of the United States car fleet, the United Kingdom curves are based on the cost of introducing technologies to the “average car”. It should also be noted that some of the technologies included in all of the analyses might be considered to change the marketability of the car, for better or worse, because of effects on safety, performance, comfort and aesthetics. Others are not yet fully commercial, and their date of commercialisation cannot be firmly forecast. Some of the most obvious in the United Kingdom analysis are shown *in italics* in Table 20. A conservative analysis of fuel economy potential might exclude these technologies, which in the case of the United Kingdom’s analysis would reduce the potential savings to around 20-30 per cent.

Table 20. UK Department of Transport Energy Saving vs. Cost Assumptions

| Low Potential | | | High Potential | | |
|---|---------------------------------------|--------------|---|---------------------------------------|--------------|
| Technology | Cumulative Change in Energy Intensity | Cost in UK £ | Technology | Cumulative Change in Energy Intensity | Cost in UK £ |
| Engine friction-advanced lubricants | 0 % | 2 | Improved Transmission | -1 % | 0 |
| Improved transmission | -2 % | 13 | Weight Reduction | -3 % | 0 |
| Low resistance tyres | -3 % | 12 | Low resistance tyres | -7 % | 15 |
| Reduced weight (not aluminium body) | -4 % | 27 | Advanced lubricants | -8 % | 2 |
| Exhaust gas recirculation | -5 % | 20 | <i>Continuously variable transmission</i> | -11 % | 22 |
| Turbo/supercharging | -10 % | 120 | Roller cam followers | -13 % | 11 |
| Engine friction-roller cam followers | -11 % | 43 | Wide throttle/variable geometry intake | -22 % | 93 |
| Aerodynamic improvements | -13 % | 67 | Other engine friction redn | -23 % | 20 |
| Engine friction - other | -15 % | 73 | Exhaust gas recirculation | -25 % | 20 |
| Multi-point fuel injection | -18 % | 143 | Aerodynamic improvement | -27 % | 27 |
| <i>Engine-off at zero load</i> | -34 % | 1300 | Multivalve engine | -31 % | 80 |
| <i>Aluminium body-in-white (basic body shell)</i> | -41 % | 650 | Multi-point fuel injection | -33 % | 53 |
| <i>Continuously variable transmission</i> | -43 % | 217 | Turbo/supercharging | -36 % | 120 |
| Wide throttle/variable geometry intake | -44 % | 200 | <i>Aluminium body-in-white (basic body shell)</i> | -42 % | 250 |
| <i>Cold start heat storage</i> | -46 % | 500 | <i>Engine-off at zero load</i> | -45 % | 193 |
| Multivalve engine | -47 % | 600 | <i>Cold start heat storage</i> | -49 % | 500 |

Note: items in italics are either not fully commercial technology, or would entail substantial changes in G vehicle design/performance that might influence the marketability of cars

Several studies (e.g. ETSU, 1994; ECN, 1995) include estimates of the costs of a range of alternative vehicle designs. These studies differ from the technology cost analyses mentioned so far in considering a small number of composite vehicle concepts, rather than a large number of incremental changes to existing vehicles. Nevertheless, the mid-range costs and fuel economy percentage improvements (taking the 1990 average as a base) for the ETSU (1994) vehicle concepts are included in Figure 20, and they can be seen to lie mid way between the Department of Transport estimates.

Some of the technologies considered in the construction of the various curves are likely to substantially increase their market penetration in the coming years, with or without government intervention — indeed, some will have done so since the studies on which the curves are based were carried out. They are used in this report as being indicative of the possible range of costs of introducing new technology to light duty vehicles. For this study, the “SRI” and “UK Department low” estimates of energy efficiency vs. cost have been used as high and low values for technology cost. This may be an overestimate of the range of uncertainty in the technology supply curve, but a more detailed study would be needed to narrow this range down. In Figure 21 these two curves are illustrated along with curves fitted using least squares fits. The equations of these curves are used for calculating the ranges of costs of fuel economy improvements in the study. The different functional forms were chosen to obtain good fits with the curves and no significance should be attached to these.

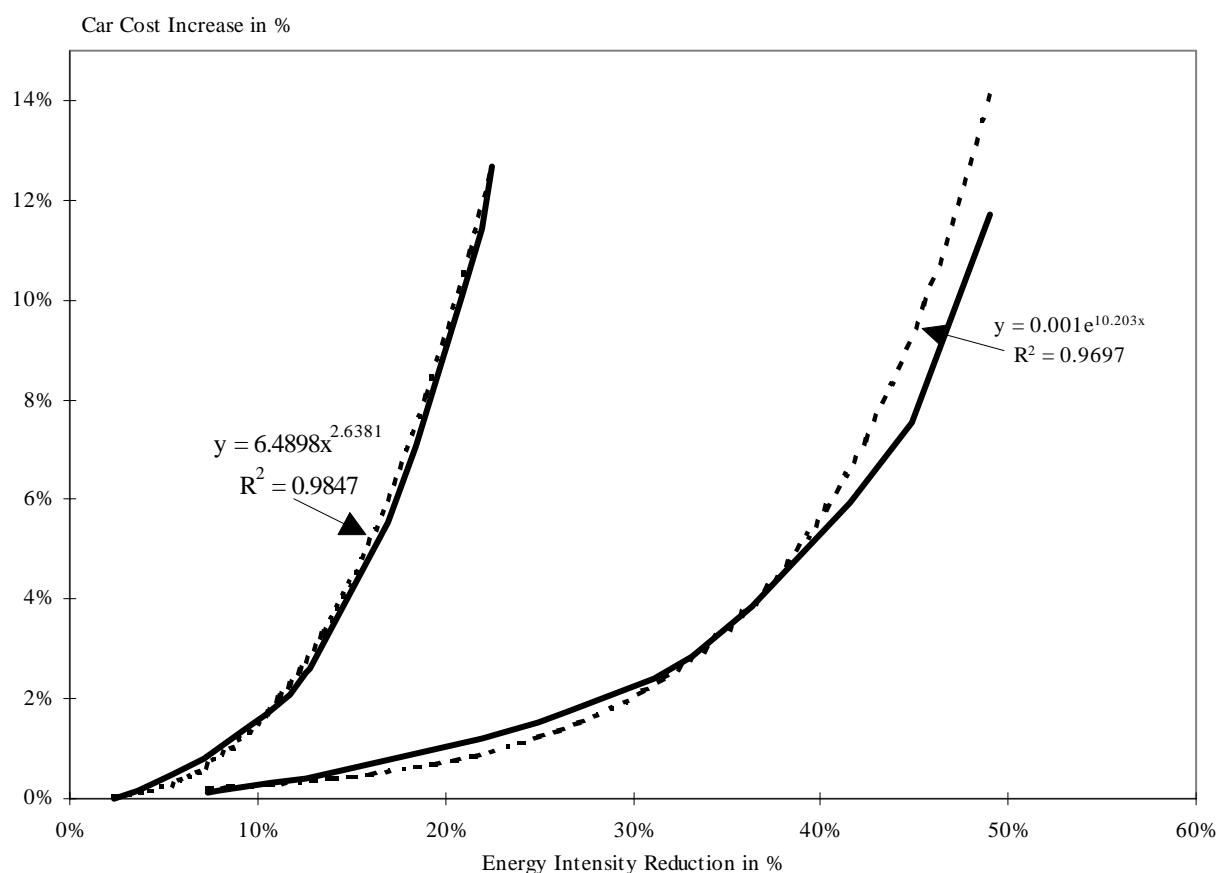


Figure 21. Range of Costs for Vehicle Energy Intensity Reductions

This graph can also be used to estimate the level of fuel economy improvement that would be “cost effective” from the consumers point of view, for a given discount rate, fuel price, and starting fuel economy level. For a typical United States driver, each L/100 kilometres reduction is worth about \$50 per year, while for a typical European or Japanese driver, it is worth about \$140 per year. If the driver seeks a four year pay-back at 8 per cent discount rate for energy efficiency technologies incorporated in the car, the value of a L/100 kilometres improvement is roughly \$180 in the United States and \$520 in Europe. When the saving is considered over the life of the car, the value becomes closer to \$400 in the United States and \$1100 in Europe.

It should be noted that the results using the gradients of these fitted curves differ slightly from those obtained by simply plotting the marginal cost-effectiveness of each technical improvement from the different studies. These curves are included here in Figure 22 because they explain the level of fuel economy improvement that each of those studies finds to be cost-effective. In this graph, the DTp High and SRI curve on the one hand, and the DTp Low and ACEEE Level 3 curve on the other, appear very close.

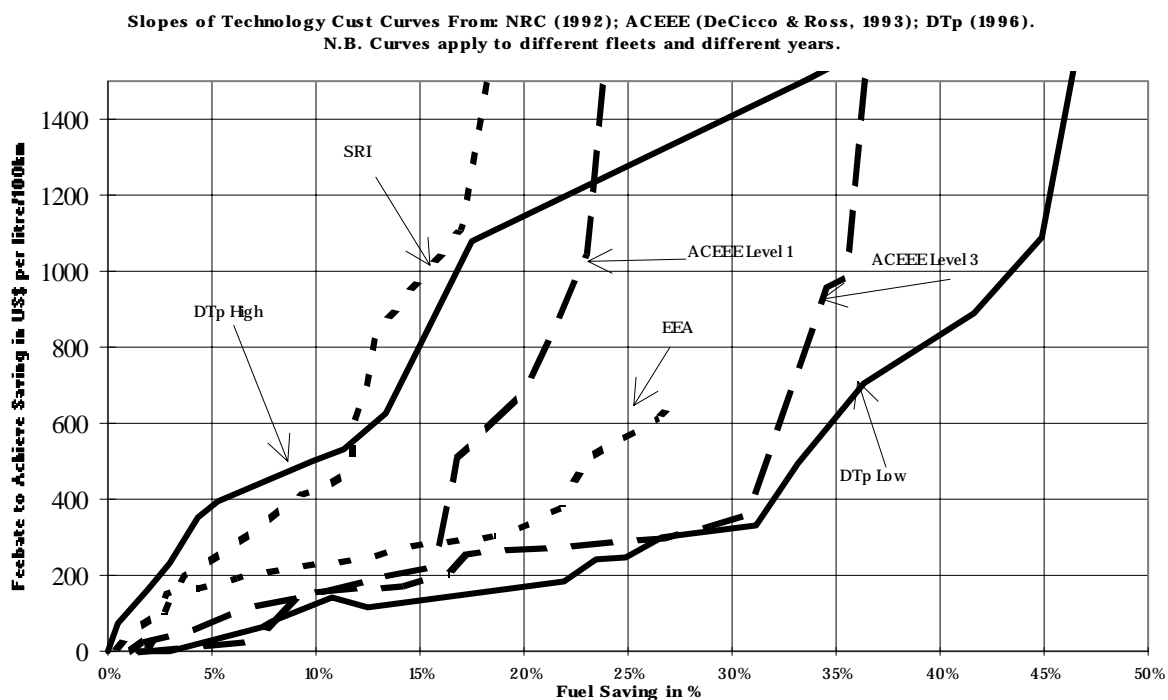


Figure 22. Technology Cost-Effectiveness

NRC (1992); ACEEE (DeCicco & Ross, 1993); DTp (1996).
 Note: Curves apply to different fleets and different years.

The Future Potential for Vehicle Energy-Intensity Improvements

By 2010, it may be technically possible to reduce energy intensities for new vehicles of most types by 25 per cent to 50 per cent without reducing vehicle performance or the quality of transport provided (see Table 5). However, the economic potential — the energy-intensity reduction that would be cost-effective — is likely to be smaller than the technical potential. As Table 5 indicates, the economic potential for energy saving in cars might be about two-thirds the technical potential. Meanwhile, the trend is for less energy saving than the economic potential, and for some key vehicle types, including cars and heavy trucks, it is possible that the fleet average energy intensity might not decrease between 1990 and 2025 without new policies. Substantial reductions in energy intensity would require new government measures and might entail reductions in vehicle performance.

Operational influences on vehicle greenhouse-gas emissions

The energy intensity of travel and freight transport is influenced by several factors other than vehicle technology. One of the strongest influences is the load factor or occupancy of the vehicle, but other factors, including driving style (or speed profile), routing, and traffic conditions are also important.

Differences in driving style can explain about 20 per cent of variations in energy use by cars, buses, and delivery vans in urban areas (Martin and Shock, 1989; Tanja *et al.*, 1992). The potential for energy saving

Table 21. Potential for Energy Efficiency
Actual energy intensities depend strongly on vehicle load factors and patterns of use.

| Mode | National Average Load Factors (passengers per seat or tonne load per tonne capacity) [†] | National Averages of 1990 Intensity (MJ/pass-km or MJ/tonne-km) | Trend 2010 New Stock 2025 Fleet Average | Economic Reduction Potential at Constant Performance 2010 New Stock 2025 Fleet Average | Technical Reduction Potential at Constant Performance 2010 New Stock 2025 Fleet Average | Technical Reduction Potential: Reduced Speed and Performance 2010 New Stock 2025 Fleet Average |
|----------------------|--|---|---|--|---|--|
| | | | | | | |
| Cars | 0.25-0.5 | 1.2 - 3.1 | 0 to -30 % | -20 to -50 % [‡] | -35 to -70 % [‡] | -60 to -80 % |
| Buses | 0.1-2 | 0.2 - 1.3 | +10 to -10 % | 0 to -20 % | -20 to -40 % | -35 to -60 % |
| Trams | 0.2-0.8 | 0.3 - 1.5 | +10 to -10 % | 0 to -20 % | -20 to -30 % | -30 to -40 % |
| Passenger Trains | 0.1-0.8 | 0.9 - 2.8 | +10 to -10 % | 0 to -20 % | -25 to -35 % | -35 to -45 % |
| Air Travel | 0.5-0.8 | 1.5 - 2.5 | -10 to -20 % | -20 to -30 % | -30 to -50 % | -40 to -60 %? |
| Average Road Freight | 0.2-0.4 | 1.8 - 4.5 | -10 to -20 % | -15 to -30 % | -25 to -50 % | -40 to -70 % |
| Heavy Trucks | 0.6-1.1 | 0.6 - 1.0 | 0 to -20 % | -10 to -20 % | -20 to -40 % | -30 to -60 % |
| Freight Trains | 0.5-0.8 | 0.4 - 1.0 | 0 to -10 % | -10 to -20 % | -25 to -35 % | -30 to -40 % |
| Marine Freight | — | 0.1 - 0.4 | +10 to -10 % | +10 to -10 % | -20 to -30 % | -30 to -50 % |
| Air Freight | n.a. | 7 - 15 | -10 to -20 % | -20 to -30 % | -30 to -50 % | -40 to -60 % |
| Sources and notes | Bose and Mackenzie, 1993; Martin and Michaelis, 1992; Davidson, 1992; Hidaka, 1993; Rigaud, 1989; Schipper <i>et al.</i> , 1993; UNESCAP, 1989 to 1992, various. (Michaelis, 1996) | | Much of the literature on trends and potentials is focused on cars from 2000 to 2005 (e.g. Difulgio <i>et al.</i> , 1990, Greene and Duleep, 1993; DeCicco and Ross, 1993; IEA, 1993a). Values here are the authors' estimates, revised following expert review, based on these and on longer-term estimates covering various transport modes in: Bleviss, 1988; Martin and Michaelis, 1992; ETSU, 1994; Lovins, 1993; Martin and Shock, 1989; Pischinger and Hausberger, 1993; Walsh, 1993a. | | | |

[†] Load factors exceeding 1.0 indicate overloading.

[‡] These high figures for the economic and technical potential in cars are in fact improbable according to many experts, but were argued for by some reviewers during the expert review of the IPCC Second Assessment Report, from which this table derives.

by “gentler driving” has been estimated to be about 10 per cent in urban areas and 5 to 7 per cent overall (Tanja *et al.*, 1992).

Energy use can also be reduced by traffic-management measures, such as computerised traffic-light control and network and junction design, to reduce congestion and unnecessary stops. Introduction of a traffic-control system in Los Angeles is estimated to have yielded a 12.5 per cent reduction in energy use (Shalldover, 1993). However, energy-use reductions resulting from computerised traffic control may be rapidly reversed because the increase in road network capacity is likely to produce additional traffic.

For commercial vehicles, computerised routing systems can be used to optimise payloads and to minimise the time spent and fuel used on the roads. For many haulage firms in industrialised countries, such systems pay for themselves through increased revenue. Some studies indicate that reductions of 25 to 30 per cent in energy use per tonne-kilometer are technically possible (O'Rourke and Lawrence, 1995).

A variety of computerised routing aids are being developed for drivers in general, some providing real-time information on congestion and the availability of alternative modes and routes. Energy-saving potentials in urban road passenger transport could range from a few percentage points in small towns with little congestion to 30 per cent in large, congested conurbations with effective public-transport alternatives (Shalldover, 1993).

Speed is an important influence on energy use by all types of vehicles. For road and rail transport, speed limits and vehicle speed limiters are mainly used for safety reasons. Moderate reductions in average road vehicle speed (e.g. from 90 km/h to 85 km/h) can give energy savings of the order of 5 to 10 per cent (Tanja *et al.*, 1992).

Technology studies that project fuel economy

Studies such as those of Duleep (1995), ETSU (1994) and DeCicco and Ross (1993) can be used as the basis to estimate the improvement in vehicle fuel economy that might be expected to occur as a result of changes in fuel price. Duleep, and most of the studies based on his work (OTA, 1994; DeCicco and Ross, 1993; Train *et al.*, 1995) assume that car purchasers will opt for a vehicle fuel-saving feature if the fuel savings over four years, discounted to the time of purchase at an 8 per cent discount rate, will pay for the additional cost of the feature. Based on this, they predict fuel economy changes in the fleet which are clearly not coming about. Indeed, the technology cost data presented in these studies indicate many vehicle and engine design features which have been in commercial production since the 1980s but are not in use in even the majority of new cars in Europe, yet would pay for themselves in fuel savings within a year. The energy efficiency gap, which amounts to excess fuel consumption by cars of about 20 to 30 per cent, mirrors those in other sectors of energy end-use, and may be explained by a combination of factors. These include consumer (and manufacturer) preferences for existing technology, consumers' lack of information, manufacturers' perception of risk associated with new technology, uncertainty about future fuel prices, and others.

APPENDIX B. ECONOMETRIC STUDIES OF VEHICLE ENERGY USE

Price Influences on Car Choice and Fuel Use

A wide variety of factors are taken into account by those purchasing vehicles, including purchase and running costs, reliability and appropriateness for the use to which the vehicle is to be put. Different purchasers will emphasise different attributes. Vehicle choice has been analysed most in the case of cars. Many of the existing models of car choice (e.g. Mogridge, 1983; Greene and Duleep, 1993; Bunch *et al.*, 1993; Koopman, 1995; DOE, 1995; Segal, 1995) implicitly assume that consumers behave, at least on average, in a rational way to maximise a utility function. Most applications of these models (e.g. Greene and Duleep, 1993; DOE, 1995) implicitly assume that this utility function is time- and location-invariant. However, many alternative models of choice are possible and analysts (e.g. Dietz and Stern, 1993; Jacobs, 1994) have questioned the validity of the frequent assumption that consumers behave in a rational way to maximise a well-defined utility function. In the following, we report the results of econometric studies but note first that the results of these studies may have very limited accuracy in predicting the effects of policies.

Few studies exist of consumer preferences and the trade-offs made between fuel economy and other vehicle attributes. DOE (1995) uses a model, based on 1978 market information, to estimate the consumer and manufacturer response to feebates in which consumers are prepared to pay approximately \$1.20-\$1.65 for a 1 mile-per-gallon improvement. The model used by Greene and Duleep (1993) to estimate future improvements in fuel economy in American cars implies consumer valuation of fuel economy at about \$50 per 1 mile-per-gallon improvement.

Many econometric studies have been made of the effects of car and fuel prices on the numbers of cars purchased, the energy efficiency of those cars and the distance they are driven.

A 10 per cent increase in gasoline prices results in 1 to 6 per cent short-term reduction in demand, according to most studies (Dahl and Sterner, 1991; Fowkes *et al.*, 1993a; Tanja *et al.*, 1992; Goodwin, 1992, Hausberger, 1996). The effect of price increases is not symmetrical with the effect of price decreases (Dargay, 1993). In the long term, fuel-price increases encourage the use of more energy-efficient vehicles, and a 10 per cent increase in gasoline prices can lead to a 5 to 16 per cent reduction in gasoline demand. The response to fuel price falls as incomes rise, all else being equal (Goodwin, 1992; Greening *et al.* 1994).

The response of travel to fuel price is an important component of the gasoline demand response. Analysts again find a range of values, ranging from 0.13 (Greene, 1992) for the short-run response, to around 0.3 for the long-run response (Jones, 1993) and for cross-sectional analyses (Greening *et al.*, 1994; Walls *et al.*, 1993)

Several analysts (Mogridge, 1993; DRI, 1991, 1994, 1995) find that historical data are consistent with car users having a constant budget (as proportion of income) for car use. This implies a price elasticity of car use with respect to total cost of -1. Much of the DRI analysis is based on this assumption.

Hausberger (1996) finds that a 10 per cent increase in fuel price in Austria would lead to:

- a reduction in the average mass of newly registered cars by 1 per cent;
- a reduction in the average rated power of newly registered cars by 0.65 per cent.

Hausberger has used an engineering model of car energy use to estimate that this would imply a 0.6 per cent reduction in energy intensity associated with vehicle downsizing.

Goodwin (1992) will be taken as the main guide in this study to appropriate levels for long-run elasticities of car purchase and use with respect to fuel and vehicle prices. Goodwin reviews research from several countries, and finds that a 10 per cent increase in gasoline prices has been found to reduce traffic by 3-5 per cent in the long-run, as a result of a reduction in car ownership and a reduction in car use (each by up to, but no more than, 3 per cent) (Goodwin, 1992). Gasoline consumption decreases by 7 per cent or more, implying fuel economy improvements of at least 2-4 per cent of which about half is obtained in the short run, and so is probably behavioural. Meanwhile, a 10 per cent increase in car price results in a reduction in car ownership of the order of 4-16 per cent (Goodwin, 1992). Assumed price elasticities are thus as shown.

Table 22. Long-Run Price Elasticities of Car Demand and Use

| Dependent Variable | Independent Variable | Price Elasticity Range | Working Value |
|---|----------------------|---|---------------|
| Traffic (aggregate car use in vkm) | Gasoline price | -0.3 to -0.5 | -0.4 |
| Car ownership | Gasoline price | -0.1 to 0.3 | -0.2 |
| Car use (km per year per car) | Gasoline price | -0.1 to 0.3 | -0.2 |
| Gasoline consumption | Gasoline price | -0.7 to -1.0 (but note IEA regional data below) | — |
| Fuel economy (L/100 km) pure efficiency | Gasoline price | -0.1 to -0.2 | -0.12 |
| Fuel economy (L/100 km) downsizing | Gasoline price | approx. -0.06 | -0.06 |
| Fuel economy (L/100 km) behaviour | Gasoline price | -0.1 to -0.2 | -0.12 |
| Car ownership | Car price | -0.4 to -1.6 | -0/9 |

In all cases, for calculations, a simple log-log relationship between variables is assumed. That is, for dependent variable Q , independent variable p , and elasticity η , $\partial Q/\partial p = \eta Q/p$. This is obviously an oversimplification, especially for large price changes, where the functional form of the relationship becomes more important.

Price Influences on Freight Energy Use

There is less information available on price elasticities of freight energy demand, although several studies have estimated price elasticities of freight transport of various commodities, and are reviewed by Oum *et al*, (1990), who find that a 10 per cent increase in freight transport costs leads to a reduction in demand in the region of 7-11 per cent, aggregated over different commodities. This is highly variable by commodity, with higher responses for transport of raw materials and lower responses for final products. The effect of price is likely to be high on the use of large trucks, for which energy use constitutes up to 25 per cent of total costs, and low on the use of small trucks, for which energy use can constitute less than 10 per cent of costs. Thus, short-term fuel price elasticities might be expected to be in the range -0.1 to -0.2.

Vouyoukas (1993) finds that freight traffic (tonne-kilometre) decreases by about 2 per cent for a 10 per cent increase in fuel price. International comparisons (based on Bennathan *et al.*, 1992) indicate that the effect of fuel price on freight traffic is very hard to separate from other influences, but an elasticity in this region of -0.1 is possible. Greene (1982) finds that short run fuel price elasticities of freight demand in the United States are very hard to detect and probably less than 0.1.

The long-run response of diesel fuel demand to price changes is expected to be somewhat stronger than the response of total traffic, as there is likely to be a technology response. International comparisons based on OECD and IEA country data for the mid 1980s indicate a figure in the region of -0.4, and this is consistent with the long-run elasticities calculated using the IEA world energy model (IEA, 1994d). Time series data for 22 OECD countries in the late 1980s indicate short-run diesel fuel demand elasticities with respect to GDP in the region of 1 to 2, and with respect to fuel price in the region of -0.3 to -0.35. These figures are averages, and the variation over time and between countries is considerable. It should be noted that price of ,and demand for, commodities, including oil, coal, steel and cement, is likely to be affected by the same world market changes that influence the price of diesel fuel, so that any price effects may not just be due to changes in the cost of freight transport.

Regional Variation in Price Elasticities

Estimates of the regional variation in price elasticities have been made using the IEA world energy model (IEA, 1994d). These are summarised in Table 23. Most are consistent with other estimates (e.g. Oum *et al.*, 1990 and Goodwin, 1992), but the European passenger travel elasticity with respect to fuel price is much higher than that mentioned above from Goodwin (1992).

Table 23. Regional Long-Run Price Elasticities for Transport and Transport Energy Demand

| Dependent Variable | Independent Variable | Elasticity | | |
|-------------------------------|-----------------------|---------------|--------|-------|
| | | North America | Europe | Japan |
| Passengers distance travelled | Cost of travel | -0.22 | | -0.26 |
| Passengers distance travelled | Cost of fuel | -0.17 | -0.84 | |
| Freight movement (tkm) | Diesel price | -0.21 | -0.1 | |
| Truck share in freight | Diesel price | -0.05 | -0.2 | |
| Truck freight (tkm) | Diesel price | | | -0.19 |
| Gasoline demand | Gasoline price | -0.46 | -1.0 | -0.49 |
| Diesel demand | Diesel price | -0.26 | -0.38 | -0.19 |
| Car fuel economy | Gasoline price | -0.4 | | |
| Air transport (pkm) | Cost of air transport | -0.41 | | |
| Aviation fuel demand | Crude oil price | | -0.08 | -0.24 |

Source: IEA, 1994d

The IEA's calculated elasticities for freight transport have been used in modelling the effects of fuel price on truck energy use, but Goodwin's elasticity estimates have been used to analyse light duty vehicle energy use. In the model for the second draft of this study, it has been assumed that road freight energy intensity has an elasticity with respect to fuel price of -0.2. This is highly uncertain and may be an overestimate, given the lack of an energy intensity response to the oil price rises during 1973/74 and 1979/80. On the other hand, a technology response at that time may have been masked by structural change (the shift in vehicle types and operating practices). While oil price rises may have been part of the stimulus for this, the same would not apply in the case of the diesel tax increases considered in this report.

APPENDIX C. EVALUATION OF THE EFFECTS OF FEEBATES AND STANDARDS

Feebates and related measures have been analysed in some detail for both the United States Government (DOE, 1995; DRI, 1991) and the European Commission (DRI, 1995). These studies form the main basis in this paper for evaluation of costs and effects of this type of measure. Independent analyses (DeCicco et al., 1993; Koopman, 1995) were also reviewed. Table 24 summarises the definitions of measures analysed by these studies.

Table 24. Feebate Options

| Measure Definition | Definition in US\$ per L/100 km | Location | Vehicle Group |
|---|---|--|--|
| DOE (1995) | | | |
| Linear, \$50 000 per gallon/mile(gpm) | Linear, \$210 per L/100 km | United States | Cars and Light Trucks (separate zero-points) |
| Linear, \$100 000 per gpm | Linear, \$420 per L/100 km | United States | Cars and Light Trucks (separate zero-points) |
| Linear, \$50 000 per gpm, one zero point | Linear, \$210 per L/100 km | United States | Cars and Light Trucks (one zero-point) |
| Linear, \$70 per mpg | Non-linear with respect to energy intensity, \$210 per L/100 km at average fuel economy | United States | Cars and Light Trucks (separate zero-points) |
| Non-linear, average \$100 000 per gpm, highest at midrange | Average \$420 per L/100 km | United States | Cars and Light Trucks (separate zero-points) |
| Size-based, \$3.75 million per gpm per ft ³ of interior volume for cars ²⁷ . Linear, \$50 000 per gpm for trucks. | Cars: \$450 per L/100 km per cubic metre of interior volume Trucks: Linear, \$210 per L/100 km | United States | Cars and Light Trucks (separate scale) |
| DRI (1995) | | | |
| Revenue neutral tax 68 Ecu/(g/km CO ₂) | \$2000 per L/100 km | Denmark, France, Germany, Italy, Spain, United Kingdom | Cars |
| Net tax 52 Ecu/(g/km CO ₂) with zero-point 20g/CO ₂ better than current average | \$1500 per L/100 km; 1040 Ecu net tax. | Denmark, France, Germany, Italy, Spain, United Kingdom | Cars |
| Koopman (1995) | | | |
| 300-500 Ecu per litre per 100 km (rate is chosen to achieve a fuel economy target equivalent to CO ₂ emissions of 179g/km and depends on fuel) | \$375-625 per L/100 km | European Union | Cars |

Source: DOE (1995)

²⁷ This is approximately \$35 000 per gpm at the 1990 fleet average interior car volume of 107.3 cubic feet (Davis, 1995).

The effect of feebates depends on both the response from manufacturers and the response from consumers. In the following, these two responses are briefly analysed.

Technical Change

In general, if a feebate is introduced with a given slope (rate of increase per L/100 kilometres of vehicle fuel economy), manufacturers would be expected to adjust their vehicle design and marketing strategies to take account of it. They can reduce the after-tax cost of each vehicle model by introducing new energy-efficient technology as long as the marginal cost of reducing fuel consumption is lower than the marginal rate of tax avoided. This means that the response of manufacturers depends very heavily on the slope of the supply curve for energy-efficient vehicle technologies. The slopes of the supply curves mentioned in Appendix A have been used in this study.

For this study, the “SRI” and “DTp low” estimates of energy efficiency vs. cost and cost gradient have been used as high and low values for technology cost.

Downsizing

In addition to a technology cost model, DOE (1995) employs a vehicle market model. This model evaluates the trade-offs made by consumers among vehicle characteristics, such as price, fuel economy, weight, interior volume, and engine power. The model implicitly accounts for the effects of vehicle weight on safety. It should be remembered that, being based on 1978 market data, the model may not adequately reflect current consumer concerns. In particular, the model may be inappropriate for the current American market, where the increase in the number of vehicles per household may have resulted in increased consumer responsiveness to fuel price and vehicle fuel economy when considering marginal travel and vehicle purchases (Walls *et al.*, 1993). The model coefficients imply that consumers value 1 mpg of fuel economy at about \$130-170 in the vehicle price.

The market model is used to estimate market shares of vehicles after manufacturers have responded to the feebates. It indicates that very little downsizing occurs as a result of the taxes, but that there is a small reduction in overall vehicle demand, as a result of the increase in vehicle costs. In the first DOE (1995) scenario with a feebate slope of \$210 per L/100 kilometres, the downsizing response results in nearly 1 per cent increase in mpg. With a feebate slope of \$420 per L/100 kilometres, DOE (1995) states that the response accounts for nearly 2 per cent increase in mpg (in fact, this response varies over the period modelled, but the response appears from graphs in the study to vary between about 1 per cent and 1.7 per cent).

DRI (1991) and DOE (1995) find that feebates in the United States would have most of their influence on fuel economy through changes in the design and marketing of vehicles by manufacturers, while the downsizing effect would be very small — at most 18 per cent of the total saving according to DRI, and closer to 5 per cent according to DOE (1995). The latter study also finds that there is a large increase in consumer surplus²⁸ as a result of introducing feebates. This is mainly because consumers save more money through reduced fuel consumption than they spend on additional energy-efficiency in cars, while reductions in vehicle performance and comfort are minimal.

²⁸ The DOE uses a model that calculates consumer utility, taking account of vehicle characteristics such as shoulder room, luggage space and prestige value, as well as monetary costs.

DOE (1995) generates scenarios to 2010 (one for each feebate scheme) in which feebates are introduced in 1995, but car manufacturers are warned and able to make preparations from 1990. In all cases, most of the manufacturers' new technology response in the form of more efficient new cars occurs before the feebates are enforced²⁹. The downsizing response occurs immediately after the feebate is introduced. Despite the considerable differences in the strength and design of the feebates considered, the effect on fuel economy and energy use is about the same in each case, with 9 to 13 per cent increase in new vehicle and total fleet fuel economy (mpg) by 2010, relative to a base case increase of nearly 30 per cent between 1990 and 2010.

The lack of difference in the DOE feebate scenarios must be attributed partly to the assumptions in the study about the technology available to improve fuel economy and the amount of this technology that is taken up in the base case. The study probably overestimates the amount of energy-efficient technology taken up in the base case, so that it exhausts the available "off-the-shelf" energy efficiency improvements that can be brought about by feebates. Less energy efficiency improvement in the base case would have left more options to be taken up, with higher feebate levels leading to greater emission reductions.

DRI (1995) appears to take a different approach to evaluating the effects that feebates would have in Europe, assuming that most of the effect is through consumers choosing to purchase more fuel-efficient car models. The DRI (1995) report is not explicit about the exact form of the model used. The 32 per cent reduction in fuel consumption that they find as a result of their modelling (see Table 25) is consistent with what would be expected as a result of manufacturers' introducing more energy efficient technology to reduce the level of feebate applied to their models. DRI find that the demand for large model cars would be reduced by about a third, while the demand for small models would be increased by about a third, as a result of the feebate. The number of cars sold would increase by 4-6 per cent. They do not evaluate the effects of reduced fuel costs on the level of driving.

Table 25. Effect of a Feebate in Six European Countries

| | 1990 | 1994 | 1995 | 1996 | 1997 | 2000 | 2005 |
|---|------|--------|------|------|-------|-------|-------|
| Tax/rebate slope in Ecu per g CO ₂ /km | — | — | — | 68 | 68 | 68 | 68 |
| Equivalent in US\$ per L/100 km | — | — | — | 2000 | 2000 | 2000 | 2000 |
| Zero point (g CO ₂ /km) | — | — | — | 174 | 165 | 150 | 125 |
| Equivalent in L/100 km | — | — | — | 7.4 | 7.0 | 6.4 | 5.3 |
| Calculated efficiency | 177 | 176 | 175 | 165 | 160 | 145 | 120 |
| Equivalent in L/100 km | 7.47 | 7.44 | 7.42 | 6.98 | 6.79 | 6.13 | 5.1 |
| Percent change from 1990 | 0 | -0.5 % | -2 % | -7 % | -10 % | -18 % | -32 % |

Source: DRI, 1995

This study estimates downsizing effects of feebates based on the responses in DOE (1995) and DRI (1995). It is assumed that the downsizing response depends on the feebate schedule and the base vehicle price according to an equation of the form $\ln(DS) = \eta \ln(P+F)$, where DS is the factor by which the fuel economy has to be multiplied to allow for downsizing, F is the feebate slope in \$ per L/100 kilometres, and P is the base vehicle price, approximately \$16,000. This form of equation is used for simplicity of calculation — the only parameter to be determined is η . Any error associated with the functional form is likely to be much smaller than the uncertainty in the size of η . The DOE results, with a 1 to 1.7 per cent fuel economy improvement from a \$410 per L/100 kilometres feebate, correspond to $\eta = -0.38$ to -0.66 .

²⁹ The manufacturer retooling time in the United States is about 5-8 years, but it is shorter in other countries.

The DRI results, with a 32 per cent reduction in energy intensity from a \$2000 per L/100 kilometres feebate, correspond to $\eta = -3.3$. This range of values of η is then used in the report to obtain a range of downsizing response estimates for different feebate levels.

Effects on Vehicle Purchases and Driving

The various studies have different findings on the effects of changes in vehicle technology and prices on the number of vehicles sold, their value, and the amount they are driven.

DOE (1995) finds that vehicle purchases increase as feebates are introduced in 1995, and decrease towards 2010. The short-term increase occurs because consumers prefer the efficient vehicles, despite their higher price, and buy them rather than second-hand cars. The longer term decrease occurs because of the large number of new vehicles on the roads, reducing the scrappage rate. The study does not examine what occurs when the market stabilises. Vehicle ownership is increased as a result of the feebates, by about 1 per cent, with a fuel economy improvement of about 10 per cent. This, along with increased driving per vehicle because of lower fuel costs, results in a 2.5 per cent increase in traffic and a 25 per cent rebound.

DRI (1995) uses an economic model (not described in the study) of the vehicle market and makes the assumption that downsizing is the main element of consumers' and manufacturers response. The study finds that a 30 per cent reduction in energy intensity is accompanied by a 4-6 per cent increase in vehicle sales. Assuming that the fuel economy improvement results in 6 per cent more driving per vehicle, there will be a total increase in traffic in the region of 10-12 per cent and a 33-40 per cent rebound.

Koopman (1995) uses an economic model of vehicle technology supply, and consumer demand for and use of that technology. He finds that, for a 12 per cent reduction in vehicle energy intensity, the value of vehicle sales increases by 1 per cent but ownership decreases by nearly 2 per cent. Car use increases by 1-2 per cent implying an 8-17 per cent rebound.

APPENDIX D. MODELLING OF FUEL PRICE EFFECTS

The effects of fuel price changes have been calculated for this study using a simple spreadsheet model to reproduce the WEC (1995) transport energy scenarios and test the effects of variations on those scenarios. The model starts from 1992 data (some estimated) for car ownership, fuel economy and distance travelled, freight traffic by truck and rail, and air traffic for eight world regions (OECD Europe, North America, OECD Pacific, central and eastern Europe, the CIS³⁰, south east Asia, Africa and Latin America). Car ownership, rail freight, truck and air traffic are calculated based on GDP elasticities, in three scenarios with different levels of GDP growth (varying by region). Assumptions are made about reductions in transport energy intensity and travel per car in the three scenarios.

Variations on these scenarios have been developed for the OECD regions, central and eastern Europe and the CIS, by making car ownership, travel and fuel economy, as well as freight traffic and truck fuel economy, dependent on fuel prices. In all cases, the dependence is based on simple log-log relationships between variables, with fuel price elasticities based on those in Appendix B. The effects of fuel price changes on truck and car fuel economy are lagged, to take account of the delay in manufacturers marketing more fuel-efficient vehicles, and the additional delay before the fleet average energy efficiency reflects changes in new vehicles.

The Scenarios

WEC (1995) describes three global scenarios of transport energy use to 2020, named “Markets Rule”, “Muddling Through” and “Green Drivers”. The scenarios are characterised as follows:

In Markets Rule, market forces prevail, creating a favourable climate for global competition. The world has been swept by privatisation, liberalisation and deregulation with trans-national companies playing a large role. Eastern Europe and the CIS, as well as the “Asian tigers”, grow rapidly, although Africa remains marginalised. Open markets and rapid technical development keep oil prices low.

In Muddling Through, the world “drifts along as it always has”. Countries tend to turn inwards, while solutions are short term and lack a wider perspective. Failure to co-ordinate energy taxes and provide incentives to save energy means that energy demand is quite high generally, while a failure to develop new energy supplies means oil prices are high.

In Green Drivers, environmental shocks lead to a strong focus on green issues. Governments introduce measures, including vehicle fuel economy standards and carbon taxes, leading to economic restructuring away from energy-intensive industry.

³⁰ WEC models the whole of the former USSR as a single region. Six Annex I Parties are former members of the USSR: the Russian Federation, Ukraine, Belarus, Latvia, Lithuania and Estonia. The first three of these are members of the CIS. These states are estimated, based on IEA statistics, to have accounted for about 75 per cent of Soviet road transport energy use in 1990.

The first two of these scenarios are used as reference scenarios for assessing the effects of measures in the current report. General trends are summarised in Table 26.

Key Assumptions

Table 26. General Trends in the WEC Scenarios.

| Trend | Markets Rule | Muddling Through | Green Drivers |
|---------------------------|---|---------------------------------------|--|
| Economic Growth, OECD | 2.8 %/year | 2.2 %/year | 2.2 %/year |
| Economic Growth, non-OECD | 5.2 %/year | 4.2 %/year | 4.0 %/year |
| Oil supply | Sufficient, US\$16/bbl | Moderate, US\$26/bbl | High, US\$12-13/bbl, demand depressed by carbon taxes |
| Lifestyle | OECD lifestyles spread rapidly | Slow adoption of OECD lifestyles | Some green consumerism in OECD, moderate adoption of OECD lifestyles elsewhere |
| Fuel Efficiency | Increasing because of high stock turnover and technical development | Moderate, following historical trends | Sharp increase driven by price incentives and regulations |

Vehicle fleet and traffic growth, and energy intensity.

Car energy demand is based on assumptions about the link of car ownership to income, as well as developments in distance driven per car and average on-road fuel economy.

The relationship between GDP and car ownership is assumed to be exponential below levels of 250 cars per 1000 in the population, with an income elasticity of 2.5 in the CIS and central and eastern Europe until 2000. The relationship is assumed to be linear for ownership levels between 250 and 450 per 1000, and then logarithmic at higher levels. The relationships are slightly modified in the different scenarios, with Markets Rule as the base case and 10 per cent lower growth in Muddling Through.

Present driving patterns are assumed to continue as at present in Markets Rule, with a slow decline in distance per car due to increasing ownership. In Muddling Through, higher oil prices and measures to control local pollution result in 2 per cent per year decline in driving per car.

Technical developments are slow in Muddling Through, giving fuel economy improvements of 0.5 per cent per year, but more rapid in Markets Rule at 1 per cent per year.

Table 27. Markets Rule scenario

| | OECD Europe | North America | OECD Pacific | CIS | Central and Eastern Europe |
|--|-------------|---------------|--------------|--------|----------------------------|
| Car Stock, 1992, million | 161.05 | 164.84 | 48.46 | 18 | 18.02 |
| MT, 2020 | 214 | 229 | 78 | 55 | 48 |
| MR, 2020 | 246 | 249 | 85 | 157 | 67 |
| Vehicle-km per car, 1992 | 13 000 | 18 000 | 11 000 | 10 000 | 12 000 |
| MT, 2020 | 10 000 | 14 000 | 9 000 | 13 000 | 12 000 |
| MR, 2020 | 13 000 | 16 000 | 11 000 | 14 000 | 13 000 |
| On-road fuel consumption, 1992, L/100 km | 9 | 13 | 11 | 12 | 11 |
| MT, 2020 | 8 | 11 | 10 | 11 | 10 |
| MR, 2020 | 7 | 10 | 9 | 9 | 9 |

Table 28. Muddling Through scenario

| | OECD Europe | North America | OECD Pacific | CIS | Central and Eastern Europe |
|--------------------------------------|-------------|---------------|--------------|-------|----------------------------|
| Total Freight in 1992, bn tkm | 1 335 | 3 270 | 351 | 4 480 | 255 |
| MT, 2020 | 2 246 | 5 629 | 651 | 4 275 | 326 |
| MR, 2020 | 3 063 | 6 846 | 841 | 8 352 | 647 |
| Rail share, % 1995 | 23 | 55 | 14 | 85 | 53 |
| MT, 2020 | 18 | 44 | 11 | 55 | 24 |
| MR, 2020 | 15 | 40 | 9 | 40 | 15 |
| Truck Energy Intensity, 1995, MJ/tkm | 4.0 | 2.5 | 5.0 | 5.0 | 5.0 |
| MT, 2020 | 3.53 | 2.21 | 4.41 | 4.24 | 4.24 |
| MR, 2020 | 3.11 | 1.95 | 3.89 | 3.73 | 3.73 |
| Rail energy Intensity, 1995, MJ/tkm | 0.35 | 0.26 | 0.35 | 0.35 | 0.35 |
| MT, 2020 | 0.31 | 0.23 | 0.31 | 0.35 | 0.35 |
| MR, 2020 | 0.27 | 0.20 | 0.27 | 0.31 | 0.31 |

The results of these scenarios for the five regions are shown below.

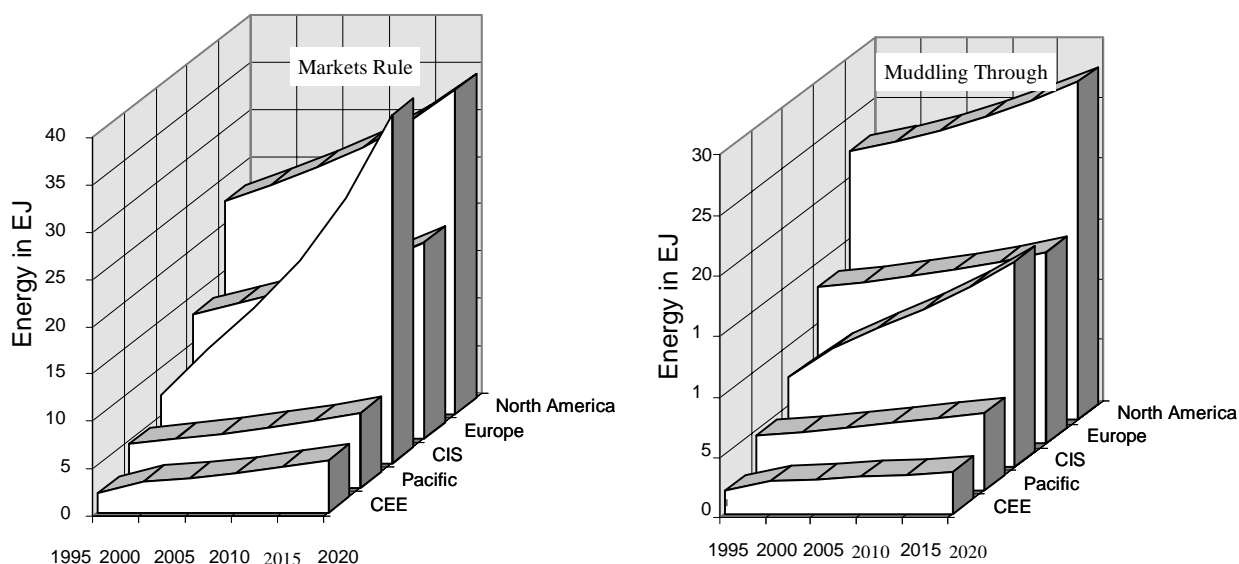


Figure 23. Regional Breakdown of Energy Use in the WEC Scenarios.

Freight energy demand is determined by mode share for road and rail, total freight transport, and the energy intensity of the two modes. The relationship between freight demand and GDP is assumed to be linear.

There is one striking difference between the WEC scenarios and others that will be reviewed below: the shape of the curves. Most other scenarios see transport energy use beginning to level off in the OECD by

about 2010, and see much less growth in the CIS. In the WEC scenarios, the continuing growth in OECD is driven by increasing freight and air transport, while passenger transport levels off or decreases towards the end of the period. The introduction to this report notes that the assumed relative importance of freight transport in the future may be proved wrong, but that at least the scenarios are not inconsistent with past trends. The high estimate of future CIS freight energy use is important to bear in mind when considering the estimates of mitigation potential in this report: low diesel prices in the CIS along with assumed price elasticities comparable with OECD Europe mean that any increment to the diesel price has a large effect. However, the CIS has historically had a very high freight intensity of GDP, and it may be that economic restructuring in the CIS will lead to much lower freight transport growth, implying smaller mitigation effects for taxes in the region.

Calculating Effects of Measures

The effects of tax measures in the two scenarios has been calculated in this paper using a set of price assumptions for the five regions as shown in Table 29. Prices in Muddling Through are incremented by 3¢ per litre in 2000 and a further 3¢ per litre in 2005, to reflect the oil price rise in that scenario.

Table 29. Gasoline and Diesel Prices in Muddling Through and Markets Rule Scenarios (US\$/L)

| Gasoline | | | | | |
|----------|--------|---------------|---------|-------|------|
| MT | Europe | North America | Pacific | CIS | CEE |
| 1995 | 0.85 | 0.29 | 1.15 | 0.3 | 0.5 |
| 2000 | 0.88 | 0.32 | 1.18 | 0.33 | 0.53 |
| 2010 | 0.91 | 0.35 | 1.21 | 0.36 | 0.56 |
| 2020 | 0.91 | 0.35 | 1.21 | 0.36 | 0.56 |
| MR | Europe | North America | Pacific | CIS | CEE |
| 1995 | 0.85 | 0.29 | 1.15 | 0.3 | 0.5 |
| 2000 | 0.85 | 0.29 | 1.15 | 0.3 | 0.5 |
| 2010 | 0.85 | 0.29 | 1.15 | 0.3 | 0.5 |
| 2020 | 0.85 | 0.29 | 1.15 | 0.3 | 0.5 |
| Diesel | | | | | |
| MT | Europe | North America | Pacific | FSU | CEE |
| 1995 | 0.6 | 0.29 | 0.76 | 0.075 | 0.4 |
| 2000 | 0.63 | 0.32 | 0.79 | 0.105 | 0.43 |
| 2010 | 0.66 | 0.35 | 0.81 | 0.135 | 0.46 |
| 2020 | 0.66 | 0.35 | 0.81 | 0.135 | 0.46 |
| MR | Europe | North America | Pacific | FSU | CEE |
| 1995 | 0.6 | 0.29 | 0.76 | 0.075 | 0.4 |
| 2000 | 0.6 | 0.29 | 0.76 | 0.075 | 0.4 |
| 2010 | 0.6 | 0.29 | 0.76 | 0.075 | 0.4 |
| 2020 | 0.6 | 0.29 | 0.76 | 0.075 | 0.4 |

The effect of changes in fuel prices on energy demand has been estimated on the approximation that gasoline is used by cars and diesel is used by freight. This neglects to take into account the large amount

of diesel used by cars in Europe and Japan and the gasoline used in road freight in North America and the CIS. Where price changes differ between the two fuels, this will introduce errors in the estimated emission changes.

As explained in Appendix B, the following price elasticities and lags in responses to fuel price have been assumed.

Table 30. Elasticities and Lags Assumed in Model

| Elasticity w.r.t. fuel price | Europe | North America | Pacific | CIS | CEE | Lag |
|---------------------------------|--------|---------------|---------|-------|-------|-------------|
| Car ownership (no. of cars) | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | 5-10 years† |
| Distance per car (km/car) | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | none |
| Car energy intensity (L/100 km) | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | 5 years |
| Total freight traffic (tkm) | -0.10 | -0.20 | -0.19 | -0.10 | -0.10 | none |
| Rail share (per cent) | 0.2 | 0.1 | 0.0 | 0.2 | 0.2 | none |
| Truck energy intensity | -0.15 | -0.15 | -0.15 | -0.15 | -0.15 | none |
| Rail energy intensity | 0 | 0 | 0 | 0 | 0 | none |

† Effect is based on effects of fuel price over previous 3 periods to take account of downsizing and technology changes. The average lag varies by region: shortest in Japan, longest in CIS.

Comparison with Other Scenarios

The WEC scenarios have been used for three main reasons:

- They are well documented, including the link between GDP and transport energy use, and can easily be reconstructed;
- They are more recent than the other scenarios;
- The range of transport energy use for 2020 in the full suite of scenarios is wider than that in the IPCC or Walsh scenarios.

The WEC scenarios were considered for use in this study alongside two other suites of scenarios. First, the Intergovernmental Panel on Climate Change's IS92 suite of scenarios, developed in 1992 (IPCC, 1995a); and second, the scenarios developed by Walsh (1993a; 1993b). The other two sets of scenarios are briefly summarised below for comparison.

IPCC IS92 scenarios

There are six scenarios in the IS92 suite. They were developed to provide indications of possible future greenhouse gas emissions to 2100. The scenarios encompass a very wide range of possible energy futures, depending *inter alia*, on GNP and population changes.

GNP growth varies by region, as follows:

Table 31. Range of GNP Growth in IS92 Scenarios

| Region | Highest (IS92e) | Lowest (IS92c) |
|---------------|-----------------|----------------|
| United States | 3.49 % | 1.94 % |
| OECD Europe | 2.94 % | 1.55 % |
| OECD Pacific | 3.77 % | 2.41 % |
| CIS and CEE | 3.25 % | 1.25 % |

Two of the IS92 scenarios are illustrated in Figure 24. IS92c is the lowest of the scenarios and has been described as having some of the characteristics of an intervention scenario (IPCC, 1995a). IS92e is the highest-growth scenario.

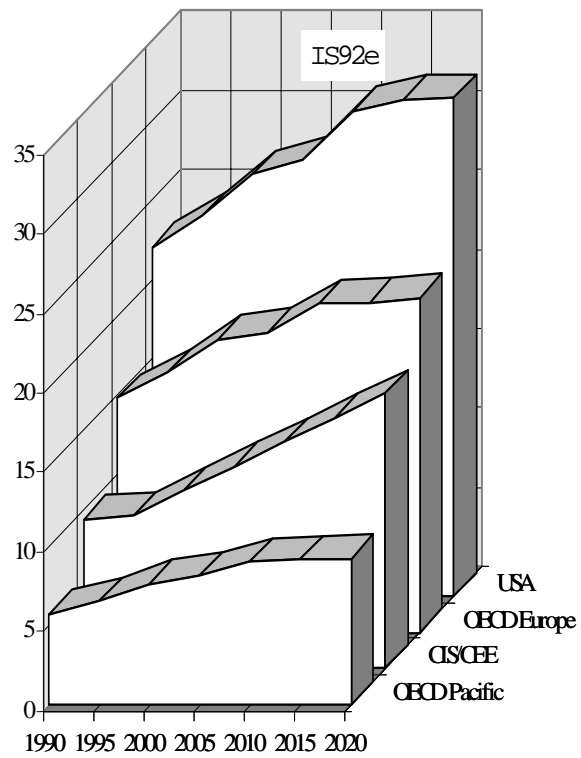
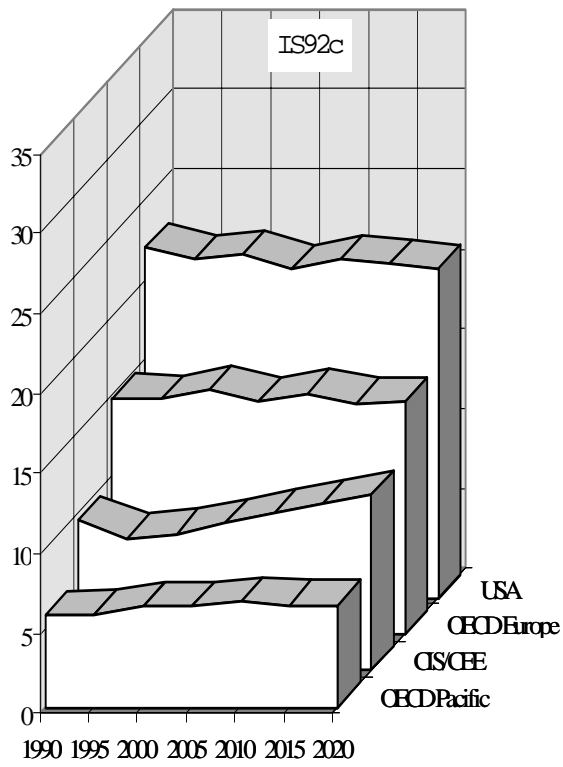
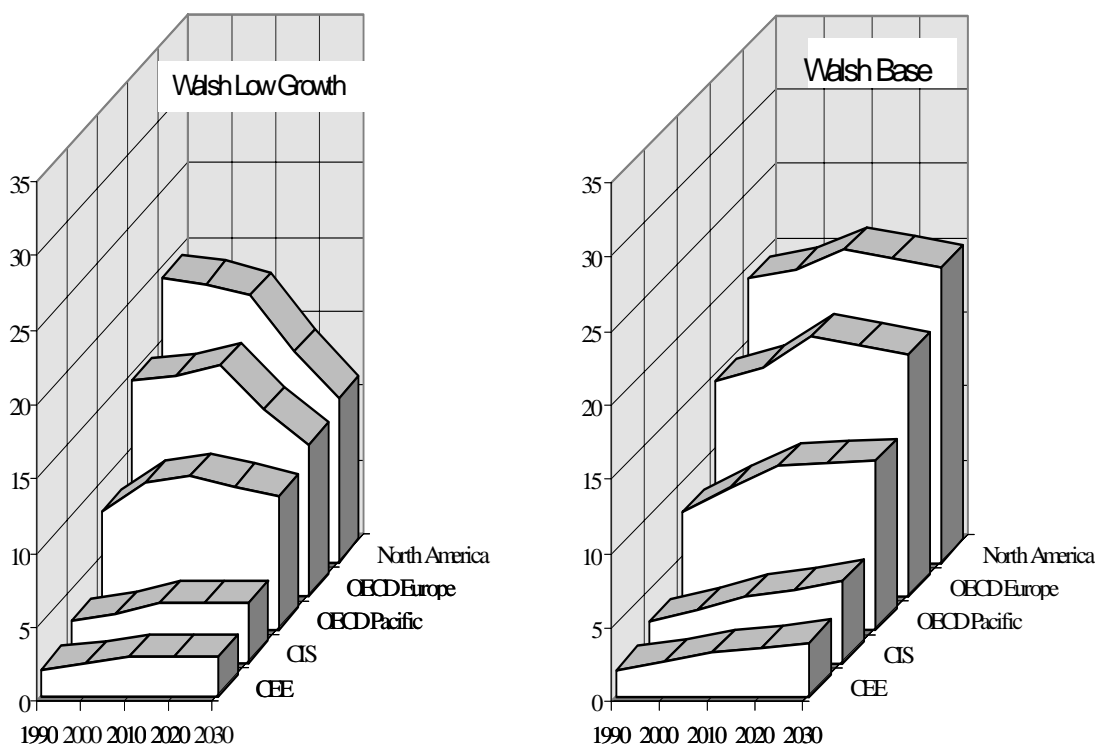


Figure 24. Transport Sector Energy Use in the IPCC IS92 Scenarios

The scenarios developed by Walsh (1993a, 1993b) have the advantage of being developed on a bottom-up basis, from vehicle stock and fuel use data, and being estimated on the basis of trajectories in vehicle ownership and mileage. Unlike the WEC and IPCC scenarios, those shown below are for road transport only, so energy use in 1990 is lower than in the other two cases.



US Annual Energy Outlook 1996

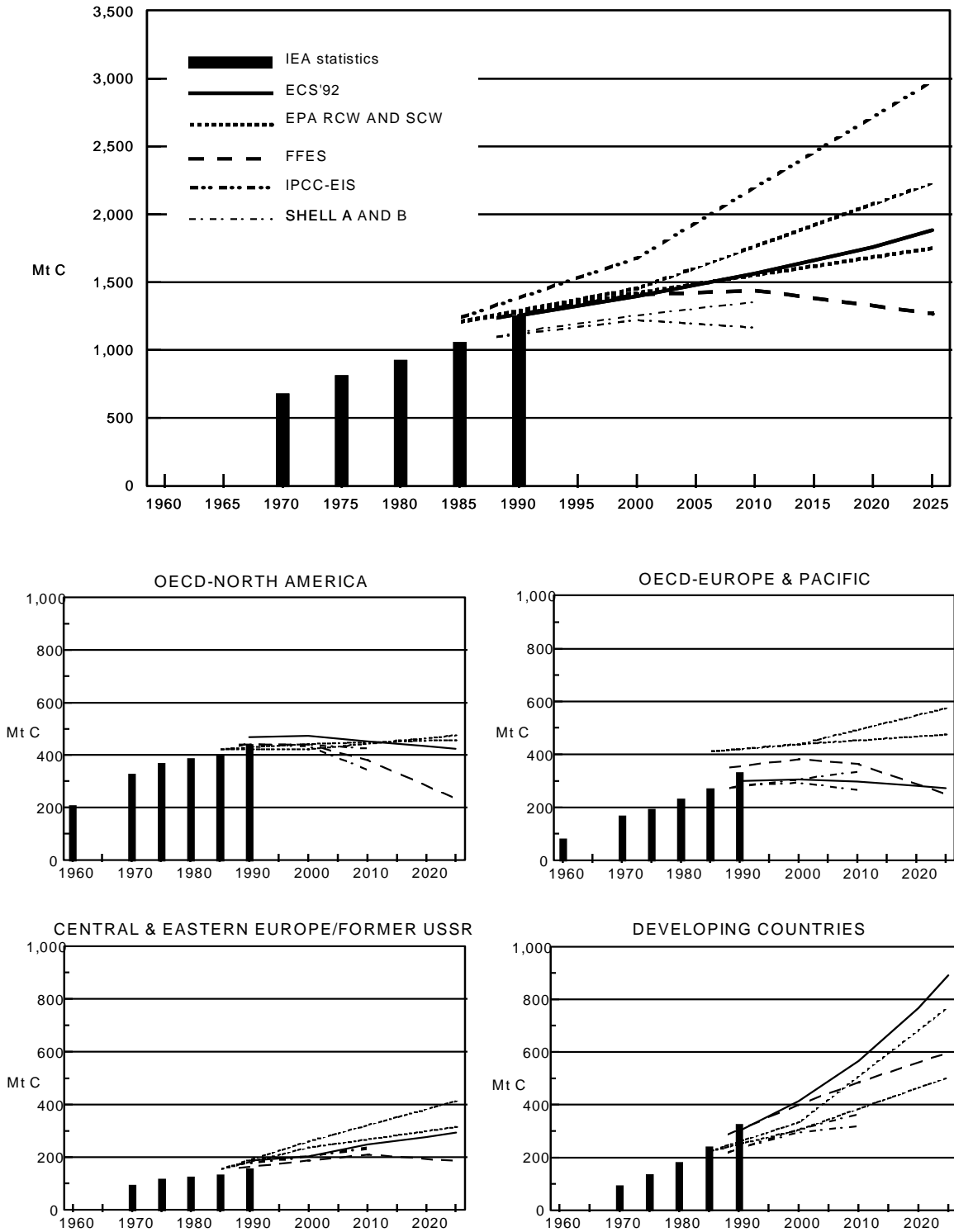
The United States Annual Energy Outlook (AEO), using the National Energy Modelling System (NEMS), might also be interesting to compare with the WEC scenarios (EIA, 1996). AEO96 is of interest because it has been fairly recently produced, and because NEMS contains one of the most sophisticated transport sector models that is available within a national energy model. The AEO96 Reference Case takes GDP growth during 1994 to 2015 to average 2.0 per cent per year, and has an oil price increasing from about \$16.5/bbl in 1993 to \$25.4/bbl in 2015 (1994 prices). Transport energy use grows from 22.9 quadrillion Btu in 1993 (24.2 EJ) to 29.9 quadrillion Btu (31 EJ) in 2015. Other scenarios test a range of oil prices, from \$20 to \$32/bbl in 2015, and economic growth ranging from 1.5 per cent to 2.5 per cent per year to find transport energy use in 2015 from 29.5 EJ to 33.6 EJ.

The two WEC scenarios, with energy use in North America growing from about 22 EJ in 1995 to 26-31 EJ in 2015, are broadly consistent with the AEO in terms of percentage growth. The absolute levels are lower (especially considering that the United States only consumes about 92 per cent of the transport energy use in North America as defined for the WEC scenarios). This is probably due to a difference in definitions but the reason has not yet been identified.

Other scenarios

The IPCC Second Assessment Report included the following diagram, which illustrates a range of transport energy scenarios from the literature. While the graphs are labelled in millions of tonnes of carbon, the range of results for growth in world transport energy use from these scenarios is broadly consistent with the ranges in IS92 and WEC.

Figure 25. Comparison of Transport CO₂-Emission Scenarios to 2025.
WORLD



Source: Grübler, 1993

APPENDIX E. FULL COST PRICING: THREE OECD COUNTRY CASE STUDIES

Three road transport case studies for France, Japan and the United States have been carried out as part of the OECD Project on the Environmental Implications of Energy and Transport Subsidies.³¹ The full case studies and project final report will be discussed in a conference in Rome, 11-12 September 1996, and will be published following the conference. The case studies examine the effects of reflecting to road users the full costs of their activities. There are three key aspects to this: (a) ensuring that road provision is fully funded through user fees; (b) improving the extent to which fees from individual road users reflect the costs associated with their road use (i.e. reducing cross-subsidies) and (c) internalising or reducing external social and environmental costs associated with road transport.

Table 32. Basic Country Transport Data

| | France | Japan | United States |
|-------------------------------------|---------|-------|---------------|
| Registered Motor Vehicles | | | |
| Cars | 24 | 37 | 143 |
| Buses | 0.077 | 0.25 | 0.6 |
| Light Trucks | 4.3 | 6.5 | 38 |
| Heavy Trucks | 0.6 | 16 | 5 |
| Total | 29 | 60 | 187 |
| Traffic (billion vehicle-km) | | | |
| Cars | 324 | 387 | 2 468 |
| Buses | 2.1 | 7.2 | 9.2 |
| Light Trucks | 71 | 2.6 | |
| Heavy Trucks | 23 | 261 | 1 000 |
| Total | 420 | 657 | 3 480 |
| Economic Data | | | |
| | France | Japan | United States |
| Exchange Rate (per 1991 US\$) | 5.64 FF | 133 ¥ | \$1 |
| GDP (US\$ bn) 1991 | 1200 | 3455 | 5656 |

Vehicle fleets and traffic levels in France, Japan and the United States are summarised in Table 32. The three countries represent the three OECD regions (Europe, Pacific, North America) and have very different transport sector characteristics:

1. France is a country with moderate population density of 105/km² — low, relative to neighbouring European countries and Japan, high, relative to North America. French cities

³¹ The study for France was provided by J-P. Orfeuill of the French transport research institute, INRETS, with funding from the French Agency for Environment and Energy, ADEME (Orfeuill, 1995). The Japanese study was provided by Professor H. Morisugi of the University of Tokyo, with support from the Japanese Ministry of the Environment (Morisugi, 1995), and US case study was carried out by S. Haltmeier of DRI/McGraw Hill, with support from the US Environmental Protection Agency (DRI, 1996).

are compact, and have high population density which falls off rapidly in their suburbs, with fairly high levels of public transport provision. Most passenger transport in France is by car, and car travel per person is higher than in other major European countries, but public transport use, especially rail use, is also higher than in most other countries. Freight transport in France is mainly by road, with only moderate use of railways. Both car use and freight volumes in France grew rapidly in the 20 years to 1991, with an 80 per cent increase in car traffic in the period. Road freight has increased while rail freight traffic has decreased.

2. Japan is a country with an average population density of 330/km², but with most of the population concentrated in a small portion of the land area in the coastal plains. Per capita rail use is higher than in France, while car use per capita is lower. Freight transport in Japan is almost entirely by road or by coastal shipping. Japan saw a very rapid increase in car use over the 20 years to 1991, with car traffic quadrupling in the period. Road freight has increased, partly at the expense of rail freight, by a factor of more than two over the same period.
3. The United States is a large country with relatively low population density of 28/km², and very high levels per person of both passenger and freight traffic. The vast majority of surface passenger transport in the United States is by car, including in most city centres. A large share of freight in the United States is carried by the railways, although road freight traffic per person in the United States is higher than total freight per person in most other countries. Car traffic has increased over the 20 years to 1991, but by a smaller percentage than in France or Japan. Road freight has also increased, but with no decline in rail freight.

In all three countries, the road network is fairly mature. However, construction of motorways continues and is the main area of network expansion.

The studies take 1991 as their base year for road transport statistics (traffic, government revenues and spending, externality estimates). They develop reference scenarios to 2010, and then assess the possible effects of changes in government policy to achieve full user fee funding. Full funding is achieved through a combination of road user charges, and measures to reduce the costs of road use.

Base Year Evaluation

Each case study starts by evaluating the balance of government spending and revenues for motor vehicle users in 1991. This raises many questions about what constitutes a government expenditure to support motor vehicle use, and what constitutes a road user payment.

The case studies use a similar approach, assessing road-related expenditure at all levels of government and including expenditure by public companies. User payments include all special taxes and fees, to government and public companies, associated with road use. Taxes that are not peculiar to road use, such as sales tax at the standard rate on vehicles, parts, fuel and services, are excluded or, in the case of Japan, only partly included. Despite this attempt at a common approach, there are areas of considerable difficulty in estimating both government expenditure and user payments. One identified in the Japanese report is the component of government expenditure that supports public and non-motorised transport — this may include the provision of sidewalks, paths, benches, lighting, policing and other facilities. This element of expenditure is not often clearly distinguished from motorised transport spending in road budgets. The Japanese report addresses this by considering two extremes: one where all government

road-related spending is for motorised vehicle users, the other where all of the spending from general revenue is considered to be for non-motorised transport. Budget allocations in the United States are perhaps more clearly defined than in other countries, with 8 per cent of road user fees and taxes assigned to mass transit expenditure.

It is still harder to identify cross-subsidies among road users, as the disaggregation of revenue data between users varies between countries, and it is not currently possible to identify definitively the costs imposed by different users. The disaggregation of revenues and outlays is not helped by the complex administrative structures in the countries studied:

- The U.S. highway system is administered by Federal and State agencies, as well as by nearly 39 000 county, township and municipal authorities. Jurisdiction over roads is decentralised, with about 80 per cent of total road mileage administered at the local level.
- In Japan, general road works are managed at a national level by the Ministry of Construction, through Regional Construction Bureaux, and at a local level by local government. The toll road system is managed separately from the general road system, and involves a number of public and private agencies (4 public corporations, 20 local authorities, 36 local public corporations, 1 private corporation).
- In France, the revenues and expenses for each category of road involve different levels of government: national, regions, "départements", and "communes".

Road user payments to the public sector

The case studies distinguish "transport-specific revenues" — funds collected from users and devoted to transport-related activities — from "general revenues", such as VAT on fuels, which go into the general budget. The split is important for evaluating subsidies: only "transport-specific revenues" can be viewed as part of payment by users for transport services. VAT on fuels, where the tax rate is the same as that on other retail goods, forms part of general taxation.

In Table 33, road user payments for the three countries are shown, broken down into taxes on fuels, taxes on vehicles, other road user charges, and non-road-specific sales taxes. The various taxes are determined in different ways in the three countries. Fuel taxes in France are determined and collected at a national level, whereas in the United States fuel taxes have a federal and a state component. The mix of national and local taxation in Japanese fuel taxes varies according to the fuel. Vehicle taxes take many forms, including: vehicle excise taxes, sales taxes and registration fees for new vehicles; and road taxes, licence fees, and insurance taxes on an annual or continuing basis.

**Table 33. Road User Payments
(US 1991\$ billion)**

| | France | Japan | United States |
|---|--------|------------------|--------------------------|
| Fuel Taxes | 17.73 | 25.6 | 39.1 |
| Vehicle Taxes (Purchase and Ownership) ^a | 6.77 | 24.9 | 10.7 |
| Other (Tolls, Penalties, Parking etc.) | 3.34 | 0.7 ^b | 11.0 |
| Total | 27.8 | 51.2 | 62.7 (59.1) ^c |
| Non-Road-Specific Sales Taxes | 19.0 | 6.9 | nq |

a) net of half of consumption taxes

b) excludes tolls, etc., which are collected by public corporations

c) net of collection expenses

nq=not quantified

Orfeuill (1995) and DRI (1996), in the French and US case studies respectively, estimate the split of road user payments between rural and urban users, and among different types of vehicle.

Public sector spending on roads

Differences among countries in the administration of public expenditure on roads make it difficult to present information from the three case studies in a common format. Table 34 shows current expenditure on road construction, maintenance, and operations (police, administrative and other road services). The distinction between construction and maintenance is somewhat blurred: a large proportion of expenditure in mature road systems is for road renewal, which can be described as either construction or maintenance. Morisugi (1995) does not make this distinction for Japan, separating only “construction” and “operations”.

**Table 34. Public Expenditure on Roads
(US 1991 \$ billion)**

| | France | Japan | United States |
|----------------------------|--------|-------|---------------|
| Construction | 7.9 | nq | 36.2 |
| Maintenance and Operations | 10.7 | nq | 33.0 |
| Current disbursements | 18.7 | 87.9 | 74.5 |

Another important distinction is between current expenditure and repayment of debt (loans or bonds). The latter may not be relevant where road construction is planned and executed by the government, funded directly from government funds. However, where some division exists between the road-building agency and the source of its funding, debt and interest payments can be a large component of spending. In Japan, the Public Highway Corporation provides and operates part of the toll road system. This system was established in the 1950s to implement a very rapid road-building programme. Of the corporation’s expenditure, 55 per cent is for debt repayments and interest (Morisugi, 1995).

The case studies break down expenditure in various ways: by type of road, by the agency responsible for the expenditure, and by the type of expenditure. Readers are referred to the original case studies for further details.

Balance of road user costs and payments

Fuel or vehicle taxes are not sufficient to cover government road-related costs in Japan and the United States, but they exceed outlays in France (see Table 35). The existing literature for individual countries reveals a very wide range in estimates of both the costs of road use, and the extent of user fees that should be considered as payments for road use. Estimates of road-related costs depend on the way in which financing is managed, and on the assumed allocation of these costs between road users and others. Lee (1993) points out that the opportunity cost of capital for road-building is higher than the interest payments on that capital, so that the cost of road provision in the United States could be as high as \$96 billion per year. In this case, road users in the United States pay only 64 per cent of infrastructure costs through user fees. On the other hand Beshers (1994) finds a cost recovery figure of up to 99 per cent. The US case study (DRI, 1996) estimates the rate of cost recovery at 79 per cent.

**Table 35. Public Sector Expenditure vs. User Fees in the Transport Sector
(1991 US\$)**

| | Public Sector Expenditure | | | | User fees | Ratio |
|---------------|---------------------------|--------------------|-------------------|---------------------------------|------------------|------------------------------|
| | Total \$ billion | per cent of GDP | Per vehicle \$ | Per unit of traffic (\$/vkm) | Total (bn \$) | Fees / public expenditure |
| France | 19 | 1.6 | 650 | 0.044 | 29 | 1.49 |
| United States | 74 | 1.3 | 400 | 0.021 | 59 | 0.79 |
| Japan (1) | 88 | 2.5 | 1500 | 0.134 | 51 | 0.58 |
| Japan (2) | | | | | | |

Cross-subsidies and other interventions

Perhaps the largest cross-subsidy between road users identified in all three case studies relates to the payment by road users for road construction and maintenance. The amounts of money that road users pay through vehicle taxes, licence fees, fuel taxes, and other fees do not relate directly to the damage caused by those road users. Some truck operators generally pay less than the costs they impose in road wear, while car drivers in some countries may pay more than their full costs, or at least a larger share of their full costs. This difference is most marked in countries where gasoline is taxed at a much higher rate than diesel fuel (Orfeuill, 1995; Morisugi, 1995). In the United States, heavy trucks are thought to pay their full costs (DRI, 1996). Medium-weight, two-axle trucks are thought to cause more damage to road surfaces than the heaviest, multi-axle trucks because these lighter trucks have higher loading per axle. These trucks are, therefore, paying less than their full costs.

A wide variety of additional distortions may affect markets for road transport. One, identified in the French and United States case studies, is the provision of free or under-priced parking spaces for employees at work. While such provision is not, in itself, a subsidy, some aspects of government policy may encourage employers to provide parking spaces while providing no incentive to provide employees with support in using public transport or bicycles. The provision of parking spaces may be encouraged, for instance, by the absence of taxation on the “in-kind” benefit, or by planning regulations that require developers to provide more parking spaces than they would as a result of market forces.

Other measures, not evaluated in the case studies, may encourage the use of cars and trucks. These include the availability in some countries of tax deductions for the cost of driving to work, government provision of compensation for accidental injury and death, and others.

External costs

Many estimates have been made of the external costs of road transport in OECD countries (ECMT, 1994). The estimates often depend on a chain of variables which have to be estimated or modelled. In the case of air pollutants, these variables include vehicle emission factors (depending on the vehicle type, location, type of driving, weather conditions etc.), pollution dispersion, reactions between pollutants, deposition on organisms and property, the physical damage caused and finally the value of that damage. Techniques for damage estimation are under active development³² and studies produce widely differing results.

³² The European Conference of Ministers of Transport (ECMT) has a Task Force on Social Costs, which is discussing and developing methodology for external cost estimation, as well as assembling new cost estimates.

Case study results

This section summarises the external cost estimates made in the case studies for the transport sectors of France, Japan and the United States. However, given the methodological and practical limitations to external cost valuation, and differences in approach between the country estimates, the scope for direct comparison is very limited.

Accidents:

Accident costs include several components which are covered to varying degrees by road user fees:

- medical costs (partly covered by insurance);
- loss of human life (partly covered through insurance);
- suffering and damage to quality of life (partly covered through insurance);
- damage to property (usually covered by insurance);
- lost production through injury and property damage (partly covered through insurance);
- police, emergency service costs (sometimes covered by road-user taxes); and
- road traffic delays (usually addressed in the context of congestion).

Most countries require road users to be insured against damage to other people's health and property. While property values, medical costs and lost earnings are relatively transparent, the value of human life is highly controversial. Meanwhile, many drivers fail to obtain insurance.

All three case studies provide estimates of accident costs based on national studies. Country estimates of the externality in Table 36 depend heavily on the value placed on human life, which ranges in the case studies from \$600k for France to \$30k for Japan, and \$0.5 to 5 million in the United States.

Table 36: External Costs of Road Accidents: France, Japan and the United States, 1991.

| | Total social costs (\$ billion) | of which externalities (\$ billion) | External cost per vehicle-km (¢/vkm) | External cost /GDP | Breakdown Among Users (%) Rural | | | | Breakdown Among Users (%) Urban | | | |
|---------------|---------------------------------|-------------------------------------|--------------------------------------|--------------------|---------------------------------|------|--------|-------|---------------------------------|------|--------|-------|
| | | | | | 2W | cars | trucks | total | 2W | cars | trucks | total |
| France | 10.6 | 7.99 | 1.9 | 0.66 % | 5.4 | 41.3 | 6.4 | 53.1 | 10.4 | 35.5 | 1 | 46.9 |
| Japan | 35.5 | 0.94 | 0.14 | 0.03 % | nq | nq | nq | nq | nq | nq | nq | nq |
| United States | 358.5 | 55.2 | 1.6 | 0.98 % | nq | 20.3 | 10.5 | 30.8 | nq | 51.8 | 17.4 | 69.2 |

nq = not quantified

Higher traffic density in urban areas tends to lead to more accidents per vehicle-kilometre than in rural areas, while lower traffic speeds mean that a smaller proportion of accidents result in fatalities. In France in 1991, 63 per cent of accidents and 28 per cent of fatalities occurred in urban areas. In the United States, 71 per cent of accidents and 41 per cent of fatalities were in urban areas. Urban areas thus account for 46 per cent of estimated accident costs in France, and 69 per cent in the United States.

Accident costs also depend on the type of vehicle: when a truck is involved in an accident with a car, the car occupants are much more likely to be killed than the truck occupants. Similarly, in an accident between a car and a bicycle, the cyclist is much more likely to die than the car driver. The French case study attempts to deal with this problem, where accidents involve vehicles of different types, by allocating half of accident costs equally among vehicles involved in each accident, and half to the heaviest vehicle involved in the accident. The U.S. case study allocates costs according to the distance travelled by each vehicle type.

Noise

Various approaches have all been used to measure the damage value associated with noise. The case study estimates are shown in Table 37.

- the French report estimates the cost of reducing noise exposure through vehicle noise reduction and soundproofing of homes to achieve indoor exposure levels below 60 dB(A). Costs would be borne partly by vehicle owners (\$0.82 billion per year), and partly by households (\$2.29 billion per). The latter cost constitutes an externality of road use if it is not recovered from vehicle users. There is a residual externality, not estimated, associated with noise exposure that occurs despite soundproofing.
- the Japanese report uses estimates based on willingness to pay studies in Germany (Kågesson, 1991). These estimates are increased in proportion to the population exposed to excessive noise in Japan, which is higher than that in Germany (OECD, 1991). The study estimates an externality of 0.32¢ per passenger-kilometre caused by passenger transport, and 0.16¢ per tonne-kilometre caused by freight transport.
- the U.S. report uses a hedonic pricing-based estimate of 0.06¢ per car-kilometre and 0.25¢ per truck-kilometre (Ketcham, 1991).

Table 37 Externality Associated With Noise Exposure: France, Japan and United States, 1991.

| | Total social costs (\$ billion) | of which externalities (\$ billion) | External cost per vehicle-km (¢/vkm) | External cost /GDP | Breakdown Among Users (%) Rural | | | | Breakdown Among Users (%) Urban | | | |
|---------------|---------------------------------|-------------------------------------|--------------------------------------|--------------------|---------------------------------|------|--------|-------|---------------------------------|------|--------|-------|
| | | | | | 2W | cars | trucks | total | 2W | cars | trucks | total |
| France | 10.6 | 7.99 | 1.9 | 0.66% | 5.4 | 41.3 | 6.4 | 53.1 | 10.4 | 35.5 | 1 | 46.9 |
| Japan | 35.5 | 0.94 | 0.14 | 0.03% | nq | nq | nq | nq | nq | nq | nq | nq |
| United States | 358.5 | 55.2 | 1.6 | 0.98% | nq | 20.3 | 10.5 | 30.8 | nq | 51.8 | 17.4 | 69.2 |

a) includes vibration effects

As most exposure to traffic noise occurs in urban areas, the U.S. and Japan case studies allocate the social cost of noise exposure to urban traffic. In France, 20 per cent of the cost is assumed to be in rural areas.

Air pollution

Air pollution causes damage to human and animal health, crops and materials. Direct valuation methods are used to estimate the social costs of the last three of these (loss of farm revenue, cost of monument renovation etc.), while indirect methods are normally used to estimate the cost of damage to human health. The OECD case studies use a mix of approaches to obtain the results in Table 38.

- The Japanese case study uses avoidance costs based on estimates from Kågeson (1993).
- The French case study considers a range of estimates, based on avoidance and damage costs, to find a wide range of possible values.
- The U.S. report uses damage-based estimates (DeLuchi et al., 1987), again, with a wide range of possible values.

Table 38. Social costs of air pollution in France, Japan and the United States, 1991.

| | Ext. costs (billion \$) | Ext. costs/veh- km (¢) | Ext. costs / GDP | Breakdown Among Users (%) | | | | Breakdown Among Users (%) | | | |
|---------------|----------------------------|------------------------------|---------------------|---------------------------|-------|--------|-------|---------------------------|-------|--------|-------|
| | | | | Rural | | | | Urban | | | |
| | | | | 2W | cars | trucks | total | 2W | cars | trucks | total |
| France | 2.84 to 6.56 | 0.68 to 1.6 | 0.24 % to 0.55 % | 0 | 16 | 4 | 20 | 5 | 71 | 4 | 80 |
| Japan | 1246 % | 1.9 | 0.36 % | | | | | | | | |
| United States | 13.4 to 201 | 0.4 to 5.8 | 0.24 % to 3.55 % | -- | 15-27 | 51-14 | 66-41 | -- | 22-39 | 12-21 | 34-59 |

Several of the components of air pollution externality estimates are very uncertain and valuations can be very subjective, providing little or no foundation for comparisons between countries.

Climate change

The country case studies use a variety of carbon emission costs as shown in Table 11, along with the externality associated with the transport sector.

Table 39. Social Costs Associated with Carbon Emissions

| | \$ per tonne of CO ₂ | Total external cost (billion \$) | External cost / veh-km (\$) | Ext. costs / GDP | Breakdown Among Users (%) | | | | Breakdown Among Users (%) | | | |
|---------------|------------------------------------|--|--------------------------------|---------------------|---------------------------|-------|--------|-------|---------------------------|-------|--------|-------|
| | | | | | Rural | | | | Urban | | | |
| | | | | | 2W | cars | trucks | total | 2W | cars | trucks | total |
| France | 5.5 to 19 | 0.62 to 2.5 | 0.0015 to 0.006 | 0.05 % to 0.2 % | 0.5 | 39 | 19.5 | 59 | 0.5 | 37 | 3.5 | 41 |
| Japan | 20 ^a | 4.0 | 0.61 % | 0.12 % | | | | | | | | |
| United States | 3.2 to 13 | 1.8 to 8.6 | 0.0008 to 0.003 | 0.03 % to 0.15 % | -- | 26-26 | 16-15 | 42-41 | -- | 37-38 | 21-21 | 58-59 |

a) secretariat estimate

The French and U.S. case studies estimate fuel consumption by each vehicle type, and hence CO₂ emissions and the externality associated with climate change. The urban-rural split is based on vehicle kilometres in each case (i.e. no allowance is made for difference in fuel economy between rural and urban areas).

Congestion

There is an ongoing debate regarding the treatment of the time lost and frustration caused by traffic congestion as an external cost. This cost can be viewed in many ways. One approach is to consider the

leisure and commercial time lost associated with traffic delays. Another is to consider the cost of road building to allow for the capacity requirements of peak traffic flows.

A theoretically correct measurement of the marginal external cost associated with delays caused by congestion can be estimated using models of traffic flow and the effects of additional vehicles. Newbery (1990) uses this approach to show that the marginal external cost for drivers in urban areas at peak hours can be as high as 36 pence/kilometre (about 50¢/kilometre). A simpler approach measures the total time spent by drivers on congested roads versus the time they would spend on a road with free-flowing traffic.

Such valuations require an estimate of the value that transport users place on time spent travelling. This value will depend on the mix of freight and passenger traffic, and within the latter group the mix of business and non-business traffic. Values will also vary according to the time of day and location.

Congestion pricing is usually proposed as a means of reducing congestion and sharing out road space, rather than as a means of internalising the costs of congestion. It is normally anticipated that congestion fees would be paid to the government, not to the other drivers who are suffering from delays. Indeed, if the latter were to occur, the average driver would end up neither gaining nor losing, apart from transaction costs.

An alternative means of sharing out road space is to allocate property rights in a competitive market. This occurs to a limited extent in some toll road systems, and in locations where alternative means of crossing a river or strait compete. However, this approach is not currently viable for local roads, where the tolls that could be collected do not justify the transaction costs.

The three case studies take various positions in this debate:

- the French report considers delays to car and truck users to be internalised in the decision to use roads, but estimates costs incurred by public transport companies as a result of congestion as well as the cost of delays to public transport users and pedestrians (CETUR/SOFRETU, 1994);
- the United States report does not address costs to non-drivers, but uses an estimate based on the loss in work productivity not borne by drivers, and the aggregation over all other drivers of the marginal increase in costs associated with the additional delay caused by each driver (MacKenzie *et al.* 1992; Shrank *et al.*, 1990);
- the Japanese report considers that congestion costs are not externalities because they are totally borne by road users.

Table 40. External Costs of Road Congestion, France, Japan and United States, 1991.

| | Ext. costs (billion \$) | Ext. costs / veh-km (¢) | Ext. costs / GDP | Breakdown Among Users (%) | | | Breakdown Among Users (%) | | |
|------------------|----------------------------|----------------------------|---------------------|-----------------------------|--------|-------|-----------------------------|--------|-------|
| | | | | Rural | | | Urban | | |
| | | | | cars | trucks | total | cars | trucks | total |
| France | 2.66 to 5.14 | 0.63 to 1.2 | 0.22 % to 0.43 % | 0 | 0 | 0 | 97 | 3 | 100 |
| Japan | 0 % | 0 | 0 % | | | | | | |
| United States | 43 to 100 | 1.2 to 2.9 | 0.76 % to 1.77 % | 0 | 0 | 0 | 60 | 40 | 100 |

Congestion is treated entirely as an urban phenomenon in both the French and the U.S. reports. The U.S. study assumes that a truck-km (light or heavy) causes twice as much congestion as a car-kilometre. The French report assumes that a light truck-kilometre causes 50 per cent more congestion than a car-kilometre, and a heavy truck-kilometre causes as much congestion as 3 car-kilometre.

Balances

Table 41 summarises the overall social cost balances in 1991, calculated in the three case studies for road transport users.

Table 41. Social Cost Balance for Road Transport Users, 1991 (US\$ billion).

| | France | Japan | United States |
|-----------------------------------|---------------|-------------|----------------|
| (1) Net user taxes & fees | 27.84 | 50.96 | 59.105 |
| (2) Public outlays | 18.69 | 87.89 | 74.49 |
| (3) External costs | 16.4 to 24.46 | 24.78 | 117.5 to 371.3 |
| (4) Balance =(1)-(2) | +9.2 | -37 | -15.4 |
| (4) Average ¢/km | +2.2 | -5.6 | -0.44 |
| (5) Balance =(1)-(2)-(3) | -7 to -15 | -62 | -133 to -387 |
| (5) Average ¢/km | -1.7 to -3.6 | -9.4 to -10 | -3.8 to -11 |
| (6) Employer-provided. Parking | 3.55 | negligible | 19 |

The social cost balance (5) is less reliable because of the uncertainty and controversy associated with external cost estimates. The figures for the three countries are not comparable, having been calculated using different methodologies and including different types of externality. Nevertheless, within each study, a negative balance indicates a finding that road users impose costs on society, which exceed their payments to the government in fees and special taxes on road use.

Orfeuil (1995) carried out a more detailed analysis for France to determine the balance for urban and rural transport and different types of vehicles (5). He found that:

- gasoline cars cover their costs (in all areas with low externality estimates, in rural areas only with high estimates of externalities);
- diesel cars and light trucks cover their costs less than their gasoline equivalents, mainly because diesel taxes are lower than gasoline taxes;
- urban road users on average do not cover their costs;

- motorcycles and heavy trucks do not cover their costs in urban or rural areas: in the case of motorcycles the main reason for this is their high accident rate.

Policy options and results

Having estimated road-user fees and costs to the public sector, and external costs in France, Japan and the United States, the three case studies investigate the effects of moving towards balancing costs and fees. This section summarises the methods chosen, the types of policy change examined, and the estimated effects on road users and the social costs they impose.

All three case studies develop a base-case scenario of traffic, fuel consumption, and CO₂ emissions in 2010. Based on these results and on any assumed changes in prices, public expenditure etc., they estimate a social cost balance for road-users in 2010. They then develop alternative scenarios in which fees and costs are balanced, and compare these with the base-case scenarios.

Base-case scenarios

Methodology

The three case studies have used different types of model to estimate reference case transport activity:

- The French report calculates the private car fleet size using a detailed car ownership model. Historical data are used to estimate future car ownership by different groups e.g. elderly people and couples. In this model the influences of income and fuel prices on car ownership are negligible, although they have an effect on distances travelled. Freight traffic is estimated in an econometric model and is closely linked to economic growth. The influence of fuel prices on freight is negligible.
- The Japanese team developed a model for their projections. The model estimates total passenger and freight transport demand by fitting logistic curves (market penetration S curves) to historical data — i.e. transport activity is assumed to depend mainly on time and had already begun to saturate by 1990. It should be noted that, while this approach has been used elsewhere, transport markets have so far exceeded analysts' expectations and have surpassed anticipated saturation levels. Road transport shares of passenger and freight transport are assumed to be determined by the gasoline and diesel price respectively. Thus, these are the main policy tools considered in the report.
- The U.S. team used the DRI/McGraw-Hill Transportation Sub-model of the U.S. Energy Model, and the U.S. Macroeconomic Model. The models are interdependent and must be solved in several iterations to determine the macroeconomic feedback effects of changes in taxes. In the reference scenario, the U.S. Macroeconomic Model is solved with an exogenous projection of the world oil price, along with other assumptions regarding economic policy and demographic trends. The results of the model (economic activity, inflation, interest rates and vehicle sales) are used to determine transportation demand. A key assumption in the United States study is that drivers operate with a fixed travel budget. This assumption feeds through into the response of drivers to various types of fee.

The reference scenarios developed in the reports estimate road transport activity levels between 1991 and 2010. The studies assume that traffic is not affected by major regulations or large changes in economic and other circumstances during the period.

France

In the reference scenario, Orfeuil (1995) assumes 2.5 per cent per year average growth in GDP. Continuing high gasoline taxes lead to a very large shift to diesel cars and light trucks. The fastest traffic growth is in freight, especially foreign trucks, and motorway traffic (see Table 42)

Table 42. Reference Scenario Traffic to 2010, France

| Traffic type | Billion vehicle-km travelled | | % Change |
|-----------------------|------------------------------|-------|----------|
| | 1991 | 2010 | |
| 2w | 17 | 17 | 0 % |
| Gasoline cars | 235 | 223 | -5 % |
| Diesel cars | 89 | 243 | +173 % |
| Light gasoline trucks | 25 | 0 | -100 % |
| Light diesel trucks | 46 | 120 | +160 % |
| Heavy trucks | 26 | 42 | +62 % |
| Buses | 2.8 | 3.9 | +39 % |
| Urban | 162.6 | 225.6 | +39 % |
| Rural | 278.2 | 423.3 | +52 % |
| Total | 440.8 | 648.9 | +47 % |

Although there is a considerable increase in revenues associated with vehicle use (tolls and parking fees), overall revenue rises a little less than overall traffic because of the shift to from gasoline to diesel fuel.

External costs in 2010 depend not only on assumed changes in the physical effects of transport but also on the value placed on those effects. The French case study gives a "high" valuation of externalities based on damage prices increasing in proportion to GDP (60 per cent increase from 1991 to 2010), and a "low" valuation based on no such increase.

Based on these changes in public sector revenues and outlays, and in externalities, the overall balance is calculated in Table 43.

Table 43. Road Users' Social Cost Balance, France, Base-Case Scenario to 2010

| | US\$ billion | | Change |
|-----------------------------|--------------|----------------------|------------------|
| | 1991 | 2010 | |
| (1) Net user taxes and fees | 27.9 | 36.2 | +30 % |
| (2) Public outlays | 18.7 | 28.2 | +51 % |
| (3) External costs | 20.1 | 18.2 - 29.1 | -9.5 to +45 % |
| (4) Balance =(1)-(2)-(3) | 10.9 | -10.2 to -21.2 | -94 % |

The characteristics of the disaggregated French balance for 2010 are similar to those in 1991:

- gasoline cars cover their costs overall, but have negative balances in urban areas;
- diesel vehicle and motorcycles have negative balances;
- figures are always worse in urban areas.

The French subsidy per vehicle-kilometre increases by 25 per cent during the period 1991 to 2010.

Japan

As a result of the assumed saturation, road passenger traffic grows relatively slowly in Japan from 869 billion passenger-kilometre in 1991 to 1 035 billion passenger-kilometre in 2010, an increase of about 19 per cent. Freight traffic grows only 2 per cent from 284 to 290 billion tonne-kilometre. Vehicle traffic overall grows 12 per cent from 657 to 738 billion vehicle-kilometre in the same period. Road shares of freight and passenger traffic are assumed to remain constant, as fuel prices do not change.

Public revenues are assumed to be linked directly to the total number of trucks and cars registered, which in turn depends directly on the volume of traffic. The regression relationships derived in the case study are not good fits to historical data, and probably underestimate future vehicle registrations. Calculated revenues from road users grow faster than traffic, while public outlays grow faster still (see Table 44). This is probably an artifact of the model and would not have occurred if revenues had been separately linked to cars and trucks. Most of the traffic growth is in cars, which have a relatively low annual distance driven per vehicle, so that the percentage increase in the total (car plus truck) fleet is larger than the percentage increase in traffic.

External costs are calculated assuming constant costs per unit of traffic.

Table 44. Road Users' Social Cost Balance, Japan, Base-Case Scenario to 2010

| | 1990 | 2010 (\$ billion) | Change |
|-----------------------------|------|-------------------|--------|
| (1) Net user taxes and fees | 71.8 | 88.2 | +23 % |
| (2) Public outlays | 87.9 | 112.5 | +28 % |
| (3) External cost | 20.7 | 24.2 | +17 % |
| <i>Of which: Noise</i> | 3.2 | 3.7 | |
| <i>Pollution</i> | 12.5 | 14.6 | |
| <i>Accidents</i> | 0.9 | 1.1 | |
| <i>GHG emissions</i> | 4.0 | 4.7 | |
| (4) Balance =(1)-(2)-(3) | 36.7 | 48.4 | -32 % |

Based on these assumptions, the deficit in the social cost balance of Japanese road users increases 18 per cent from 5.6 to 6.6 US¢/vehicle-kilometre between 1991 and 2010, while the deficit in public sector road funding increases over 30 per cent from 2.5 to 3.3 US¢/vehicle-kilometre.

United States

As a result of the fixed budget constraint, miles travelled by cars and car substitutes are determined by the cost per mile of driving, the number of drivers, and income. Freight traffic is a function of fuel cost and economic activity. In the base case, the cost of fuel is taken as a proxy for the cost per mile of driving — thus, the price of fuel and the fuel economy of the fleet have a strong influence on the projected fleet mileage.

Light duty vehicle (LDV) fuel economy increases (in mpg) at 0.8 per cent per year from 18.6 mpg in 1991 to 21.6 mpg in 2010, and heavy truck fuel economy increases at 1.0 per cent per year from 5 mpg in 1991 to 6 mpg in 2010. Real GDP increases at 2.3 per cent per year over the period. The cost of gasoline is roughly constant to 2000 and then increases by about 20 per cent to 2010. Overall the cost of driving decreases slightly to 2000, and then increases again to slightly exceed 1991 levels in 2010. The resulting reference case traffic is shown in Table 45.

Table 45. Vehicle Miles Travelled in the Reference Case

| | 1991 | 2000 | 2010 |
|-----------|------|------|------|
| Peak LDV | 814 | 1044 | 1258 |
| Other LDV | 1167 | 1433 | 1671 |
| HDV | 113 | 162 | 208 |

In the reference case, total highway disbursements increase in real terms from US\$90 billion in 1993 to US\$105 billion by 2010, or 1 per cent annually. The share of user fees as a source of funds holds steady at 75 per cent over the forecast period.

Subsidy removal: scenario description and results

France

“Synthesis” scenario:

The French report, noting the political difficulty in raising fuel taxes sufficiently to internalise costs, investigates a strategy relying more on regulations and agreements. As such measures are hard to model, the French study makes a number of assumptions regarding their effects.

Four new measures generate additional revenue: parking fees in towns; taxation on employer-provided parking; suppression of free parking in city centres; reduction of tax exemptions related to travelling to work by car. Public income increases by 8 per cent compared to the Base Case with most of the increase coming from light vehicles in towns.

Expenditure requirements decrease relative to the Base Case because of reduced urban traffic, but this is offset by an increase in spending on measures to reduce noise and accidents. Overall, public sector outlays decrease marginally (by 0.5 per cent) relative to the Base Case.

The Synthesis scenario incorporates measures to reduce noise, local pollution, greenhouse gas emissions, and accidents. The principal measures are:

- Progressive increases in investment in noise protection, resulting in a one-third reduction in noise exposure.
- Introduction of routine vehicle emission inspections, with the obligation on owners to ensure that their vehicles meet the original emission standard under which they were licensed. This measure is assumed to reduce emissions by 15 per cent and fuel consumption by 5 per cent (through improved engine maintenance).

- Withdrawal of the 50 per cent reduction in annual licence fee applied to vehicles over five years old with the increased revenue being used to reduce taxes on low income households. This is assumed to increase the rate of car scrapping, especially for those vehicles that cannot meet emission standards and require extensive maintenance work. The result is a further 35 per cent reduction in urban pollution.
- A mix of measures to improve road safety, including restricting access to the most dangerous vehicles to very experienced and save drivers, increasing road patrols, investing in safety measures etc. These measures reduce accidents by 24 per cent.
- Additional measures, in particular parking controls and fees, reduce urban traffic by 11 per cent.

The overall effect of these measures on road transport externalities can be seen in Table 36.

Table 46. External costs (high estimates) of road transport in France, 2010

| Synthesis Case vs. Base Case | | | |
|------------------------------|-----------------|----------------------|------------|
| | Base US\$ bn | Synthesis US\$ bn | Difference |
| Noise | 3.83 | 2.58 | -33 % |
| Pollution | 4.54 | 3.18 | -30 % |
| GHG | 5.59 | 4.94 | -12 % |
| Accidents | 9.77 | 6.75 | -31 % |
| Congestion | 5.37 | 4.60 | -14 % |
| Total | 29.10 | 22.05 | -24 % |

The resulting social cost balance is still negative but the deficit is half that in base case. The remaining subsidy is still predominantly to gasoline light duty vehicles in urban areas.

Table 47. Social cost balance for road users, France, 2010

| | Base US\$ bn | Synthesis US\$ bn | Change |
|-----------------------------|-----------------|----------------------|--------|
| (1) Net user taxes and fees | 36.2 | 39.02 | +8 % |
| (2) Public outlays | 28.2 | 28.09 | -0.5 % |
| (3) External costs | 18.2 to 29.1 | 13.8 to 22.1 | -24 % |
| (4) Balance =(1)-(2)-(3) | -21.2 | -2.9 to -11.1 | +47 % |

The French report notes that the residual subsidy to road-users could be eliminated through increases in fuel tax. These would ideally be higher for diesel than for gasoline, and for urban areas than for rural areas. The average tax increase required on road transport fuel is between 6 and 22 US¢ per litre, depending on the size of the externality estimate and assuming no effect on fuel consumption.

Japan

"Fair Pricing" scenario:

The Japanese report develops a model to determine "fair prices" for diesel and gasoline. The underlying hypothesis of the model is that the components of the balance (public income, public outlays, external costs) are directly correlated to the number of registered vehicles, which in turn is determined by fuel prices. Macro-economic consequences are not studied.

In this scenario, gasoline and diesel taxes are set equal, and the tax rate is then adjusted until the model gives a zero balance. The model is in fact solved in an iterative process, with the residual balance in each iteration used to determine the change in fuel tax before the model is solved again.

Table 48 gives the results of this modelling process. To give a zero balance in 2010, fuel prices would need to reach 155 ¥/litre or US\$1.17 per litre, representing a 41 per cent increase in gasoline prices and a 109 per cent increase in diesel prices. Higher fuel prices lead to traffic (total vehicle-kilometre) in 2010 reduced by 12 per cent relative to the base case — i.e. returned to the 1991 level.

Freight transport, with a 20 per cent reduction in traffic, is affected more than passenger transport because the diesel price increases more than the gasoline price. The reduction in road freight is assumed to lead to an increase in rail and sea freight.

Overall, public income is increased relative to the base case as a result of the fuel tax increase, despite reductions in other revenues associated with vehicle use. Meanwhile the reduced traffic results in less need for public expenditure. External costs are not significantly affected.

Table 48. Results "Fair Price" Scenario, Japan, 2010

| | 2010 Base Case | 2010 "Fair Price" |
|-----------------------------|-------------------|----------------------|
| Gasoline Price | 110 ¥/litre | 155 ¥/litre |
| Diesel Price | 74 ¥/litre | 155 ¥/litre |
| Road Travel | 945 bn pass-km | 901 bn pass-km |
| Road Freight (| 282 bn tonne-km | 229 bn tonne-km |
| (1) Net user taxes and fees | 107.65 | 144.31 |
| (2) Public outlays | 135.17 | 116.67 |
| (3) External cost | 29.55 | 27.64 |
| Of which: Noise | 4.56 | 4.27 |
| Pollution | 17.81 | 16.72 |
| Accidents | 1.39 | 1.25 |
| GHG emissions | 5.73 | 5.35 |
| Balance | -57.07 | 0 |

A sensitivity analysis shows that, with externality unit prices rising relative to those in 1991, by a factor of two to 2010, the "fair price" for diesel and gasoline would be 185 ¥/litre (US\$1.39/litre).

United States

The United States report presents two alternative scenarios, in which subsidies are eliminated through road user fees. In both scenarios, the current set of user fees are left in place to pay for general roadway services. New user fees are introduced so that expenditures on road transport out of general tax revenue can be eliminated. This allows for a reduction in federal personal income taxes, state and local property taxes, state sale taxes, and state corporate and personal income taxes.

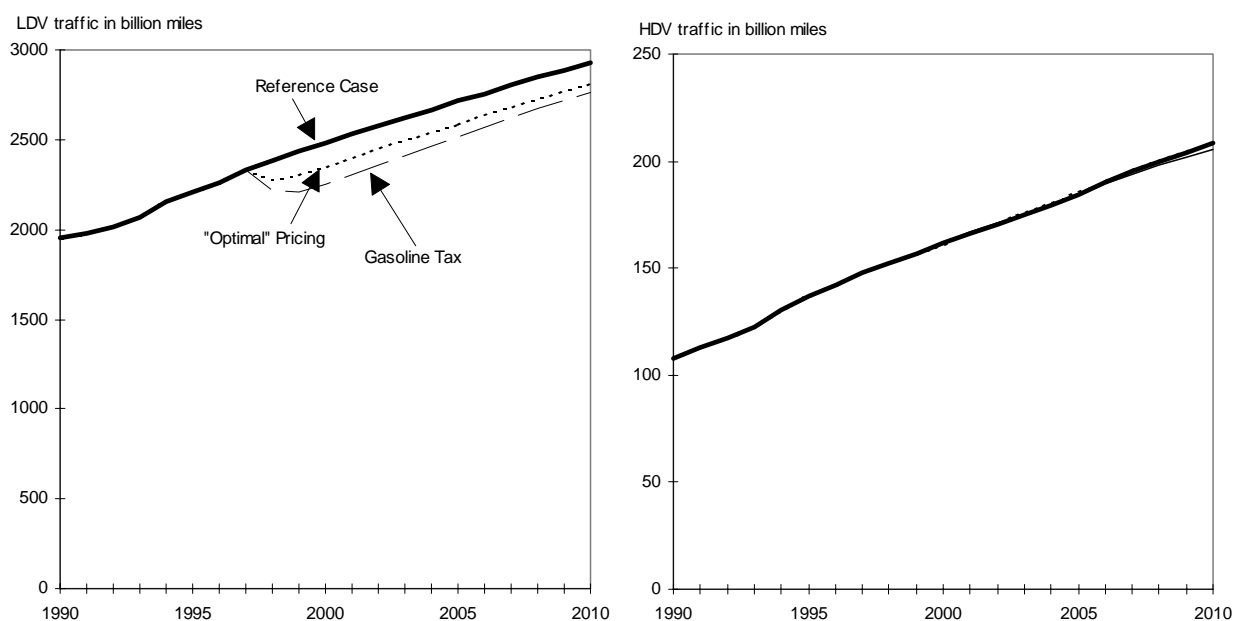


Figure 26. Traffic Levels in US Case Study Reference and Alternative Scenarios

"Optimal Pricing" scenario

In this scenario, congestion costs are internalised to car drivers through congestion pricing and parking fees, weight per axle fees for trucks finance road and highway construction. The new fees gradually replace other existing sources of funding for road and highway construction, including fuel taxes. The fees are included in the DRI model as changes in the cost per mile of driving. At the same time, highway spending is reduced slowly towards "optimal" levels which are thought to be about 65 per cent of historical levels. By 2010, highway spending is reduced to 90 per cent of the Base Case level. This is not assumed to affect the level of traffic.

The increased cost per mile of light duty vehicle use results in a 4 per cent drop in vehicle kilometres travelled. There is no change in total freight tonne-kilometres, because the DRI transportation model treats freight traffic as a function of the cost per gallon of fuel. However, the weight-per-axle fees causes a shift to larger vehicles with more axles.

Fuel consumption falls by 12 per cent relative to the Base Case, resulting in a proportionate reduction in CO₂ emissions.

"Gasoline Tax" scenario

In this case, gasoline tax and parking costs are increased to fully cover highway expenditures and congestion costs. Diesel tax is unchanged because the large trucks that are responsible for the majority of diesel use are thought to cover their costs already, while half of medium-size trucks, which do not cover their costs, use gasoline. Nevertheless, it is recognised that this approach is a less-than-optimal solution to "full-cost pricing" for road users.

The final retail price of gasoline is 33 per cent higher in 2000 and 16 per cent higher in 2010 than in the base case. As a result of this, light duty vehicle traffic is reduced by 6 per cent relative to the Base Case; freight tonne-kilometre is reduced by 1 per cent; and total highway fuel use is 15 per cent below the Base Case in 2010, with LDV fuel use reduced by 18.5 per cent. LDV fuel economy improves as a result of the increased gasoline price, through a combination of model mix-shifting and technical improvements.

Economic Effects

DRI (1996) investigate the effects of user-fee road funding on the economy using the DRI US Macroeconomic Model. Because the increased road-user fees are used to reduce other types of taxation, they tend to reduce consumer prices in other parts of the economy. However, the net effect is an increase in consumer prices. Demand for vehicles is reduced, with a decrease in particular in sales of light trucks, slightly offset by an increase in car sales. Nevertheless, in the short run, reduced demand for imported gasoline leads to an increase in spending on other goods, and hence increased domestic economic activity. The subsequent economic response depends on the way the Federal Reserve reacts to the inflationary pressure from the increased cost of driving. If the Federal Reserve does not accommodate the increased inflation, economic activity is reduced below that in the reference case by an increase in interest rates. This reduces investment and hence productive capital and GDP. Reduced spending on roads further reduces GDP during 2006-2010. However, DRI (1996) expect that interest rates would subsequently fall, pushing GDP back up.

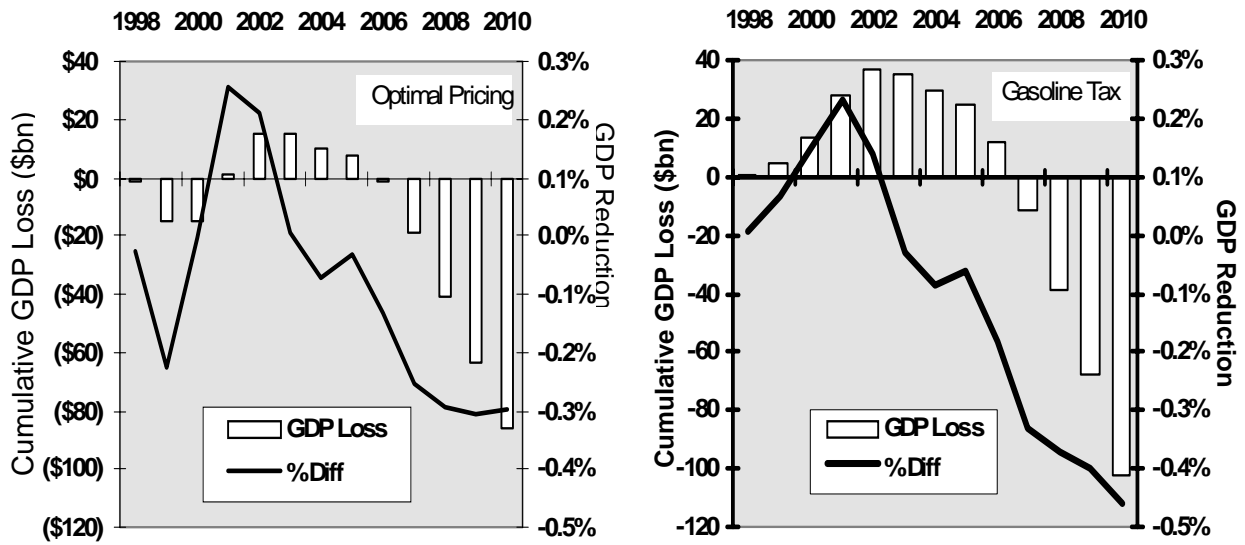


Figure 27. Economic Effects of Full User-Fee Road Funding in United States

If the Federal Reserve does accommodate the increased inflation, GDP losses are increased in the early years, but decreased later.

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