University of London
Centre for Transport Studies
ESRC Transport Studies Unit

NEW ROAD VEHICLE TECHNOLOGIES AND THE FUTURE OF MOTORING TAXATION

Graham Parkhurst

ESRC TSU publication 2001/2
July 2001

Also available at http://www.ucl.ac.uk/~ucetgpp/roadtech.htm

Address: Dr G P Parkhurst
Research Fellow
ESRC Transport Studies Unit
Centre for Transport Studies
University College London
Gower Street
London WC1E 6BT
Tel: +44 20 7679 1587
Fax: +44 20 7679 1586
Email: graham@transport.ucl.ac.uk

SUMMARY

Overview

1. Pro-environmental transport policies and technological change in the automotive sector will have tax revenue and tax system implications for governments worldwide, and particularly that of the UK, where motoring taxes have been acknowledged to be critical to the maintenance of public spending plans.

2. The present paper seeks to appraise the possible problems that may arise from the twin UK Government policy strategies of increasing restraints on traffic growth and promoting fuel efficiency, which can be hypothesised to affect the quantity and pattern of national fuel consumption. Estimates are presented of the potential magnitude of changes in tax revenue from car use only over the decade 2000-2010; the period for which a national transport plan has been published. Constraints that can be expected to affect motoring taxation policy over a longer timeframe are also identified.

3. It is found that taxation revenue from car use will reduce over the decade, unless increases in duty rates are made. The extent of the reduction will be strongly influenced by the rate of adoption of alternative-fuel vehicles. A second key finding is that there will be a considerable widening in the range of vehicle efficiency performance over the next decade, which suggests that any significant fuel duty increases could lead to some motorists being unreasonably disadvantaged. Consideration is given to alternative means of raising revenue from car users; in particular the levels of toll per kilometre that would be necessary were the lost revenue to be raised from a system of motorway tolling.

Pressures for more efficient and less polluting vehicles

4. A number of motivations exist for the automotive industry, at the continental and global levels as well as the national one, to supply more efficient and less polluting vehicle technologies. Similarly, incentives exist in some countries, including the UK, for consumers to wish to drive them.

5. Despite significant reductions in noxious vehicle emissions in recent years, certain urban areas will nonetheless have unsatisfactory air quality in 2005, raising the prospect that vehicles, particularly the more polluting ones, will be subject to greater traffic restrictions.

6. The UK is party to European and international agreements to limit climate change emissions. Global warming is one motivation for Government policy, which seeks to avoid a portion of the 22% traffic growth that is otherwise forecast to emerge. The Department of the Environment, Transport and the

Regions (DETR)[1] has examined policy options that could limit traffic growth to 8% over the period, but the most likely policy compromise will be to restrain traffic growth to 17% by implementing the *Basic Plan* (BTYP) scenario of the *Ten-Year Plan for Transport* (TYP). With the BTYP, CO_2 emissions are expected to decline compared with levels in 2000, but there would not be a significant contribution towards meeting the overall national target of a 12.5% reduction on 1990 levels.

7. Between 1992 and 1999, successive UK administrations operated the 'fuel escalator' policy. In conjunction with a sudden increase in world oil prices, the policy resulted in an increase in UK pump prices to unusually high levels in 2000. The increases triggered high-profile lobbying for a reduction in fuel duty. In the event, world oil prices reduced and costs at the pump returned to more typical levels. Although the fiscal pressure on motorists subsequently reduced, there are indications from the crude oil market that prices may increase again in the future. In any case, the experience of a temporary period of higher prices may continue to exert an influence on motorists when replacing vehicles. There is also evidence that the policy resulted in somewhat less car travel and, hence, lower fuel consumption.

Efficiency and emissions policies with tax implications

8. Agreements have been made between the European Commission and motor manufacturers. These are likely to lead to a 25% reduction in CO_2 emissions by 2008 and possibly a 35% reduction by 2012. Doubts have been expressed about the ability of the automotive industry to achieve the targets, but a range of technical and policy measures are being introduced which have the potential to achieve that end.

9. Over the last few years, the UK Government has introduced schemes for: Vehicle Excise Duty (VED) discounts for most existing cars; CO_2-related VED bands for those bought from March 2001; and, from April 2002, a new company car tax regime. Each of these measures is expected to result in a decline in tax revenue per vehicle as purchasers choose more efficient vehicles, which use less fuel and attract a lower tax rating.

10. Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) have a much greater market share in some other countries (*e.g.* Australia, Italy, The Netherlands) than they do in the UK. However, the increasing availability of refuelling points, the widening range of 'off the shelf' road fuel gas (RFG) models available for purchase new, and the recent period of high petrol and diesel prices are all factors which are promoting growth in the market. The discounted fuel duty rate for RFGs is also a significant factor. However, the RFG market is likely to grow, with implications for fuel duty policy. The

[1] Following the June 2001 general election, whilst this paper was in the final stages of preparation, the DETR became the Department of Transport, Local Government, and the Regions (DTLR) following the reorganisation of government departments and their responsibilities. However, the name DETR is retained throughout for clarity.

fledgling market will remain particularly sensitive to changes in duty rates for the foreseeable future, which means the 2001 budget decisions to reduce RFG duty and to hold it constant in real terms until 2004 are significant.

Analysis of magnitude of tax implications

11. Assuming policies to improve the efficiency of new cars are successful, a 31% reduction in average CO_2 emissions from new cars will result in a reduction of the fleet-wide average by around 12% by 2010. Allowing for traffic growth in line with the 'basic' scenario of the *TYP* and assuming tax rates are not raised, revenue from fuel duty and VAT on fuel sales from car use will be £0.4 billion higher in 2010, in 2000 terms. However, assuming traffic growth is stabilised in 2000, then a further efficiency improvement will cause a £0.5 billion reduction in revenue from car use by 2012. Transport policy options that have been considered for inclusion in the TYP, which are intended to lead to lower traffic growth, would result in a reduction in revenue of up to £1.0 billion by 2010; £1.8 billion by 2012.

12. Improved efficiency will result in the 'centre of gravity' of the car fleet moving from VED band D towards band A. Under the same conditions of basic TYP traffic growth, and VED rates remaining unchanged, CO_2-differentiated VED will result in £0.4 billion less revenue from car owners in 2010, compared with 2000. Combining the implications of more efficient cars for fuel duty and the new VED regime, revenue in 2010 will be similar to that in 2000 under the BTYP, but will be £0.8 billion lower than 2000 in 2012.

13. The likely level of uptake of RFGs by 2010 is hard to predict. Supposing RFG vehicles were to comprise 10% of the car fleet in 2010, *i.e.*, somewhat higher in the UK in 2010 than the proportion in 2000 in The Netherlands, and the current level of duty discount over petrol and diesel were to remain, then duty would be £1.3 billion lower than 2000 in 2010 given basic *TYP* traffic growth.

14. Given RFG adoption at the 10% level and the assumption that traffic growth can be halted in 2010-12, the combined effect of the three policies is found to be £1.2 billion less tax revenue by 2010, and £2.1 billion less in 2012, compared with 2000. However, there are particular uncertainties about traffic growth and the take-up of RFGs. If traffic growth is slower (*i.e.* between 8-13% 2000-10, and take-up of RFGs or some other similar technology which either attracts a tax dispensation or is very efficient is greater (*i.e.* so that 20% of the car fleet makes use of an alternative technology), then the revenue implications could be a reduction of up to £3.3 billion by 2012. The latter figure is equivalent to a fifth of combined current duties (including VAT) from road fuel use in cars and VED from car ownership.

Policy-response constraints in the next decade

15. A scenario is likely to develop in which *new* cars are, on average, 31% more efficient by 2010, whilst the car fleet *in general* is around 12% more efficient. The efficiency of comparable models (for example *supermini* cars bought in 2000 and 2010) may differ by a factor of three or more. Hence, there will be a

period of at least 15 years in which a decreasing majority, and then a declining minority, would be particularly (and arguably unfairly) disadvantaged by an increase in fuel duty rates. For that period, Government may be limited in the extent to which it can replace lost fuel tax revenue by raising duty rates.

16. The taxation policies in respect of VED and RFGs will be two other downward pressures on the demand for heavily taxed petrol and diesel. As in the case of greater fuel efficiency, Government may be limited in the extent to which it can apply the most obvious response of reversing the policies. Motorists that have responded to incentive measures are likely to campaign against such a move. This is particularly true in the case of those who adopt RFGs, as the vehicles currently cost more than petrol models to purchase and the fuel product element of the total fuel costs per kilometre for RFGs is actually *higher* than for petrol or diesel. Hence, it is only the duty regime that makes RFGs attractive and that produces the environmental benefits from substituting petrol and diesel.

Greater challenges to motoring taxation policy in the future

17. Even if political objections to increasing fuel duty rates do not emerge, or can be overcome, in the long-term two factors suggest that the current fuel tax regime will become untenable.

18. First, super-efficient technologies are likely to enter the market. A number of major manufacturers will develop ranges of petrol-electric hybrid vehicles 2001-2003. Such vehicles will require up to 75% less fuel than the best conventional internal combustion engine (ICE) cars available today. Hybrid vehicles could be the choice of 20% of purchasers of new cars by 2010. The first mass-produced fuel-cell models are also programmed to enter the marketplace in 2003 and could potentially achieve 10% market penetration by 2010. The use of natural gas as a fuel for hydrogen production onboard vehicles is expected to result in consumption and emissions reducing to 40% of current CNG-powered cars. At current duty rates, revenue per km would be around 6% of the sum currently derived from the average petrol ICE vehicle. Fuel duty and VAT would have to rise to 92% of the retail price of CNG to achieve similar tax returns per km.

19. Second, practical problems are likely to be raised by the increased use of alternative fuels. Widespread use of mains electricity as a road fuel would create a case for a new tax regime for owners of battery-electric technology, as has been the case for the use of natural gas from the national grid. Combined VAT and duty would have to be 81% of total costs to match current levels of petrol duty. However, the potential for tax fraud would be a great concern. Hydrogen-based technologies are capable of achieving the automotive 'holy grail' of consuming only renewable energy and producing only water. The transition to a 'hydrogen economy' may make it difficult to separate fuel production and consumption for tax purposes. It may also be hard to determine which energy consumption is domestic and which for road use. 'Road fuel duties' may cease to be a tenable concept when there is no traded commodity as such to tax.

Alternatives to simply increasing fuel duty rates

20. A system of fuel tax rebates to allow those with low incomes and inefficient cars to avoid the effects of increased duty rates could be considered. However, such policies may be bureaucratic to operate for a number of special case groups. The selection of a particular means-tested threshold for disposable income can be expected to generate objections. Such a policy would also undermine both the intention of applying reasonable fiscal pressure on motorists to encourage their transfer to less environmentally damaging technologies whilst at the same time undermining attempts to reduce car dependence by improving rural public transport.

21. A new tax could be introduced based on the annual distance driven. Supposing fuel tax were to be entirely replaced by the new regime then a rate of around 8p/km would be required to raise the same amount of revenue. In practice, it would not necessarily be desirable to entirely replace the fuel tax regime, as a kilometre-tax would not reflect fuel efficiency and would be even less related to the incidence of congestion on different roads than the current fuel tax regime. The potential for fraud would also be significant.

22. A parking tax based on the number of car trips made to non-residential private car parks could provide a new revenue stream whilst at the same time targeting facilities that tend to be car dependent. According to the rates applied, the policy can be expected to have as much or more influence on congestion levels as fuel taxation. However, parking charges for 'out-of-town' shopping centres have been considered by the DETR and were not included in the 1998 White Paper on Transport Policy.

23. The possibility of introducing road-pricing schemes into the UK has been debated in recent years. In current policy development, though, government proposals are limited to permitting local authorities to introduce hypothecated urban cordon tolls and workplace parking charges. Inter-urban road pricing is, however, included in some of the policy scenarios considered by the DETR and could provide an alternative means of raising revenue for national purposes. Other European Union states, notably France and Italy, already apply distance-based motorway tolls. In addition to raising revenue, some scheme variants could specifically target congestion as well as raise revenue and/or seek to restrain overall traffic levels. However, the present paper examines road pricing only as a means of raising revenue.

Outline of a motorway tolling approach to revenue substitution

24. Although road pricing is a politically contentious policy, it may become more acceptable in the context of more efficient vehicles if the alternative would be fuel duty increases. The burden of greater taxation would be borne by companies (who may pass the costs on and may experience lower transport costs if there is less congestion) and private motorists on relatively high incomes. These two groups of travellers tend to drive relatively new vehicles and travel a disproportionately large share of national vehicle-km, and so would otherwise experience significant reductions in travel costs due to greater

fuel efficiency. Increasing fuel duty would instead place the cost burden on those with relatively old cars, who are more likely to have lower incomes. Charging for the motorway network also affects the class of road for which a reasonable public transport alternative often exists, without targeting motorists in particularly car dependent locations. Traffic displacement remains an issue, but, as in other countries, key sections of motorway that perform a bypass function could in some cases remain free at the point of use.

25. If tolls were to be introduced only on the motorway network, they would be levied on approximately 20% of current car-km. In order to replace revenue lost from the three policy measures considered in the present paper, the toll rates would need to be around 1.7-3.4 p/km for cars in 2010 under basic *TYP* traffic growth, increasing to 2.8-4.5 pence/km by 2012. If lower rates of traffic growth apply in practice, rates would need to be up to 2.6-5.7 p/km by 2010 and 3.8-6.8 p/km by 2012. Current toll rates for cars in France and Italy are around 3-4p/km.

26. Rather than the toll revenue passing entirely to the general exchequer, the possibility would exist for part of the revenue to be a user-charge; used to fund motorway maintenance and any future construction directly from the income stream. Such a policy would be in the spirit of the November 2000 Government commitment to hypothecating any future road fuel duty increases for improvements to public transport and modernisation of the road network. Indeed, given the possibilities of duty cuts in the short-term and falls in demand in the future, it may be the only way in which the commitment has practical significance. Alternatively, the tolls could be partially hypothecated for the development of public transport.

Contents

1 OVERVIEW

The UK Government has adopted policies that seek to reduce the emissions of climate change gases and noxious pollutants, including those from road transport sources. The specific goals and strategies have largely resulted from agreements with the other European Union member states. International negotiations have also been important in the case of climate change gases, notably the Kyoto Protocol.

Regulatory, voluntary agreement, and fiscal incentive measures are all being applied in support of the emissions goals. The present paper considers the hypothesis that, if these policies are successful, then the vehicle fleet that evolves will yield significantly less tax revenue for the UK Government. The potential magnitude of change in revenue from car use is examined and an initial assessment is made of the available options for making good any deficits that may arise.

2 POLICY DRIVERS OF TECHNOLOGICAL CHANGE IN THE AUTOMOTIVE INDUSTRY

Three main motivations exist for the automotive industry to supply more efficient and less polluting vehicle technologies and for consumers to wish to drive them.

1. National and European air quality and vehicle specifications legislation, including minimum vehicle emissions standards and the threat that polluting vehicles will be subject to traffic restrictions according to air quality criteria.
2. Voluntary agreements between the motor industry and the European Commission that cars sold in Europe will become less polluting and more efficient over time.
3. Policies for high fuel duty rates in the EU states, combined with fluctuations in global crude oil prices. In 2000 the incentive for greater efficiency was perceived by a number of motorists and interest groups to have become excessive, leading to protests, road blockades and high-profile campaigns for taxes to be cut in a number of EU member states.

Sections 2.1-2.3 consider the policy context of these three circumstances.

2.1 Control of Noxious Emissions and the UK Air Quality Strategy

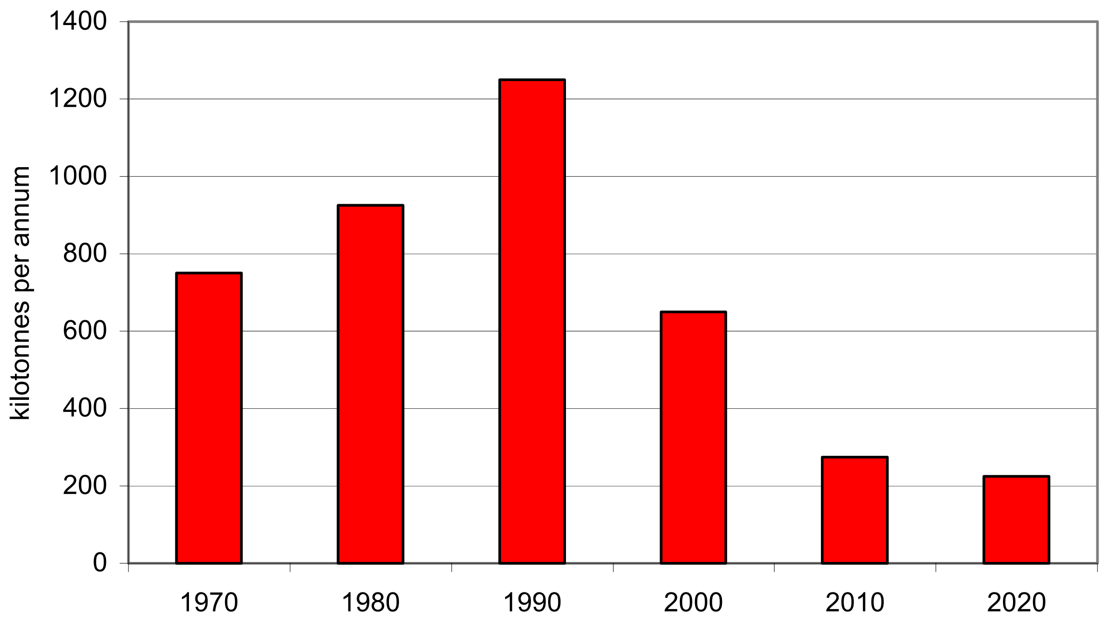
Agreements between the European Union, car manufacturers and fuel producers (the *Auto-Oil programme*) have resulted in a number of regulatory standards being set for petrol and diesel vehicle emissions. Successive 'Euro' directives from 1993 have resulted in changes such as the introduction of catalytic converters and significant reductions in exhaust emissions, including the elimination of lead additives from petrol and the restriction of sulphur content from 500 mg/kg to 150 mg/kg. The Department of the Environment, Transport and the Regions (DETR 1999a) reports that, in the decade 1989-1999, the improved standards have contributed to a reduction in CO emissions from road transport by 40% and of Volatile Organic Compounds (VOCs) by 30%, despite traffic growth.

The benefits of stricter pollution controls continue to emerge as the vehicle fleet is renewed. Most UK cars are scrapped when between 14 and 17 years of age (CfIT[2] 2000). The current average age of the vehicle fleet is around seven years. Vehicle replacement decisions and car ownership growth mean that this age is declining, for example from 7.4 years in 1998 (DETR 1999b: Table 3.5) to 6.8 years in 1999 (DETR 2000a: Table 3.5).

The UK now has around 10 million cars fitted with catalytic converters, meaning that something less than half the reduction in pollution implied by Euro I is yet to be experienced. In 1997, taking into account both the fact that newer cars are driven further per year and the increase in the proportion of the car fleet which is powered by diesel, pre-Euro I cars were responsible for 83% of the Nitrogen Oxides (NO_x) emitted from all cars and 82% of the Particulates (PM_{10}).

The strictest set of emission standards agreed to date, Euro IV, is applicable to private cars from 2006 (although some compliant vehicles are already on the market). In the expectation that most UK cars will be replaced over the next 15 or so years, the fleet will be near-universally Euro IV-compliant around 2020. Hence, DETR data (CVTF[3] 1999) demonstrate that the levels of pollution derived from road traffic peaked around 1990 and predict a decline until around 2015 where they will stabilise or possibly begin a slight increase (Chart 1).

Chart 1: Forecast change in levels of NO_x emissions[4] from road vehicles



Source: CVTF (1999: Chart 4)

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[2] *Commission for Integrated Transport.*

[3] *Cleaner Vehicles Task Force*

[4] NO_x emissions are generally regarded as being most representative of overall air pollution levels.

Nonetheless, the air quality assessments conducted by local authorities have concluded in some cases that, even with improvements expected as a result of the Euro programmes, additional local air quality management measures will be necessary. For example, the NO_2 and PM_{10} 2005 objectives will not be met in several large conurbations, including London and Birmingham (DETR 1999a). Problems will also remain in some smaller cities: Oxford is expected not to achieve the NO_2 objective (Oxford City Council 2000).

According to the Environment Act 1995, *Air Quality Management Areas* (AQMA), which may involve traffic restraint measures, should be established if it is forecast that the specific targets will not be met in 2005. Transport strategies that are motivated by the fulfilment of air quality policies have already been introduced[5] and future Local Transport Plans can contain measures aimed specifically at achieving the 2005 targets. In principle, these could take the form of permanent traffic restrictions for all or part of the day, or be exclusions based on day-to-day assessments of prevalent air quality. Whilst restrictions hitherto in the UK have been of the permanent type, in other countries, notably Italy, temporary traffic bans are a sanction that is occasionally applied in a wide range of cities in the case of severe pollution events.

Zero and very low emission vehicles will often be treated as special cases with respect to these regulations. Freight vehicles running on low pollution fuels are expected to be given exemptions to the proposed central London toll cordon. In February 2001, the Royal Mail was reported as aiming to have up to 5,000 electrically powered vehicles available for operation in AQMAs by 2005 (Kemp 2001).

2.2 National transport policy and restraint of climate change emissions

Following the statutes of the *Road Traffic Reduction (National Targets) Act 1998 (RTRA)*, the DETR (2000b) published a review of progress towards possible traffic reduction scenarios in early 2000. During the review process, CfIT was asked by DETR to consider the issue of national targets. The response concluded that, given the firmest application of White Paper (DETR 1998) measures, Government policy ought to be able to approach stabilisation of road traffic (zero growth) by 2010, and even result in reductions in particular places, without undermining economic objectives (CfIT 1999). CfIT further argued that, despite interim growth, it should also be possible to return traffic congestion to 1996 levels over the same period, in fact one way in which economic detriment would be avoided by the policy.

The former Secretary of State for the Environment, Transport and the Regions, John Prescott, reflected this ambition in arguing that

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[5] One such example is the *Oxford Transport Strategy*, which resulted in increased pedestrianisation and closure during the day of the main through-route crossing the city centre. The strategy was implemented following support from a public inquiry that considered evidence about future air pollution levels in Oxford. It was found that the strategy would promote achievement of the NAQS objectives (Parkhurst 2000).

> *"If the measures in the white paper are applied very intensively, we would be close to halting growth in national traffic levels in ten year's time, while delivering reductions in traffic to below 1996 levels in our major cities"* (DETR 2000b: 4).

The *RTRA* review (DETR 2000b) estimates that under a 'do-nothing extra' policy context (*Scenario A*) there would be 32% traffic growth 1996-2010. However, the combination of the following policy measures to reduce CO_2 emissions per kilometre would leave total emissions from road transport effectively unchanged:

- energy efficiency agreements with vehicle manufacturers to cut emissions by 25% for the average car purchased new, by 2008;
- the effects of the fuel-price 'escalator' policy, in operation 1992-1999;
- a new graduated Vehicle Excise Duty (VED) regime; and
- reform of company car taxation.

These measures are considered further in subsequent sections.

At the other extreme, the most stringent package of measures (*Scenarios D/D1*) would include policies to

- maximise modal-shift,
- alter the current nature of goods distribution activity, and
- implement urban road pricing and/or workplace charging in all areas and at relatively high levels.
- Additionally, *Scenario D1* features inter-urban road pricing.

The effect would be to limit traffic growth to an 18% increase on 1996 levels and result in CO_2 emissions from road transport in 2010 of 27.8 million tonnes of carbon (MtC): 9% below 1996 levels and 3% below 1990 levels. However, *Scenario D* would allow for just 9% traffic increase on 2000 and *Scenario D1*, 8%.

Later in the same year, the *Ten-year Plan for Transport* (*TYP*) presented some similar scenarios based on the year 2000 to outline actual and possible government policy measures for reducing CO_2 emissions from the transport sector (DETR 2000c, 2000d). The *Basic Scenario (BTYP)* foresaw the successful implementation of a programme centred around public transport expansion and targeted road investments, to be worth £121 billion in 2000-terms by the end of the decade - a 75% real-terms increase over the decade 1990-2000. The BTYP was expected to avoid some traffic growth and to lead to 1.6 MtC less being emitted from road and rail transport than would otherwise have been expected in 2010 under the *Baseline Scenario* ('do nothing extra'). The BTYP was also expected to result in 0.9 MtC less being emitted in 2010 compared with 2000.

Other TYP scenarios include measures that have not yet been adopted as Government policy or are somewhat outside the policy process.

- *Constant Motoring Costs* (CMC); DETR assumes that a 20% decline in motoring costs will occur due to greater efficiency and falling crude oil prices (DETR 2000d). The CMC scenario represents the outcome should this decline for some reason not occur.

- *Urban Road Pricing* (URP); this policy is expected to be pioneered in London. The scenario assumes it spreads to many other urban areas, but it is currently unclear whether that is likely to occur.
- *Workplace Parking Charges* (WPC); as in the case of URP, pilot schemes are expected but it is unclear whether they will become widespread.
- *Inter-urban Road Pricing* (IURP); the scenario assumes that tolls are applied by national government to the trunk road network, but there are no plans for any implementation.

The scenarios incorporating these elements are forecast to result in lower traffic growth than the BTYP. Table 1 compares the traffic growth and CO_2 change outcomes of three variants of the TYP and RTRA review *Scenario D1*, which implies greater restraint than the TYP.

Table 1: Estimated road traffic growth in TYP scenarios

2010 scenario	*Change on 2000 (%)*	
	Traffic	*CO_2 emissions*
Baseline	+22	+2.3
BTYP	+17	-4.0
BTYP + CMC	+13	-7.3
BTYP + CMC + IUP + WPC + IURP (BTYP + extra)	+12	-7.9
Scenario D1	+8	-8.2

Data sources: DETR (2000b: 7, 13, 17); DETR (2000d: 27, 29)

Hence, Government policy is to restrain traffic growth, mainly through improving the alternatives to car travel, but possibly with new motoring charges. Road traffic growth will nonetheless occur under all likely scenarios. Similarly, CO_2 emissions will decline compared with 2000 levels under all except the *Baseline Scenario*, but even the most stringent scenario would deliver only one-quarter of the reduction on 1990 levels that would be necessary were the transport sector to be expected to meet the overall national target of a 12.5% reduction.

2.3 Reducing exposure to high fuel costs

Between 1992 and 1999, successive UK administrations operated a policy known as the 'fuel escalator'. Duty increases, initially 5% per annum and from the change of Government in 1997 6% per annum, caused prices to increase above the rate of inflation. Other EU Governments have operated similar policies, although mostly with less rigour, and in all cases with relatively favourable regimes for diesel fuel.

Aside from the motivation of raising revenue, the transport policy relevance of the measure was to encourage the purchase (and by extension the production) of more efficient cars. There is evidence that the 'escalator' has had an effect on some motorists' driving behaviour, including the distance they drive. A survey of motorists by the RAC (2000) found that only a minority (39%) would not make any changes in their driving behaviour, whilst 24% would drive less, 14% would consider changing their vehicle for a more efficient one and 10% would switch to other forms of transport for some journeys. From a review of studies, Glaister & Graham (2000) have concluded that, on average, fuel consumption declines by 3% in the short-run following a 10% increase in price, and perhaps double in the long-run, whilst traffic reduces by a lesser amount, perhaps 3% in the long-run.

In 1999, though, prices rose considerably and the escalator policy was suspended in a context of growing public unease about fuel costs. On top of the effects of the earlier taxation increases, the high costs were the result of crude oil prices rising from around $10 a barrel in September 1999 to peaks of $30-35 a year later.

Subsequently, in the 2000-1 national budget (HM Treasury 2000a), the duty on Ultra-Low Sulphur Petrol (ULSP) was reduced by 1p per litre with effect from October 2000, in order to promote the production and sale of this less-polluting fuel[6]. Nonetheless, pump prices of unleaded petrol had increased by 34% between January 1999 and June 2000 (Bolton & Twigger 2000) and political objections were sufficient to result in a 'blockade' of fuel supplies by farmers and lorry drivers in September 2000.

Following OPEC interventions to increase production in autumn 2000, and a mild winter in Europe and the US, which reduced the demand for heating oil, world oil prices dropped back to $20 a barrel by January 2001. As a result, unleaded petrol prices fell by 10%, to around 78 p/l, and OPEC began reversing its action in order to stabilise prices, resulting in a 5% production cut from February 2001. The target price range sought by the 40% of producers represented by OPEC is reported to be $22-28 a barrel (Denny 2001).

In the Budget for 2001-2, further duty cuts were made for ultra low sulphur fuels[7]. The cost of the changes to the Treasury, based on consumption by all road vehicles, was estimated to be around £1.1 billion in each of the financial years 2001-2, 2002-3, and 2003-4 (HM Treasury 2001: Table A.11).

In mid April, following a further OPEC production cut and sharply rising demand for car fuel in the US, crude oil prices rose by 20% in a week (from $25 to $29 a barrel). Subsequent increases in pump prices in the UK countered much of the reduction that had been brought by the budget duty cuts. Suggestions began to circulate in the media that the *ad hoc* protest organisations that had contested the level of fuel prices the previous September would begin to agitate again (Gow & Macalister 2001), all in the context of a General Election campaign expected to culminate that June. The situation was compounded by a decision by Iraq, the world's second largest producer of oil, to suspend exports from 4 June in protest at UN economic sanctions (Walsh & Walsh 2001). In the event, the issue of fuel prices

[6] Cuts in the tax on Ultra Low Sulphur Diesel (ULSD) between 1997 and 1999 are credited with having already eliminated by then the supply of higher sulphur diesel (HM Treasury 2000b).

[7] A 2p per litre reduction in respect of Ultra Low Sulphur Petrol and a 3p per litre reduction for Ultra Low Sulphur Diesel were made, together with a temporary three-month cut (until 14 June 2001) for normal unleaded, reflecting the fact that low sulphur fuel did not yet have sufficient market penetration to be a realistic alternative. Government also noted that making no change to the nominal rate of duty on other fuels represented a cut in real terms of around 1p per litre.

did not receive much attention in a campaign that was dominated by demands for better public services, rather than tax cuts. By mid-July, the Iraqi protest had ended and world supplies were again buoyant. OPEC again announced a 4% cut in production, with the immediate effect of pushing prices back above $25 a barrel (Stewart & Macalister 2001).

In the longer-term, uncertainties about crude oil prices are likely to increase rather than decline. Some geologists emphasise the importance of production costs, and suggest that prices will inevitably rise once the 'easy to extract' half of oil reserves has been exploited (Campbell & Laherrier 1998). Interestingly, though, some producers appear more concerned about the effect of falling demand on price. In July 2000, Sheikh Yamani (Saudi Arabian Oil Minister 1962-86) expressed the opinion that oil prices will begin a terminal decline from 2005 as hydrogen power begins to replace oil (RMI 2001)[8].

In summary, there is considerable uncertainty about future fuel prices. Fluctuations have both travel-behavioural and political implications. However, in whichever band fuel prices settle in the near future, the experience of a temporary period of higher prices may continue to exert an influence on motorists when replacing vehicles.

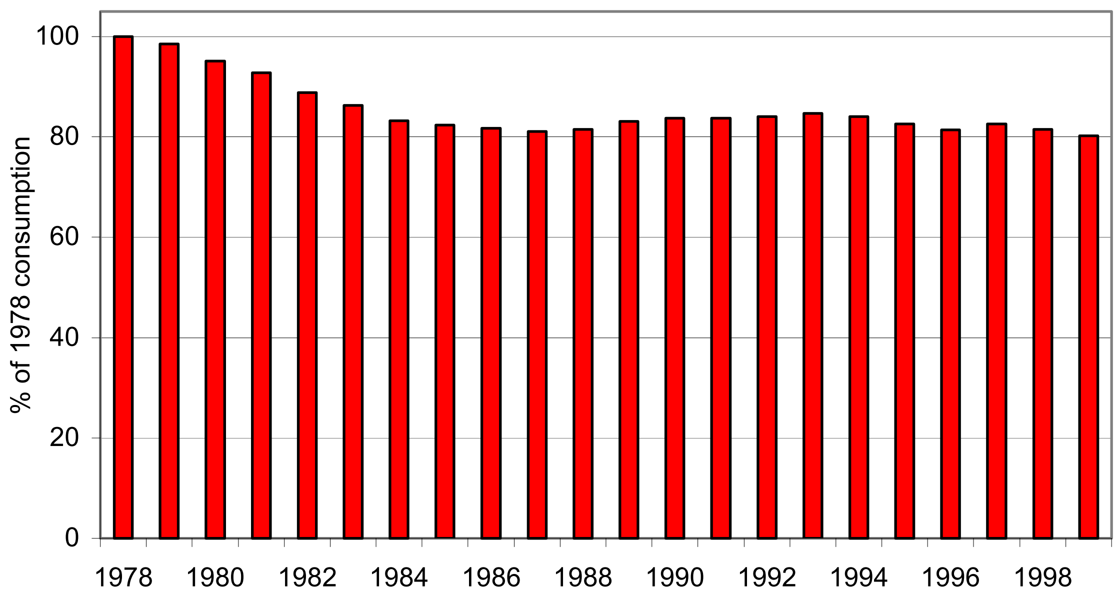
[8] The implications for crude oil extraction taxation are obviously significant for the UK, but not addressed in the present paper.

3 SPECIFIC POLICIES FOR GREATER EFFICIENCY AND LESS POLLUTION

3.1 Agreements with manufacturers to reduce CO_2 emissions

As indicated in Section 2.1, significant reductions in the noxious emissions from petrol and diesel engines have been achieved over the last decade. However, fuel consumption has not shown a similar reduction. Although there are signs of a slight downward trend since 1997, in general the significant improvements of the 1980s did not persist into the 1990s (Chart 2).

Chart 2: Changes in fuel consumption of two-wheel drive petrol cars 1978-99



Elaboration on data from DETR (2000a: Table 2.5)

A review of studies of other European countries has reported a similar pattern of decline through the 1980s, followed by a much slower reduction since in Denmark, whilst the Italian, Swedish and Dutch fleets showed no reduction in the 1990s (Van den Brink & Van Wee 2001: 75-6).

Notwithstanding these aggregate data - which taken in isolation appear to suggest that whole-fleet fuel consumption could continue to rise given traffic growth - a faster rate of efficiency improvement can be expected over the next decade, as the main manufacturers supplying the European market have committed themselves to greater overall efficiency for future models. For example, the voluntary agreement signed in 1998 between the European Union and the Association des Constructeurs Européens d'Automobiles (ACEA) has three dated targets for improvements in efficiency (Table 2), to be measured as the average emissions of new vehicles actually sold, rather than the average of the available model range.

Table 2: Implications of EU-ACEA agreement if fully implemented

	Average emissions of CO_2 (g/km)	*Approximate fleet average petrol consumption required to achieve target (l/100km)*	*Implied improvement on 1999 (%)*
EU new car average 1999	185	8	-
Interim target - 2003	165-70	7	9
Target - 2008	140	6	24
Subject to review - 2012[9]	120	5	35

Source: 1999 average figure from CEC[10]/ACEA (undated); required consumption data derived from analysis of current models listed in VCA (2000).

The agreement is not legally binding and, in addition to manufacturers making more efficient models available, is contingent upon:

- fuel producers providing the formulations of petrol and diesel which are prerequisites for the more efficient engines proposed,
- government policies encouraging consumers to choose relatively efficient models, and
- purchasers actually choosing the more efficient models.

Supportive measures adopted by the UK Government include:

- the 'fuel escalator' policy described in Section 2.3;
- VED reforms and RFG discounts considered in the following Sections 3.2 and 3.3; and
- a new company car taxation regime from April 2002, under which tax liabilities for employees with cars provided by their employers will be determined mainly according to CO_2 emissions.

The present paper does not appraise this latter measure, which is an income tax liability, but it is likely to be particularly influential on purchasing behaviour, as around half of new cars bought in the UK are purchased by companies, those company car users who more than a small number of business-km per year will face large increases in tax liability, and the CO_2 values defining the taxation bands will be gradually tightened on an annual basis[11].

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[9] The final target relates to an EU policy aspiration dating from 1996, to reduce emissions from new cars to an average of 120 g/km by 2005-10.

[10] *Commission of the European Communities.*

[11] The difference in taxable value between the least and greatest polluting cars will be £12,500, creating a variation in tax liability of up to £2,750 per annum for a standard-rate taxpayer and £5,000 for a higher-rate taxpayer. The Inland Revenue (IR) believes that removing incentives to achieve mileage thresholds and introducing efficiency incentives will yield a 1.5-3% reduction in CO_2 emissions from road transport as a whole. A 2% reduction in CO_2 emissions from company cars themselves is also expected between 2000 and 2002, as companies choose more efficient cars in preparation for the new regime (IR 2000: 1-2).

The potential for improvements in efficiency are indicated by observations that differences between currently available models of similar size and power output (TRI/ECU, 2000: 94), and similar size and engine capacity (Sakaguchi, 2000: 898), can be greater than 20%. Nonetheless, the voluntary nature of these agreements has led to negative judgements about the likelihood of them being successfully fulfilled and the real-world significance of the changes if they are fulfilled. Kågeson (2000: 1) has argued that the manufacturers' strategy for achieving the targets, based on the introduction of common-rail diesel engines and direct injection petrol engines to 90% of new vehicles, together with some others being powered by internal combustion engine (ICE)-petrol hybrids and fuel cells, will only achieve half of the agreed reduction.

If particular comparable models also show a wide range of efficiency, then the same seems to be true of manufacturers' ranges, as some are claiming significant progress. Fiat Group (2000: 23) reports that the replacement for the *Punto* model is on average 10% more efficient than the previous model, and resulted in a 4% improvement in the efficiency of the Fiat range. The efficiency of the model range does not automatically imply that consumer choices will result in a more efficient fleet, but as the *Punto* is the most popular car in the range this is a likely outcome.

The case of the largest EU manufacturer, Volkswagen, exhibits well the strategy of increasing fleet efficiency by selling a greater proportion of diesel-fuelled vehicles. The German sales experience (Chart 3, overleaf) indicates that fuel consumption (and by extension CO_2 emissions) declined by 24% between 1980 and 1998 (18% between 1990 and 1998).

Consequently, in the German market at least, VW claims to be already within the 2003 target, and the company requires only modest further improvements (5-10%) to achieve the 2008 target.

Notably, in addition to offering relatively efficient cars, neither Fiat nor Volkswagen is significantly involved in the growing market segment of heavy four-wheel drive vehicles, which are responsible for offsetting efficiency gains from other model classes in aggregate analyses.

Volkswagen Group (VWG) also succeeded in being the first major manufacturer to mass-produce a four-seat ICE model with combined-cycle fuel consumption lower than 3 l/100km[12]. Although that particular model was not available as a right-hand drive vehicle at the time of writing, VWG cars with diesel engines that already achieve the 120 g/km 2012 unconfirmed target are available in the UK[13].

Kågeson's (2000: 10) key objection to the diesel-substitution strategy is that, because the fuel is generally taxed at about 65% the level of petrol in the EU, traffic growth is likely to be greater due to the lower fuel costs per litre. Hence, higher total travel will erode the apparent efficiency benefit of lower emissions per kilometre.

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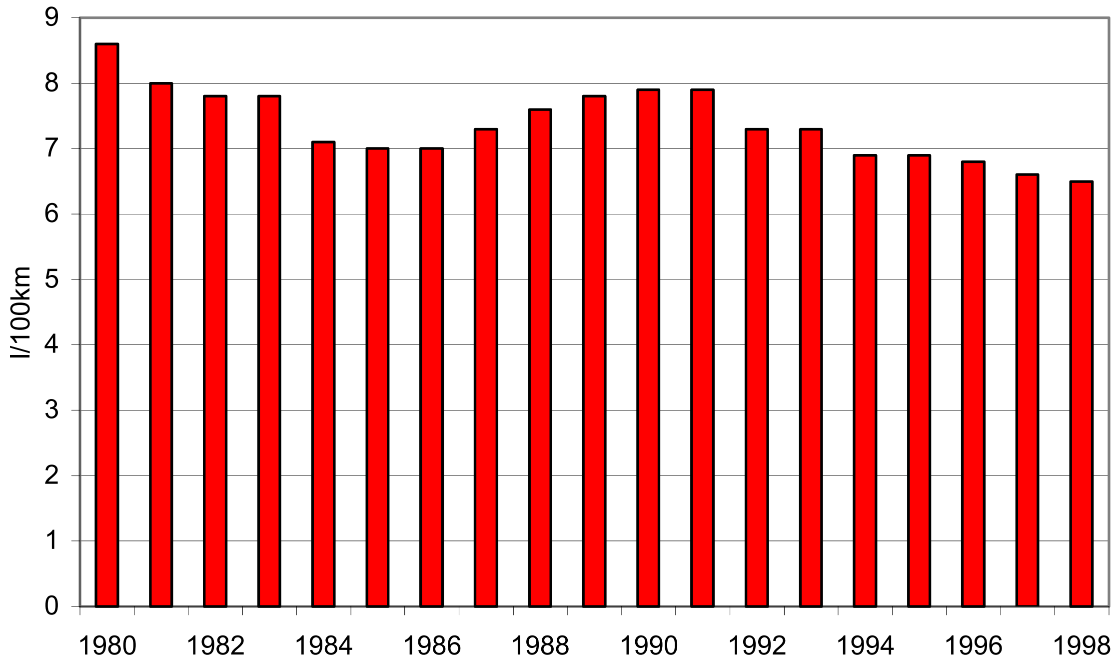
[12] The 1.2 TDI version of the VW Lupo, with combined-cycle CO_2 emissions of 90 g/km.

[13] Particular models of the Volkswagen Polo, Volkswagen Lupo, and Seat Arosa ranges, as listed in the July 2000 edition of the Vehicle Certification Agency guide (VCA 2000).

Chart 3: Average consumption of Volkswagen cars sold in Germany 1980-1998



Source: Volkswagen AG[14] (VW 2000)

The diesel-related elements of the strategy may, however, be of particular influence and consequence in the UK. First, as Kågeson acknowledges, the UK is the one EU state in which diesel tax levels are actually higher than those for petrol. Hence, it can be supposed that traffic generation due to lower costs will be a smaller effect. Second, only around 12% of new cars currently sold in the UK are diesel fuelled, compared with an EU average market share which has increased to 25% in the last decade (*Op. cit.*: 17).

New diesel models currently available in the UK, weighted to adjust for sales of different cylinder capacities, produce 11% less CO_2 than petrol models with similar engine capacities (Appendix 1). Road fuel gases (RFGs) offer similar opportunities[15], without raising the concerns about higher NO_2 and PM_{10} pollution associated with diesel vehicles. Assuming that the diesel and RFG cars have a similar engine capacity to the petrol cars they are chosen to substitute, doubling their market share would reduce average new-car CO_2 emissions by around 1.5%. Slightly more significant would be the effect of universal application of common rail diesel technology, which suggests an 8% reduction in average diesel car CO_2 emissions/km (Kågeson

[14] For the purposes of historical comparison, VW has inflated three-way cycle consumption data by 10% to approximate New European Driving Cycle (NEDC) data. The temporary interruption of the trend for greater efficiency around 1990 is partly explained by the introduction of catalytic converters, which increased petrol car fuel consumption by around 10%.

[15] The eight LPG models available for purchase new in the UK in 2000 had average emissions values of 181.1 gCO_2/km, also around 5% lower than the petrol car average.

2000: 17), which, if diesel cars made up a quarter of the UK fleet, would reduce overall average emissions per km by around 2%.

Similar doubts exist in the case of direct-injection petrol engines. Van den Brink & Van Wee (2001: 90) take issue in general with the fact that the standard European test cycle underestimates real-world fuel consumption by Dutch and German cars by 10-17%[16], but also note that the adoption of direct injection creates a reason to believe that this 'reality gap' will increase in the future. A technical characteristic of direct injection engines introduced to date means that the emissions reduction is disproportionately large at low engine loads. As the standard test cycle over-represents low-load situations, there could be a tendency for the overall efficiency to be exaggerated. Hence, direct injection could help manufacturers fulfil the agreement whilst not yielding the full extent of implied benefits in practice.

However, further technological refinements requiring low sulphur fuel may be able to address this situation, so that the benefits of 10-15% reduction in consumption are experienced over a wider range of load conditions. Low sulphur petrol is now becoming increasingly available in Europe, including the UK. In 2000, only 1% of new cars sold in Europe had a direct injection petrol engine, but the design changes necessary to increase that share are relatively minor and technological transformation could potentially be rapid (Kågeson 2000: 19). In theory, if universally applied to new petrol cars in the UK, fleet emissions per km would reduce by up to 11% (allowing for a declining market share for petrol). Hence, this measure alone could provide nearly half of the 2008 target. Nonetheless, in practice it is reasonable to assume that not all cars will be equipped with the technology by then, and the actual reduction will be somewhat less.

Overall, from the refinement of ICE design, it is possible to identify the potential of approaching two-thirds of the improvement necessary to achieve the 2008 target in the UK. More radical technological change could provide the difference, depending on the rate of market transformation. Significant developments have been made since 1997, with the mass production of two petrol-electric hybrid-drive cars by the Japanese manufacturers Honda and Toyota. These models achieve combined-cycle CO_2 emissions of 80 and 114 g/km respectively, and were both introduced into the UK market in 2000[17]. Both manufacturers have had difficulty matching production to worldwide demand. Vehicles powered by hydrogen fuel cells could also make a contribution in the second half of the decade (described further in Section 5.2.1 below).

Sakaguchi (2000: 903) has argued that similar technological measures proposed as part of a very similar efficiency improvement strategy for Japan are potentially adequate, depending on the rate of their diffusion, which will in turn be a function of speed of technological development and consumer acceptance. Similarly, whether

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[16] One growing explanation is that the use of air conditioners, which are not switched on during the standard test, increases engine consumption by around 10%.

[17] The two-seat Honda Insight coupe and the four-seat saloon Toyota Prius, capable of combined cycle efficiency of 3.4 and 4.9 l/100km respectively.

the European targets are fully achieved is likely to depend on the extent to which these new alternatives are both marketed and purchased.

3.2 Emissions-related Vehicle Excise Duty

As part of its response to concerns about high road fuel duties, the UK Government extended the discounted VED rate in the 2001-2 Budget. The change brought cars with engines of between 1,200 and 1,549cc into the £100 charge band, with backdating to 1st November 2000. As a result, the share of the fleet subject to the discount increased from 16% to around half; with the effect that the average VED paid will decline to around £125 in 2001-2.

From the same month, any vehicles purchased new became subject to a four-band VED structure, with models allocated to bands mainly according to their CO_2 emissions, although with a secondary dimension determined by engine fuel type (Table 3).

Table 3: Emissions-related VED for private cars purchased new from March 2001

Bands	*CO_2 (g/km)*	*Alternative fuel*	*Petrol*	*Diesel*
A	≤150	£90	£100	£110
B	151-165	£110	£120	£130
C	166-185	£130	£140	£150
D	186+	£150	£155	£160

Most new cars in 2001-2 will attract band C and D charges, resulting in an average charge similar to that paid in 2000-1, around £150. Taking the new regime and the discount measure for old cars together, the cost has been calculated to be £430 million in 2001-2, declining to £250 million in 2003-4, as a greater proportion of the fleet becomes subject to the new regime. Additionally, holding the standard rate of £155 constant represented a real-terms cut of around £5, costing £85 million in forgone revenue in 2001-2 (HM Treasury 2001: Table A.11).

The VED differential change moves the taxation emphasis away from fixed motoring costs (and so towards distance-related costs), with the effect of making car ownership slightly less expensive. Given the initial degree of tax differentiation (a range of £70 per annum between the highest and lowest-priced licences) the measure may be effective only at the margin. The measure is perhaps worth £1,000 over the life of a car, and so may be influential where it borders on fuel prices perceived to be high. It discount will also be relatively significant when the car is in the second hand market, after some years of depreciation.

Based on policy developments in other EU member states, further incentives to encourage the ownership of less polluting cars may be introduced in the future. In Germany, the tax on initial car purchases also reflects the efficiency of the vehicle.

Discounts can amount to as much as 6% of the purchase price[18]. In some other European countries (*e.g.* France, Italy) subsidies have also been made available to promote the purchase of new cars where a relatively polluting one is scrapped[19]. Whilst there has been concern that such schemes provide a subsidy to the motor industry (an important element of the domestic economies of France and Italy), such a scheme has been mooted for the UK (CfIT 2000). However, under any UK scheme, the purchase of a new, rather than second-hand, car might not be obligatory, so extending the range of eligibility.

3.3 Promotion of alternative fuels

A range of alternative technologies to petrol and diesel-fuelled ICEs has existed in market niches in UK road transport for many years. Natural and coal gases have been used to fuel vehicles in Europe since the 1930s, particularly during times of oil scarcity. In recent years, though, RFGs have gained non-trivial market shares in some countries other than the UK. Table 4 illustrates the case of Liquefied Petroleum Gas (LPG), for which Australia, the Netherlands and Italy are already much larger markets. Virtually all taxis in Japan run on LPG. Considering additionally Compressed Natural Gas (CNG) vehicles, the Italian proportion for RFGs is 4.4% and that of Australia, 7%.

Table 4: Proportions of vehicles powered by LPG worldwide

Market	*No. Vehicles*	*% of world fleet*	*% of local fleet*
UK	23,000	0.6	0.1
Australia	570,000	14.3	4.8
Italy	1,100,000	27.5	3.7
Netherlands	360,000	9.0	6.4
North America	400,000	10.0	0.3
World-wide	4,000,000	-	-

Sources: LPGA (2000), Australian Statistics Bureau (ASB 2000), Italian National Statistical Service (Istat 1998), LPM Corporation (2000)

Further growth in the worldwide market share can be expected as air quality regulations become stricter. For example, the Supreme Court of India (SCI 2001) ruled in July 1998 that all public service and commercial vehicles should operate within Delhi solely on CNG (or in some cases other low emission fuels) by April 2001.

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[18] The relatively efficient Volkswagen Lupo 1.7-litre SDI has a car purchase tax discount of €256 on a list price of €11,760 whilst the ultra-efficient Lupo 1.2 TDI attracts a €767 discount on a list price of €13,549.

[19] For example, an Italian motorist possessing a car without a catalytic converter and perhaps of negligible residual value could have purchased in August 2000 a Daewoo Matiz with an 8% list-price discount worth €593-775 (£350-450) depending on the model chosen (Daewoo Advertisement in *La Repubblica*, 27 August 2000).

Mainstream manufacturers are now more active in bringing these alternative technologies into the UK marketplace. RFGs, particularly LPG, are being made more attractive by a number of additional factors. Restrictive clauses on the purchase of new RFG model variants, such as limitations on the warranties not applied to conventional-fuel models, are becoming less common. Refuelling facilities are increasingly available: growing at a rate of five outlets per week and expected to be available in 1,000 UK service stations (around 10% of the total) by the end of 2001 (Sheridan 2000). Technological progress has also made the alternatives more practical, notably the possibility to switch 'seamlessly' to a reserve tank of petrol in the absence of an RFG refuelling point. However, high oil prices and favourable government policies are probably the most significant factors explaining why the market has become more receptive. In addition to giving large RFG duty discounts, the UK Government supports the use of alternative fuels through the *Powershift* scheme, which gives grants to the value of up to 75% of the additional costs of purchasing a non petrol or diesel vehicle or of converting a vehicle to operate on RFGs or electricity.

The main societal benefit of the use of RFGs to power ICEs is the significant reduction of noxious emissions that results in comparison with conventional fuels. There is also a smaller benefit with respect to petrol in terms of lower CO_2 emissions per unit engine capacity. However, the lower energy density of RFGs compared with petrol or diesel means that consumption by volume is actually greater for a given distance travelled by RFG cars of equivalent size, weight, and engine capacity. The product prices of RFGs are also higher per unit volume than petrol and diesel. Table 5 indicates that for eleven models produced in both petrol and LPG versions by GM, Fiat, and Volvo, LPG costs per kilometre are two-thirds of those for equivalent petrol models. However, the fuel product cost element for LPG is actually greater than for petrol. In the absence of a fuel taxation discount, RFGs would actually cost the individual motorist more to use than conventional fuels.

Table 5: Fuel product and tax costs allowing for consumption differences by 11 matched models

	2000		*2001*	
Fuel	*Petrol (@£0.84/l)*	*LPG (@£0.40/l)*	*Petrol (@£0.81/l)*	*LPG (@£0.37/l)*
Consumption (l/100km)	8.50	11.58	8.50	11.58
Cost to consumer/100km (£)	7.14	4.63	6.89	4.28
VAT/100km (£)	1.25	0.81	1.21	0.75
Duty/100km 2000-1 rates (£)	4.15	0.87	3.90	0.52
Product cost/100km (£)	1.74	2.95	1.79	3.01

Sources: VCA (2000), Fiat Italia SpA (undated), Volvo Car UK Ltd (2000)

Future developments may increase the efficiency of RFG vehicles, and hence their intrinsic competitiveness with conventional fuels. Adapting vehicles designed to operate on petrol to use RFGs results in weight and efficiency penalties, whilst the limitations of gas supply favour the purchase of dual-fuel models, which have two sets of onboard fuel storage and delivery equipment. As the network of RFG stations develops, single-fuel operation will be encouraged. Similarly, as RFG operation begins to be considered at the vehicle design stage, consumption can be expected to fall somewhat. Fuel product costs may also fall as consumption increases, allowing economies of scale. At the present time, though, the low price RFGs, and hence their attractiveness to consumers, is entirely a product of the tax system.

The tax discount for LPG was 69% in 2000-1 and rose to 75% following the 2001-2 Budget duty reductions. A similar situation would apply in the case of CNG, but neither factory-equipped models nor the fuel are readily available to the private motorist in the UK at the time of writing. Although ongoing Government commitment to the current tax differentials between fuels cannot be assumed, policy does suggest short-to-medium term policy strategy. The *TYP* includes a qualitative target to accelerate the take-up of lower emission vehicles. In the 2001-2 budget (HM Treasury 2001: para 6.49), following a decision for no change for 2000-1, duty on RFGs was reduced by 40% from 15 p/kg to 9 p/kg *"in order to maintain the existing duty differential between road fuel gases and the most commonly available petrol and diesel"*. Rather than merely maintain the differential, however, the reduction in fact considerably increased the discount for RFGs. The Treasury expects the cost of the change to be very small in the near future, estimated at £5 million in 2003-4 (*Op. cit.*: Table A.11). Equally important was the announcement that RFG duty would not be increased in real terms before 2004, and possibly longer, in order *"to provide the stability needed to encourage growth in the road fuel gas market"*.

RFGs are not the only alternative fuels that attract tax concessions. A new duty rate for bio-diesel of 25 p/l offering a 20 p/l discount over ULSD was also introduced for 2001-2. Electric vehicles offer zero local emissions and, depending on the means of electricity production, can offer a CO_2 reduction benefit. They are not subject to any fuel tax; the use of electricity as a 'road fuel' is currently indistinguishable from domestic consumption and attracts no excise duty. VAT is, though, levied at the domestic fuel rate of 5%. Given the efficiency of current electric vehicles, tax revenue is currently worth around 5p per 100km.

4 ANALYSIS OF TAX REVENUE IMPLICATIONS OF POLICIES

The present section reports the findings of an analysis of the tax revenue implications of transformation of the vehicle market to greater efficiency. Five traffic growth scenarios are considered; four from the TYP, together with the more stringent *RTRA* review *Scenario D1* (Table 6).

Table 6: Traffic growth scenarios considered in analysis

Scenarios	Growth 2000-2010
'Do nothing extra'	22%
Basic measures of ten-year plan for transport (DETR, 2000c)	17%
Basic plan with constant motoring costs (DETR, 2000c)	13%
Basic plan with new motoring charges (DETR, 2000c)	12%
High charges and land use measures (DETR, 2000b Scenario D1)	8%

The expected effects of policies are built up cumulatively: improvements in vehicle efficiency, followed by changes in VED, followed by market penetration of alternative-fuel vehicles.

4.1 Effect of improved efficiency of petrol and diesel engines

In order to calculate the change in tax revenue that would be expected to result from lower fuel consumption per vehicle, the implications of the promised change in the average consumption of new cars Europe-wide has to be interpreted for new cars bought in the UK as well as for the UK car fleet as a whole. This is achieved by using the efficiency of new cars sold in 2000 in the UK as the benchmark.

4.1.1 Current UK car fleet efficiency

Appendix 1 summarises an analysis of the efficiency of the new car models offered in the UK market in July 2000, weighted in bands to reflect the range of cylinder capacities and engine fuel-types actually purchased. Table 7 provides a summary of this analysis.

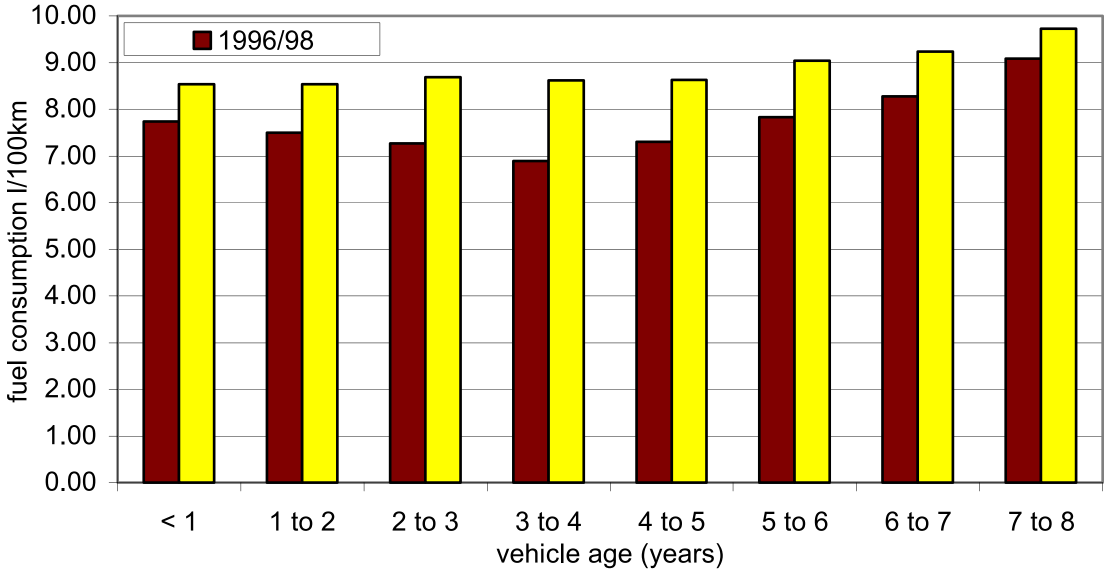
Table 7: Estimated average fuel consumption and CO_2 emissions of cars sold in the UK in 2000

Fuel type	Petrol	Diesel	All	Diesel/petrol (%)
Consumption l/100km	7.96	6.51	7.78	81.8
Emissions g/km CO_2	190.5	169.2	187.9	88.8

Other evidence reveals that the figure for average emissions from new cars sold in the UK in 2000 actually provides a suitable approximation for the efficiency of the whole fleet in 2000.

Although the fuel consumption of vehicles can be expected to increase somewhat with age if maintenance standards decline, in practice the National Travel Survey (DETR 1999b: Table 2.5, DETR 2000a: Table 2.4) shows that the consumption of petrol and diesel cars up to six months old in 1996-8 and 1997-9 was reported as identical to that of the whole fleet (8.07 l/100km in the earlier period and 8.99 l/100km in the latter period). Furthermore, as shown in Chart 4 below, there is some evidence that vehicles that are currently of medium age are the most efficient on UK roads. Hence, the average CO_2 emissions from all UK cars were slightly above the EU average (188 rather than 185 g/km).

Chart 4: Fuel consumption in use of four-wheel cars up to eight years old



Source: elaboration on NTS data presented in DETR (1999b) Table 2.5, DETR (2000a) Table 2.4.

Van den Brink & Van Wee (2001: 76, 84-5) have reported that, following a 1% per annum reduction in the period 1980s, the consumption of the Dutch passenger car fleet has not reduced since 1990. The explanation for this is that the average weight, engine capacity, and inflation-adjusted price of new vehicles bought in the Netherlands have all increased, as a result of higher safety standards and greater competition between manufacturers, as well as greater consumer demand for relatively high-specification models, for example with air conditioning units. A similar explanation seems to explain the UK trend.

4.1.2 Future UK car fleet efficiency

In addition to the average efficiency estimation, four other assumptions are made.

- New cars sold in 2008 will achieve the target of average CO_2 emissions of 140 g/km. Furthermore, there will be further progress 2008-2010 beyond the 2008 target towards the suggested 2012 target of 120 g/km, so that new cars in 2010 achieve 130 g/km, a 31% improvement on 2000.
- The improvement in new car efficiency is gradual, so that fleet evolution is steady.

- Based on data presented in the National Road Traffic Forecasts (NRTF) for Great Britain, the approximate rate of increase in car ownership in each scenario is assumed to be two-thirds of the rate of increase in traffic (DETR, 1997: Tables 1, 8). Allowance is made for car ownership growth, which means that relatively efficient vehicles are added to the fleet at a faster rate than relatively inefficient ones are eliminated.
- All cars are assumed to travel an equal, average, distance each year[20].

Table 8 indicates the influence of the expected market transformation on whole-fleet CO_2 emissions, given an improvement from 187.9 g/km in 2000 to 130 g/km for new cars, and various levels of car ownership growth in line with the traffic growth scenarios summarised above in Table 6.

Table 8: Evolution of UK car fleet average CO_2 emissions for different levels of ownership growth

	Change for new cars		*Fleet emissions given ownership growth 2000-10:*					
Year	*Average CO_2 emissions*	*Cumulative reduction %*	*14.7%*	*11.3%*	*8.7%*	*8.0%*	*5.3%*	*0%*
2000	**187.9**	-	187.9	187.9	187.9	187.9	187.9	187.9
2001	181.4	3.5	187.3	187.4	187.4	187.4	187.4	187.4
2002	174.9	6.9	186.3	186.4	186.4	186.4	186.5	186.6
2003	167.5	10.8	184.8	184.9	184.9	185.0	185.0	185.2
2004	162.0	13.8	182.8	183.0	183.1	183.1	183.2	183.5
2005	156.5	16.7	180.5	180.7	180.8	180.9	181.0	181.4
2006	151.0	19.6	177.8	178.1	178.3	178.3	178.5	178.9
2007	145.5	22.5	174.9	175.1	175.3	175.4	175.6	176.1
2008	**140.0**	25.5	171.5	171.8	172.1	172.1	172.4	172.9
2009	135.0	28.1	168.0	168.3	168.5	168.6	168.8	169.4
2010	**130.0**	30.8	164.1	164.4	164.6	164.7	165.0	165.5

Further details of the calculations are indicated in Appendix 2.

Hence, a 30.8% reduction in average CO_2 emissions from new cars would result in a fleet-wide average reduction of 11.9-12.7% by 2010.

4.1.3 Revenue implications

In calculating the effects of greater efficiency on fuel tax revenue, the following additional assumptions and baseline data are specified.

- Car and taxi traffic in 2000 was 3.79 billion vehicle-km (bvkm)(DETR 2001).

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[20] In practice, new (soon to be relatively efficient) cars are driven twice as far per year in the UK as cars of average age (Zachariadis, Ntziachristos & Samaras 2001: Figure 3 – after Hickman), but this inverse observed relationship between vehicle age and annual distance driven has not been included in the analysis.

- Fuel duty income in 2000 was £14.97 billion, based on 1998-9 income from private and light goods (PLG) vehicles of £16.36 billion (DETR 2000a: Table 1.20) factored by 0.855[21] to discount light goods traffic (not considered by the present paper) and inflated by 3.4% to allow for the Spring 1999 unleaded petrol duty increase. For subsequent years it is assumed no real-terms duty rate increases occur.
- Additionally, VAT on fuel duty from car use, worth £2.62 billion in 2000, is included, together with VAT on the fuel product cost element. It is assumed that petrol and diesel product prices will fluctuate, depending on world oil prices, around the £0.16/l mark (equivalent to pump prices of 78 p/l), and so VAT will be worth £1 billion per annum. VAT rates are assumed not to change.
- Changes in CO_2 emissions and fuel consumption are assumed to be perfectly correlated.

Table 9 indicates the tax revenue outcome that would be expected in 2010 under the traffic growth scenarios.

Table 9: Fuel tax and CO_2 emissions implications for different traffic growth scenarios

Scenario	*Baseline*	*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
Traffic growth 2000-10 (%)	22.0	17.0	13.0	12.0	8.0
2010 traffic (bvkm)	463.48	444.48	429.29	425.49	410.29
Change in CO_2 emissions & fuel demand (2000 = 100)	107	102	99	98	95
Change in revenue (£ billion)	+1.23	+0.44	-0.18	-0.34	-0.96

The analysis suggests that, under the *Baseline Scenario*, traffic growth would mean that fuel consumption and CO_2 emissions increase by around 10%, resulting in an additional £1.2 billion in fuel tax revenues in 2010. The *BTYP* is also forecast to result in an increase of lower magnitude, worth £0.4 billion. However, if the *BTYP* occurs in the context of *CMC*s, traffic growth would be substantially lower and fuel consumption and CO_2 production (from car traffic alone) would reduce slightly. Notably, though, the 2010 plan with extra motoring costs[22] would not have a major effect over and above that including *CMCs*. A more noticeable reduction of £1 billion would result from *Scenario D1*.

Table 10 extends the analysis to examine the implication of transport policies actually resulting in the stabilisation of traffic growth in the period 2010-12, combined with car manufacturers continue to make progress towards the 120 g/km 2012 target.

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[21] DETR (2000a) Table 4.9 indicates that light goods vehicles travel 14.5% of total PLG distance.

[22] As noted in Section 2.2, constant motoring costs plus extra costs (one or more of workplace parking charges, urban road pricing, inter-urban road pricing).

Table 10: Outcome if traffic restraint scenarios lead to stabilisation 2010-2012[23]

Scenario	BTYP	BTYP + CMC	BTYP + extra	D1
Change in fuel demand (2000 = 100)	98	94	93	90
Change in revenue (£ billion)	-0.46	-1.08	-1.23	-1.84

The table indicates a decline in tax revenue ranging between £0.5 and £1.8 billion emerges by 2012. CO_2 emissions would also decline compared with 2000 levels.

4.2 Effect of lower VED for efficient vehicles

Table 11 indicates the revenue implications for 2010 of introducing emissions-related VED for new cars under the different traffic growth scenarios. The following assumptions are made.

- The number of cars in the national fleet in 2000 is assumed to be 23.24 million, allowing for 2% growth on the 1999 total of 22.78 million (DETR 2000a: Table 3.1).
- Car owners paid a total of £3.51 billion in VED in 2000, based on an average charge of £150 per vehicle. (Hence, allowance is made for the dual-band system introduced by the 2000-1 budget - 10% of owners paying the lower rate of £100 rather than £155 - but not for the 2001-2 decision to extend the discount band).
- As noted in Section 4.1.2, car ownership growth is assumed to occur at a rate two-thirds that of traffic growth for each scenario.
- As the average car CO_2 emissions will be around 165 g/km by 2010 (Table 8), the average VED paid will decline from £150 (nearly all cars in Band D) to £120 (most cars distributed between bands A-C).
- VED rates are assumed to increase only in line with inflation and CO_2 band values and boundaries are expected to remain similar.

Table 11: Tax implications of the new VED regime in 2010

Scenario	Baseline	BTYP	BTYP + CMC	BTYP + extra	D1
2010 Car fleet size (millions)	26.64	25.87	25.25	25.09	24.47
2010 VED income (£ billions)	3.20	3.10	3.03	3.01	2.94
Change 2000-10 (£ billions)	-0.28	-0.37	-0.44	-0.46	-0.54

Under all 2010 scenarios, the growth in car ownership is insufficient to offset reduced Government revenue per car from VED. The tax revenue liability would be up to £0.5 billion. As the 'average' car will still be in Band B in 2012, there is no major additional implication, should traffic growth stabilisation occur beyond 2010.

[23] It is judged that stabilisation of traffic growth 2010-12 would not be a realistic possibility under the baseline scenario, so the calculation is not included.

When combined with changes in fuel tax income (Table 12), the *BTYP* continues to show a minor revenue increase for 2010. By 2012, however, in the context of stabilised traffic growth, the gain becomes a net loss of £0.8 billion. Under more stringent traffic reduction scenarios, the loss could amount to around £1.5-2.4 billion.

Table 12: Implications of efficiency improvement and new VED regime combined (£ billions)

Scenario	*Baseline*	*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
2010	+0.95	+0.07	-0.62	-0.80	-1.50
2012	-	-0.83	-1.52	-1.69	-2.38

4.3 Effect of take-up of alternative technologies

The present section considers two different possible levels of adoption of RFGs by UK motorists by 2010: 10% and 20% of the car fleet. The lower level is equivalent to the British fleet share rising to that of The Netherlands or Australia, with some further growth by the end of the period. The higher level reflects the aspirations of RFG promoters. For example, BG International has reported the desire to achieve 10% market share for CNG alone by the end of the decade.

The following additional assumptions are made.

- RFGs continue to benefit from tax discounts of 69% over ULSP (taking into account higher consumption/km)[24].
- The rate of development of gas-fuel ICE technology matches improvements in petrol/diesel ICE efficiency.

No allowance is made for the adoption of other technologies by 2010, such as battery-electric or fuel cell vehicles, as these can be expected to compete with RFGs within the alternative fuel market sector.

Table 13 indicates that the tax implications of RFG adoption by 2010 are of the order of £1.3-2.6 billion, depending on the traffic growth scenario and the assumed take-up rate of RFGs.

Table 13: Tax implications in 2010 of car fleet adopting RFGs (£ billions)

Scenario	*Baseline*	*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
10% market share	-1.37	-1.31	-1.27	-1.26	-1.22
20% market share	-2.73	-2.63	-2.54	-2.52	-2.43

24 Duty rates examined are those in force in the 2000-1 Budget year. The 2001-2 Budget increased the discounts to 75% for RFGs, but the implication is not included in the analysis.

Notably, conversely to the implications of the other two policies considered above, the magnitudes are greatest where traffic growth is highest, as the tax discount is per km not per car, and the fuel change reduces pollution, not fuel consumption.

Table 14 indicates the combined influence of the policies that would all these be expected in 2010 for the two levels of RFG take-up. The key finding is that, under all scenarios, a reduction in tax income occurs when all three changes are considered. For likely scenarios, with 10% take-up of alternative fuels, the tax revenue implications are a reduction in revenue of £0.9-2.5 billion per annum, rising to £2.2-3.7 billion with the 20% level.

Table 14: Combined effect of efficiency, VED and RFG changes in 2010 (£ billions)

Scenario	*Baseline*	*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
10% take-up of RFG	-0.42	-1.24	-1.89	-2.06	-2.71
20% take-up of RFG	-1.79	-2.55	-3.16	-3.32	-3.93

Table 15 indicates that the stabilisation of traffic growth 2010-2012 (and no further take-up of RFGs) 2010-2012 would increase these amounts to £2.5-3.4 billion per annum in 2012, given 10% take-up by 2010, or £3.7-4.5 billion, given 20% take-up by 2010.

Table 15: Combined effect of efficiency, VED and RFG changes in 2012 (£ billions)

Scenario	*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
10% take-up of RFG	-2.08	-2.73	-2.89	-3.54
20% take-up of RFG	-3.33	-3.94	-4.09	-4.69

Chart 5 suggests the likely evolution of tax revenues for the different traffic growth scenarios appraised, given RFG take-up at the lower level of 10% fleet share. Assuming reasonably smooth implementation of the TYP, revenue would peak by 2003 and decline to 2000 levels by about 2005. Notably, even in if the TYP has no effect, 22% *Baseline Scenario* traffic growth is insufficient to maintain revenue throughout the decade.

Chart 5: Evolution of motoring tax revenues under different traffic growth scenarios

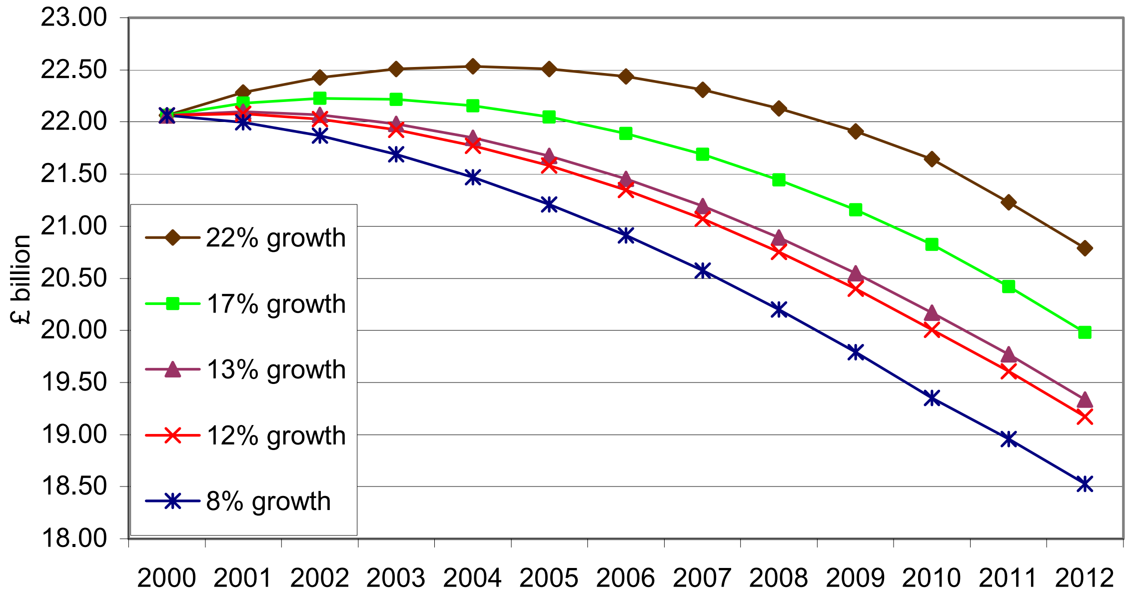

Table 16 summarises the percentage of tax revenue from car use in 2000 that could potentially be lost under likely policy scenarios by 2010 and with traffic stabilisation by 2012. The range is wide: 6-21%, depending on the level of traffic restraint and extent of alternative fuel use.

Table 16: Proportion of 2000 revenue likely to be lost under likely policy scenarios (%)

Scenario		*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
2000-10 (restraint)	10% take-up of RFG	6	9	9	12
	20% take-up of RFG	12	14	15	18
2010-12 (stabilisation)	10% take-up of RFG	9	12	13	16
	20% take-up of RFG	15	18	19	21

In conclusion, the analysis in Section 4 has confirmed the hypothesis that pro-environmental road transport policies do potentially have non-trivial tax revenue consequences for the UK Government. The magnitude of any revenue forgone will reflect a range of factors including:

- the extent to which government is prepared to implement traffic restraint policies,
- the actual and relative levels of fuel duty and VED, and
- the level of progress towards increasing the efficiency and cleanliness of vehicles.

In the context of the *BTYP*, the sums at stake would be 6-12% of current tax revenue from car use only, around £1.2-2.6 billion in 2010 at current prices, possibly rising to £2.1-3.3 billion (9-15%) by 2012.

If motoring costs do not (as expected by DETR) reduce, due to further oil supply problems or significant new charges, traffic growth will be lower and the tax revenue reduction would be up to £4.7 billion by 2012: equivalent to a fifth of revenue from car use in 2000.

5 POSSIBLE POLICY RESPONSES TO DECLINING REVENUE

5.1 Constraints on duty policy over the next decade

Broadly speaking, total national fuel consumption depends on the efficiency of the vehicle fleet, the total distance driven, driver behaviour (*e.g.* driving style and cruising speed) and the extent of road congestion. Levying duties on fossil fuels is a means of influencing both emissions and traffic levels. The need for such policies is likely to continue into the foreseeable future. Fuel taxation is also an important generator of Government revenue.

In the short-term, to 2003, traffic growth is likely to occur in a context of minor, initial, improvements in average efficiency combined with gradual take-up of less-polluting fuels. These trends are consistent with an actual increase in motoring taxation revenues without any increase in duty rates. However, beyond 2003, the demand for diesel and petrol will begin to fall. In additional to petrol and diesel vehicles becoming more efficient, successful operation of both the discounted RFG duty and differentiated VED policies will directly reduce revenue. In order for revenue levels to be maintained, either duty rates would need to rise or some other fiscal measure be introduced.

5.1.1 Petrol and diesel duty

There is strong evidence that Government will encounter political constraints if it seeks to protect revenues by simply increasing petrol and diesel duties. By 2010, some motorists will be driving cars capable of 3 l/100km or better. Others will continue to drive vehicles bought in the late 1990s and early 2000s, with average consumption nearly three times higher, around 8 l/100km, and including middle-range two-litre capacity models requiring 9 or 10 l/100km.

Fuel duty rate increases in this context would in effect be recovering duty which is no longer paid by those with relatively efficient cars from those with relatively inefficient cars. Those with newer cars, such as the commercial fleet operators and richer private motorists, would be relatively able to afford the smaller per km increases they would face. Poorer private motorists, facing greater proportional increases in fuel costs, would have the choice of: simply paying the higher tax burden, driving less, or replacing their vehicles with more efficient models. In practice, some motorists may not be able to afford either to drive as much or replace their vehicles, and would have to drive less or give up private car use altogether.

There would be some environmental policy benefits from such an outcome, although Stokes (1996: Table 1 & Figure 2) shows that the UK households in the lowest quartile of income were responsible for just 7% of the annual national distance driven and Hickman (reproduced as Figure 3 in Zachariadis *et al.*, 2001) demonstrates that UK cars are driven much more intensively in their first years of life[25]. Therefore, any reductions in relatively polluting car-km as a result of the poorest motorists changing their car use behaviour would have a disproportionately small effect. Hence, there is a risk that a policy for higher fuel tax duty would be socially regressive in the sense that it would deter the travel of less well-off motorists who use their cars relatively sparingly, whilst producing only small environmental benefits.

Furthermore, higher fuel costs might initiate a new cycle of efficiency upgrading, which would further polarise the differences between rich and poor motorists whilst undermining attempts to protect fuel duty revenues.

In time, but not before 2015-20, the range in fuel efficiency exhibited by the car fleet may begin to reduce. This will only occur once the time lag before the serviceable life of relatively inefficient vehicles comes to an end, and if the pace of further efficiency gains slows. In any case there will be a period of at least 15 years in which a decreasing majority of motorists, and eventually a declining minority, would be particularly, and arguably unfairly, disadvantaged by further increases in petrol and diesel duty rates.

5.1.2 RFG duty and VED

Another obvious means of countering revenue reductions would be simply to reverse the policies of providing environmental incentives and increase VED or RFG duty rates.

Climate change politics in fact support a case for higher fuel duty on RFGs. The European Commission has proposed a road fuel taxation strategy that relates the CO_2 emissions per unit of equivalent consumption of a fuel directly with the rate at which it is taxed. RFGs do produce less CO_2 per kilometre than petrol, but the reduction is of the order of 25%, whilst the duty discount is now nearly 75%. However, the UK Government has recently reiterated its resistance to energy tax harmonisation measures and, as noted in Section 3.3, committed in the 2001-2 budget not to increase duty on RFGs in real terms before 2004.

However, air quality policy objectives urge the retention of high levels of discount, as the proportions of noxious pollutants avoided by using RFGs instead of petrol and diesel are of a similar order to the discount. As noted in Section 3.3, though, the fuel product costs of RFGs are actually higher than petrol or diesel under present market conditions, and consumers would generally not voluntarily accept these higher costs in order to create the public benefit of lower pollution. As the majority of cars that are intended to run primarily on RFGs also have the possibility to use petrol, motorists would be able to switch between the two, depending on a combination of convenience and price factors. The disincentives for using a non-standard fuel, for example more restricted availability than petrol and specialised insurance arrangements in some cases, suggest that a significant tax incentive will be necessary for many years to come, if RFGs are to remain attractive.

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[25] The typical car is driven an average of 23,000km in the first year of life but by the time it is ten years old this distance has declined by nearly half, to 13,000km. The annual distance driven reduces further, to 7,500km, a decade later.

Individuals and businesses using RFGs will have invested £1-2,000 extra per car in buying more expensive models or converting existing cars. Various assumptions about the stability of the price differentials between RFGs and conventional fuels will have been made, and some will be assuming that the policy is long-term. Considerable ill feeling could be created if government is seen to be penalising those who have invested in cleaner technology. RFG 'incumbents' are likely to resist plans to increase duty rates, although resistance may be reduced in the cases in which motorists had already recouped the cost of their investments by having access to cheaper fuel. Reduction or removal of the incentive could halt the transfer to RFGs and would probably reverse it.

5.2 Longer-term challenges for the duty regime

Even if political objections to increasing duty rates do not emerge, or can be overcome, other reasons suggest that the current regime will in any case become untenable in the long-term. Much more radical technological change is likely to greatly increase efficiency and new fuels will create major practical problems for a system based on taxation at the point of sale.

5.2.1 Expected technological developments

The *Hypercar Center* at the Rocky Mountain Institute (RMI) in Colorado, USA monitors the technological pronouncements of the automotive industry worldwide. Although not a methodologically rigorous *Delphi* study, the exercise produces a useful picture of industry intentions. Whilst it can be argued that the claims may be optimistic, the counterview is that manufacturers' developments are often more advanced in secret than they are prepared to admit in public, for reasons of commercial strategy. Certainly, the recent petrol-electric hybrid and high-efficiency diesel developments by Honda, Toyota, and VW have kept to, or even anticipated, their published timetables. Table 17 (overleaf) provides a chronology of intended developments over the next two decades.

A number of major manufacturers, particularly Japanese companies but also Ford, will develop ranges of petrol-electric hybrid vehicles during the period 2001-2003. Typically, such vehicles require 20-50% less fuel than conventional ICE cars. However, Volkswagen will take the concept further with an ultra-lightweight diesel-electric hybrid version of the *Lupo* that will require 75% less fuel than the most efficient ICE cars generally available today (CEC 2000). Industry opinion suggests that hybrid vehicles could be the choice of 20% of purchasers of new cars by 2010.

From 2003, the first fuel-cell models are programmed to appear. As technical difficulties remain with hydrogen refuelling, and there is also the need to establish a supply network, most manufacturers will take the interim step of producing vehicles that refuel with petrol, methanol or natural gas. One of those fuels will then be used as a raw material for hydrogen production onboard, in order to supply the fuel cell[26]. Another limiting factor for fuel cells may be the availability of platinum for use in their catalyst membranes, unless an alternative catalyst can be found (Borgwardt 2001: 199). Nonetheless, some commentators believe that fuel cells could potentially achieve 10% market penetration by 2010, although the share of one alternative technology will depend upon the success of the others, including advanced ICE and ICE-hybrid technologies.

Table 17: Automotive industry predictions about technological development

Year	Development	Announcement
By 2002	Toyota to achieve production of a three-model range of hybrid-drive vehicles in addition to Prius	September 2000
	Honda to produce hybrid-drive Civic to accompany Insight	May 2000
By 2003	DaimlerChrysler AG to produce first fuel cell buses to be sold for $1.6 million each for trials in European cities	April 2001
By 2004	EU/VW research project to result in production of a lightweight diesel hybrid-drive Lupo model achieving 1 l/100km (285 mpg)	September 2000 (CEC & VW Chairman)
	Ford to market a range of hybrid-drive vehicles	January 2000
	Ballard Power Systems to have produced more than 250,000 fuel-cell units suitable for cars	Pearce (2000)
	Ford Focus MkII and Mercedes A-Class MkII to be offered with Ballard fuel cells	11 July 2000 (Daily Telegraph Motoring)
	Honda to market fuel-cell Civic	May 2000
By 2005	Entire Honda model range to be either hybrid-drive or fuel-cell powered	January 2000
	Daimler-Chrysler/Ford/Ballard Power Systems and Toyota to be producing at least 100,000 fuel cell vehicles per annum each	October 1997
By 2010	20% of cars in US to be hybrid-drive	June 2000 (Ford Chairman)
	10% (100,000s) of GM production to be fuel-cell vehicles	June 2000
	10% of new German cars to be hydrogen-powered	2000 (German Transport Minister)
By 2020	50% of new vehicles to be hydrogen-powered and 20% of all vehicles	May 2000 (Deutsche Shell Director)
	25% of world market to be fuel-cell vehicles	2000 (GM)

Sources: RMI (2001) unless indicated otherwise.

Table 18 reports the results of a road trial of a particular model equipped with fuel cells deriving hydrogen from different fuel sources.

[26] German industry is, however, reported to be pursuing the approach of refuelling cars with hydrogen mass-produced on the forecourt or industrially, which is likely to be the most efficient, least polluting approach.

Table 18: CO_2 Emissions from vehicles powered by fuel cell variants

	CO_2 emissions (g/km)	Reduction in CO_2 (% of petrol model)
Petrol ICE	248	-
Petrol Fuel Cell	193	22
Methanol Fuel Cell	170	31
Natural Gas Fuel Cell	75	70

Source: elaboration on data from Pearce (2000), derived from a 1000-km trial of the Mercedes A Class equipped with a conventional petrol engine or fuel cells supplied with hydrogen derived from petrol, methanol, or natural gas.

The CO_2 emissions results demonstrate that, in the first instance, fuel cell vehicles supplied with petrol or methanol would have a modest, rather than radical, influence on fuel consumption and emissions. Adoption of hydrogen-rich natural gas (mainly constituted by methane) would bring a reduction of a greater order of magnitude: the level of CO_2 emissions would be less than a third that from current typical ICE cars.

In the decade 2000-2010, ICE-hybrid or fuel cell technologies are likely to appeal to the same market sector, and hence to some degree will be in competition. However, from the perspective of the taxation implications of technological change in that period, competition between alternative fuels will not be of great importance, as each is likely to result in a similar efficiency improvement.

In the following decade (2010-20), though, transition to a hydrogen-based economy is likely to make greater progress. Both fuel cell and ICE technologies are theoretically capable of yielding the automotive 'holy grail' of consuming only hydrogen produced from a renewable source, and in turn producing only water, but as the technologies develop, the inherent efficiency benefits of fuel cells over ICEs, such as mechanical simplicity, are likely to become significant.

Furthermore, as fuel cell technology comes to be built into the vehicle from the design stage, synergies will be achieved, in particular offering the potential for reduced vehicle weight (Lovins & Lovins 1995). Fuel cells themselves produce electrical rather than mechanical energy, and so they are particularly suitable for generator-battery storage hybrid implementations, suggesting that the two approaches will in fact be combined, leading to greater efficiency than indicated in Table 18.

In summary, in addition to the revenue changes analysed in Section 4 which are expected in the next decade, changes in the technical context of motoring and fuel sales suggest that the taxation system will have to undergo significant adaptation in order to collect similar levels of revenue. Future changes are likely to include:

- much greater improvements in efficiency in the longer term than the changes proposed by the current agreement between the authorities and car manufacturers;
- the introduction of methanol (sometimes containing petrol as a low-volume additive) as a road fuel;

- a wider role for natural gas as a fuel for hydrogen production; and
- the supply of hydrogen as an RFG.

5.2.2 Some tax implications of technological change

The taxation implications of using natural gas to produce hydrogen for fuel cells are perhaps the most straightforward to predict. Consumption and emissions per car-km could reduce to around 30% of current CNG-powered ICEs. Except under very high traffic growth scenarios, such an efficiency improvement implies significant reductions in road fuel consumption in the UK. Setting on one side the possible political problems of increasing CNG duty (outlined in Section 5.1.2), Government could simply increase the duty rate to the same extent that efficiency reduces consumption. At 2001-2 duty rates, total tax revenue per car-km travelled using CNG is around 20% of that derived from ULSP. With efficiency gains, that revenue would decline to 6%. Supposing the entire car fleet were to operate on CNG, then to derive the same amount of revenue as currently produced by tax on ULSP and ULSD, combined duty and VAT on CNG would have to be increased by a factor of 27. Assuming stable product prices, then the proportion of fuel costs per kilometre that would be fuel duty and VAT would increase from 33% currently to 92%.

There are, though, likely to be other difficulties, which will prove harder to resolve. One of these will be applying the regime devised for 'mineral oils' to situations involving other fuels. For example, electric car energy costs are around 1p per car-km. Not allowing for any future efficiency gains (and assuming that the 5% VAT rating remains), a duty rate equivalent to 5p per km would have to be introduced in some way, in order to match current levels of revenue from ULSP and ULSD. Taxation would account for 81% of total fuel costs per km, rather than the 5% at present. Special meters, and probably plugs, would be required to administer the recharging of batteries at a higher tax rate than is levied on domestic electricity. Nonetheless, given the enormous differential that would be created, the problem of fraudulent recharging from the domestic supply might be impossible to overcome.

The matter of fuel duty fraud is by no means a new one. The introduction of the first tax on petrol in 1909 was resisted by Customs and Treasury officials precisely because it would be so easy to obtain petrol - then used for a much wider range of domestic purposes – duty free and then use it for dutiable motoring (Plowden 1971: 88-89). By 1919 it was estimated that 20-30 million gallons per annum of duty-free petrol were being used for motoring (*Op. cit.*: 148), a problem that was apparently not fully resolved until petrol use came to be dominated by demand for motoring. It was reduced, however, by moving the emphasis of motoring taxation away from fuel duty, towards vehicle type and horsepower rating.

This historic evidence suggests that, in the short-term at least, adapting the taxation system to the use of fuels such as hydrogen and methanol, assuming they are not also introduced as domestic fuels, might actually be more straightforward than the cases of natural gas and electricity. Nonetheless, insurmountable practical difficulties may nonetheless arise in the future, particularly in the case of hydrogen. One vision is that vehicle fuel-cell units would never be fully switched off (due to the constraints on long-term on-board hydrogen storage). Instead, the energy derived would contribute to domestic electricity consumption, or could even be fed into the national grid (English 2000). If so, consumption would not be easily desegregated from production. Determining which consumption is domestic and which for road use for the purposes of taxation would be impossible. Furthermore, the raw materials for energy production might eventually be water and solar power, used to produce hydrogen by electrolysis. Road fuel duties might cease to be a tenable concept if motorists were to power their cars on hydrogen produced domestically from natural resources.

In summary, recent political protests about fuel prices and the increasing range of vehicle efficiency suggest short-to-medium term constraints on increasing duty rates. Future falls in world oil prices or a reduction in the range of vehicle efficiency would ease these constraints. Some particular loser groups, such as the mobility impaired or rural car-dependent poor, may continue to present a strong case against increasing rates, but the greatest problems for taxation policy in the future, may not necessarily be the public perception that prices are excessive. Section 5.3, below, offers an initial assessment of some of the options for revenue replacement that would be available to government.

5.3 Revenue-increasing alternatives to fuel duty rises

At the national strategic level, Government would have a choice whether to seek to replace motoring taxation revenues at all, or merely raise other taxes (*e.g.* income tax) or perhaps indirectly related taxes (*e.g.* solar panel tax). However, as motoring taxation policy has transport policy aims as well as a revenue-raising role, it is assumed that fiscal measures will continue to be applied for motoring.

5.3.1 Targeted subsidies

A system of fuel tax rebates for specific groups, such as those on low incomes and owning inefficient cars, could be considered. The intention would be to implement a general increase in fuel duty rates whilst not placing an unreasonable, unavoidable burden on these groups.

Schemes with a similar practical character (*e.g.* rebates administered on a selective basis according to place of residence) have been operated elsewhere for different policy reasons. Some Italian border regions administer special rebate schemes for local residents to avoid cross-border refuelling traffic and other market distortion effects due to Swiss and Slovenian prices being lower. Motorists who have their primary residences close to the Swiss border with Lombardy can apply for a discount permit enabling them to purchase petrol and diesel at a reduced tax rate. The discount tariff is structured in three bands, worth around 5%, 10% and 15% of the pump price and increasing in value with proximity to the border.

However, such policies may be bureaucratic to operate for a number of special case groups in the UK. Providing discounts to those with mobility impairment certificates could be relatively straightforward, although the level of impairment necessary for eligibility and the amount of discount might be contested. Deciding which geographical areas are sufficiently remote from services or public transport to reach them would probably be even more controversial. In both cases, meanstesting would be necessary if such a policy were to be seen as fair, but the selection of a particular disposable income threshold would generate objections.

Rebates would reduce the fiscal pressure on motorists, so prolonging the circulation of relatively polluting, inefficient cars, as well as running contrary to attempts to reduce car dependence through improving rural public transport. Pressures already fall disproportionately on motorists with relatively low incomes and, as noted in Section 5.1.1, on average they drive a disproportionately low share of annual distance travelled by the car fleet.

5.3.2 Odometer tax

As every car is required by law to have a functioning odometer, it would be possible to introduce a new kilometre-tax based on the annual distance driven. Based on the data reported in Section 4, the average UK car travelled 16,350 km (10,100 miles) in 2000 at an average fuel cost of £1,765, of which £1,335 was tax. Supposing fuel tax were to be entirely replaced by the new regime, then a rate of around 8p/km (13p/mile) would be required to raise the same amount of revenue. In practice, as such a tax would not reflect fuel efficiency, it would not be desirable to entirely replace the fuel tax regime. Instead, the new tax could be levied at a much lower rate and used to spread some or all of the effects of any future increase in motoring taxation across all motorists, so limiting the extent to which those with inefficient vehicles are exposed to higher fuel costs, without entirely removing the incentive to move to new technologies.

Records of vehicle mileage are already logged on MOT certificates, which suggests one potential way of administering the tax, but cars less than three years of age do not require MOT tests, and so would need to be subject to special arrangements. The tax could be collected along with the payment of VED. However, measures would be needed to minimise the considerable efforts to defraud the system that would otherwise be expected, such as spot-checks to ensure that motorists had not disconnected the speedometer drive or failed to have a broken one repaired. In practice, a separate tamper-resistant device fitted directly to a drive shaft might be necessary.

The scheme would have some similarities with the company car taxation regime in force until April 2002, which includes annual distance travelled as a factor in calculating liabilities. Unlike that regime, though, discounts would not be offered for higher distances driven, to avoid encouraging additional traffic. Nonetheless, a transport policy disadvantage of the odometer tax is that it would be even less related to the incidence of congestion on the road network than is the current fuel tax regime.

5.3.3 Car dependence tax

Parking charges for 'out-of-town' shopping centres have been considered by Government, but were not included in the 1998 White Paper on Transport Policy (DETR 1998), which supported only workplace parking taxes if sought by local policy makers. A tax based on car-trip generation for non-residential premises with private car parks could provide a new revenue stream whilst at the same time targeting facilities that tend to generate both a large absolute number and a large proportion of car movements. Companies could either absorb the costs or pass the tax on to users of their facilities. If the tax were applied according to actual use of the car park, by installing vehicle counters, rather than basing the tax on car park capacity, there would be a greater incentive for the company to reduce its tax liability by promoting alternatives to car travel. Depending on the rates applied, the policy has some potential to influence car use and road congestion, particularly in the immediate environs of the facilities themselves.

5.3.4 Road pricing

Road pricing has been strongly promoted by some commentators in recent years. In addition to raising revenue and restraining overall traffic levels, variants of the tolling approach could also target vehicle occupancy, through the provision of high occupancy toll lanes charged at a lower rate, or congestion, by varying the levels of toll through time according to traffic density. Other European Union states, notably France and Italy, already apply non-congestion related motorway tolls, which in part compensate for the lower fuel duty rates in those countries with respect to the UK.

In current policy development (DETR 1998, 2000c), UK Government proposals are limited to

- permitting local authorities to introduce *hypothecated* urban road tolls, and
- discussion of, but no firm commitment to, inter-urban road pricing.

Notably, hypothecation implies that revenues from local schemes, except for the VAT element, would not benefit the Treasury. Hence, were URP to be successful in deterring car travel, it would be another policy which has the effect of reducing fuel duty revenue, not a policy to replace it.

The possibility of IURP is included in the *BTYP + extra* and *D1* scenarios considered in Section 4, and the toll revenue would not be hypothecated for local authority purposes, although it may be hypothecated for extra expenditure on public transport. Indeed, if the predicted rate of traffic growth under these two scenarios does occur in the context of a non-hypothecated IURP scheme being included in the traffic restraint package, then the means of replacing the revenue lost from reductions in other motoring taxes is inherent in the package. If, though, the same amount of traffic restraint were to be achieved without the IURP option, or the tolls are hypothecated, then the shortfall would not be covered.

5.4 Outline of a motorway-tolling approach to revenue substitution

5.4.1 Public acceptability of motorway tolls

The case for road pricing is perhaps strongest when applied to the motorway network: a network restricted to particular classes of vehicles, dedicated to providing for relatively high speed, used for relatively long journeys, and with relatively high maintenance costs. Congestion increases are also expected to be particularly high on the inter-urban road network over the next ten years (DETR 2000d).

The UK motorway network, which generally links major cities, also serves the travel market niches in which the public transport system, particularly the rail network, is best able to compete by offering an attractive alternative to car use. Indeed, without motorway tolls, lower motoring costs could undermine the patronage generation potential of the considerable investment proposed by the TYP in the strategic north-south railways.

In the context of lower fuel bills due to more efficient cars and growing wealth, it can be supposed that the majority of motorists would continue to prefer the convenience and speed of motorway travel, even if a premium charge were introduced. A political strategy to increase the perceived acceptability of motorway tolls might be appropriate to introduce a small real-terms cut in road fuel duties alongside the initiation of tolls, in order to emphasise the trade-off.

Nonetheless, as motorways tend to duplicate the general-purpose road network, alternative routes would tend to attract some motorists who object to paying tolls. The rates of diversion would need to be carefully managed by local implementation policy. Sections of road network that might suffer excessively from redistribution could be exempt from charges, such as occurs in the case of some orbital roads around urban areas in France and Italy. Speed limit policy may also have a role to play. Notably, French motorways have a speed limit (in dry weather conditions) of 130 km/h compared with 112 km/h in the UK, whilst single carriageway *routes nationales* (which in France have legally to be available as parallel toll-free alternatives) are generally limited to 90 km/h rather than the 97 km/h highest limit for single-carriageway roads in the UK. The 44% difference in speed limit between the two road classes in France creates a greater incentive to use the tolled roads than would be expected if tolls were introduced for UK motorways in the context of the current 16% differential.

Motorway tolls would not tend to increase motoring costs *within* the most rural regions, such as Cornwall, mid-Wales, East Anglia, The Borders and the Highlands, where there are few motorways, nor in the more rural Shire counties, such as Dorset and North Yorkshire. Politically, this would provide a response to two 'rural' concerns. The first of these is that people in rural areas are obliged to drive further due to the longer distances to facilities. Second, rural people on relatively low incomes who might choose not to own cars, were they living in urban areas, in fact choose to own them due to the poor rural public transport alternatives[27].

Nonetheless, road-pricing schemes are in general vulnerable to accusations of being socially regressive. Such claims could be true if the new charges were additional to, rather than alternatives for, fuel duty increases. In any case, motorway tolling is less

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[27] By rehearsing this argument the intention is not necessarily to promote it. Indeed, there is evidence that although rural motorists travel on average 25% further than urban motorists (Cullinane & Stokes 1998) their fuel consumption is just 10% higher than urban motorists, due to lower congestion (Boardman 1998). Recent research commissioned by the BBC, considering all motoring costs including vehicle depreciation, has argued that urban commuting is more expensive than rural commuting, despite the facts that rural motorists tend to drive further and pay more per litre for fuel (Harrabin 2001). Furthermore, allowing motoring costs to decline would tend to make rural public transport even less viable.

likely to be regressive than other forms of charging, such as a fixed-price-per-entry urban cordon toll. As the annual distances travelled by motorists is closely related to their incomes, age of car (Section 4.1.1) and whether they are travelling for business, those car users that make above-average use of motorways will pay the largest share of tolls, but will also be the group most able to afford them. Commercial travellers would have the possibility of passing the costs on to their customers. Both relatively wealthy private motorists and commercial drivers tend to drive relatively new vehicles and so will be the early beneficiaries of increasing efficiency and declining fuel costs. In the absence of tolls being introduced, this group of motorists will actually pay less for their motoring and would be expected to drive more.

5.4.2 Levels of toll required to substitute lost fuel duty and VED revenue

Assuming that tolls are introduced only on the motorway network, then they would be levied on around 17% of car-km currently travelled (DETR 2001: Table 4). Table 19 indicates the levels of toll per km that would need to be in place by 2010 in order to compensate for the reductions in tax revenue presented in Table 16 (above), under different transport policy scenarios and rates of market transition to RFGs.

Table 19: Motorway toll for passenger cars (pence/km) required to recover lost revenue

Scenario		*BTYP*	*BTYP + CMC*	*BTYP + extra*	*D1*
Efficiency gains + VED changes + 10% take-up of RFG	2010	1.7	2.6	2.9	3.9
	2012	2.8	3.8	4.1	5.1
Efficiency gains + VED changes + 20% take-up of RFG	2010	3.4	4.4	4.7	5.7
	2012	4.5	5.5	5.7	6.8

For comparison, Table 20 indicates the tolls levied between some principal French cities in 2000. Italian motorway tolls for cars were similar, or slightly higher, at around 4p/km for the Milan-Turin route.

Table 20: Examples of French autoroute tolls in 2000

route	*km*	*Total toll (€)*		*€/km*		*£/km*[28]	
		car	*HGV*	*car*	*HGV*	*car*	*HGV*
Paris-Lyons-Paris	925	50	128	0.05	0.14	**0.03**	0.09
Paris-Marseilles-Paris	1,538	84	206	0.05	0.13	**0.03**	0.08

Toll data from *Association des Sociétés Françaises d'Autoroutes* (ASFA 1999)

Under most BTYP scenarios, UK tolls required to replace lost tax revenue could be comparable to those in France, although if greater traffic restraint were to apply in a context of wide take-up of RFGs then higher levels of toll would probably be necessary.

[28] At an exchange rate of €1 = £0.63.

In practice, rather than the tolls being an entirely un-hypothecated tax, it might make sense for part of the revenue to be a user-charge, so as to fund motorway maintenance and any future construction directly from the income stream. Such a policy would be in the spirit of the November 2000 Government commitment to hypothecate any future road fuel duty increases for the purposes of *"improving public transport and modernising the road network"* (HM Treasury 2000c: para 6.62). Indeed, given the current political pressure to cut rather than raise fuel duties in the short-term, and the likelihood of falls in demand for the high-taxed fuels in the future, it may be the only way in which the commitment has practical significance.

Notably, revenue from French motorway tolls (from all classes of vehicles) in 1999 was €5.17 billion (ASFA 2000), most of which was spent on construction and repairs, whilst 22% (€1.14 billion or £0.72 billion) was levied in government taxation (excluding VAT on construction projects). Depending on prevalent UK road policies, the proportion spent on construction could be lower and the tax element greater.

In the longer term, tolls would probably be applied to a wider range of roads and contribute an increasing proportion of Government income from motoring, as fuel taxation and VED revenue streams decline.

6 CONCLUSION

Successive UK Governments, over a number of decades, have enjoyed growing tax revenues from motoring as a result of increasing car ownership, increasing distance travelled per car, and only modest increases in average efficiency. The present paper finds that these increases in road traffic nationally will be insufficient to 'compensate' for greater per unit efficiency, the UK Government can no longer rely on revenue growing into the future, especially if the transport policies which Government itself has committed to introduce prove to be effective at restraining traffic growth.

In addition to the prospects for eventual stabilisation of traffic growth and vehicle ownership growth, an important trend suggesting the possibility of an actual decline in taxation revenue is the likelihood of a significant improvement in new passenger car efficiency, which will have a gradually more important influence as the car fleet is renewed over a period of around 15 years.

Responding to increased vehicle efficiency by raising fuel duty rates would be one way of protecting tax revenues whilst continuing to pull a pro-environmental policy lever. However, political constraints are likely to make fuel duty increases at least as contentious as they have been in recent years. A widening range of vehicle efficiency will tend to result in any increases in fuel duty being disproportionately paid by those with relatively inefficient cars, who tend to drive least.

Similar situations are likely to arise in the case of Government policies to promote more efficient and less polluting cars through emissions-related VED and duty incentives for alternative fuels. A policy-reversal leading to increased excise rates may be seen as penalising citizens who have made 'altruistic' choices whilst potentially reversing valuable progress in the diffusion of low-pollution technology.

Furthermore, it can be noted that even greater challenges to the established system of vehicle taxation are likely to emerge in the future, notably as a result of the adoption of the hydrogen fuel cell. Some of the broad implications of such developments have been acknowledged in the present paper as being more practical than political: about *how* to tax the fuels rather than *whether* higher taxation rates would be possible. Indeed, it would be prudent to begin planning for a future when it will no longer be possible to rely on fuel consumption taxes at all and to begin the transition towards a motoring taxation system functioning on a different basis.

A transfer from fuel sales taxes to a distance or congestion-related charge for road use would also reduce government exposure to the political and economic uncertainties of global and national fluctuations in oil price, supply and demand. However, the most advanced UK policy discussions have accepted only the case for urban road tolls, which would be hypothecated to local authorities, with little consequent benefit for the Treasury.

The introduction of tolls to most existing and any new UK motorways may offer the most effective and fairest means of covering the potential shortfall in taxation, as it will tend to raise the revenue from those most likely to be enjoying the benefits of more efficient motoring and most able to pay the new charges. Although public acceptability remains a problem, falling individual expenditure on car fuel may ease the case for acceptance. Over time, tolls would come to represent a larger proportion of motoring costs. They would possibly be extended to other roads or could incorporate a congestion or vehicle ridership-related element.

Tolls could also form part of a more radical initiative for a wholly or partly self-financing motorway network, which would offset motoring revenue reductions by relieving the Treasury/DETR of the burden of supporting the most expensive class of roads.

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APPENDIX 1: ESTIMATION OF CO_2 EMISSIONS FROM EXISTING CAR FLEET

DETR (2000a: Table 3.4) indicates that there were 19.96 million petrol-engine cars registered in Great Britain in 1999 and 2.81 million diesel-engine cars. Cars with other propulsion types amounted to less than 0.1% of the national fleet. Hence, petrol cars amounted to 88% of the fleet and diesel cars 12%.

Analysis of data from the VCA and DETR enabled the calculation of average emissions figures for vehicles in nine engine capacity bands (Table 21). Weighted to allow for the engine-size distribution of the fleet, these provide the basis of a calculation that the average CO_2 emission figure for petrol cars in 2000[29] was 190.5 g/km.

Table 21: Estimation of average petrol car emissions for engine capacity bands

Engine capacity band (cc)	No models available in July 2000	Average CO_2 emissions for new models in July 2000 (g/km)	No of cars in 1999 fleet (000s)	CO_2 emissions if 2000 fleet driven 1 km (kg)
0-700	10	117.3	17.3	2,029
701-1000	34	145.5	1,433.7	208,557
1001-1200	10	156.0	2,274.2	354,781
1201-1500	179	171.1	5,510.2	942,836
1501-1800	347	195.8	5,922.2	1,159,316
1801-2000	347	217.2	3,179.0	690,508
2001-2500	155	243.7	733.6	178,818
2501-3000	106	262.4	487.1	127,814
3001+	163	340.9	403.5	137,552
Totals	1,351	-	19,960.9	3,802,211

Sources: availability of models from VCA (2000), breakdown of car fleet by engine capacity specially provided by DETR.

Table 22 (following) repeats the analysis for diesel cars, resulting in an average of 169.2 gCO_2/km in 2000.

Overall, the UK car fleet in 2000 is found to have emitted an average of 187.9 g/km, with emissions from diesel cars having been 11% lower than petrol cars once actual consumer purchasing behaviour is considered. Hence, the UK average emissions for cars purchased new are currently slightly higher than the average for the EU of 185 (Table 2).

[29] As presented by Chart 2 (Section 3.1), fuel consumption performance has not altered significantly over the last decade. Therefore the average CO_2 emission figure calculated here can be represented as applying to the whole fleet, not only cars purchased in 2000.

Table 22: Estimation of average diesel car emissions for engine capacity bands

Engine capacity band (cc)	No models available in July 2000	Average CO_2 emissions for new models in July 2000 (g/km)	No of cars in 1999 fleet (000s)	CO_2 emissions if 2000 fleet driven 1 km (kg)
0-700	0	-	0.3	Negligible
701-1000	2	90.0	1.7	151
1001-1200	0	-	0.4	Negligible
1201-1500	3	127.3	89.0	11,329
1501-1800	31	154.2	999.6	154,165
1801-2000	190	161.1	1,209.3	194,765
2001-2500	68	215.5	356.5	76,817
2501-3000	27	246.1	120.3	29,615
3001+	12	261.1	33.0	8,621
Totals	333	-	2,810.0	475,464

Sources: as Table 20.

The level from diesel cars is somewhat less than the 25% difference (46 gCO_2/km) found between similar engine capacity band classes for petrol and diesel cars. The main explanation seems to be that purchasers buy a larger capacity diesel model than they would petrol model to compensate for performance differences, so consuming part of the potential environmental benefit. However, manufacturers' decisions to offer a relatively small range of diesel models with engine capacities of less than 1,800cc may encourage this consumer behaviour. Notably, one third of diesel vehicles purchased in recent years in the UK have an engine capacity of less than 1,800cc, whilst 90% of the diesel models available have engines that are larger than 1,800cc. The same phenomenon of limited choice at the efficient end of the market also applies in the case of petrol cars, but is less marked than for diesels.

APPENDIX 2: EVOLUTION OF CAR FLEET EFFICIENCY

Increases in car ownership will have a positive influence on the rate of reduction of average fleet consumption. A cohort analysis was undertaken to estimate this effect.

It is assumed that cars are scrapped when (and only when) they reach 15 years of age. Each new cohort is assumed to have the average efficiency in the given year of purchase. That average efficiency is taken to be that required to give steady-rate improvement towards the dated targets agreed with the car manufacturers. These changes, combined with stability in fleet emissions in recent years, result in the matrix of CO_2 emissions for a given age of vehicle in a given year shown in Table 23.

Table 23: average emissions for vehicles of given age for 2000-2012

	Average emissions given age (years):														
Year	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
2000	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9
2001	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4
2002	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9
2003	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5
2004	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0
2005	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5
2006	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0
2007	187.9	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5
2008	187.9	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5	140.0
2009	187.9	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5	140.0	135.0
2010	187.9	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5	140.0	135.0	130.0
2011	187.9	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5	140.0	135.0	130.0	125.0
2012	187.9	187.9	187.9	181.4	174.9	167.5	162.0	156.5	151.0	145.5	140.0	135.0	130.0	125.0	120.0

Each new cohort will also be larger than the previous one, depending on the extent of car ownership growth assumed in each scenario. Tables 24-28 show the emissions outcomes for the five levels of growth. In general the differences are found to be small, but do have influence when applied to the aggregate national situation.

Table 24: Evolution of vehicle fleet emissions for years 2000-12 given 14.7% ownership growth

Age (yrs)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	all
Year	Millions of cars of given age:															total
2000	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	23.2
2001	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	23.6
2002	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	23.9
2003	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	24.3
2004	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	24.6
2005	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	24.9
2006	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	25.3
2007	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	25.6
2008	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	26.0
2009	1.549	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	26.3
2010	1.549	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	26.6
2011	1.549	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.549	26.6
2012	1.549	1.549	1.549	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.890	1.549	1.549	26.6
Year	Average emissions weighted by number of cars of given age															Ave-rage
2000	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	187.9
2001	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	187.3
2002	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	186.3
2003	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	184.8
2004	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	182.8
2005	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	180.5
2006	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	177.8
2007	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	174.9
2008	291.0	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	264.6	171.5
2009	291.0	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	264.6	255.1	168.0
2010	291.0	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	264.6	255.1	245.7	164.1
2011	291.0	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	264.6	255.1	245.7	193.6	160.5
2012	291.0	291.0	291.0	342.7	330.5	316.5	306.2	295.8	285.4	275.0	264.6	255.1	245.7	193.6	185.9	156.5

Table 25: Evolution of vehicle fleet emissions for years 2000-12 given 11.3% ownership growth

Age (yrs)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	all
Year	Millions of cars of given age:															total
2000	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	23.2
2001	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	23.5
2002	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	23.8
2003	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	24.0
2004	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	24.3
2005	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	24.6
2006	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	24.8
2007	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	25.1
2008	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	25.3
2009	1.549	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	25.6
2010	1.549	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	25.9
2011	1.549	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.549	25.9
2012	1.549	1.549	1.549	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.812	1.549	1.549	25.9
Year	Average emissions weighted by number of cars of given age															Ave-rage
2000	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	187.9
2001	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	187.4
2002	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	186.4
2003	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	184.9
2004	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	183.0
2005	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	180.7
2006	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	178.1
2007	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	175.1
2008	291.0	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	253.7	171.8
2009	291.0	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	253.7	244.7	168.3
2010	291.0	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	253.7	244.7	235.6	164.4
2011	291.0	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	253.7	244.7	235.6	193.6	160.6
2012	291.0	291.0	291.0	328.7	316.9	303.6	293.6	283.6	273.7	263.7	253.7	244.7	235.6	193.6	185.9	156.6

Table 26: Evolution of vehicle fleet emissions for years 2000-12 given 8.7% ownership growth

Age (yrs)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	all
Year							Millions of cars of given age:									total
2000	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	23.2
2001	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	23.4
2002	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	23.6
2003	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	23.8
2004	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	24.0
2005	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	24.2
2006	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	24.4
2007	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	24.6
2008	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	24.8
2009	1.549	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	25.0
2010	1.549	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	25.2
2011	1.549	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.549	25.2
2012	1.549	1.549	1.549	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.549	1.549	25.2
Year							Average emissions weighted by number of cars of given age									Ave-rage
2000	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	187.9
2001	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	187.4
2002	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	186.4
2003	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	184.9
2004	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	183.1
2005	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	180.8
2006	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	178.3
2007	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	175.3
2008	291.0	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	245.1	172.1
2009	291.0	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	245.1	236.3	168.5
2010	291.0	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	245.1	236.3	227.6	164.6
2011	291.0	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	245.1	236.3	227.6	193.6	160.8
2012	291.0	291.0	291.0	317.5	306.1	293.2	283.6	273.9	264.3	254.7	245.1	236.3	227.6	193.6	185.9	156.6

Table 27: Evolution of vehicle fleet emissions for years 2000-12 given 8% ownership growth

Age (yrs)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	all
Year								Millions of cars of given age:								total
2000	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	23.2
2001	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	23.4
2002	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	23.6
2003	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	23.8
2004	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	24.0
2005	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	24.2
2006	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	24.4
2007	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	24.5
2008	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	24.7
2009	1.549	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	24.9
2010	1.549	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	25.1
2011	1.549	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.549	25.1
2012	1.549	1.549	1.549	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.735	1.549	1.549	25.1
Year							Average emissions weighted by number of cars of given age									Ave-rage
2000	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	187.9
2001	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	187.4
2002	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	186.4
2003	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	185.0
2004	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	183.1
2005	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	180.9
2006	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	178.3
2007	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	175.4
2008	291.0	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	242.9	172.1
2009	291.0	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	242.9	234.2	168.6
2010	291.0	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	242.9	234.2	225.5	164.7
2011	291.0	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	242.9	234.2	225.5	193.6	160.8
2012	291.0	291.0	291.0	314.6	303.4	290.6	281.1	271.5	262.0	252.4	242.9	234.2	225.5	193.6	185.9	156.6

Table 28: Evolution of vehicle fleet emissions for years 2000-12 given 5.3% ownership growth

Age (yrs)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	all
Year								Millions of cars of given age:								total
2000	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	23.2
2001	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	23.4
2002	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	23.5
2003	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	23.6
2004	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	23.7
2005	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	23.9
2006	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	24.0
2007	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	24.1
2008	1.549	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	24.2
2009	1.549	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	24.4
2010	1.549	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	24.5
2011	1.549	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.549	24.5
2012	1.549	1.549	1.549	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.673	1.549	1.549	24.5
Year								Average emissions weighted by number of cars of given age								Ave-rage
2000	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	187.9
2001	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	187.4
2002	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	186.5
2003	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	185.0
2004	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	183.2
2005	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	181.0
2006	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	178.5
2007	291.0	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	175.6
2008	291.0	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	234.2	172.4
2009	291.0	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	234.2	225.9	168.8
2010	291.0	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	234.2	225.9	217.5	165.0
2011	291.0	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	234.2	225.9	217.5	193.6	161.0
2012	291.0	291.0	291.0	303.4	292.5	280.2	271.0	261.8	252.6	243.4	234.2	225.9	217.5	193.6	185.9	156.7