The cost-effectiveness of carbon abatement in the transport sector

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EXECUTIVE SUMMARY

The abatement of greenhouse gas emissions in order to avert the most serious consequences of climate change will not be cheap. However, neither will adaptation to the effects of a changing and volatile global climate. Sir Nicholas Stern reviewed precisely this issue and concluded that, by incurring costs *now* to avoid serious and more expensive future consequences, money spent on mitigation could be a wise investment. However, for this to make the best economic sense, the costs of abatement should not exceed the value of the damage of that carbon over its lifetime - the social cost of carbon (SCC).

The effect of this debate has been to shine an intense spotlight on the costs of carbon reduction. In recent years, many global and UK based studies have compared sectors of the economy and individual policy instruments according to their potential to save carbon and the costs this would incur. The conclusions to these analyses are remarkably consistent: *carbon abatement will be more expensively achieved in transport than other sectors such as residential, industry or energy supply.*

This paper examines the background and robustness of this assertion. The discussion can be distilled into three crucial issues which, depending on how they are handled in any analysis, together dictate whether or not transport measures will be deemed a more or less cost-effective route to carbon reduction. In short, these are the ***assumptions*** about future costs and level of travel demand, the ***methods*** applied to compare policies for cost-effectiveness and the ***evidence*** base used in relation to different types and combinations of policy instrument.

Assumptions

In summary, there are four principal assumptions which repeatedly underpin the assertion that carbon abatement is more expensive in the transport sector.

Firstly, conclusions about the high cost of carbon abatement in the transport sector appear to emanate from models which essentially assume a business as usual baseline for travel demand growth. This, in turn, is based on a highly static view of the economy and consumer demand which is still almost entirely oil dependent and predicated on a continuation of the link between transport activity and economic growth.

The expectation that transport is expected to be one of the fastest growing end users of energy into the future emanates from a partial examination of the literature. This partial picture leads to a conclusion that travel behaviour change is too difficult and any evidence suggesting otherwise is not robust. It also emanates from a failure to consider an alternative future where oil is not as cheap and plentiful as it is today. This may have a variety of implications for the analysis such as the effect of overestimating economic growth and/ or stability (and hence travel demand), downplaying the risks of relying on conventional technologies and overlooking the role of innovation towards alternative fuels and lifestyles.

Yet, most importantly, the costs of achieving carbon reductions are self evidently higher if travel demand is assumed inevitable than if an alternative, less pessimistic trajectory is adopted. This is because the higher the travel demand assumed, the greater and costlier the task of reducing its impacts. Instead, cost-effectiveness needs to be assessed against a responsive and dynamic trajectory of traffic growth into the future.

Secondly, whilst the emphasis in research and policy is placed on technical solutions to carbon reduction from transport, analysis reveals these solutions to be more expensive than behavioural interventions. The costs of vehicle manufacture and the production of alternative fuels are thought to be expensive in the longer term. Indeed, the UK Government's own analysis of the technical transport solutions included in its Climate Change Programme (the Renewable Transport Fuel Obligation and the EU Voluntary Agreements between motor manufacturers regarding fuel efficiency improvements), shows them to be more expensive than other measures such as smarter choices, fuel duty, sustainable distribution and the reduction of motorways speed limits.

It has to be noted, however, that estimates of the cost to manufacturers in meeting new targets imposed by the EU on new car vehicle efficiency vary by a factor of 10. Moreover, historical evidence suggests that manufacturers' forecasts of the costs of complying with regulation very often turn out to have been overly pessimistic. Also, cost assumptions are inflated by the negative macro-economic effects that get factored into the calculations. This includes any detrimental effect to the vehicle manufacturing and fuels sectors given the contribution they make to the UK's economic growth and employment objectives. On the other hand, the notion that innovation in the alternative energy sectors can also be valuable to the economy is often not considered. In addition, policies which successfully improve vehicle efficiency (or indeed reduce travel demand) may involve a reduction in public revenues (from fuel tax forgone) making some instruments more costly in welfare terms. In addition, the estimates of technology costs often fail to consider the cost-effectiveness under varying policy contexts, some of which may provide a better framework for demand creation and innovation.

Thirdly, transport solutions often come out as more expensive because of the effect of 'comfort taking' or 'rebound'. This is where some of the cost or time benefits introduced by, say, more efficient engines, make it more affordable for car owners either to drive more or to trade up in vehicle specification (e.g. larger engine sizes or more in-car accessories). This not only counteracts the carbon reductions which would otherwise have taken place, but also generates other disbenefits such as increased air pollution, congestion or road accidents due to higher traffic levels. The clear implication is that the carbon reductions delivered through improved vehicle technology will be smaller in scale and higher in cost in the absence of other complementary 'locking-in' measures.

Fourthly, any reduction in travel demand or indeed alteration of car purchasing habits is often assumed to have a high welfare penalty to consumers. Travel demand is assumed to generate utility for individuals which, in the aggregate, may outweigh the cost to society of the externalities caused by this activity. For example, many economists argue that bigger cars generate more welfare as consumers are willing to spend more on a bigger car than a smaller car. Yet, this conclusion is also based on a static view of the economy. In other words, whilst it may appear to be difficult to reduce demand *now* (although this paper also presents evidence to refute this assumption), a change in policy context may also change the cost-effectiveness of different actions. For instance, rising oil prices or supply volatility may increase the desire and utility for less car dependent lifestyles. It is also questionable the extent to which the welfare costs of as yet unfulfilled demand should be factored in to any analysis.

Methods

As with most problems, there are many potential solutions to climate change. Which is selected will be at least in part dependent on how the problem is evaluated. Current policy emphasis based on neo-classical economic theory suggests we may want to know what we are willing to pay to save a tonne of carbon. To do this, we compare the costs of reducing the emissions with the social cost of carbon (how much the damage is 'worth') in order to decide whether we think this is worthwhile. This leads to a discussion about the ability to assess impacts, the value of future impacts to today's society and the different conclusions generated by considering these issues under assumptions of more or less successful policy delivery in the future. This is because the SCC will be lower at any given time *with* climate change policies in place (thus less damage assumed) than under business as usual.

Whilst cost-effectiveness analysis may be an appropriate means of identifying the cheapest way of achieving a particular goal such as carbon reduction, it has inherent limitations with regard to the assessment of transport policies where the policy objectives are not necessarily only to reduce carbon emissions. The essential feature of transport policy must not be lost in any assessment of the cost of carbon abatement: namely that traffic levels may be legitimately reduced for reasons other than carbon reduction such as congestion relief; improved accessibility; reduced local environmental damage; better fitness and health; productive use of scarce land and resources etc.

The focus on a static picture of cost-effectiveness also disadvantages many transport policies which become more cost-effective when looked at in combination with other measures (e.g. the locking-in of efficiency gains from road pricing) and when the timescale of the impacts are taken into consideration (e.g. quick wins from speed enforcement or travel planning).

Evidence

Analysis has been applied to a narrow set of transport policies without due account of the emerging evidence on the potential for demand reduction in this sector. This paper presents evidence relating to smarter choices, mode shift to non-motorised modes and from air to rail in the UK, together with economy wide assessments which highlight the potential for small scale infrastructure improvements. Combined with evidence on the potential for changes in car purchasing behaviour to achieve significant emissions reductions, this all points to the need to take seriously those strategies which change travel behaviour to increase transport system efficiency. **Many studies that have compared mobility and air quality strategies have concluded that demand management strategies are among the most cost-effective in that they can reduce a trip, mile of travel or tonne of carbon for a relatively modest amount of money.** Demand-side strategies may not be the *primary* solution to these problems. Nevertheless, they are an *essential* part of the solution in order to increase the likelihood of net carbon reductions being delivered from technical applications and in order to insulate against possible economic discontinuities due to supply side constraints and climate change.

Of course, it is not only the transport sector which is sensitive to these issues relating to assumptions, methodology and evidence. Nevertheless, it may be the case that these variables are more critical for transport solutions than for other sectors. For instance, downplaying the importance of timescale and cumulative emissions may lead to a disregard of cheaper, demand side solutions; assumptions about oil availability may grossly underestimate the impact on this most oil dependent sector of a reliance on distant technical solutions; emphasis on cost-effectiveness may forget the fact that most transport solutions are implemented for other reasons than carbon reduction; preoccupation with public acceptance may lead to a disproportionate weight attached to assumptions about welfare costs.

Recommendations for further research

There are a variety of important gaps in the evidence base. These relate to policies which have not been systematically assessed for their implications on carbon emissions and costs of abatement such as road building; the potential for carbon reduction from road user charging, public transport and land use planning; the potential for cost-effective carbon reductions from freight; the cost of instruments to reduce emissions from aviation and shipping; the potential for carbon budgeting at the local level and the integration of assessments of adaptation into evaluations. Most importantly, **there is a dearth of evidence on the potential for packages of policies which can lock-in the benefits of technical efficiency gains or increased road capacity.**

Policy recommendations

There are three main policy recommendations which flow directly from an examination of the evidence:

1. The Government should adopt a more dynamic approach to the shadow price of carbon. In the wake of Stern and Eddington's recommendations that the carbon price is important and that 'the prices must be right', the Government is placing much emphasis on policy approaches which internalise the cost of carbon. Yet, Stern was clear that the purpose of pricing is to deliver on policy goals – i.e. the goal determines the price. Instead, it could be argued that the Government is letting the price determine the goal by relying on internalising the cost of carbon to reach carbon reduction targets and by relying on the shadow price of carbon (SPC) as a framework for policy appraisal.

Instead, many believe that the approach to the priorities for carbon abatement policy needs to be more dynamic by starting with the stabilisation goal and then adopting a price of per tonne of carbon related to the cost of achieving this (using a marginal abatement cost curve). The current Government approach – to base the carbon price purely on the damages of climate change consistent with a given target – could lead to perverse consequences as the more ambitious the carbon reduction target, the lower the social cost of carbon needed to help achieve it. This could result in weaker policies, the delaying of abatement and fluctuations in the carbon price. The Government have agreed that there is 'merit in considering a move towards a marginal abatement cost based approach to calculating the SPC' and this paper strongly recommends a review of the Government's approach in line with this.

2. Cost-effective carbon reduction from transport requires a market transformation approach to affect demand *reduction* and innovation. Carbon price can only be regarded as one prerequisite to cost-effective carbon reduction, it is by no means a panacea. The unpriced nature of the emissions that cause climate change are only one market failure that characterise the problem. Others include innovation failures and failures that inhibit behaviour change.

On innovation, the issue is not just how much do low carbon technologies cost, but how to direct the continuing investments that will be necessary towards low carbon transport technologies in ways that will stimulate innovation and reduce these costs.

On behaviour, the evidence on the potential for travel reductions to be made relatively cheaply and with co-benefits such as safety and accessibility has been downplayed. This includes the potential for fiscal policies to achieve significant, cost-effective and sustained carbon reductions. The evidence suggests that most individuals have some room to alter their behaviour in ways that may reduce car use through altered mode choice or trip lengths, by better coordination of their daily activities, or, in the longer term, by adjusting their choice of work or housing location. In other words, individual travel behaviour change can manifest itself in a variety of ways. The literature shows that these changes are already being encouraged through mechanisms such as smarter choices and investment in non-motorised modes and that the there is great potential for further demand reductions. Instead, the emphasis on technological solutions from transport disregards the need for near-term action to reduce emissions in line with the need to stabilise atmospheric concentrations to avoid runaway climate change.

Thus specific policy instruments will be necessary alongside carbon pricing to change behaviour, whilst supporting the development of a market through regulations and technological developments, which themselves will be subject to an assessment of their relative carbon benefits and value for money.

3. The rebound effect is not inevitable – policies can be targeted to reduce its effect. The rebound phenomena clearly shows the shortcomings of the current focus on vehicle technology - as most CO_2-emissions come from increased mileage. To obtain the full potential savings from increased vehicle efficiency would require complementary measures to restrain demand increases in which case the costs of achieving the reduction would fall. Given the strength of the rebound effect in the transport sector, accepting it as inevitable rather than something to be concertedly mitigated by policy using fiscal (e.g. fuel duty) and regulatory instruments (e.g. mandatory minimum vehicle standards), will lead to spurious conclusions that carbon abatement in transport is more expensive.

Evaluations of cost effectiveness need to be explicit about the increased costs due to the rebound effect and to consider the optimum combination of policy instruments. Transport policy then needs to be designed to explicitly mitigate the rebound effect.

Put alongside the gaps in the evidence base identified, these final conclusions highlight the difficulty in making any definitive conclusions about where the most cost optimum carbon reductions can be made. Nevertheless, the newly created Climate Change Committee is set to identify the potential carbon abatement from the ‘tradeable’ and non tradeable sectors. Transport, apart from aviation, is non tradeable and requires robust evidence base and analysis in order to develop carbon budgets that deliver what is needed. On this basis, it would appear irresponsible to dismiss the large body of evidence which exists to suggest that travel behaviour change - in all its guises from car purchasing, to location choice, driver style and mode shift – offers a serious foundation for non-marginal, relatively inexpensive carbon reductions from both passenger and freight transport. The precise figures on costs and impacts are less important than the consensus that is emerging about the scope for demand side policies to deliver.

1.0 Introduction

Several key economy-wide and/or global perspectives on the economics of climate change have acknowledged the important role that behaviour change and demand management could play in reducing carbon from the transport sector (HM Treasury, 2006; IPCC, 2007; King, 2007). However, each study cites limited evidence on the effectiveness of such policies to deliver sustained behaviour change and carbon reduction. Together with assumptions about future growth in demand, technology and welfare costs, the studies conclude that transport cannot contribute to significant cost-effective carbon reductions in the short term[1]

This paper explores the basis for this assertion by examining the nature and the quality of the evidence base that underpins it. The paper is divided into a further three main sections as follows:

- Section 2.0 explores the background to the claims about the cost of carbon reduction in the transport sector;
- Section 3.0 provides an overview of the main methods used to evaluate the costs of climate policy options and the limitations with the prevailing approach;
- Section 4.0 summarises the state of the evidence base for assessing the cost-effectiveness of carbon abatement from transport.

The implications for climate change policy are discussed before concluding with observations on those areas most in need of further examination in order to improve the evidence base for policy making in this area.

2.0 The cost of carbon reduction from transport – background analysis

2.1 Why the emphasis on cost-effectiveness?

Policies to address climate change involve substantial sums of money. Nevertheless, the Stern Review (HM Treasury, 2006) concluded that, by incurring costs now to avoid serious (and more expensive) future consequences, money spent on mitigation is likely to

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[1] These questions were also addressed in a seminar organised jointly by the UK Energy Research Centre and Campaign for Better Transport. The report of this meeting is at: http://www.ukerc.ac.uk/TheMeetingPlace/Activities/Activities2007/071023economics_transport_UKERCprogramme.aspx

be a wise investment. Stern estimated the annual costs of stabilising at 500-550 ppm CO_2e to be around 1% of GDP by 2050, indicating the order of spend which may be necessary globally.

Thus, climate stabilisation will not be cost-free. However, to ensure it remains economically (and publicly) supportable we would ideally spend no more than is necessary to avoid damaging welfare and economic growth. Under these terms, emissions targets must be reached at the lowest cost to society by taking full account of the costs and benefits in framing policy.

2.2 Government assessments of costs of carbon abatement from transport

The Stern report concluded that carbon reductions will be more expensively achieved in the transport sector as compared to other sectors in the economy:

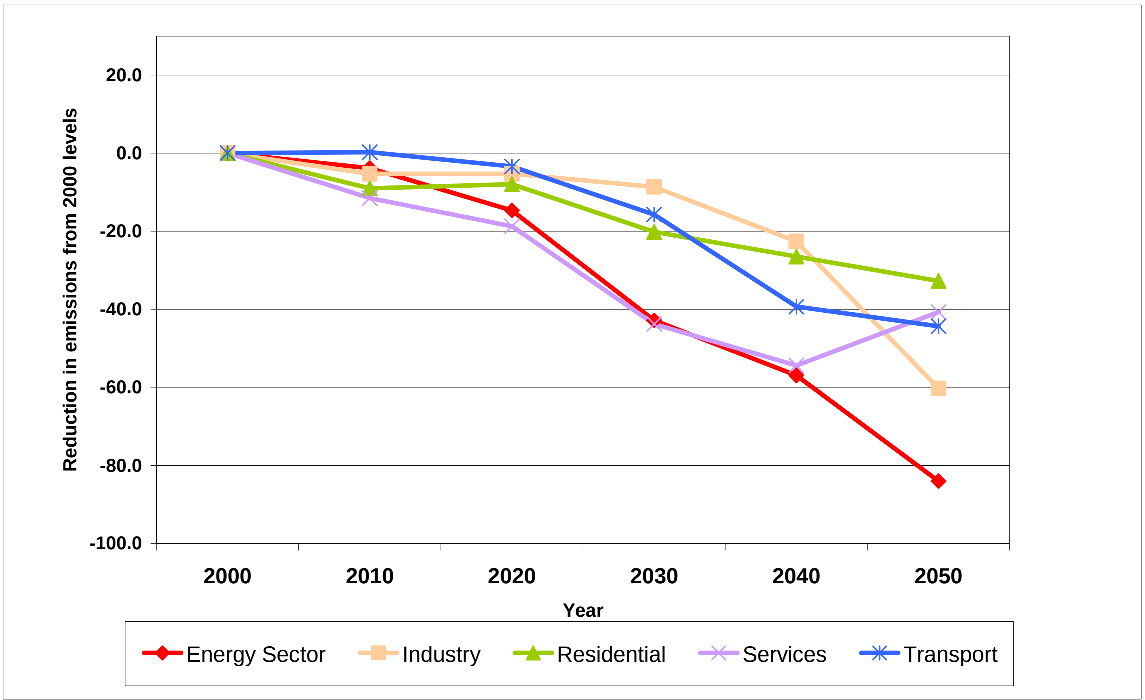
> *Transport is one of the more expensive sectors to cut emissions from because the low carbon technologies tend to be expensive and the welfare costs of reducing demand for travel are high. Transport is also expected to be one of the fastest growing sectors in the future. For these two reasons, studies tend to find that transport will be among the last sectors to bring its emissions down below current levels.*
>
> HM Treasury, 2006, Annex 7c

This has been reaffirmed by supporting analysis to the Energy Review (DTI, 2003) and the Energy White Paper (EWP) (DTI, 2007) and cost-effectiveness analysis of individual instruments evaluated as part of the Government's Climate Change Programme (CCP) (Defra 2006a, 2006b, 2007b).

The Government has used a cost-optimization model of the entire energy system to assess the role that each sector might play in a carbon constrained future when a variety of competing technologies and options are open for development. This model, *MARKAL,* provides a framework for evaluating alternative technology pathways and exploring future energy scenarios, not for predicting the future or creating a single forecast (Strachan et al.). *MARKAL* thus provides insights into supply options and comparative abatement costs of various technologies. The model was used as background analysis for the EWP and included a 'Macro' module to allow aggregated feedback between energy supply and demand as well as direct calculation of macro-economics variables linking to GDP. This is called ‘Markal-Macro’.

A major outcome from the modelling is that transport measures could make a significant contribution towards a cost-effective, economy-wide move to cut carbon emissions by 60% by 2050, falling possibly by as much as 45% against 2000 levels by the end of the period[2]. In the short to medium term (up to about 2020), the model indicates that technological developments in transport would do little more than offset the rise in carbon emissions that would otherwise have occurred due to growing demand for transport (CfIT, 2007). More cost effective opportunities for net carbon abatement would be realised in other sectors such as energy, industry, residential and services, as the economy moves towards its long-term target (see Figure 1).

Figure 1: Sectoral cost-effective carbon reductions by sector to 2050 from Markal-macro



Source: DTI, 2007a (Chapter 7, p237), Central scenario, 2030+ trajectory. Energy includes electricity generation and upstream oil and gas production. Data provided by Strachan et al., 2007, cited in CfIT (2007).

Studies examining economically justifiable responses to climate change from a global perspective have arrived at the same conclusion. Three global analyses were examined

[2] See Anable and Bristow (2007) for a discussion. This appears to be a greater reduction than that achieved by the residential or service sectors. However, this would not be the case if 1990 had been used as the base year as these other sectors had already begun making significant reductions in emissions between 1990 and 2000 whereas transport had not.

by CfIT in their recent report on Transport and Climate Change (CfIT, 2007). These studies conclude that, at best transport will begin to decarbonise to some degree by 2050, though cost-effective reductions in transport to 2030 are largely confined to improvements to oil-based transport vehicles and biofuels applied largely to the car market (IPCC, 2007; Enkvist, 2007). At worst, the transport sector may be the only sector to see an absolute increase in emissions (Blok et al., 2001). Each report acknowledges a role for demand management, but nevertheless concentrates its analyses on technological solutions and the obstacles to carbon reduction in this sector, including consumer preference and the lack of policy frameworks.

At the individual policy level, UK Government cross-sectoral analysis shows that within every sector, not just transport, there is a range of cost-effectiveness of policies. However, it seems there are measures in the domestic and business sectors that could yield greater net benefits than from transport. This analysis is discussed in section 4.2.

2.3 Why is it claimed to be more expensive to reduce carbon from transport?

From all these analyses, there are four principle reasons which repeatedly underpin the assertion that carbon abatement is more expensive in the transport sector:

- **Assuming a 'business as usual' baseline**
- **Technology costs**
- **Rebound effects**
- **Welfare costs**

2.3.1 Assuming a 'business as usual' baseline

Assessments of policy costs into the future need to make assumptions about the future demand for transport. This demand will be itself dependent on the future price of fuel and availability of transport. Studies which conclude that carbon abatement from transport will be more costly tend (i) to assume that travel demand will continue to grow, albeit with some slow down of growth, into the future, and (ii) that oil will be as easily available and as cheap as it is today.

The first of these assumptions leads to the expectation that transport is expected to be one of the fastest growing end users of energy into the future. Studies of the economics of climate change have concluded that behaviour change is difficult and raise questions as to the robustness of the evidence base surrounding the cost-effectiveness of behavioural and wider packages of measures (HM Treasury, 2006; IPCC, 2007). Yet, this assumption is controversial for two reasons. Firstly, as will be discussed below, the evidence suggests that travel behaviour may be more malleable than is often assumed. Secondly, by setting assessments of cost-effectiveness against assumptions of (inevitable) future growth in travel demand , the costs of achieving reductions are self-evidently higher than if an alternative, less pessimistic or dynamic trajectory is assumed (Goodwin, 2007; UKERC, 2007).

The second of these assumptions pays no regard to the emerging and lively discussion on 'Peak Oil'. Peak oil is the time when the maximum rate of the global production of oil has been reached, recognising that it is a finite natural resource affected by the rate of depletion (Bentley and Smith, 2004). The rate of depletion will be influenced by economic, market and policy developments that are uncertain. No one knows for sure how much oil the world has, but many geologists and oil industry experts recognise that "Peak Oil" will be reached within the first 5 - 20 years of the 21st Century. The market adjustments that may be required to balance demand and supply, together with higher prices and the knock on effects on the economy could significantly change the assumptions used in the evaluation of cost optimal solutions to carbon reduction and may change the degree to which reliance on long term technological fixes are appropriate to tackle both issues of carbon reduction and energy security.

2.3.2 Technology costs

Given the emphasis placed on technical solutions to carbon abatement in the transport sector in most modelling exercises, assumptions relating to the capital, operation and running costs of near to market and future technologies is a crucial component of any assessment.

Longer term technological developments in this sector are expected to attract large fixed costs in vehicle manufacturing, sunk costs and difficulties in achieving the efficient scale for bringing new technologies to market. Similarly, the potential for alternative fuels to contribute to CO_2 reduction in road transport is affected by the difficulty in estimating their resource costs and costs associated with capital spend and products generated alongside the fuel. In addition, the evaluation of the cost-effectiveness of a downsizing of this sector due to a shift in car ownership and use is also affected if the (potentially negative) macro-economic effects are included. This is due to the important contribution the vehicle manufacturing and fuels sectors to the UK's economic growth and employment objectives. It is also true that policies which successfully improve vehicle efficiency (or indeed reduce travel demand) may involve a reduction in public revenues (from fuel tax forgone) making some instruments more costly in welfare terms (Buchan, 2008).

However, a number of doubts can be expressed in relation to the pessimistic assumptions relating to technology costs in this sector.

Firstly, the recently commissioned King Review on low carbon cars for the UK Government concluded that market ready technology could reduce CO_2 emissions per new car by 30% (on a like for like basis) within 5 to 10 years (King, 2007). Whilst the cost per car would increase, the fuel economy savings would represent good economics to the purchaser. Indeed, even more recent research for the DfT shows that drivers would be willing to pay an extra £510 to buy a car that would cut fuel costs by £1 per 100km, giving a payback period of 3-5 years at an average annual distance of 10000 – 17000km (Cambridge Economics, 2008).

Secondly, the estimates for the cost of vehicle efficiency improvements vary considerably between authors and over time. In section 4.3 we point to how estimates of the cost to manufacturers in meeting new targets imposed by the EU on new car vehicle efficiency vary by a factor of 10, and that these costs are crucially dependent on the lead-in times for manufacturers, and supporting policies to stimulate demand and innovation.

Finally, evaluations of cost-effectiveness are highly sensitive to the assumptions made about the availability and cost of oil. In particular, the relative cost-effectiveness of alternative fuels is affected by the assumed cost of oil in future years and all policies are affected by the economic growth assumptions which are themselves based on assumptions about oil prices and energy security. We return to the issue of energy security and oil price availability in section 4.3.

2.3.3 The rebound effect

In an analysis of the effectiveness and costs of a given measure or policy, transport solutions often come out as more expensive because of the effect of 'comfort taking' or 'rebound' (Sorrell and Dimitroupoulos, 2007). This is where some of the cost or time benefits introduced by, say, more efficient engines, make it more affordable for car owners either to drive more or to trade up in vehicle specification (e.g. larger engine sizes or more in-car accessories). This effect has been one reason why vehicle efficiency improvements have not lead to a corresponding decrease in vehicle emissions in recent years. This in turn not only counteracts the carbon reductions which would otherwise have taken place, but also generates other disbenefits such as increased air pollution, congestion or road accidents due to higher traffic levels (Anable and Bristow, 2007). The clear implication is that the carbon reductions delivered through improved vehicle technology will be smaller in scale and higher in cost in the absence of other complementary 'locking-in' measures.

We return to the significance of planning for the rebound effect and 'locking-in' the benefits of policies to improve cost-effectiveness in section 4.2 below.

2.3.4 Welfare costs

In addition to technology costs, Stern claimed that the welfare costs of reducing the demand for travel outweigh the economic benefits. He did not define these costs specifically. However, he is clear that his definition of (social) welfare economics is the study of economics from the perspective of maximizing the sum of 'utility' or happiness which itself arises from consumption (HM Treasury, 2006, Chapter 2). The implication is that travel demand generates utility for individuals which, in the aggregate, may outweigh the cost to society of the externalities generated by this activity.

This approach to welfare economics can be applied to mode choice, distance travelled and car purchasing. For example, many economists argue that bigger cars generate more welfare as consumers are willing to spend more on a bigger car than a smaller car. In this case, the price differential between big and small cars is taken to be equivalent to the revealed welfare preference for car size (Kampman et al., 2006). Thus, policies to stimulate downsizing of vehicles could generate welfare losses to society if the monetised carbon benefits are lower than the price difference between smaller and larger cars. Likewise, policies which increase the cost of travelling may increase consumer surplus (the difference between the maximum that consumers would be willing to pay for a good and what they actually do pay).

This is a hotly contested issue within the context of climate change mitigation. Other economists have highlighted the importance of relative welfare. For instance, although the owner of a large vehicle may experience status benefits, his/ her neighbour may feel worse off as a result. These can be termed perverse welfare effects and may warrant some discounting of the benefits accounted for by price differentials alone (ibid). This issue exposes issues of the definition of 'happiness' and the distribution of welfare across society and generations. The assessment of policies in terms of how happy they make people feel also predisposes many policies towards the most publicly acceptable solutions.

We return to all four of these main reasons usually cited as responsible for the high costs of abatement in the transport sector (travel demand growth and oil price assumptions; technology costs; rebound and welfare costs) in our analysis of the evidence in section 4.0.

3.0 Approaches to evaluating the costs of climate policy options

At a national level, a key part of maintaining the discipline of finding the most economically optimum solutions is the ability to compare the cost-effectiveness (cost per tonne of CO_2 abated) of different policy measures in order to choose those with best value for money (BRC, 2007). Indeed, the UK Government's general approach to tackling climate change is to achieve reductions in emissions in the most cost-effective way across the whole of the economy rather than having targets for specific sectors.

Thus ideally, policy should be evidence-based and backed up by robust analysis of the cost per tonne of carbon saved utilising a uniform methodology across government departments (NAO, 2006a). In practice, the process of calculating the cost-effectiveness of a measure is complex and hampered by the need to make assumptions about, for example, the future price of oil and technology, damage costs, as well as the demand for transport.

Approaches to costing are key to the evaluation of alternative climate policy options. However, there are a variety of ways to address costs, impacts, effectiveness and efficiency of policy instruments and the outcome depends on how the costs are attributed, whether the costs of environmental damage are assessed and on other variables such as the magnitude and form of the discount rate applied.

Sustainable development demands fundamental changes in the way environmental costs and benefits are included in the comparison of different policies. Broadly speaking, there are two approaches to the assessment of value for money of policy measures:

- Cost benefit analysis
- Cost-effectiveness analysis

Related to cost-effectiveness analysis is a further concept:

- The social cost of carbon

3.1 Cost benefit analysis (CBA)

CBA requires total costs to be compared against total benefits. The costs included are both the abatement costs and the damage costs. The benefit-cost ratio (BCR) is calculated by comparing the lifetime resource costs in constant prices – including monetised carbon and other emissions and changes in utility of the base case with new case. The difference between the two is the net benefit or cost to society.

For climate policy, however, the emphasis on cost-benefit analysis may be inappropriate. In addition to the costs and benefits which cannot be given monetary values (a problem in all cost evaluations), the uncertainty around climate change means that it is not necessarily possible to accurately quantify even those damage costs that could at least theoretically be monetised, thus it is a difficult way to proceed in the assessment of carbon mitigation options.

3.2 Cost-effectiveness

With its emphasis on only the *abatement costs* of implementing policies (i.e. the cost per tonne of carbon saved over the lifetime of the policy or measures[3]), cost-effectiveness analysis may be a more appropriate means of simply identifying the cheapest way of achieving a particular goal – in this case a percentage reductions in carbon emissions by a target date. Cost-effectiveness analysis does not normally specify or cost the social benefits / disbenefits and is in this sense more a kind of efficiency criterion and can be preferred to CBA in the environmental sphere due to the difficulty of monetising ancillary effects (Kampman et al., 2006).

Nevertheless, it seems reasonable that assessment should encompass costs (or benefits) beyond pure abatement costs, as well as the timing of the emissions reductions. The limitations with cost-effectiveness analysis are discussed in section 4.

[3] cost-effectiveness = NPV costs less NPV benefits divided by carbon saved so a policy with a c-e of -£10/MtC produces benefits per tonne carbon

3.3 The social cost of carbon

In cost-effectiveness analysis, carbon itself is not discounted or valued in monetary terms. However, in order to decide whether it is worthwhile, neo-classical economic theory suggests we may also want to know what we are willing to pay to save a tonne of carbon. This current policy emphasis in the UK aims to ensure the long term carbon reduction goal is achieved in the most cost-effective way aided by consistency in appraisal across policy areas. To achieve this, the social cost of carbon is used.

The social cost of carbon (SCC) is the damage done by a tonne of carbon when it is emitted, because of its effect on the climate, summing the full global cost of the damage it imposes over the whole of its time in the atmosphere. The calculation of SCC requires an estimate of both the physical impacts of climate change, and an attribution of a monetary value to these impacts. The estimates of the social costs assess the impacts of climate change over time by quantifying the damage to health, environment and the economy caused by each tonne of carbon emitted. These costs are discounted, to reflect the future value of these costs and benefits (the time value of money). The issue is complicated by the fact that society should have a lower discount rate than individuals, since a high 'social' discount rate essentially means that future generations are less valued. Stern recommended a low discount rate because of the vast potential risks if global warming forecasts are correct.

The indicative value is meant to signal what society should be willing to pay now to avoid future damage. It is set to aid broad comparison of policies within and between sectors according to the resources required to save an equal amount of carbon. In neo-classical economic theory, the optimal degree of climate change, or abatement, is achieved when, at a certain level of emissions/atmospheric concentration of carbon and emissions abatement, the SCC is equal to the cost of reducing emissions. The latter - the cost of reducing carbon emissions by one tonne – is the marginal abatement curve (MAC). When the damage costs (SCC) are equal to the costs of reduction, this is meant to incentivise abatement activity so that the world can achieve its emissions reduction goals. The MAC has the advantage over the SCC of being related to existing activities and technologies and thus being observable in the present time (Ekins, 2007). However, the MAC varies across sectors, across technologies, over time and according to the degree of abatement being undertaken (ibid). The MAC might increase with the level of abatement or it may reduce as new technologies and economies of scale come on line to reduce the costs.

The concept of SCC is highly contested. The main difficulties lie in relation to the uncertainties over impacts, the basis of the monetary evaluation of these impacts and the ethical considerations of the discount rate used. These difficulties are compounded by the fact that the SCC varies according to the eventual concentration of climate emissions in the atmosphere and therefore according to any stabilisation goal and the emissions trajectory adopted to achieve it (Ekins, 2007). In other words, the SCC will be lower at any given time *with* climate change policies in place than under business as usual (Defra 2007a). The SCC therefore relies on actions in other countries and the stabilisation goal.

This subject is confused by the Government's shift from using the *social cost* of carbon (SCC) to the *shadow price* of carbon (SCP) as the basis for incorporating carbon emissions in cost-benefit analysis and impact assessments. In December 2007, Defra issued new guidance on the price of carbon that should be used in policy appraisal across Government (Defra, 2007f). This *shadow* price of carbon is for use in all policy and project appraisals with significant effects on carbon emissions – whether positive or negative. The SPC is based on the SCC but is said to take more account of uncertainty, is based on the trajectory proposed for stabilisation of carbon emissions and can be adjusted to reflect estimates of the marginal abatement cost (MAC) required to take the world onto the stabilisation goal; and other factors that may affect UK willingness to pay for reductions in carbon emissions, such as political desire to show leadership in tackling climate change[4]. In other words, the SCC is used to arrive at global targets and the SPC is used to reflect UK willingness to pay (Helm, 2007). The Defra guidance suggests this means that whereas the SCC is determined purely by our understanding of the damage caused and the way we value it, the SPC can adjust to reflect the UK policy and technological environment.

Exactly how uncertainty is reduced by the switch to the SCP or how it is based on the stabilisation trajectory in line with abatement costs is unclear to this author, as it was to various reviewers of the new Government guidance (Ekins, 2007; Watkiss, 2007). It is beyond the scope of this paper to review the arguments. However, all analyses recognise that the value of SCC upon which the SPC is based is very uncertain. The Stern Review gave estimates of the future path of the SCC under different stabilisation paths and noted that estimates in the literature range from 0 to £2,000/tonne (HM Treasury, p323). If the damage consistent with a 550ppm CO_2e stabilisation target is assumed, modelling for

[4] See 'How to use the Shadow Price of Carbon in policy appraisal: Interim Guidance', http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/HowtouseSPC.pdf

Stern produced a value of SCC of around $30 per tonne CO_2e (t/CO_2e) in 2000 prices, which translates into around £70 per tonne of carbon (t/C)[5]. The current guidance adopts a SPC based on this figure which, in 2007 prices, equates to £25/tCO_2e (£92/tC). The SPC applied in appraisals should be specific to the year in which carbon is emitted (or abated) so that this figure is to be uplifted annually to account for inflation and a 2% increase to allow for the extra damage costs as greenhouse gas concentrations rise (Defra, 2007f).

This estimate is considerably lower than most of the Stern estimates. This is because the price is dependent on the path of emissions. Within the Stern range, the *tighter* the emissions target, the *lower* the SCC will be, since there will be less damage from climate change. For a business as usual trajectory, Stern estimated a SCC of around $85/t$CO_2$e, or £53/t$CO_2$e (£194t/C).

The UK Government SPC figure (£25/tCO_2e (£92/tC)) is what they call 'target-consistent' and thus assumes that globally we will be relatively successful in tackling climate change and hence the damage from any tonne of carbon will be lower than under a business as usual scenario. Government justified this approach at a recent seminar on this topic, by explaining that so long as we are on track to meet our target then the shadow price of carbon consistent with the UK effort towards stabilisation at 450 – 550 ppm CO_2e can be considered appropriate, if not on track, the costs should increase (UKERC, 2007). Others believe that this approach could lead to perverse consequences as the more ambitious the carbon reduction target, the lower the social cost of carbon needed to help achieve it. This could result in weaker policies, the delaying of abatement and fluctuations in the carbon price.

Nevertheless, with respect to the current policy to adopt SCP as the basis for incorporating carbon emissions in cost-benefit analysis and impact assessments, it is important to understand that where a proposed policy intervention is set to cost more than the SPC, it would normally be ruled out unless there are other, stronger reasons for supporting it. Hence our emphasis in the remainder of this paper on the need for a more robust assessment of the costs of carbon abatement in the transport sector.

[5] The rate of converting carbon (C) to carbon dioxide (CO_2) is fixed at 12/44.

4.0 How much does it cost to abate carbon in the transport sector? The state of the evidence

Given the emphasis the costs of carbon abatement, it is necessary to assess the state of the evidence in this area. In general, the evidence on the cost-effectiveness of carbon abatement in the transport sector is limited: few measures have been thoroughly and systematically assessed for their carbon saving potential and evaluation methods are often inconsistent.

The purpose of this section is not to present the evidence on cost-effectiveness (to the extent that it exists) of individual measures to reduce carbon from transport. Instead, it has reviewed the literature and drawn conclusions about the predominant focus of this evidence, the main gaps in our understanding and the consequences of these gaps on the policy choices that have or may be taken in the transport sector.

In summary, the main issues to arise from the review of the evidence are as follows:

1. **The emphasis in evaluation and policy has been on technological solutions**
2. **The UK Government's own analyses shows technology options to be expensive**
3. **Estimates of the costs of transport technology into the future are uncertain**
4. **The urgency of the problem and the timing of emissions savings have been downplayed**
5. **The evidence on the cost-effectiveness of fiscal instruments has been downplayed**
6. **The evidence on the cost-effectiveness of behavioural instruments has been downplayed**
7. **Carbon pricing and emissions trading cannot be relied upon to reach our climate goals**
8. **Packages of policies need to be evaluated**
9. **The assumption that travel demand will automatically increase leads to higher cost assessments**
10. **Carbon reduction is not the only goal**
11. **Cost-effectiveness is a difficult measure to use as an instrument of comparison across timescales, policies and studies**
12. **Some policy instruments have not been systematically evaluated in terms of carbon abatement and cost-effectiveness**

These will now be discussed in turn.

4.1 The emphasis in evaluation and policy has been on technological solutions

There are two main ways of reducing carbon emissions in the transport sector. One is to improve the energy efficiency of vehicles or reduce the carbon content of the energy used (supply side). The other is to secure changes in travel behaviour (demand side). To the extent that the carbon impacts and cost-effectiveness of transport policies have been assessed at all, the emphasis is almost exclusively on supply side, technological solutions, particularly car passenger technology, at the expense of measures to influence behaviour.

The MARKAL model (Figure 1) is an example of influential Government analysis which has been almost entirely focused on technological possibilities with limited consideration of demand-side policy and behaviour change. The Markal-Makro variant of the model can incorporate some behaviour change induced through the price mechanism, but key modal shifts such as to non-mechanised modes or shifts in purchasing cannot be included (Anable and Bristow, 2007).

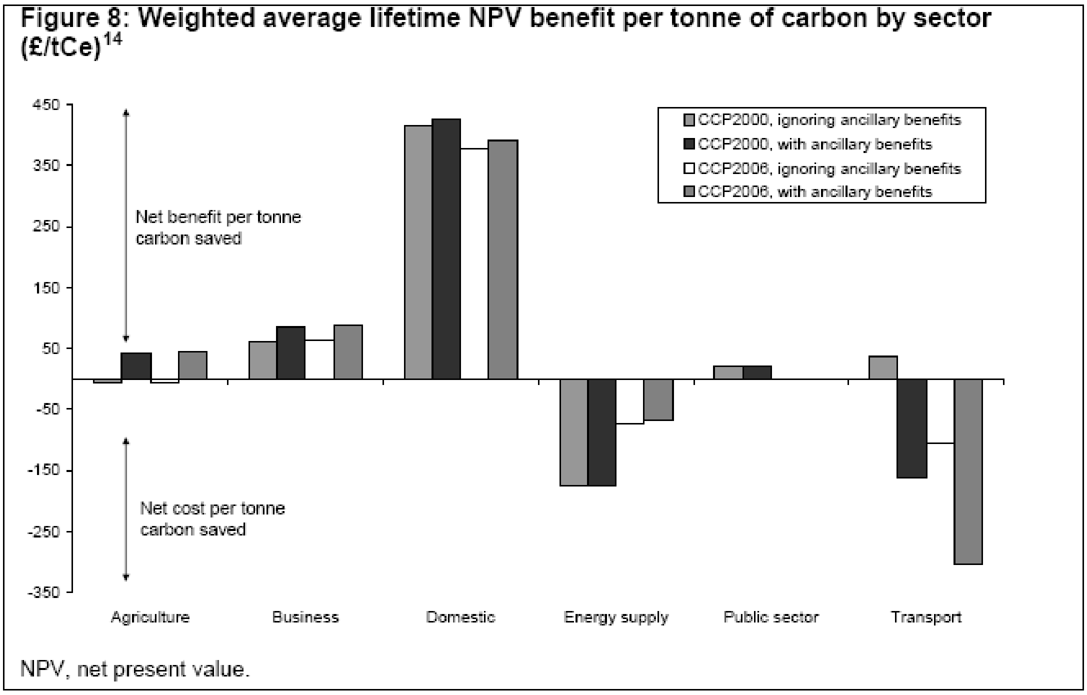
This emphasis on technical options is despite that fact that (i) there is abundant evidence that behaviour change measures can also be effective, particularly in combination with technical measures (see 4.6 and 4.8 below) (ii) the UK Government's own analyses shows technology options in the transport sector to be expensive compared to other measures (section 4.2) and (iii) estimates for costs of technologies into the future are uncertain (section 4.3).

4.2 The UK Government's own analyses shows technology options to be expensive

Where the Government has undertaken cost-effectiveness evaluation of a number of policies either already included in the Climate Change Programme (CCP), or being evaluated as potential additions to the programme (Defra, 2006a; Defra 2007b; DTI 2007b), it shows that the technological transport measures included are more expensive than other measures.

The analysis for the CCP aimed to undertake a systematic and consistent approach across all of the policy areas included (DTI, 2007b). It provides a breakdown of cost-effectiveness in terms of cost per tonne of carbon saved, both including and excluding the effects of ancillary impacts (see Figure 2). The Net Present Value (NPV) of the policies has also been calculated (all the benefits minus all the costs) – the costs and benefits are estimated over the lifetime of the measure. The analysis assesses distribution (who meets the cost – consumers, businesses, taxpayers, road users); public expenditure; competitiveness; air quality and other social and environmental impacts and security of energy supply.

Figure 2: NPV analysis of individual polices included in the Climate Change Programme (CCP)

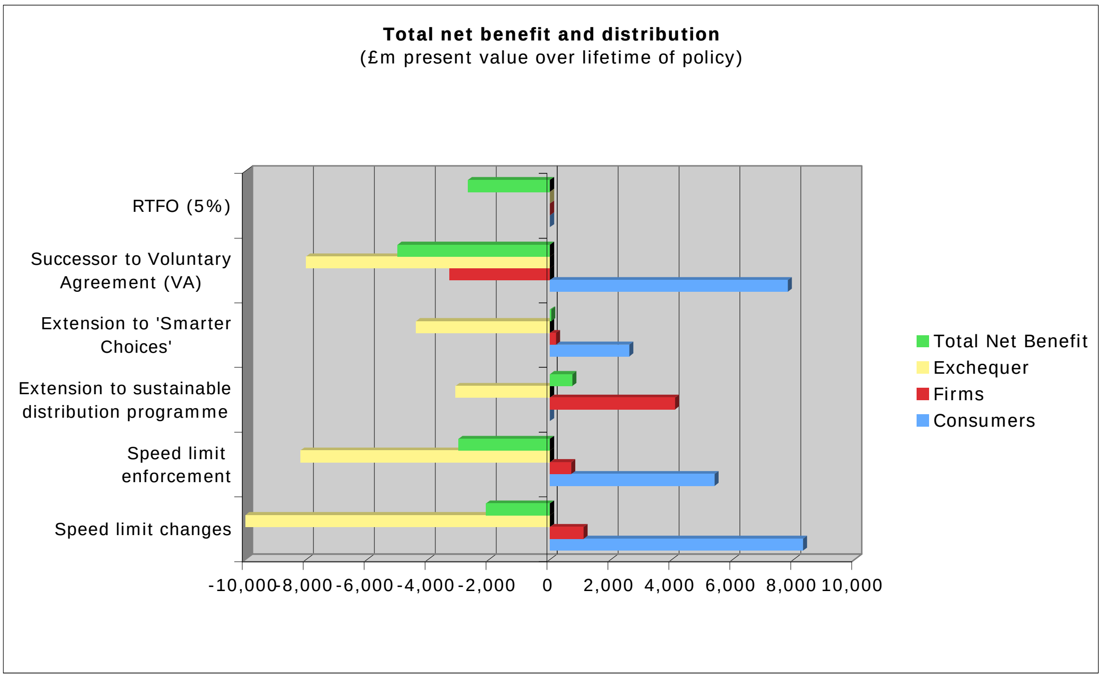


Source: Defra 2007b, p.21

Figure 2 shows transport measures to be among those which result in the least benefit to society, particularly if ancillary benefits are considered such as increased congestion due to the extra motoring induced as vehicle efficiency improves and cost per mile falls (see section 4.10). However, this analysis only includes two transport policies: (i) a successor to the Voluntary Agreements (VA) to reduce average new car fuel emissions between the EC and automobile producers based on a target of 135g/km CO_2 in 2020 and (ii) the Renewable Transport Fuels Obligation (RTFO) set at 5% of fuel sales in 2010/11 (Defra, 2007b).

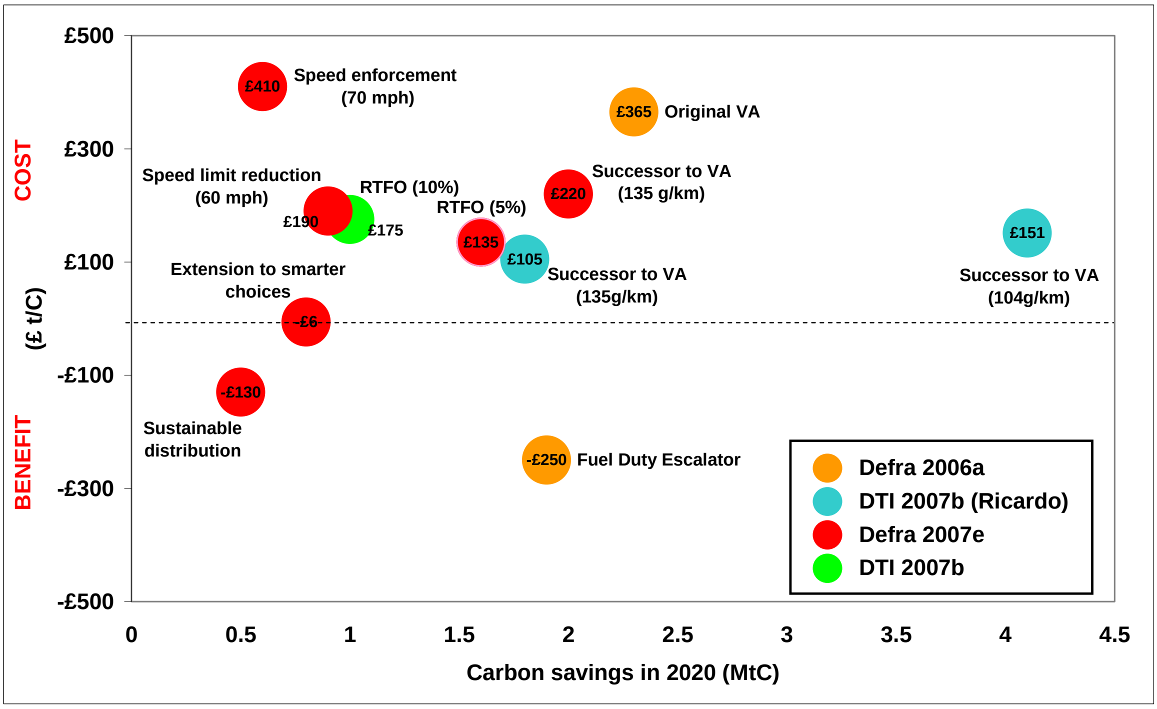
Government analysis has evaluated more policies than just the VA and the RTFO, including ‘softer’ policies such as smarter measures, sustainable distribution and speed limit enforcement and reduction (Defra, 2007b). There is clearly considerable variety in the level of cost-effectiveness of those measures considered, ranging from measures yielding a significant net benefit to society, expressed as a negative cost (e.g. the impact of the now abandoned ‘fuel duty escalator’) to those which would reduce carbon at significant cost (such as the original Voluntary Agreements). Figure 3 shows the results of the analysis of existing and potential CCP policies by Defra (2007b) and Figure 4 shows the cost-effectiveness of various policies assessed at various times for the CCP plotted against the size of emissions savings expected by 2020.

Figure 3: Total net benefit and distribution from the Defra analysis of existing and potential CCP policies



Source: Base data Defra 2007b analysed by Paige Mitchell, Slower Speeds Initiative (unpublished)

Figure 4: Comparative cost-effectiveness data from various studies assessing carbon impacts and costs by 2020 of current or potential policies in the CCP



Source: See key on diagram for source data. Graph reproduced from CfIT (2007) with speed enforcement and reduction added. The figures should be treated with caution as the evaluations are taken from different studies with different baselines.

Together, these figures show:

- The Government's current CCP includes some of the least cost-effective measures from transport;
- With the exception of the Fuel Duty Escalator (FDE), measures expected to deliver significant CO_2 savings (i.e. different versions of the Voluntary Agreements (VA) and its successor and the Renewable Transport Fuels Obligation (RTFO)) appear relatively expensive;
- The larger scale, technology based measures are more expensive than the smaller-scale measures – smarter choices and sustainable distribution;
- These technology measures are more expensive than the mid-range social/ shadow cost of carbon (c £92/tC in 2007 prices);
- Even despite harsh assumptions on costs and emissions reductions, speed limit reduction could be more cost-effective than the successor to the VA. If the timescale (the fact that it could be a quick win) could be factored in to the analysis, this renders the policy even more attractive.

- Movement towards the higher RTFO target (10% as opposed to 5%) would seem to mean adopting a less cost-effective commitment than the present one. Other studies conclude that biofuels and hydrogen perform best in terms of carbon saving in sectors other than transport (Anable and Bristow, 2007);
- There may be the opportunity to lower the cost of the original VA by aiming for a tighter carbon target but over a longer period of time.

The following conclusions can be drawn about specific policy areas evaluated in these exercises:

4.2.1 Vehicle efficiency improvements

There are three main issues surrounding the costs of technology.

Firstly, technological change appears to be more expensive than other behavioural and fiscal policies in the programme.

Second, rapid technological change appears to be relatively more expensive to achieve than that achieved at a slower pace. This is demonstrated by the various analyses of the VA and its successor. The costs of the original VA (with a target of 140g/km CO_2 by 2008) are the highest of all the assessments even though this is the weakest target. This is because the original target involved comparatively rapid change – achieving 140g by 2008. However, the estimates for a successor to the VA are more pessimistic in assuming, firstly that we only reach 162g by 2008 and secondly a slower rate of change thereafter (e.g. 135g by 2020). Even so, the costs of the new targets for vehicle efficiency are seen to be high compared to other policies considered.

It is only the most recent estimates from the DTI that suggest the possibility of a net benefit from changes to new vehicle efficiency. Their figures are based on two different studies, one at the European level and the other of the UK market and the net benefit figures arise from the European study (not shown in Figure 4). It is probably worth noting that average new car emissions in the UK are higher than the European average – so the estimates from a specific UK study may be more accurate (shown in Figure 4).

Third, the costs of technology change are higher when the 'rebound effect' is factored in. Although the carbon savings of technology are potentially substantial, the Government's assessment admits that as a result of lower operating costs of more efficient vehicles, consumers will choose to drive more; to increase comfort levels through the increased use of air-conditioning and other energy using in-vehicle appliances and to select larger vehicles. This is also true for biofuels.

In addition to more emissions, increased congestion is another effect of the increased travel induced through the rebound effect. The rebound effect is evident in the sensitivity of the Government cost-effectiveness analysis to the inclusion of congestion as an ancillary impact. Where congestion effects were included in the analyses of the VA, it led to as much as a fourfold increase in the cost per tonne of carbon saved (DTI, 2007b). Figure 2 shows the cost of achieving 135g/km CO_2 by 2020 through the successor to the VA at £105/tC per tonne carbon (Ricardo assessment). If the calculation included the costs of congestion, this increases to £460/tC (DTI, 2007b). However, the Government 'expect congestion to be tackled through other policies', the costs of which are not included in the analysis.

This clearly shows the shortcomings of the current focus on vehicle technology - as most CO_2-emissions come from increased mileage. To obtain the full potential savings from increased vehicle efficiency would require complementary measures to restrain demand increases in which case the costs of achieving the reduction would fall.

4.2.2 Biofuels

Figure 4 indicates that biofuels are also a relatively expensive option for reducing carbon emissions. There are a number of concerns with respect to the increased use of biofuels in transport: CO_2 savings vary considerably depending on the type of biofuel; other adverse environmental impacts can arise through changes in land use and deforestation and the price for food crops such as maize can be driven upwards on world markets thus affecting those who rely on these staple food sources (CEC, 2006; SDC, 2006; House of Lords, 2006). In October 2007, the UN Special Rapporteur on the Right to food highlighted the negative impact on hunger when biofuels replaced food production[6]. Earlier in the year, the UN issued a major report urging governments to take a cautious approach to developing biofuels (UN, 2006). The costs incurred by such developments are difficult if not impossible to estimate in standard comparative evaluations of policies. In addition, Biofuels and hydrogen perform best and most cost-effectively in terms of

[6] In October 2007, the UN Special Rapporteur on the Right to food highlighted the negative impact on hunger when biofuels replaced food production (see: http://www.un.org/News/briefings/docs/2007/071026_Ziegler.doc.htm)

carbon saving in sectors other than transport. Given the cost of such measures it would seem best to allocate them to the energy sector (Kampman et al., 2006).

4.2.3 Speed enforcement/ reduction

Speed policy appears to be very high cost in this analysis. However, as Anable and Bristow (2007) explain, the calculation assumed relatively high costs of enforcement which may be based on more expensive and outdated technology. It also uses a set of emissions factors which have not yet been put out to peer review and adopted as the standard figures. These new emissions factors show newer cars to be more efficient at high speeds and therefore reduce the savings from speed enforcement in the calculation. If the analysis were to take into account the fact that carbon savings from this policy could be achieved quickly, this would add greatly to its value *vis a vis* other policies such as vehicle fuel standards.

4.2.4 Smarter choices

Smarter choices are seen to be cost-effective measures with significant potential to save carbon. The Defra analysis suggests that the NPV of such a strategy is positive largely due to time savings. This is in spite of the fact that the Government analysis adopted relatively conservative estimates of the potential effectiveness of Smarter Choices. For instance, unlike Cairns et al. (2004) which concluded that smarter measures could potentially achieve a 11% reduction in national road traffic/ 15% in car traffic (and up to 24% / 26% in peak-time urban areas) in a supportive policy environment after 10 years of intensive application[7], the CCP appraisal assumes only 5.3% reduction in car traffic by 2020 (after 14 years of implementation). Moreover, the Defra document still states "*these estimates should be regarded as optimistic since the modelling was based on evidence from case studies and it is uncertain whether these policies should be scaled up to a national level'*".

4.3 Estimates of the costs of technologies into the future are uncertain

The cost-effectiveness of policies to reduce carbon cannot be assessed against a background of a stable, 'business as usual' future. There are a variety of elements that may change to mean that the most cost optimal solutions will also differ as time

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[7] The study defined this as being the 'high intensity' scenario as '*an expansion of activity, commitment and resources to a substantially higher level than that in place at the time of the report, which would still be consistent with practical and realistic experience, and feasible levels of expenditure, given the known constraints of staffing and funding generally'*

progresses – either causing cost estimates to be lower than expected due to pessimistic assumptions or higher due to neglect of plausible future events such as fuel shortages due to ‘peak oil’. By reporting the average cost per unit of carbon reduction over the lifetime of the policy, a single cost-effectiveness figure conceals the fact that costs may change over time (e.g. as technological know-how increases) or as oil prices change.

Firstly, the costs of technology into the future are uncertain. Indeed, the costs may not be as high as is sometimes assumed. For instance, aside from the Defra figures examined above, there are varying estimates for the cost of the VA to reduce average new car fuel emissions between the EC and automobile producers. The financial agency Moody’s Investor Services has estimated the additional costs of complying with the proposed successor to the VA and the 2012 targets to implement CO_2-reduction limits of 130g/km for the average fleet will be significantly lower than the industry is currently suggesting (Moody’s Investors Service, 2008). Moody's says the cost of complying will be between €300 and €1,000 a car compared with the EU estimate of €1300 and the €3,650 predicted by ACEA, the European car industry association. Moody's says that car makers will benefit from economies of scale and cost sharing with suppliers by collaborating in research and development.

Others suggest that the VA need not be expensive if motor manufacturers are given enough lead-in time to coincide with their own innovation cycle plus supporting measures on the demand side (ACEA, 2007). The issue is not just how much do low carbon technologies cost, but how to direct the continuing investments that will be necessary in energy systems towards low carbon technologies in ways that will stimulate innovation and reduce these costs. Costs are crucially dependent on the success of policies to direct investment and stimulate innovation (Koehler et al., 2005). This market transformation theory has proven true in other sectors (such as household appliances) where efficiency improvements have taken place at zero or low cost despite predictions to the contrary. Indeed, the car industry has a long and undistinguished track record of over-estimating costs of complying. US information shows auto industry estimates are typically 2 – 10 times actual costs and regulator estimates can be up to double actual costs (Hwang and Doniger, 2004).

Second, it is also apparent that the target of 120g/km could be met with changes in vehicle purchasing alone probably through a combination of moving to best in class and to smaller cars. As mentioned above, the King Review on low carbon cars concluded that market ready technology could reduce CO_2 emissions per new car by 30% (on a like for like basis) within 5 to 10 years (King, 2007). Although there is evidence to suggest consumers would be willing to pay a premium for more efficient vehicles (Cambridge Economics, 2008), research is mixed as to why stated consumer preference towards fuel efficiency is often not reflected in their final purchases (Lane, 2005). It would seem that to encourage take up requires a consistent *package* of measures combining several fiscal instruments. This includes graduated Vehicle Excise Duty and possibly car purchase tax or feebates[8] to encourage take up, combined with information both in the form of car labels, but also in the form of better regulated car advertising to promote the fuel efficiency characteristics of a vehicle (Buchan, 2007).

Third, a crucial factor in the changing cost environment could be the increasing need for energy security against a background of 'peak oil'. As already mentioned, the market adjustments that may be required to balance demand and supply, together with higher prices and the knock on effects on the economy could significantly change the assumptions used in the evaluation of cost optimal solutions to carbon reduction. At the very least, evaluations need to present cost-effectiveness results alongside explicit assumptions (for example, about economic growth and oil prices) and sensitivity analysis. This may change the degree to which reliance on long term technological fixes are appropriate to tackle both issues of carbon reduction and energy security.

4.4 The urgency of the problem and the timing of emissions reductions have been downplayed

Another reason why the cost optimal solution may change as time progresses is to do with the progress of carbon reduction *vis a vis* stabilisation targets. Carbon reduction is not just a matter of marginal cost to be traded against other items – more important are *total cumulative emissions* released over a certain period. In other words, it is the timing and rate of carbon reduction which count. As Stern clearly stated, *the benefits of strong, early action far outweigh the costs* (see Buchan, 2007, for a discussion on cumulative emissions trajectories). The optimum stabilisation goal and thus the most cost-efficient solution will rise over time for as long as there is no emissions abatement because any given goal becomes more expensive to reach the less time there is to achieve it.

[8] Feebates provide a rebate on the purchase of fuel-efficient vehicles funded by a surcharge on the purchase of fuel inefficient vehicles.

However, cost-effectiveness analysis for the CCP did not reflect different potential scales of implementation, the total amount of carbon saved, the timing of polices and how soon carbon reductions are made. It may be that changes in these variables are more critical for transport solutions – such as the ability for some demand management policies (such as speed enforcement) to make early carbon reductions (NAO, 2006a). If the timescale (the fact that it could be a quick win) could be factored in to the analysis, this could be an attractive instrument on many levels (Anable and Bristow, 2007). Instead, the emphasis on technological solutions disregards the need for near-term action to reduce emissions in line with the need to stabilise atmospheric concentrations to avoid runaway climate change.

4.5 The evidence on the cost-effectiveness of fiscal instruments has been downplayed

A review of the CCP analysis by the National Audit Office (NAO) concluded that fiscal policies had not been subjected to the same quality assurance process as other policies in the CCP (NAO, 2006a). Yet a measure such as fuel duty offers an effective instrument with a negative net cost or positive net benefit (Figure 4). A recent review of hundreds of transport policy options across Europe concluded:

> *Carbon and fuel taxes are the ideal measures for addressing* CO_2 *emissions. They send clear signals and distort the economy less than any other approach*.
>
> ECMT, 2007

Despite this, and despite the CCP analysis concluding that the now abandoned Fuel Duty Escalator was among of the most successful and cost-effective policies in the CCP, there is, however, no mention of energy taxes in the most recent Energy White Paper (DTI, 2007a).

4.6 The evidence on the cost-effectiveness of behavioural instruments has been downplayed

Total CO_2 from transport is a product of both the efficiency of the vehicles we use and how much we use them. Therefore, in reality, it is impossible to separate the consideration of technology from that of behaviour. At the very least, behaviour has to change in order to purchase more efficient vehicles, to buy and use different fuels or fuel mixes (Anable and Bristow, 2007). After more efficient vehicles are purchased, it is important that their benefits are not eroded through increasing speed and journey distance. More fundamentally, changes in behaviour can secure carbon savings in the absence of technological change simply by optimising what we already have. Stern's conclusions were consistent with this as he stated:

> *The removal of barriers to behavioural change is a third essential element, one that is particularly important in encouraging the take-up of opportunities for energy efficiency.*
>
> HM Treasury, 2006

Behaviour change can be facilitated by smarter measures, eco-drive programmes and targeted campaigns and marketing. Behaviour change in the form of smarter choices, wider measures and sustainable distribution is set to save 1.1 MtC by 2020 in the CCP, or only 10% of the savings in the Programme[9] (CfIT, 2007). Yet, the Government's own analysis and the wider literature demonstrates a degree of consensus that measures that encourage behavioural change are the most cost effective and can yield net benefits (Defra, 2007b).

The evidence on various policies to secure carbon savings by incentivising and influencing travel choices and patterns, suggests there are policies available which would offer significant, quick, cost effective and publicly acceptable routes to carbon reduction. Goodwin sums up the evidence by saying:

> *… at a disaggregate level there is now an overwhelming (and uncontested) evidence base that travel behaviour does change … A large amount of case-study and monitoring evidence, and modelling using dynamic forms … indicate that changes in the volume of car travel in the order of 20%-30% can be achieved without great pain or overwhelmingly expensive initiatives. This includes studies of a wide range of 'smart' or 'soft' measures, which typically require few sticks and provide many carrots, which tend to reduce the car use of those people or locations treated by figures of over 10% overall. Studies of road pricing, re-allocation of road capacity (pedestrian areas, bus lanes, cycleways, etc) give similar figures.*
>
> Goodwin, 2007

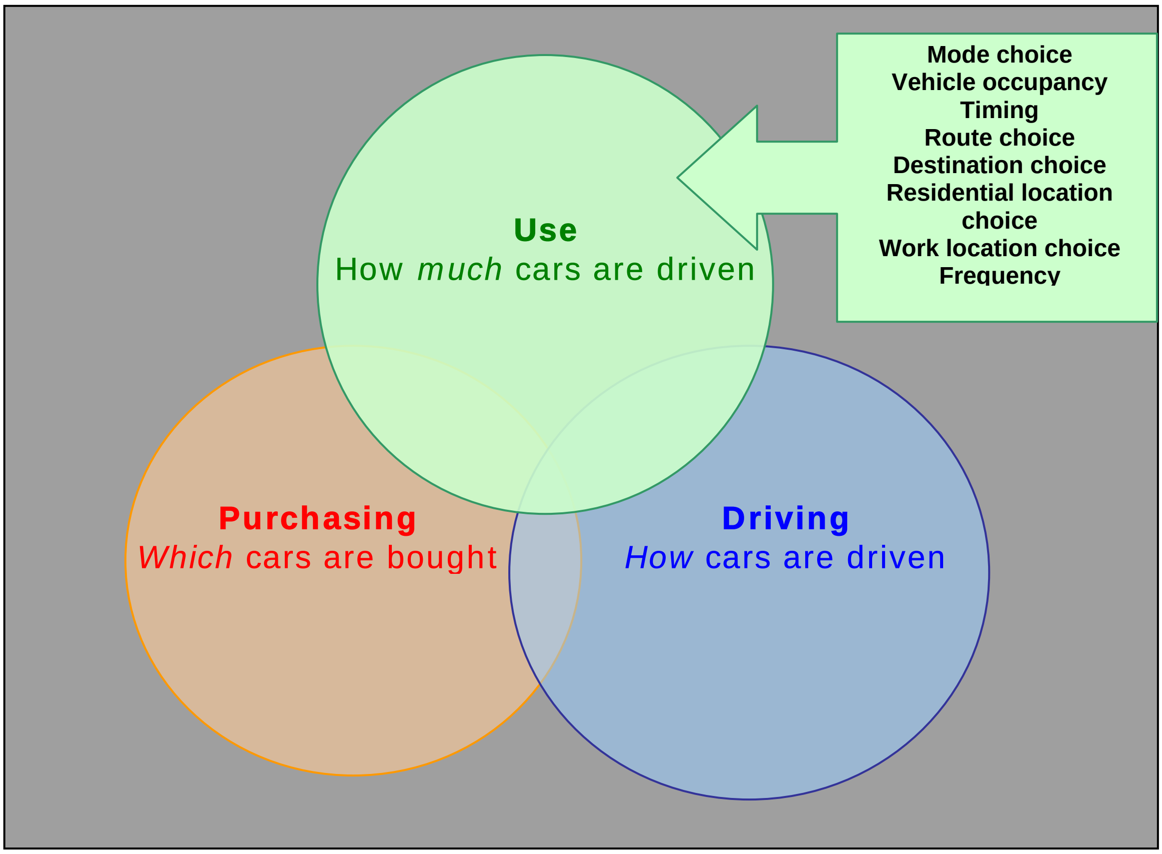
[9] This includes 'wider transport measures (0.8 MtC); 'local authority policies' (0.2 MtC) and 'sustainable distribution, Scotland' (0.1 MtC) (Defra, 2006b; DTI, 2007a).

Despite this evidence, many evaluations of transport policies assume that people are locked into behavioural patterns and travel demand will not be easily reduced. It is undoubtedly true that prior land-use and transport planning decisions have caused many to be locked into some degree of car dependency. However, in spite of these constraints, most individuals and households do have some room to alter their behaviour in ways that may reduce car use through altered mode choice or trip lengths, by better coordination of their daily activities, or, in the longer term, by adjusting their choice of work or housing location. In other words, individual travel behaviour change can manifest itself in a variety of ways.

It is possible to identify at least three types of behavioural changes required to secure emissions reductions from the transport sector, summarised in Figure 5:

(i) Changes to the *amount* cars are driven
(ii) Changes to vehicle purchasing behaviour
(iii) Changes to the *way* in which vehicles are driven

Figure 5: Categories of travel behaviour change



It is beyond the scope of this paper to outline in detail the evidence in relation to each type of policy instrument[10]. Instead, Table 1 summarises a selection of up to date findings on the traffic reduction impacts (and, where possible, carbon savings and cost-effectiveness data) of instruments specifically designed to 'lock-in' the benefits of the technology changes aimed primarily at informing individuals of changes they voluntarily can make to their driving style and influencing driver behaviour. However, as already noted, there is substantial scope for emissions savings to come from changes in car purchasing habits, some of which we are seeing emerge at least in part due to new tax regimes such as a reformed Company Car Tax in the UK (Anable and Bristow, 2007).

Table 1: A selection of carbon impact and cost-effectiveness evidence relating to behavioural transport measures applied in the UK to date

Travel or emissions reduction for selected best practices	Indications of costs and co-benefits
Smarter Choices (general)	
• Taken together, smarter measures could potentially achieve a **11%** reduction in national road traffic/ 15% in car traffic (and up to 24% / 26% in peak-time urban areas) in a supportive policy environment after 10 years of intensive application (Cairns et al., 2004) • CCP appraisal assumes only 5.3% reduction in car traffic by 2020 (after 14 years of implementation) (Defra, 2007b)	• For the different soft factors, the cost of facilitating choices by individuals to reduce their car use in most cases ranged from about **0.1p to 10p per vehicle kilometre saved (10:1).** (Cairns et al., 2004). It concluded 1.5p per km average and with a congestion cost of 1.5p/km removed, on average every £1 spent on well-designed soft measures could bring about £10 of benefit in reduced congestion (more in congested conditions). • Analysis for the CCP using a different cost estimates for congestion and counting fuel tax revenue foregone as a 'cost', estimated the average cost ratio in the high intensity scenario to be **4:1** (Anable et al., forthcoming) • The recent publication of the CCP appraisal of smarter choices (Defra, 2007b) indicates a net benefit of **£-6/tC** saved, largely due to congestion benefits. This is the figure for the mid point between high (5.3% car traffic reduction by 2020) and low intensity (1.8% by 2020). Air quality benefits are additional.

[10] The review of these policies is largely based on two sources which have recently attempted to collate this information in the UK context. The first is for the Commission for Integrated Transport (Anable and Bristow, 2007). The second is work being carried out for the UK Energy Research Centre (UKERC) which is publishing information on the carbon reduction potential and cost-effectiveness of each policy instrument as IMPACT (Interactive Manual of Policies to Abate Carbon from Transport) available at www.ukercimpact.org

	Co-benefits • positive cost:benefit ratio partly because smarter measures help to achieve a number of government objectives at the same time, including cutting both congestion and carbon emissions • Other co-benefits: social inclusion, health benefits, cost savings to businesses and paving the way for 'harder' policies • Increased mobility and accessibility
Individualised marketing (IM)	
• An independent review of the outcomes of 11 individualised marketing (IM) schemes across the country (ITP, 2007) revealed 9 of these demonstrated significant reductions in car use. Eight 'TravelSmart' projects achieved reductions in *car trips* ranging from **9 to 13 %.** • Sustrans have estimated the potential carbon savings and cost-effectiveness of an intensification of IM in the UK (Sustrans, 2007): assuming a 10 year programme covering all 18.5 million households in *urban* areas in England, the estimated annual carbon savings are based on the lower vkm reductions achieved in recent large-scale TravelSmart programmes and will save **0.6 MtC pa**. (rising to 0.9 MtC if all 24.7m household were included).	• The recent evaluation for the DfT (ITP, 2007) found cost-effectiveness improved as scale of the projects increased, with larger scale schemes ranging between **2p and 13p per km saved** in the first year (including monitoring costs). This equated to between £20 and £38 per household targeted. Over a ten year period the cost-benefit analysis was positive at **30:1**. • Sustrans has developed a model to calculate the cost per tonne of carbon saved by the TravelSmart project (Sustrans, 2007). The input cost of the project over the project time frame is calculated using Net Present Values (NPV), i.e. using a discount rate. Initial estimates of the benefits of the TravelSmart scheme put the figure at **£582 t/C** with the project taken over a time frame of one year, but over a 60 year timescale falls to **-£-29.42t/C**. Co-benefits • As with smarter choices (general) + potential for neighbourhood cohesion and community benefits ,
Travel plans	
• Have cut lone car commuting and car trips to schools, by **18%** (work) and **23%** (schools) (Cairns et al., 2004)	• cost to the local authority of £2-£4 per head**, 0.1p-2p per km** saved. Co-benefits • As for smarter choices (general)
Car clubs	
• Membership of car clubs in the UK is growing exponentially, exceeding expectations, primarily as the commercial operators have extended their reach into London. • The commercial car club sector in the UK is expanding at a rate of 200%+ per year. Between 2006 and 2007 this grew	• The recent appraisal of a proposal for a national car club network submitted to the DfT from Carplus calculated the £13m investment would result in a cost-benefit ratio of almost **10:1**. Co-benefits • Integration – car clubs can be the string

<table>
<tr><td>275% from 6172 members to 23146 members (156% the year before). Approximately 200 000 members are expected by 2012 (Carplus, 2007).
Evidence from UK car club operators indicates that car club members reduce their mileage by an average of approximately 65% on joining a scheme, and increase their public transport use by 40%.
Over 1000 Tonnes of CO2 per annum in year 1, rising to 0.14 MtC per annum after 25 years, based on a grant from the DfT for almost £13m to support a national network of car clubs (Carplus, 2007).</td>
<td>to bind package of measures (travel plans, cycle programmes and infrastructure, public transport improvements, etc.).
Choice – enables voluntary behaviour change
Access – increases transport equity
Finance – average car users save £000s.
Housing affordability – savings fund significant mortgage payments. Helps first time buyers – important for UK housing industry
Young Drivers - encourage car use as pay as you go rather than parent provide. Start the habit early: Universities are a big target.
Families – opportunity to become single car family.</td></tr>
<tr><td colspan="2">Teleconferencing</td></tr>
<tr><td>A survey of BT scaled up to the whole company found that replacing business travel with teleconferencing is eliminating 859,784 face-to-face meetings a year. Each conference call is saving a minimum 40 kg of travel-related CO_2 emissions and all conferencing calls are creating a net saving of at least 0.03 MtC per annum. Air travel accounted for 48% of avoided miles but only 8% of avoided trips (James, 2007).</td>
<td>Conservative calculations also suggest that each replaced meeting avoids travel and subsistence costs of at least £178, and frees up at least £120 of management time for more productive purposes. These figures equate to at least £135 million of avoided travel and subsistence costs, and £103 million of opportunity benefits for BT as a whole. These benefits appear to be at least 10-15 times greater than the costs of providing the conferencing services.</td></tr>
<tr><td colspan="2">Sustainable travel towns</td></tr>
<tr><td>3 towns in the UK were chosen as ‘show cases’ of smarter choices.
After 2 years, 12-13% reduction in car use and big increases in alternative modes.
In Darlington (which is also a cycling demonstration town), walking has increased by 11%, cycling by 54% and trips as a car driver have reduced by 6% over the whole town.
Isolating these wider effects, the individualised marketing has resulted in a 14% increase in walking and cycling, a small increase in public transport patronage and a corresponding reduction in trips as a car driver (–5%) and as a passenger (–12%). In addition, individualised marketing is resulting in a relative reduction of 5% car kilometres against baseline levels.</td>
<td>The Government has allocated £10m over 5 years to fund three Sustainable Travel Towns to become showcases of 'smarter choice' packages.
Darlington is both a sustainable travel town and a cycling demonstration town, so receives an additional £1.5 million for the development of new cycle routes.</td></tr>
<tr><td colspan="2">Upgrading of West Coast mainline</td></tr>
<tr><td>London-Manchester air/rail share has moved from 60%/40% to the reverse</td>
<td>The NAO estimate final programme spend is likely to be £8.6 billion. This is</td></tr>
</table>

<table>
<tr><td>since the upgrading of the West Coast mainline rail route
Reduced journey times since September 2004 have helped Virgin West Coast to increase its share of the growing London to Manchester rail/air market. The number of monthly passenger rail journeys between London and Manchester increased by 55% between September 2004 and April 2006, to 194,000. Over the same period, monthly journeys by air between London and Manchester fell by 8% to 154,000 (NAO, 2006b)</td><td>around £300m over budget (NAO, 2006b).
.</td></tr>
<tr><td colspan="2">Walking and Cycling (general)</td></tr>
<tr><td colspan="2">There is very little analysis of the carbon benefits of mode shift to walking and cycling. In order to be able to estimate the reduction in emissions for air pollutants and CO_2 that would result from increased promotion of bicycle transport, the shift from motorised private transport to bicycle transport in terms of vehicle kilometres and journeys has to be known.

The potential offered by cycling and walking as a means of transport is often underestimated because the bicycle is primarily a mode of transport for short distances. However, nearly a quarter of car journeys are less than 2 miles and over half of all journeys made by car are less than 5 miles (DfT, 2006j), a distance over which use of walking and cycling can bring time advantage over the car. Indeed, research on the impact of smarter choices found significant modal shift is possible: 50% of all local car trips in non-metropolitan towns could be replaced by walking, cycling and/or public transport (Socialdata / Sustrans, 2005). Mackett (2000) estimates that if 20% of car trips of less than 5 miles were replaced by cycling/walking, car emissions could fall by approximately 4.8%. However, other research has been less optimistic, finding that actions to encourage transfer from cars to walking and cycling could reduce the distance travelled by car by about 0.3% for walking and 0.4% for cycling, which would result in only around a 1% reduction in carbon emissions (Bristow et al., 2004). This latter study suggests alterations to land use need to be integrated with transport policies to achieve significant traffic reduction from these modes.

Nevertheless, vehicle emissions are particularly high over short journeys because fuel consumption is disproportionately high due to the cold engine and because the catalyst is not yet working at full efficiency. For these reasons, the emissions reduction effect, including for local air quality, when journeys otherwise made by car are made by bicycle is particularly high. There are also significant health benefits from the uptake of non-motorised modes.</td></tr>
<tr><td colspan="2">National cycling network</td></tr>
<tr><td>The National Cycle Network is now 12,000 miles, carried c338m trips in 2006; usage is growing at 5%+ per year.</td><td>n/a</td></tr>
<tr><td colspan="2">Small scale infrastructure improvements (general)</td></tr>
<tr><td>‘… well-targeted, small-scale interventions can often deliver the highest returns...’ (Eddington Transport Study (2006): Volume 3 Section 1.69).</td><td>The Eddington report demonstrated that small scale interventions give best value for money.</td></tr>
<tr><td colspan="2">Road space reallocation</td></tr>
<tr><td>A comprehensive global study of what happens when road space is reallocated (i.e. due to bus lanes or unexpected events) reported an average 18% of traffic went ‘missing’ from the road network (Cairns et al., 2002).</td><td>n/a</td></tr>
</table>

Eco-driving (cars)	
• Driving style impacts on energy consumption and the Driving Standards Agency (DSA, undated) found that eco-driving training leads to an immediate **8.5%** improvement in fuel efficiency for drivers on a set course after two hours of training. • In the recently launched Act on CO_2 campaign, DfT says that if all drivers in the UK followed the Smarter Driving tips, CO_2 emissions from cars could be cut by **8%** and motorists would save over £2bn in fuel bills. • Smokers et al. (2006) estimated the average reduction in practice is in the order of 5-10% and the effects of training tend to diminish over time (from 10%), but some savings are maintained (around a 3% reduction). • A calculation for CfIT assumed a conservative 4.5% efficiency saving (to avoid double counting with speed enforcement) and this was set to deliver savings of around **0.3 MtC** in 2020 (CfIT, 2007).	• Although the impact of promoting eco-driving is relatively small, these measures are cost effective as long as savings are maintained in the longer term. • The costs of promotion vary widely depending on the efforts put in place: while an introduction to eco-driving as part of the driving license tuition may be cheap to implement, a large scale campaign to raise awareness amongst all drivers, notably those that would not voluntarily participate in training courses, would require more financial input. • Drivers would save on fuel bills. Research by the Energy Saving Trust showed 36% of drivers would consider paying £50 for a two-hour eco-driving lesson if this were to pay for itself in fuel savings within 8 months (EST, 2005). • In summary, this is a low cost measure but one that is difficult to implement as it requires information, training and for each individual driver the will to change behaviour and stick with the changes over time. It may be easier to incentivise changes in fleets. There is also a potential rebound effect by lowering cost per mile travelled. • Eco-driving can be aided by the use of in-car technologies such as fuel-economy meters and tyre pressure monitoring systems. Co-benefits • Safety improvements • Traffic flow improvements • Better maintained vehicles • Equitable.
Speed enforcement	
• Currently, 56% of drivers exceed the UK motorway speed limit, 19% at speeds over 80 mph (DfT, 2006c). • The estimation of total carbon savings from enforcement of speed limits vary largely due to the different emissions factors used. These factors determine the degree to which carbon emissions are expected to increase as the speed of vehicles increase • Defra (2007b) calculate the carbon savings from strict 70 mph enforcement as **0.6 MtC** and Anable et al. (2006) as **1MtC** per annum. The retrospective figures for 60mph are **0.9 MtC** and **1.9 MtC**.	• Using pessimistic assumptions regarding the cost and scale of enforcement needed, Defra (2007b) calculate 70mph blanket enforcement as costing **£410t/C** and 60mph as **£190t/C**. • Anable and Bristow set out the arguments why enforcement may not be as costly as the Defra analysis assumes. Co-benefits • Safety improvements • Traffic flow improvements • Consistent with downsizing of the car market • equitable

London congestion charging	
• Pricing and associated measures have led to an overall 4% mode switch from car to other modes across the whole of London and 16% traffic reduction in central London (TfL, 2007)	• The scheme generated net revenues of £123 million in 2006/2007 (TfL, 2007). • Infrastructure costs of around £162m were incurred in implementing the scheme, equivalent to £196m in market prices. These have been converted to an annual cost by depreciating over 10 years and applying an opportunity cost of 5 percent, to give an equivalent annual cost of about £25m. • A cost-benefit analysis of the central London scheme suggests that the identified benefits exceeded the costs of operating the scheme by a ratio of around **5:1** with an £5 charge, and by a ratio of **7:1** with an £8 charge (TfL, 2007). Co-benefits • Public transport and cycling / walking infrastructure improvements • Reduced congestion • Improved journey time reliability • More efficient distribution of goods and services • Stimulates changes in car purchasing patterns and innovation • Air quality and safety improvements

Whilst an impartial picture, Table 1 shows that driving (and flying) behaviour is to a significant degree malleable and that past trends need not be assumed to continue indefinitely. It is true that these policies will (i) benefit from synergistic effects when implemented along side each other (ii) be more successful when supported by ‘harder’ instruments such as tax incentives, parking restrictions, technical assistance (broadband, real time information, in car instrumentation) and investments in alternatives to the car. Moreover, as the Eddington report shows, there is good evidence that small scale projects can have very good value for money (Eddington, 2006) The report specifically looks at walking and cycling projects and finds that these have large positive cost-benefit ratios: it also suggests the same could be true for measures such as travel plans that aim to change travel behaviour. More generally, Eddington underlines the case for funding measures that make better use of existing infrastructure, such as better bus services, traffic management and longer trains (as well as road pricing), before funding new fixed infrastructure.

It is also important to note that ‘behaviour change’ is not restricted to personal travel. As the Commission for Integrated Transport stressed in a comprehensive report on transport and climate change last year, there are significant savings to be made in the lorry and van fleet through shifts in practice such as empty running, consolidation of loads, eco-driving, and modal split (CfIT, 2007).

The debate with behavioural measures is consistently framed in terms of how the shifts will translate into system wide impacts and whether the changes will be sustained over the longer term. The answer to this in both cases lies with the framework conditions at site level, local and governmental level to develop a consistent and integrated set of policies. Goodwin sums this up when he says:

> *The reasons why this potential has not been delivered at aggregate level is because the instruments themselves are not yet applied intensively or even widely, and because the instruments, though powerful, are very fragile to being undermined or reversed if other, inconsistent, policies are actually providing an increase in traffic. This is still the case.*

Goodwin, 2007

4.7 Carbon pricing and emissions trading cannot be relied upon to reach our climate goals

In the wake of Stern and Eddington's recommendations that the carbon price is important and that 'the prices must be right', the Government is placing much emphasis on policy approaches which internalise the cost of carbon.

As explained above, the Government is placing much importance on the shadow price of carbon based on the social cost of carbon as a basis for optimal (cost-effective) investment decisions. It is argued that the goal of optimality is reached where the social costs of carbon is equal to the cost of reducing it (see section 2.3).

Many believe this approach is unrealistic, not least due to the uncertainties concerning possible climate change damages and how they vary with different emission trajectories. Instead, it may make more sense to start with the UK emissions target that will contribute to global mitigation to achieve a stabilisation concentration towards the bottom of the range suggested by the science (given that even the 450 ppm concentration runs a significant risk to global climate system), and then to adopt a price of carbon related to the cost of abatement (the Marginal Abatement Curve (MAC)), reviewing this as it changes according to the level of abatement achieved (globally), new solutions and scientific understanding.

This is a quite different approach to that based purely on the damages from climate change and on the attempt to achieve ‘optimality’. In other words, the policy of internalising carbon costs can only deliver if we can identify/ the market can determine the price of carbon that would be consistent with the 60/90% carbon reduction target. But given the uncertainties, it would be better to identify the stabilisation goal and understand the costs of achieving this.

Indeed, Stern was clear that the purpose of pricing is to deliver on policy goals – i.e. the goal determines the price. Instead, it could be argued that the Government is letting the price determine the goal by relying on internalising the cost of carbon to reach carbon reduction targets. This is certainly the case for aviation where carbon reductions are being sought through the entry of the sector into the emissions trading scheme from 2011/12. However, there are at least three fundamental flaws to this approach.

1. Firstly, the internalisation of the cost of carbon does not eliminate the role for cost-benefit analysis and appraisal as specific investment decisions will necessitate such evaluations.
2. Secondly, it does not provide the policy architecture to ensure that the sum of all policy appraisals ensures this carbon cap will be adhered to. Essentially, the current system of policy appraisal based on NPVs means that climate change can effectively be traded off against other welfare benefits. Also, a carbon price provides the option of buying a way out of carbon abatement.
3. Thirdly, Stern estimates that it could take 10-20 years to establish fully functioning, universal carbon pricing. Emissions trading, as well as being dependent for success on crucial aspects of its design (such as the setting of the cap and distribution of allowances) is in the early stages nationally and regionally and an international framework is yet to be established.

In summary, therefore, carbon price can possibly be regarded as prerequisite to cost-effective carbon reduction, but is no means a panacea. The unpriced nature of the emissions that cause climate change are only one market failure that characterise the problem (Defra, 2007f). The other two are innovation failures and failures that inhibit behaviour change. Thus specific policy instruments will be necessary alongside carbon pricing to change behaviour, whilst supporting the development of a market through regulations and technological developments, which themselves will be subject to an assessment of their relative carbon benefits and value for money.

The Government have agreed that there is '*merit in considering a move towards a MAC-based approach to calculating the SPC, and we therefore intend to review the guidance within the next* year' (Price et al, 2008). This will also be a consequence of moving towards the system of carbon budgeting in the Climate Change Bill, whereby emissions will be capped over five year periods and an independent body (the Climate Change Committee) will report on progress and budget setting (HM Government, 2007).

4.8 Packages of policies need to be evaluated

Although different policies will be required for different 'market failures', it must be recognised that in reality, the policies for one 'market failure' interact with the others (Ekins, 2007). For example, policies to internalise the carbon externality raise the prices of activities associated with it and thus stimulate innovation; policies to stimulate behaviour will reduce the abatement costs and therefore increase abatement associated with any given carbon price. These multiple interactions between policies create the need to assess policy packages and avoid evaluating policy instruments in isolation. Yet, policy measures are mostly assessed in isolation without necessarily identifying the best *combination* of measures and the value of an integrated approach.

Although the evidence on cost-effectiveness of transport policies is unavailable in any systematic way, the literature strongly suggests that packages of measures can be effective in promoting savings in the transport sector (Anable and Bristow, 2007). In order to be most effective, measures in the transport sector need to be part of an integrated strategy. For instance, as explained above, transport solutions often come out as more expensive because of the 'rebound effect'. The erosion of the carbon benefits and knock-on congestion disbenefits caused by the rebound effect leads to poor cost-effectiveness of measures to improve vehicle efficiency. This metric would be improved if complementary tax savings such as fuel duty and vehicle purchase and circulation taxes were implemented at a level to lock-in the efficiency gains.

Overall, behavioural shifts in purchasing and use can increase the total carbon savings from technological change, and improve its affordability. However, the instruments to do this are not necessarily under the control of one Government department. For example, the Department for Transport has little control over the fiscal measures such as fuel duty that are a critical part of any strategy.

In conclusion, packages of measures are more important than individual policy instruments. However, the evaluation of combinations of interrelated measures is arguably an impossible task. It could be argued that ‘policies’ and policy programmes such as the cost-effectiveness evaluations carried out for the CCP shown in Figures 3 and 4, cannot in themselves be evaluated. This is because policies such as the Voluntary Agreements are a only a framework for the implementation of technical measures. The delivery of the efficiency gains will come about due to a mixture of technical requirements and supporting fiscal incentives so that the cost-effectiveness of the Voluntary Agreements or its successor cannot itself be measured. Thus, when examining policy, we need to be aware of synergistic / overlapping effects.

4.9 The assumption that travel demand will automatically increase leads to higher cost assessments

As already discussed, the expectation of significant future growth in travel demand contributes to the conclusion that carbon abatement in this sector will be relatively costly to achieve (section 2.3.1). As Goodwin (2007) points out, *achieving a target is all about comparing levels in a base year with levels in a future year*. However, when assuming future trajectories for the transport sector, the ‘without policy baseline’, ‘counterfactual’ or ‘do minimum’ scenario almost always assumes the worst case scenario – thus assuming greater policy hurdles and thus greater costs than may necessarily be the case. For instance, the base case for the assessment of the cost-effectiveness of transport measures usually assumes that the continuation of traffic growth is inevitable and that technology would not progress in the absence of policy. Goodwin suggests:

> *Such an appraisal is largely useless for carbon reduction strategies. It leads to the proposition that the transport sector is going to get worse, and having got worse will be very expensive to reverse (hence the Stern conclusion).*
>
> Goodwin, 2007

Instead, he suggests:

> *An appraisal methodology suitable for assessing the transport contribution to carbon reduction objectives must start from now, and construct a trajectory year by year for achieving it. For technical reasons, as it happens such an approach would also more clearly reveal the other, non emission-related, advantages of such policies, which would help to secure their acceptance.*

Goodwin, 2007

4.10 Carbon reduction is not the only goal

In order to undertake robust cost-effectiveness analysis for climate change policies, ancillary factors must be stripped out to arrive at a pure "cost of carbon". Yet, most transport policies seek to achieve a number of objectives, only one of which is carbon reduction and where the monetised value of additional benefits is often uncertain. As Goodwin summarises, these alternative goals may be include:

> *… relief of congestion, greater efficiency of use of transport networks, improved quality of movement and access to activities and opportunities, improved social inclusion, improved commercial success in city centres, reduced accidents, better fitness and health, expenditure savings on expensive infrastructure and maintenance, reduced local environmental damage, more productive use of scarce land and other resources, and reduced nervous tension and stress.*

Goodwin, 2007

Any individual policy measure will have a range of impacts in addition to its effectiveness measured in terms of carbon savings – some with a monetary cost attached and some with a benefit. In general, the policy impacts can generally fall into direct costs and ancillary impacts:

Table 2: Direct costs and ancillary impacts of policy measures

Direct Costs	Ancillary Impacts (costs and benefits)
Up-front costs associated with new investment *E.g. Cost to the car purchaser, through a higher purchase price.*	Comfort taking/ rebound effect. *E.g. where consumers who have acquired a more fuel efficient car and drive further rather than using less petrol*
Ongoing running costs (including marketing). *E.g. Saving in terms of fuel costs to the user if the no. of kilometres travelled stays the same.*	Increase or reduction in air quality impacts
Administrative costs incurred by government and its agencies	Increase or reduction in safety impacts
Costs incurred by other firms and individuals affected by the policy. *E.g. The Government will be affected as tax revenues will change*	Increase or decrease in traffic congestion

Source: Anable and Bristow, 2007, adapted from NAO, 2006a.

In addition to those impacts listed in Table 2, policy assessments could take into account other non-quantifiable impacts such as security of supply; social inclusion and equity; effects on competition and innovation, impacts on biodiversity and regeneration and potentially even the public acceptability of the policy. Indeed, the social distribution of impacts might mean a more expensive policy is more desirable than the cheaper one.

For much of the analysis used to assess the CCP and the EWP, ancillary benefits were at best assessed qualitatively in the analysis. Where ancillary impacts were monetised, these included only air quality and congestion effects – impacts such as noise, safety, health and social inclusion were not monetised in the analyses. As explained in section 4.2.1, where congestion effects were included such as due to the rebound effect from efficiency gains secured through the Voluntary Agreements, the policy was more expensive per tonne of carbon saved (Figure 2).

Thus, assessment is based almost exclusively on carbon reduction and monetary costs without consideration of other impacts, particularly those that are difficult to quantify. The Better Regulation Commission concluded:

> *It will be important to distinguish between policies which are primarily carbon reduction measures and those which also have other objectives. Policies with primary objectives other than carbon should be assessed on those first with potential carbon impacts considered as a secondary benefit*.

BRC, 2007

4.11 Cost-effectiveness is a difficult measure to use as an instrument of comparison across timescales, policies and studies

The reliance on the least cost approach across sectors requires policies to be compared to each other across sectors, timescales, locations and different scales of implementation. However, a single cost-effectiveness figure per policy instrument such as those generated by the cost-effectiveness exercise in the CCP may be inadequate to make such comparisons.

In general, the evidence on the cost-effectiveness of measures in the transport sector is limited, few measures have been thoroughly assessed in this way and methods used are often inconsistent. Indeed, it is reasonable to say that any cross study comparisons should be viewed with extreme caution as the methods, assumptions and indicators vary a great deal between studies. Anable and Bristow (2007) identified the following key variants between studies:

Figure 6: The challenge of comparing cost-effectiveness estimates

Starting points – more recent studies contain more up-to-date data which may reflect, for example, slower than anticipated progress in policy implementation, or a new understanding of relationships or changes in technological rates of progress;

Baselines – studies vary in the nature of the baseline forecast especially with respect to the extent to which current policies assumed to succeed, partially succeed or fail. For example, an assessment of a 10% Renewable Transport Fuels Obligation (RTFO) could start from the current situation or could assume achievement of 5% by say 2010;

Start and end dates – different time periods for abatement affect when carbon emissions will be reduced. Yet, the earlier the reductions, the more cost effective will be the policy.

Scope - does the study cover the UK, Europe or the world? This too will affect starting points and baselines;

Assumptions about the strength and pace of intervention - and / or degree to which measures are assumed to be implemented: for example, speed limits of 70mph, 55mph or 50mph and the types of road affected;

Assumptions about the behavioural response to measures - for example the assumed behavioural response to price signals (elasticity of demand);

Assumptions about whether demand is assumed to be fixed or changes over time;

Assumptions with respect to costs of technological developments over time;

Definitions of cost-effectiveness and cost benefit analysis;

Definitions of cost - for example given per tonne of oil equivalent, or per gigajoule etc;

Discount rates - the value of costs and benefits in the future and the equity between generations;

Currencies and indicators – e.g. of tonnes of carbon versus CO_2 or energy;

Purpose and focus - for example, some studies examine the effects of specific policies prior to or after implementation whilst others examine routes to achieving target reductions in CO_2 and others are focussed on different impacts such as air pollutants or oil consumption.

Source: Anable and Bristow, 2007

Many of these problems in undertaking any comparisons between studies were also identified in by Kampman et al. (2006) which reviewed the cost-effectiveness of technical measures to reduce CO_2 emissions in transport. This led the authors to conclude:

…different cost-effectiveness studies cannot generally be combined and compared because the assumptions and methodologies differ so much. Choosing the most cost-effective pathway for society to combat global warming is therefore difficult with present knowledge

(Kampman et al., p3).

Anable and Bristow (2007) identify the key differences between studies as the range of costs and benefits included; the extent to which demand is assumed to respond to changes and assumptions made on the future prices of new technologies.

4.12 Some transport policy instruments have not been systematically evaluated in terms of carbon abatement and cost-effectiveness

Finally, the emphasis on the appraisal of transport technology options in the Government analysis and the wider literature, means that a number of potentially significant policy options have not been systematically evaluated in terms of carbon abatement and cost-effectiveness. These include:

- *Road building* – once a road is built, there is little assessment of what happens in the way of induced traffic and carbon emissions. Even though there is a Post Opening Project Evaluation (POPE), these are often delayed and unpublished and therefore have little impact on policy formation. In a report for CPRE, three case studies in 2006 found traffic flows to be near or in excess of what had been predicted for 2010 and a review of ten POPEs found these to concentrate on reassessing the economic benefits (Matson et al., 2006). It would be desirable to assess how much additional CO_2 has been generated as a result of new road building on a year by year basis. However, net effects on traffic generation and carbon not assessed (ex-post).

- *Road user charging* - national road-user charging is currently being suggested by Government as the best hope for congestion relief (Anable and Shaw, 2007). If implemented, vehicles will most likely be charged per vehicle-mile based on the marginal congestion cost imposed, with people travelling on congested roads at peak times paying more than those using quieter roads at off-peak times. Politically, it may also be necessary for national congestion charging to begin revenue neutral with the option of an ‘environmental premium’ at a later date (DfT, 2006). Local road user charging schemes simply impose an additional charge for entering a charging zone. However, it carbon reductions cannot be guaranteed by road charging as it is dependent on the implementation path chosen. Fiscal neutrality, if achieved by scaling down other motoring taxes, may only achieve carbon neutrality as traffic is increased during the off-peak, and traffic speeds may increase (Grayling et al., 2004; Glaister and Graham, 2005; SMF, 2007). However, it is possible that road user charging could be structured to encourage the uptake of more efficient vehicles, such as emissions related congestion charging in London (AEA, 2007). It is also possible that a charge per use may encourage behavioural changes by highlighting the cost per journey (Anable and Bristow, 2007).

- *Public transport* – the net effect of increased use of public transport and specific measures to reduce the carbon intensity of alternative modes have not been examined to any great extent. There is great potential here not only in terms of vehicle efficiency but in driver behaviour and operational effectiveness.

- *Freight* – light goods vehicles are one of the fastest growing segments of travel demand, yet with little policy attention. There is evidence that sustainable distribution is cost effective (McKinnon, 2007), but very little analysis of policies that may be applied to the van fleet. As with buses, there is great potential here not only in terms of vehicle efficiency but in driver behaviour and operational effectiveness.

- *Land use planning* – the carbon implications of government land use policy at the local as well as at the macro level (i.e. hospital closures; parental school choice; inter-regional distribution of economic activity) could be significant but remain an under evaluated area of policy. This could be a task for the Climate Change Committee.

- *Aviation and shipping* – government targets for carbon reduction exclude emissions from international aviation and shipping as they are outside the scope of international agreements. However, emissions from these modes are increasing rapidly. Yet, there is very little information on the effectiveness and cost of measures to reduce emissions from these modes.

- *The potential for carbon reduction at the local level* – the Climate Change Bill which lays down a system of carbon budgeting for successive five year periods may need to consider the extent to which, and the way in which, the carbon targets and budgets might operate at regional and local levels. This will need to identify a role for the English RDAs and local authorities in supporting national energy policy (for example, by publishing carbon saving projections from their regional and local measures) and this, in turn, will require analysis of the cost-effectiveness of carbon reduction policies over this geographical scale.

- *Adaptation* - the costs of mitigation and adaptation are inter-related: There is a demand for information on the costs of adaptation to judge the best adaptation on cost-effectiveness grounds and to assess the trade-offs between adaptation and mitigation.

In addition, as already discussed, policy measures tend to be evaluated in isolation even though packages of policies appear to be more cost-effective than isolated instruments.

5.0 Discussion and conclusions

The discussion in this paper can be distilled into three main issues which, depending on how they are handled in any analysis, together dictate whether or not transport measures will be deemed a more or less cost-effective route to carbon reduction. In short, these are the *assumptions* about future costs and level of travel demand, the *methods* applied to compare policies for cost-effectiveness and the *evidence* base used in relation to different types and combinations of policy instrument. To date, a narrow set of transport policy instruments have been assessed in isolation for their carbon abating potential and, where they have been examined, pessimistic assumptions about future traffic growth and welfare costs and optimistic assumptions about the price and availability of oil have led to the conclusion that carbon reduction will not be achieved economically from this sector.

Firstly, estimates of cost-effectiveness are critically dependent on the future that is assumed. Conclusions about the high cost of carbon abatement in the transport sector appear to emanate from models which essentially assume a business as usual baseline. This in turn is based on a highly static view of the economy and consumer demand which is still almost entirely oil dependent and predicated on a continuation of the link between transport activity and economic growth.

The two most important assumptions are the level of traffic growth and the availability and cost of conventional fuels in future years. It would appear that most models used to explore potential future energy pathways assume that the demand for travel will not slow significantly in years to come. The costs of achieving carbon reductions are self evidently higher if travel demand is assumed to grow than if an alternative, less pessimistic or dynamic trajectory is adopted. Analyses also tend to assume that oil based fuels will continue to exist at ‘affordable’ prices and quantities. This may have the effect of overestimating economic growth and/ or stability (and hence travel demand), and downplaying the cost of reliance on conventional technologies and the role that could be played by innovation towards alternative fuels and lifestyles.

Another important assumption relates to welfare costs. Any reduction in travel demand or indeed alteration of car purchasing habits is often assumed to have a high welfare penalty to consumers. Yet, this is also based on a static view of the economy. In other words, whilst it may appear to be difficult to reduce demand *now* (although the evidence also refutes this assumption to some extent), a change in policy context may also change the cost-effectiveness of different actions. For instance, rising oil prices or supply volatility may increase the desire and utility for less car dependent lifestyles. It is also questionable the extent to which the welfare costs of as yet unfulfilled demand should be factored in to analysis.

Secondly, as with most problems, there are many potential solutions to climate change. Which is selected will be at least in part dependent on how the problem is evaluated. Current policy emphasis based on neo-classical economic theory suggests we may want to know what we are willing to pay to save a tonne of carbon and compare this against the social cost of carbon in order to decide whether we think this is worthwhile. Whilst cost-effectiveness analysis may be an appropriate means of identifying the cheapest way of achieving a particular goal such as carbon reduction, it has inherent limitations with regard to the assessment of transport policies where the policy objectives are not necessarily only to reduce carbon emissions. It also disadvantages many transport policies which become more cost-effective when looked at in combination with other measures (e.g. the locking-in of efficiency gains from road pricing) and when the timescale of the impacts are taken into consideration (e.g. quick wins from speed enforcement or travel planning).

Thirdly, analysis has been applied to a narrow set of policies without due account of the emerging evidence on the potential for demand reduction in this sector. Evidence relating to smarter choices, mode shift to non-motorised modes and from air to rail in the UK, together with economy wide assessments which highlight the potential for small scale infrastructure improvements, all point to the need to take seriously those strategies which change travel behaviour to increase transport system efficiency. Many studies that have compared mobility and air quality strategies have concluded that demand management strategies are among the most cost-effective in that they can reduce a trip, mile of travel or tonne of carbon for a relatively modest amount of money. Demand-side strategies may not be the *primary* solution to these problems, but nevertheless, are an *essential* part of the solution in order to increase the likelihood of net carbon reductions being delivered from technical applications and in order to insulate against possible economic discontinuities due to fuel and infrastructure constraints and climate change in the future.

There are, however, a variety of important gaps in the evidence. These relate to policies which have not been systematically assessed for their implications on carbon emissions and costs of abatement such as road building, public transport, land use planning and aviation and shipping. They also relate to the assessment of packages of policies to understand their combined impact in terms of carbon reduction and potential optimisation of resources due to synergistic effects.

Of course, it is not only the transport sector which is sensitive to these issues relating to assumptions, methodology and evidence. Nevertheless, it may be the case that these variables are more critical for transport solutions than for other sectors. For instance, downplaying the importance of timescale and cumulative emissions may lead to a disregard of cheaper, demand side solutions; assumptions about oil availability may grossly underestimate the impact on this most oil dependent sector of a reliance on distant technical solutions; emphasis on cost-effectiveness may forget the fact that most transport solutions are implemented for other reasons than carbon reduction; preoccupation with public acceptance may lead to a disproportionate weight attached to assumptions about welfare costs.

These conclusions have far reaching implications for policy aimed at reducing the UK's carbon emissions, as follows:

1. The Government should adopt a more dynamic approach to the shadow price of carbon

In the wake of Stern and Eddington's recommendations that the carbon price is important and that 'the prices must be right', the Government is placing much emphasis on policy approaches which internalise the cost of carbon. Yet, Stern was clear that the purpose of pricing is to deliver on policy goals – i.e. the goal determines the price. Instead, it could be argued that the Government is letting the price determine the goal by relying on internalising the cost of carbon to reach carbon reduction targets and by relying on the shadow cost of carbon as a framework for policy appraisal.

However, this approach may be too inflexible and inaccurate to help us to reach our targets in the short window of time that we have to avert dangerous climate change. There are a variety of elements that may change to cause the most cost optimal solutions to differ as time progresses, not least the uncertainties concerning possible climate change damages and how they vary with different emission trajectories. Many believe that the approach to the future and marginal abatement cost assessments need to be more dynamic by starting with the stabilisation goal and then adopting a price of carbon related to the cost of achieving this. The current Government approach – to base the carbon price purely on the damages of climate change consistent with a given target – could lead to perverse consequences as the more ambitious the carbon reduction target, the lower the social cost of carbon needed to help achieve it. This could result in weaker policies, the delaying of abatement and fluctuations in the carbon price. The Government have agreed that there is 'merit in considering a move towards a MAC-based approach to calculating the SPC' (Price et al., 2008) and this paper strongly recommends a review of the Government's approach.

2. Cost-effective carbon reduction from transport requires a market transformation approach to affect demand *reduction* and innovation

Whilst carbon price can possibly be regarded as prerequisite to cost-effective carbon reduction, it is by no means a panacea. The unpriced nature of the emissions that cause climate change are only one market failure that characterise the problem. Others include innovation failures and failures that inhibit behaviour change. Thus specific policy instruments will be necessary alongside carbon pricing to change behaviour, whilst supporting the development of a market through regulations and technological developments, which themselves will be subject to an assessment of their relative carbon benefits and value for money.

On behaviour, policy focuses primarily on changing what motorists drive rather than how much they drive. Yet, notwithstanding the scope for vehicle downsizing, this emphasis on technological solutions disregards the need for near-term action to reduce emissions in line with the need to stabilise atmospheric concentrations to avoid runaway climate change. The evidence on the potential for travel demand reductions to be made relatively cheaply has been downplayed. This includes the potential for fiscal policies to achieve significant and sustained carbon reductions. Particularly in a carbon focused policy context, the additional benefits (besides energy conservation and emission reductions) of reducing mileage and the additional congestion and accident costs that result when increased fuel efficiency stimulates additional vehicle mileage, should be explicitly targeted by policy.

On innovation, the issue is not just how much do low carbon technologies cost, but how to direct the continuing investments that will be necessary towards low carbon transport technologies in ways that will stimulate innovation and reduce these costs. The current debate on mandatory emissions standards for new cars taking place at the European level must consider the dependence upon policies to direct investment and stimulate innovation and demand in order for the market to transform successfully. Moreover, the costs of compliance are likely to be lower than currently estimated by car manufacturers as the track record of such predictions shows to be the case.

3. The rebound effect is not inevitable – policies can be targeted to reduce its effect

The rebound phenomena clearly shows the shortcomings of the current focus on vehicle technology - as most CO_2-emissions come from increased mileage. Although increased efficiency confers economic benefits in its own right, its effectiveness in reducing fuel consumption and emissions depends on how consumers alter behaviour in response to cheaper energy services due to improved efficiency. To obtain the full potential savings from increased vehicle efficiency would require complementary measures to restrain demand increases in which case the costs of achieving the reduction would fall. Given the strength of the rebound effect in the transport sector, accepting it as inevitable rather than something to be targeted by policy using fiscal (e.g. fuel duty) and regulatory instruments (e.g. mandatory minimum standards) to lock in the benefits will lead to conclusions that carbon abatement in transport is expensive.

This final point also leads to the need to consider the optimum combination of policy instruments to achieve cost-effective reductions as single policy evaluations can result in misleading conclusions with serious consequences for the likelihood of cost-optimal, early progress on carbon reduction.

Put alongside the gaps in the evidence base highlighted in section 4.12 - systematic assessment of the effects of road building; the potential for carbon reduction from road user charging, public transport and land use planning; the potential for cost-effective carbon reductions from freight; the cost of instruments to reduce emissions from aviation and shipping; the potential for carbon budgeting at the local level and the integration of assessments of adaptation into evaluations – these final conclusions highlight the difficulty in making any definitive conclusions about where the most cost optimum carbon reductions can be made.

Nevertheless, the newly created Climate Change Committee is set to identify the potential carbon abatement from the 'tradeable' and non tradeable sectors. Transport is non tradeable (apart from aviation from 2011/12) and requires a robust evidence base and analysis in order to develop carbon budgets that deliver what is needed. The precise figures on costs and impacts are less important than the consensus that is emerging about the scope for demand-side policies to deliver. On this basis, it would appear irresponsible to dismiss the large body of evidence which exists to suggest that travel behaviour change - in all its guises from car purchasing, to location choice, driver style and mode shift – offers a serious foundation for non-marginal, relatively inexpensive carbon reductions from both passenger and freight transport.

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