National project on transport policies to address climate change

Phase One

Perspectives

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Project funded by
MTRU
Transport 2000

May 2007

UK transport and climate change study

Phase One
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Summary

Introduction and context

The overall aim of this project is to contribute to, and help to progress, the development of a low carbon pathway for transport policy in the future. It is in two parts, the first describing the context in terms of climate change and its impact on transport, the second providing a draft set of detailed policies which would radically reduce the carbon footprint of Britain's transport system. It is the findings of this first phase of the project, entitled "Perspectives", which are summarised here.

Recent reports such as the Stern Review set out the broad sweep of policy direction, as does the draft Climate Change Bill. However, what is needed to move forward is a more comprehensive, integrated and detailed set of proposals. The overall aim is to describe "how do we get where we want to be" in a realistic and practical manner.

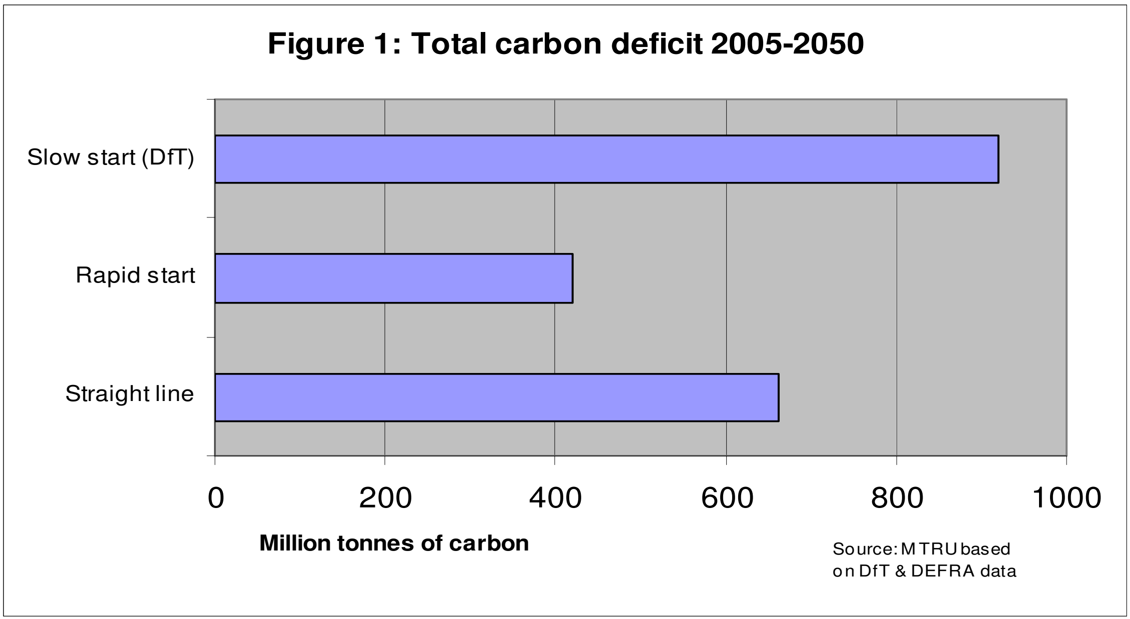
In order to develop detailed transport policies, it is essential to derive a set of guiding principles and answer some of the key questions in relation to climate change.

For this reason, Phase 1 contains a brief review of the climate change context within which transport needs to work, addressing issues such as:

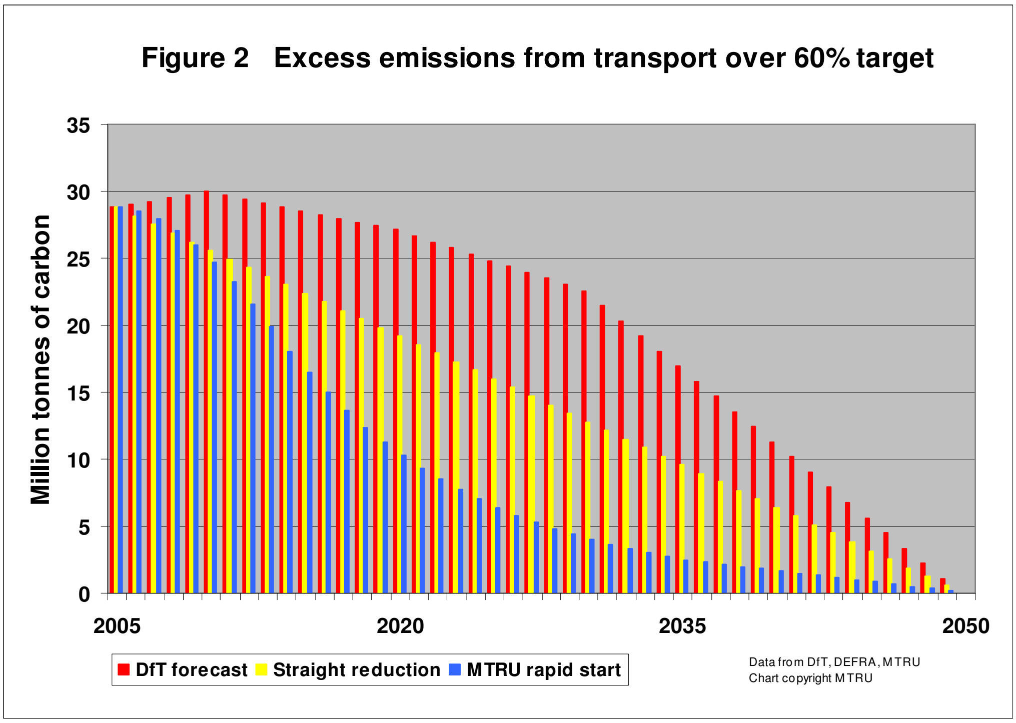
- Do we need to make significant early progress or can we start slowly?
- If other sectors make reductions above their targets, should transport be allowed to exceed the national targets?
- How much can be achieved by technology and how much by changing behaviour?
- What mix will be required of regulation, voluntary agreement and taxation?
- What is the role of biofuels and will there be competition between land for food and land for fuelling transport?
- How useful is maintaining and planting forests, and how damaging is forest clearance?
- Is it possible to calculate the damage costs of greenhouse gas and translate it into a tax?
- Can pollution trading schemes and markets be created which will ease the transition to lower levels of GHG?
- How can damage many years in the future be given a value today?
- What are the real future costs of changing behaviour now?
- How can the measures to avoid climate change be applied fairly?
- How can the people affected by policies to avoid climate change be engaged?

The first phase of the project begins to address these questions and goes on to create the objectives and principles which are used to generate policies.

An example of this is the way the rate of reduction of greenhouse gases has a dramatic effect on the total emissions over the next forty to fifty years. The fresh analysis contained in this report, exemplified in Figure 1 below, shows the total amount of emissions over a given period for different rates of reduction. It is this which determines the level of climate change, not a target, however tough, which is decades away.



This has major implications for transport because changing travel behaviour can start to make a difference to greenhouse gas emissions quite quickly - in a short timescale of 5 to 10 years. The report sets out clearly what rate of progress is needed and how far this from current expectations. This is shown in Figure 2 below.



What is more, if the financial framework is implemented fairly, the net cost of taking action in transport is among the lowest available. This is very different from current views that actions on transport are among the most expensive. This is mainly due to the prediction that more efficient vehicles reducing the cost of road use and thus generating traffic. It does not apply to behavioural change. If the "rebound" effect of extra traffic is avoided, reducing transport emissions becomes one of the most cost effective means of meeting Government targets. Any carbon reduction policy which reduces traffic is also likely to have significant congestion and air quality benefits.

Tackling climate change through transport is also one the most equitable – expenditure on transport rises with income, while heating and lighting is a larger proportion of lower income household expenditure. The report shows that the need for a rapid start and low cost makes action on travel behaviour a key priority for policy development.

Present policy is in fact moving in the opposite direction. By 2020, DEFRA estimates that transport emissions will be 17% higher than the base year (1990), even excluding international aviation. The rest of the UK's emissions will be 27% lower. This means that the Climate Change Bill targets could be met, if transport meets its fair share, rather than being allowed to significantly increase its emissions. If transport were to continue to increase its emissions, other sectors would have to reduce their 2020 figure by a further 15%. Achieving this in sectors such as business, agriculture and energy supply, which are already aiming to reduce their emissions by over a quarter, is simply not credible.

Policy framework

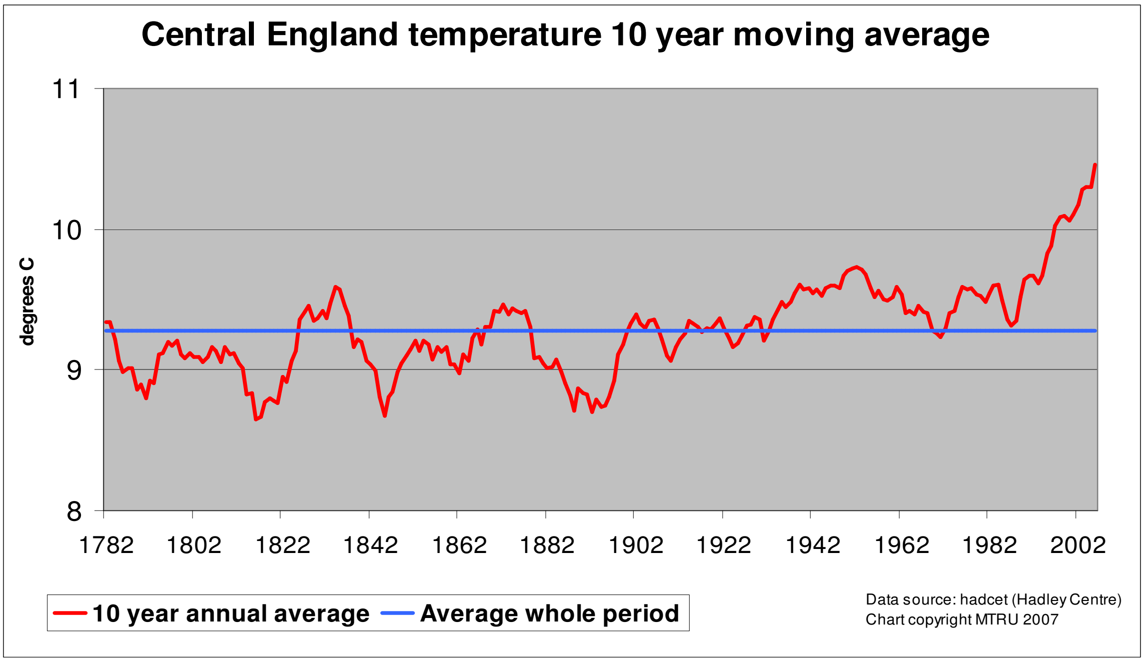
- Transport policies to combat climate change should be based on three principles:
    - The main objectives must be individually identified and clearly stated. *(Rational).*
    - It must be clear to those who are affected how the mechanism relates to the objective. *(Transparent).*
    - For those people who reduce their travel by one mode, or incur additional cost, there is an alternative available. *(Equitable).*

- New charges to encourage change in transport use for the purpose of reducing greenhouse gases should not be used for raising general revenue. Income should be returned, for example through lump sum payments (equitable but less productive in GDP terms) or reduced national insurance (less socially progressive but probably GDP positive).

- Policies must be comprehensive and integrated across all modes and take land use planning into account. Issues such as the availability of alternative choices and rebound effects (such as more efficient vehicles encouraging more car use) must be included.

Key findings

- Using actual measurements from the UK, as plotted in the chart below, the recent rise in temperature can be seen in a UK version of the well known “hockey stick” diagram.



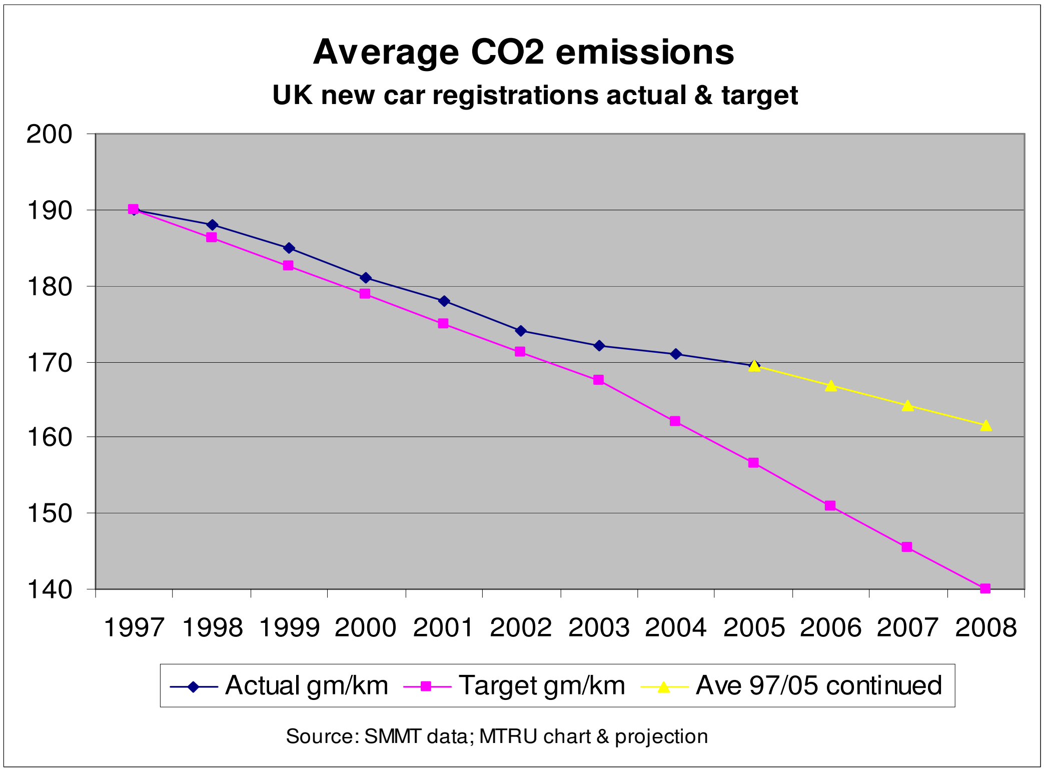
- Greenhouse gas (GHG) reduction targets for single years in the distant future can be very misleading. The key test is the total amount of GHG emitted between now and the target dates. A slow start can mean twice as much emissions over a “safe” level between now and 2050.
- Changing travel behaviour will deliver significant GHG reductions within a shorter timescale compared to improving vehicle efficiency.
- Opportunities to influence transport choice are diverse, plentiful and well known, and are among the lowest net cost for carbon reduction of any sector.
- Carbon charges on private transport are socially more equitable than other sectors, for example home heating, because the proportion of income devoted to travel is higher among the more affluent.
- Improving vehicle efficiency must be combined with policies for demand management to avoid generating traffic.
- The creation of pseudo markets in carbon emissions may or may not succeed in future but is as yet unproven and limited in application.
- The estimation of a social cost for carbon has created considerable debate but has to be adjusted outside normal conventions in order to address the issue of responsibility to future generations. The value is always dependent upon the assumptions made.
- Carbon pricing is better approached by considering the level of reduction required and using price as one of the means to achieve the desired end. This need not prevent, and is likely to support, the development of more sophisticated market mechanisms.

- An objectives based approach gives economic policy a tighter focus and is more transparent to those affected.
- The implications of a move towards biofuels have not been well understood, in some cases it would be preferable to plant trees and carry on using fossil fuel. The competition for land for biofuel or for food and the impact on world food prices must be taken into account, as must the burning of forest in order to plant biofuel crops.

Policy example

In order to illustrate the approach for Phase 2, which will involve an integrated set of policies for the transport sector as a whole, the example of improving vehicle efficiency has been examined in Phase 1.

The original Government intention was that average fuel efficiency, and thus carbon emissions, for new cars sold would fall by 26% between 1995 and 2008. This was to be achieved through a voluntary agreement with manufacturers. It is now clear that the target will not be met by some considerable margin.



This report's proposal seeks to achieve a similar result to the original target through a different approach which changes vehicle taxation and includes the recycling of revenue back to UK residents.

With regard to more efficient vehicles, an impact is sought first at the point of purchase. To avoid generating more traffic, fuel duty is raised slowly over time. VED would be used as a reinforcing measure only and is not proposed at the high levels suggested by some other commentators. This appears to be both more efficient and more equitable.

In this context the MTRU proposals have the following elements:

1. Specific objective to reduce GHG emissions by improving total vehicle efficiency, with a neutral impact on use.
2. Sales tax is compatible with the levels of efficiency which are technically feasible and the cost savings achieved by manufacturers **not** adopting fuel efficient technology.
3. Tax is avoidable by purchasing energy efficient vehicles.
4. Compatibility with EU and national voluntary or mandatory targets to improve average fuel efficiency.

A long term, integrated approach is proposed as follows:

Efficiency targets for new cars sold which are broadly in line with the previous voluntary agreements with manufacturers and the new EU targets. The reference target for grams of carbon per kilometre (gm/km) will be reduced gradually every year at least until 2020.

Sales tax applied on a sliding scale according to carbon emissions above the reference target for all new cars. Initial suggestion is for £50 per gm/km over the reference level.

Fuel duty applied so that the average fuel cost per kilometre for private cars should stay the same if the more efficient vehicles are bought. This starts at 1-2p per litre per year rising to 4p per litre per year in 2020. It is separate from any fuel duty increase to reduce use as an alternative to congestion charging.

VED would also be on a sliding scale linked to emissions but slightly less than today for cars with average efficiency. The suggested rate is £2 per gm/km over target level, minimum charge £20, not applied retrospectively.

Income recycled, for example through a lump sum at the end of the tax year.

Next Steps

Phase 2 of the report will build on the findings summarised here to produce a set of policies covering all UK modes including freight, domestic air and rail. It will also suggest interim policies for international air and shipping to and from the UK pending any European or global agreements.

1 Introduction, principles and objectives

The aim of this project is to contribute to, and help to progress, the development of a low carbon pathway for transport policy in the future. Other sectors have made some progress in developing such policies, energy standards for new housing is a good example. Although some technical work has been undertaken on high efficiency vehicles and new fuels, work on the behavioural changes required in transport to address climate change is only just beginning. Reports such as the Stern Review [1] set out the broad sweep of policy direction, as does the draft Climate Change Bill [2]. However, what is needed to move forward is a more comprehensive, integrated and detailed set of proposals. Thus the overall study focusses on "how do we get where we want to be" in a realistic and practical manner.

The first part of the research focuses on the transport context, and considers issues such as what the current policies can achieve, and how well they are working. It also defines some important principles for the approach to developing policy as follows:

1. The main objectives must be individually identified and clearly stated. *(Rational).*
2. It must be clear to those who are affected how the mechanism relates to the objective. *(Transparent).*
3. It must be clear to those who reduce their travel by one mode, or incur additional cost, there is an alternative available or that there is a feasible course of action which will avoid the additional cost (*Equitable).*
4. Any revenue raised as part of transport policies to address climate change must be returned directly to those affected in a way which does not undermine the objectives *(revenue and policy neutral)*

In this case the underlying overall objective is to reduce the greenhouse gas emissions from transport.

This first part also includes an important analysis of how rates of progress towards targets affect total emissions over the policy period (now until 2050) and how this interacts with the final target level which is required. The real world example of California is used to illustrate this point, as well as the best estimate of the current UK transport and climate change policies.

The implications of the Stern Review for transport, especially in relation to economics and ethics, are set out, and the different approaches to putting a price on carbon assessed, including the creation of "carbon markets". The effectiveness of offsetting (from planting trees to burying CO2) and biofuels is also considered.

While the second part of the research will build policy packages which could achieve the desired rates of reduction, an indication of how this would work is given. This relates to the failure of the voluntary agreement with car manufacturers to achieve real advances in fuel efficiency. Thus a proposal is provided at the end of the report on rates of fuel duty, purchase duty and excise duty over the medium term (next 15 years).

While focussing on transport, this cannot be done in isolation from two other major policy areas: land use and communications. The reason is that changes in both determine a significant proportion of the demand for transport and its patterns of expression. It is also important to recognise the human factors, the most obvious of which is the desire to maximise individual welfare through personal, private transport.

However, individual responses are not always entirely self interested or short term and the issue of public acceptability, confidence and participation needs to be addressed throughout the project. Thus the study will also draw on an analysis of why people travel (journey purpose) rather than total traffic flows.

There are thus four fundamental principles on which the project is based:

1 The need to reduce greenhouse gases from transport is not only a long term aim it is absolute - any gain reduces risk and the only short term "safe" limit is the target level. Thus while long term targets are important, there will be no undue emphasis on distant end states. There is also a double benefit for transport, both the economic and social cost of reducing emissions can be low and in some cases the policies to reduce emissions are beneficial in their own right.

2 No scenario will be realistic unless it takes into account the interplay between land use planning and non-travel communications and integrates them into a package. This has held back some research which has become compartmentalised, even within transport (for example by focussing on one mode at a time). Accessibility in the widest sense (for people to goods, services and each other) needs to be maintained and enhanced while achieving carbon reduction. The approach therefore is not based on pricing to manage demand but on fulfilling people's travel needs through new means and setting a fiscal framework to "push and pull" change.

3 The overall responsibility for setting the regulatory and financial framework must rest with central Government and consistency is needed across policy areas. Large scale infrastructure and local transport spending are centrally controlled, while demand management, for example parking policies and charging, has a weak central framework.

3 Finally there is the need to recognise that there must be a partnership between policymakers and the public if the process of policy development and change is to achieve its aims. There must be transparency, a commitment to retain choice, and a sense of fairness about how policies are applied. It will be important to avoid dependence on a form of centralised, predictive planning within the central Government strategic framework.

2 Context and perspectives

This report examines transport policy in the UK and how it can contribute to wider policies to tackle climate change. Thus it does not get involved in arguments about whether or not humankind is the source of increasing greenhouse gas (GHG) in the atmosphere, or estimate its precise impact. In this regard it has benefited from the recent International Panel on Climate Change (IPCC) Fourth Report [3]. This is essentially a consensus view among scientists across the world that climate change:

- is happening and will lead to significant increases in temperature;
- has potentially very serious consequences; and
- is mainly the result of human activity.

This latest IPCC report has been able to respond to some of the alternative explanations offered for global warming, including sun spot and volcanic activity (both of which do affect climate). The report is a consensus and tends to be cautious, for example it does not take into account the most recent data on the rate of melting of Greenland ice sheets because the data is over too short a time period. However, research is continuing and the IPCC report moves to a higher level of certainty than before on the three key findings listed above.

Other studies take on the task of translating climate change into strategic policy making. One of the most recent and exhaustive of these is the report to the UK Government produced by Sir Nicholas Stern in November 2006 [1]. This used various computer models to show how large the range of impacts might be and how much we should spend to avoid future costs. It focuses on the economic justification for taking action now to avoid climate change. It has caused a series of responses and debates internationally which have also clarified some of the key issues.

However, the Stern Review does not set out specific proposals for policies in individual sectors such as transport, other than support for carbon taxes and carbon trading schemes in principle. Stern recommends that these should be pursued at the global level.

The focus of this project is to produce more detailed, practical policies which can be implemented now, and which will begin to address climate change in relation to the transport sector. Before doing so it is important to establish the principles on which these will be based and put them in context. This in turn requires a discussion of the key issues and arguments about how to approach climate change. Examples are:

- Do we need to make significant early progress or can we start slowly?
- If other sectors make reductions above their targets, should transport be allowed to exceed the national targets?
- How much can be achieved by technology and how much by changing behaviour?
- What mix will be required of regulation, voluntary agreement and taxation?

- What is the role of biofuels and will there be competition between land for food and land for fuelling transport?
- How useful is maintaining and planting forests, and how damaging is forest clearance?
- Is it possible to calculate the damage costs of greenhouse gas and translate it into a tax?
- Can pollution trading schemes and markets be created which will ease the transition to lower levels of GHG?
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Planet greenhouse - basics

Before addressing these issues it is important to outline a few of the most relevant aspects of the science behind climate change, and the predictions about how it will affect the planet. As regards the greenhouse effect itself, this starts with energy from sunlight being absorbed by the Earth's surface, which warms up. The surface then gives off a large proportion of this energy in the form of heat (infra-red radiation). The make up of the atmosphere has a strong influence on how much sunlight gets to the surface of the Earth, and how much energy is given off [4].

When the greenhouse effect is stable, it moderates this warming and cooling cycle. Without it, the heat gain and loss would lead to extreme differences between day and night time temperatures. By day, some of the Sun's energy is reflected away before it gets to the surface by gases such as sulphur dioxide, by particles such as soot and by certain types of clouds. Other components in the atmosphere prevent some of the heat given off from the Earth from escaping. Without this moderating effect, most current life forms could not exist.

Different gases in the atmosphere have different effects. Molecules like carbon dioxide, nitrous oxide, methane and water vapour are good at letting sunlight through while retaining the Earth's heat and it is these which are referred to as greenhouse gases. They stay in the atmosphere for different periods of time and some are better than others at keeping in the heat. Some gases in the atmosphere like nitrogen and oxygen do not have this insulating effect. The strength of greenhouse gases varies widely, for example methane is considered to be 23 times stronger than carbon dioxide and nitrous oxide is 296 times stronger [5]. This takes into account the fact that neither methane nor nitrous oxide persist in the atmosphere as long. Even after allowing for these factors, carbon dioxide is still the dominant cause behind the increasing greenhouse effect.

To allow comparison, the impact of all GHGs is often described in terms of carbon or carbon dioxide equivalent. However, different sources give figures in tonnes for one or the other, and this can be confusing because carbon dioxide is approximately 3.67 times heavier than carbon. Thus DEFRA uses millions of tonnes of carbon equivalent (MtCe) while most sites which offer to offset people's emissions use tonnes of CO_2 [6]. Targets for more efficient cars are also expressed in the UK in CO_2 emissions per kilometre [7].

While carbon dioxide is not the strongest greenhouse gas, it is by far the most plentiful in the atmosphere. Ice samples have shown that for hundreds of thousands of years CO_2 was relatively stable, particularly within long term cycles of warming and cooling which included the advance and retreat of the glaciers [8]. It should be noted that such major cycles occur over tens of thousands of years and are influenced by external changes such as the Earth's orbit around the Sun. There are cycles of temperature change which occur over much shorter periods, but these are generally less extreme. For example the 2005/6 UK winter was correctly predicted to be a slightly colder one due to a cycle of storm patterns in the North Atlantic (NAO) which occurs over tens of years [9].

Currently there is about 35% more carbon dioxide in the atmosphere than the highest level ever found in the ice records [2]. Putting this into the best models of climate we have predicts the sorts of rises we have (although not perfectly). Other factors such as the increased reflection of the Sun's energy due to pollution or volcanoes (global dimming) complicate the issue, as does the natural variability of the climate, but not sufficiently to prevent the conclusion that the warming we are currently experiencing is broadly in line with what we would expect from the increasing amounts of greenhouse gas in the atmosphere.

Without reproducing the well-known 1000 year global "hockey stick" diagram [10], the warming we are experiencing in the UK is pretty clear. We are fortunate enough to have records going back to 1659 for average monthly temperatures in central England [11]. These are the longest set of measured recordings in the world. It should be noted that a lot (though not all) disagreement over the hockey stick relates to how past temperatures have to be inferred from data such as tree rings, historical description or boreholes. All of these have their problems.

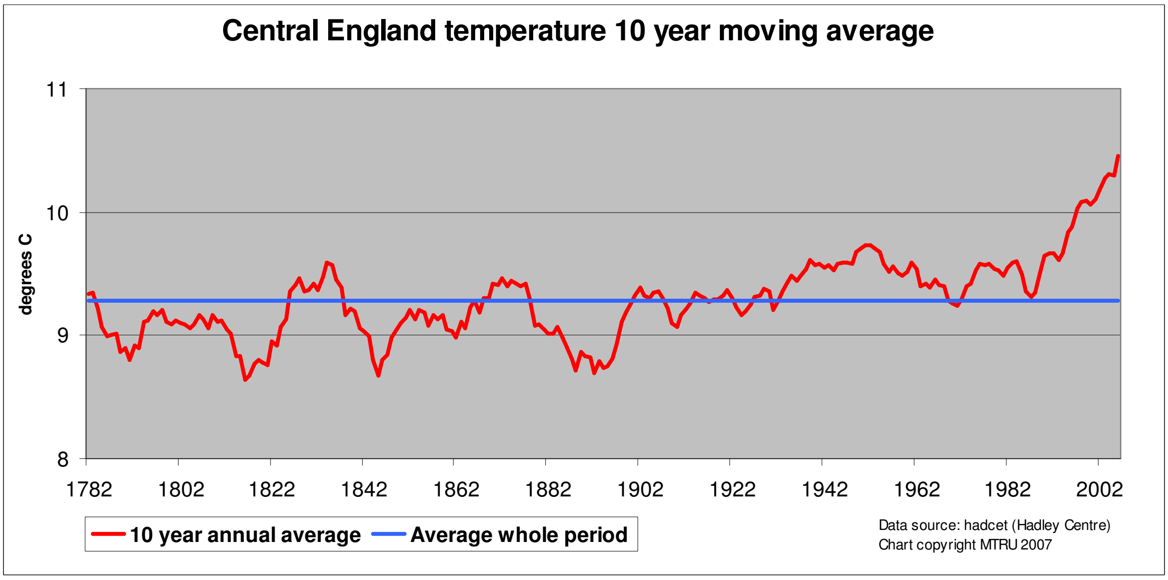
Since 1772, the central England series relies on daily maximum and minimum measurements and has been extensively checked and reported over many years prior to its relevance to climate change [12]. There are several prominent features of this dataset as analysed for this report.

First, six of the ten warmest years ever recorded have occurred in the last ten years. Secondly, individual highs are coming in closer proximity to each other. Until 1948/49, no two years in succession had exceeded an average temperature of 10 degrees. This happened again in 1975/76, 1989/90 and in 1994/95. Only one of the last ten years has been below 10 degrees (2001) and 2006 was the warmest ever, at 10.83.

Overall, the average temperature over the last decade (10.46) is almost a degree warmer than the Met Office baseline of 9.47 – the average for 1961-1990.

Finally, it is also possible to produce the UK's own hockey stick diagram, with the important difference that it is based on actual temperature measurements, rather than using a variety of methods to estimate temperatures, as is done for the original. These results use the daily records from the Hadley Centre dataset [11].

Figure 2.1



How much do we need to reduce the production of greenhouse gas?

Before deciding what sort of measures will be needed, it is necessary to set out objectives for how much greenhouse gases should be reduced. The effects of higher levels of GHG are the subject of intense activity using computer models of the climate. The first area of uncertainty is how the GHG in the atmosphere will alter climate in general, and temperatures in particular. A second stage, estimating the scope and extent of the costs and benefits which might arise, creates an additional area of uncertainty. It is of course extremely difficult to produce reliable models of future climate change because the sorts of temperature rises which are predicted are so far outside our experience and any reliable data.

Warming is already causing climate change but there may also be key trigger points where temperatures rise sufficiently to cause a major event. These include a step change in the rate of melting of the Greenland and Northern Polar ice sheets and release of greenhouse gas trapped in deep cold parts of the oceans or frozen tundra (methane hydrates). We have not yet fully established the relationship between temperature and rates of plant growth. For example, increased carbon dioxide may stimulate plant growth in early years but this could be reversed as emissions and temperatures rise.

Such events are also likely to have secondary impacts such as the cutting off of the Gulf Stream (with up to an 8 degree temperature drop in parts of North Western Europe) and significant sea level rise. These risks have already been identified, sometimes called “low probability high risk” events. In fact, reduction in the Gulf Stream’s warming effect is seen by the IPCC as probable, but not within this century [13]. One continuing problem is that the level of temperature rise which would trigger them is not certain and the climate, while it is changing, is not changing evenly.

Thus the first step in addressing climate change is itself uncertain – the question is how much do we need to reduce the current greenhouse gas deficit. This in turn depends on where we want to be by when. Most commonly, targets have currently been set at around 2050, either for a 60% or 80% reduction in emissions from 1990 levels [1,2,14]. This seems a reasonable date, after all most of today's children (at least in the developed world) will still be alive, as will many adults. In London, a 60% reduction target has been set much earlier, for 2025 [15].

Considering that we know that the current levels are causing climate change and that there are very significant risks and uncertainty, we could put forward a few reasonable scenarios for that date without necessarily depending on reliable models. These are not based directly on emissions, but on the concentration of GHG in the atmosphere. This is what actually causes the problem and is the basis for the United Nations Framework Convention on Climate Change (UNFCCC)[16]. These basic approaches could be:

1 *Restore long term atmospheric stability*
To be at the historically stable level for GHG in the atmosphere by 2050 and stable thereafter *(warming continues in the short term, slows until 2050 and then stops).*

2 *Hold current levels of GHG, moving towards stability*
To be at the current level in 2050 and reducing towards the historically stable level *(warming continues but eventually slows to a halt after 2150).*

3 *Hold current levels of GHG indefinitely*
To be at the current level of GHG in the atmosphere in 2050 and stable thereafter *(warming continues at least at the current rate).*

4 *Damage limitation*
To be at higher level of GHG than today in 2050, but one which will slow down climate change so that damage is within acceptable limits *(warming continues at an accelerating rate)*

5 *Business as usual*
Do nothing and assume humanity will adapt to whatever climate change occurs *(warming continues indefinitely at an accelerating rate)*

These options are based on the not unreasonable goal of returning the Earth's atmosphere to a more stable balance in terms of the greenhouse effect. Considering whether we could achieve these options is informative because it reveals the significance of the task ahead.

The first two options represent a least risk approach in which there is a reasonable chance of avoiding the worst outcomes of climate change. However, no Government is proposing policies which would achieve any of the first **three**, let alone the first two. The problem is that there is already so much GHG in the atmosphere, and that much of it will be there for the next century.

In addition, the current level of emissions will not be reduced to a level at which GHG in the atmosphere will start to fall until after 2050. Thus most commentators believe that GHG will rise, even if action is taken now, to a level approximately double the historically stable level. This is the level assumed by the Stern Review after a reduction programme has been undertaken. It approximates to Option 4 above. However, in terms of Option 4, there must be some doubt about how "acceptable" this would turn out to be.

An "acceptable" level of GHG depends on unknowns such as:

- the exact rate of temperature increase over the next 50 years;
- the precise temperature at which climate "events" or "triggers" would occur; and
- the scale of any feedback mechanisms which might amplify (or diminish) climate change
- the relationship between climate change and the impact on society, including GDP but also other measures of social welfare such as mass migration, conflict and equity.

In fact, predicting the effect of the most likely GHG level does not have to be the central issue and is clearly open to irresolvable uncertainties. The safest policy, avoiding risk until, perhaps, we do know more, is to aim to get as close as possible to the stability level. In this case, Option 4 should be seen as an absolute limit, not the preferred outcome.

If we become certain, a few decades from now, that 20%, 30%, or 60% higher levels of GHG have little impact on the climate, then policy could be adjusted. However, at the moment there is no guarantee that even current levels for CO_2 (about 35% more than the historically stable level) will not cause very severe damage. The distinction is made here between assessing probabilities, which are based on modelling, and a decision made on the basis of achieving a known stable level.

Thus the first conclusion must be that there is no national, or international, plan to restore, even within a century, the state of atmospheric stability that was present before human activity began to disturb it. This helps to put some of the proposals in context and is one of the reasons behind the principle, underlying this report, that exceeding the current targets for GHG reductions is always a benefit. This only ceases to be true when the stability level gets very close. This condition will not be met for at least fifty and probably a hundred years. The issue of how much it costs to achieve the reductions, and how this can be minimised or eliminated, is considered later.

This basic principle, combined with a new analysis of how rates of progress influence total emissions, leads to the development of a "rapid start" strategy for GHG reductions. This contrasts strongly with the widely supported idea that a slow start, followed by rapid progress several decades from now, is the preferred approach.

Before considering in more detail why a greater sense of urgency seems justified, there remain two contextual issues which need to be addressed. First is the question of where human activity fits in the global cycle of GHG production and absorption. Secondly is the issue of where GHG is currently being produced, how much is emitted per head of population, and how this relates to current and future GDP. These are huge areas for discussion but are covered briefly here only insofar as it is necessary for policy development in the rest of this report.

Is most of the carbon dioxide in the air from burning coal and oil?

One frequently encountered criticism of current climate projections is that burning coal and oil produces only a tiny amount of carbon dioxide compared to that produced by natural occurrences. This is quite correct but completely misleading.

The Earth's land based eco system puts about 60 billion tonnes of carbon into the atmosphere each year while burning fossil fuel is less than 5.5 billion [17]. However, the Earth's eco system also absorbs just over 60 billion tonnes a year as part of its life cycle. Take away 10% of its carbon dioxide production and you lose 10% of its absorption. The oceans give up about 90 billion tonnes of carbon through evaporation but receive about the same amount back through rainfall and other precipitation. Both are essentially closed systems which, if anything, would tend to slightly reduce carbon dioxide. Vast amounts of carbon are in fact locked away in the Earth's surface (for example in soil) and most of all in the deep oceans - estimates put the latter at about 38,000 billion tonnes. This is more than the carbon stored in plants, especially trees.

On the latter point, there is a significant amount of carbon released when land, especially forest, is cleared for agriculture. Agriculture itself adds to the greenhouse effect through other gases, for example methane from rice fields [18] and ruminant animals [19] (such as cows) and through the use of nitrogen fertilizers. The overall effect is equivalent to about one billion tonnes of carbon, although some sources put this higher. This is a key reason for many commentators, including Stern, recommending an urgent programme to prevent the burning of forests, in particular for land clearance. It is very clearly a policy which needs to be pursued and offers significant early benefits. Amid stories of forest being burned to make way for plantations to make bio fuel, this is an area where uncompromising action by national Governments is urgently required.

It has to be said that, as with all global agricultural, carbon and climate statistics or forecasts, there are uncertainties as to the precise numbers. However, the evidence of natural carbon systems which are in balance is well established, as is the production of significant quantities of greenhouse gas from human activities and the measurement of their concentrations in our atmosphere.

Before discussing the basic policy pathways to GHG reductions, it is also important to understand where GHG is being produced, and what types of human activities are responsible.

Where is greenhouse gas produced?

It is widely understood that people in developed countries are responsible for the highest levels of GHG emissions per head. This does not include the GHG emissions which are "exported" – in other words goods which are manufactured in developing countries but consumed elsewhere in the world.

Comparing national emissions

It would be wrong, however, to see this as the defining figure for understanding where and why emissions are produced. Thus China's GHG per head is low but its global contribution is high (and growing fast). It is also a high carbon economy, as measured in GDP per tonne of carbon dioxide (see Table 1 below). Population is also a major factor and one which is often undervalued. To illustrate this, the increase in world population since 1990 has been 1.19 billion. Simply using the world average for CO2 production (1.14 tonnes per head) this would have raised emissions by 19%. Even if the UN low forecast for population growth [20] is correct, it would rise by another 1.4 billion people by 2050. Since 1990 this would represent a 48% increase in emissions from population growth alone.

This complexity illustrates the need for a globally agreed approach to GHG pricing (whether through regulation, taxes or artificial markets). It also shows how difficult this would be to fit within a simple unified framework, for example linked to emissions per capita. In this context, the question becomes what can be done by whom in a reasonable timescale (years rather than decades) and how this is encouraged and funded. Actions would need to have an early impact, and support, or at least not inhibit, the adoption of more "perfect" solutions.

Growth of "exported" emissions and value of local actions

Of course, the emission figures above are also changing because the world economy is growing, led by some key developing nations such as China and India, and by former Eastern Bloc countries, some of which are now in the EU. These tend to produce manufactured goods more cheaply than in developed countries and thus much of the production has shifted from those countries which industrialised first. The goods are then imported back into countries like the UK. For example, between 1992 and 2005, Chinese exports grew almost tenfold and now represent about 39% of all China's GDP [21]. In 1985 exports were only 10% of GDP [22]. China already accounts for 15.5% of the world's carbon production, more than the EU 25 (14.6%) [23]. In a sense, countries such as the UK have exported much of their production of manufactured goods and the carbon emissions that go with it. However, this also leads to industrialisation in the manufacturing country, together with growth in home consumption. This includes purchasing and using energy intensive items such as cars, electrical equipment and air conditioning.

Thus one factor which concerns people and often seems to create inaction through a feeling of helplessness is the assumed growth in countries like China swamping any efforts in countries like the UK to reduce carbon dioxide emissions. One well known approach is “contract and converge” [24] meaning that in the long term all people in the world should increase or reduce their carbon emissions to the level needed to avoid climate change. This requires greater reductions in carbon dioxide per head in the UK than the target of 60% by 2050. It also allows short term growth of GHG emissions in developing countries, followed by modest reductions so that everyone has a similar carbon “footprint” at some future date (this is often taken as 2050, but could be earlier, or later). This extreme change in the developed world, at the same time as increasing GHG elsewhere, causes public unease and thus political resistance. It should be noted that using a simple GHG “per head” measure is not sufficient, because this does not relate directly to how much climate change is being influenced. This actually depends on population levels as well as emissions per head. To illustrate this point, Table 2.1 sets out some basic GHG data for major producers.

Table 2.1
Greenhouse gas emissions by economic area compared to GDP
Percent of total (2003), GDP (2005 per tC, tC per head, 12 largest emitters

	Percent of global emissions	GDP per tonne of Carbon (US dollars)	Tonnes of Carbon per head
United States	21.6	8,208	5.43
China (exc Hong Kong)	15.5	2,001	0.86
European Union 25	14.6	10,347	2.33
Russia	5.6	1,568	2.85
India	4.8	2,282	0.33
Japan	4.6	14,840	2.64
Canada	2.1	6,813	4.88
South Korea	1.7	6,144	2.59
Mexico	1.6	6,635	1.10
Iran	1.4	1,800	1.57
South Africa	1.4	2,254	2.23
Australia	1.3	6,773	4.85

Sources: CDIAC, World Bank (Atlas method – exchange rate based)

Action across national boundaries

There are two very important reasons why any crisis of confidence in the ability of individual nations, or groups of nations, to deal with climate change is not fully justified. The first is that countries like China and India are well aware of the problems of climate change and have their own policy initiatives to avoid it.

Some of the offsetting projects sponsored by the US and European countries, while inadequate in scale and subject to double counting, at least assist in the communication of a shared effort to act on this most global of problems. They also move investment, though on a very small scale, towards low carbon development. The issue here is to address the current imbalances in a practical way. To suggest that non-industrialised countries should enjoy a brief period of profligate energy use, on the grounds that the developed world had one, is not only illogical, it ignores the impact of such growth "locking in" behaviour to high GHG emissions. It also assumes that such an approach is still one that is to be universally admired and adopted. In fact, China and India have their own energy efficiency targets and need to be supported, not discouraged, in this regard. Examples of specific actions are cultivating waste ground for biofuel [25] and improving rice cultivation to avoid methane production.

The second reason is that the UK and the EU can work directly to create confidence in the rapidly growing economies that a low carbon strategy should guide expansion from now on, and that it will work. This can come about in two crucial ways. The first is by developed countries doing it themselves – not just in terms of legislation or policy but in terms of achieving targets and creating technological and behavioural change.

The second is indirect but just as important. There is a direct line of responsibility for the GHG we have exported in order to manufacture goods for our consumption at home. It would be possible to reflect this at the point of consumption. For example, any imported goods could have a carbon emissions rating for their production and could be taxed accordingly. This would include the energy cost of production and transport. The latter is often very significant. This could be done using national, sectoral or product averages or with an agreed certification procedure. It would provide a short term remedy, at least in the freight field, to the problem that international air and sea transport have been deemed to be outside international climate change agreements, including UNFCCC[16] and Kyoto [26].

International monitoring will be a crucial part of any climate change policy programme, and much of the basic structure for a system such as the one above are in place already. A good example is the reporting mechanism agreed under the UNFCCC which has near universal participation (190 countries including all major emitters [27]. This was agreed in 1994 and is separate from the later, supplementary Kyoto protocol, agreed in 1997. Kyoto has now been ratified by most countries, with approval between 1998 and 2005, but with the notable exception of the US. Despite this, 168 countries have ratified, including all the top 12 emitters (see Table 1) except the US and Australia.

Of course, a worldwide system of green taxes, for example on shipping or aviation fuel, and global standards for energy production, would make this unnecessary. Agreeing anything resembling such a system does not appear to be on most political leaders' agendas and thus a local tax to represent the non-national GHG component, introduced on a relatively short timescale, appears to be a reasonable option. It will not inhibit, and is in fact likely to encourage, proper worldwide agreements to emerge.

Transport emissions and those from other sectors

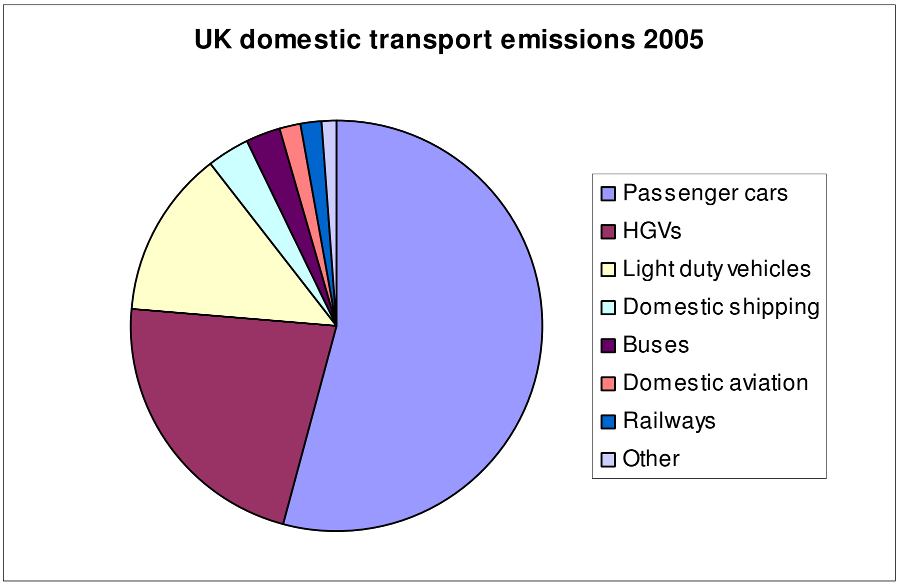
In assessing emissions from transport there are two ways of assessing the data. The first is to consider the direct emissions from transport, the second is to add in the emissions that occur on items such as refining the fuel and manufacturing the vehicles. These would otherwise be attributed to other sectors such as industry or power generation. The first is "source based", the second an "end user" figure. The difference can be substantial, for example in the UK the CO2 emissions by source from transport are about 23.5% of the national total, but by end user they are 28.3%. This excludes international travel.

Globally, transport's share is lower, at about 14% of GHG emissions [28],[29]. This includes international shipping and aviation, but not the higher level of warming caused by aviation emissions. Research is continuing on exactly how much more warming is caused by emissions at high altitudes (including water vapour such as contrails). Current data suggests an increase of 1.9 to 4 times. Doubling the impact would be a reasonable approximation.

Within global transport emissions, road use accounts for 76%, domestic air for 5%, international air for 7% and sea for 10% (all 2000 figures). This does not include any adjustment for high level emissions from aviation.

Considering the UK total, there are different sources, such as the Office for National Statistics (ONS) [30] and DEFRA [31]. These vary slightly, but reveal key growth areas, such as emissions from HGVs. For example, using the 1990 base, ONS has road freight emissions growing by 48%, while DEFRA has their growth at 30% (2002). Both sources are, however, close for cars and vans, where the increase is 6.1% and 6.7% respectively. Using the most recent DEFRA data the UK's transport emissions can be broken down as shown in Figure 2.2.

Figure 2.2

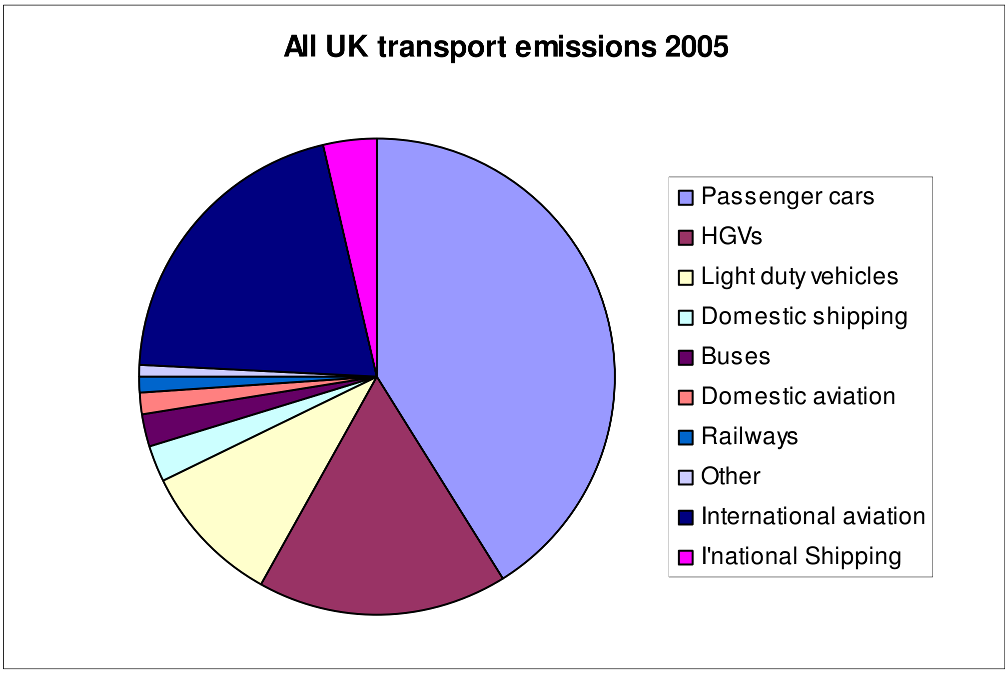


Source: DEFRA

These figures are for domestic transport only. While private cars and vans are dominant, at 72% of the total, it is interesting to note the importance of HGVs at 24%. Non-road transport only accounts for 7%.

This picture changes when international travel and transport serving the UK is included. However, there are some problems with identifying exact emissions. The best available statistics are for the supply of fuels which are used for international shipping and aviation, known as bunker fuels. There is clearly some fuel used for transport passing through the UK. However, to give some indication of the extent of international transport, the bunker emissions are included in Figure 2.3 below.

Figure 2.3



Source: DEFRA

Immediately the importance of aviation expands to account for 21% of the total. Road transport is still dominant, but at 70% instead of 96%. It should also be noted that the inclusion of international aviation and shipping would cause the transport share of the UK's GHG emissions to rise from 28% to 33%.

Using the DEFRA figures it is clear that the greatest increases are in aviation, up 20.4 MtCO2e from 1990 to 2005, followed by HGVs, up 6.6 MtCO2e, and vans, up 5.4 MtCO2e over the same period.

Perhaps the most significant fact for the UK is that, while overall emissions fell by 6% from 1990 to 2005, transport emissions overall grew by 10.6% (domestic only) and by 24.6% if international aviation and shipping are included. On any analysis this sector must form a major focus for emissions reduction.

3 Targets, totals and rates of progress

Current project and the Climate Change Bill

This section is based on work undertaken for this project, published in November 2006, and revised in February 2007. Since that date, two of the principle concerns in the paper have been recognised in the draft Climate Change Bill [2]. These were: the need to consider overall emission totals over a period of time, and the need for interim targets. The Bill is, however, only a draft at this stage (March 2007) for consultation. The key arguments presented in the paper remain valid and indeed support the principles of the Bill. The Government target for national CO2 emission reductions in 2020 is in fact in line with that contained in the original report (and reproduced below) as the “rapid start” scenario. This section has been updated in light of the Bill and will be used to contribute to the consultation process.

The importance of rates of progress for climate change

One of the key issues in assessing the success or failure of any public policy is how far it achieves its objectives. In the case of climate change, the UK target for carbon emissions of “60% reduction on 1990 levels by 2050” [1, 2], is straightforward and easy to understand. There is also the Kyoto target of a 12.5% reduction by 2008-12. The Government forecast [32], based on current policies, is that transport will fail to meet this target, even excluding air travel. In fact, there are no specific interim targets for transport to guide policymaking, only a range of estimates from 2005 to 2020 based on current policy aspirations. This position would change if the draft Climate Change Bill is enacted later this year. This contains an interim target of a 26-32% reduction of CO2 by 2020. It also proposes total carbon budgets for five year periods, rather than relying solely on an end date target.

Total carbon budgets are crucial, because the rate of progress towards the target for 2050 is, in the case of greenhouse gas emissions, just as important as the end date itself. In other policy areas it may be acceptable to seek to achieve a certain end state at a fixed date in the future. When addressing climate change, the crucial policy goal is not to achieve a specific reduction by the end of a policy programme, it is to release as little carbon as possible between now and the programme’s end date. It is this which actually influences the level of greenhouse gas in the atmosphere in 2050. Carbon dioxide produced today will still be contributing towards the greenhouse effect well beyond 2100. Thus it is essential to start making significant progress as soon as possible. The analysis in this section gives an idea of just how important this might be.

The significance of the rate of progress is one of the reasons behind the idea of setting annual targets, and can be illustrated by looking at the total carbon emissions between now and the target date (2005 to 2050).

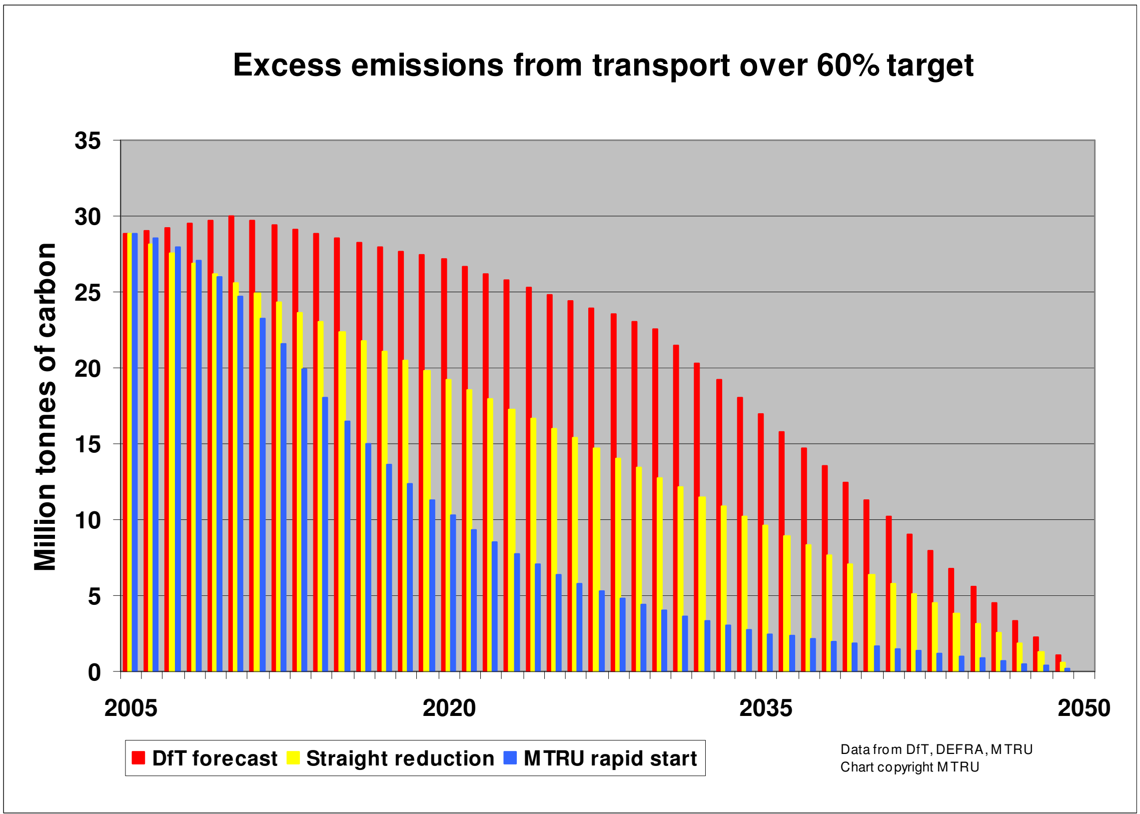
In Figure 3.1, all the assumed policy programmes deliver the end date target of a 60% reduction. However, each one causes a very different amount of carbon to be released over the whole time period.

The “slow start” series is calculated using the emission data and forecasts from the UK’s climate change programme for 2020 and 2030 [30, 31]. These are then extrapolated so that they reach the 2050 target.

The “straight line” is simply that – reductions occur at the same level every year. This is really used for reference purposes.

The “rapid start” is based on a series of policy changes which combine technological improvement with demand management – broadly those being developed for this project.

Figure 3.1



Detailed spreadsheets which have been used to produce these charts are available on www.transportclimate.org and the assumptions for all the charts are set out in the References and Sources section at the end of this report [33]. The three scenarios above were chosen to illustrate likely outcomes for different policies relevant to this study, but the analysis can be applied to other established scenarios for the UK and elsewhere.

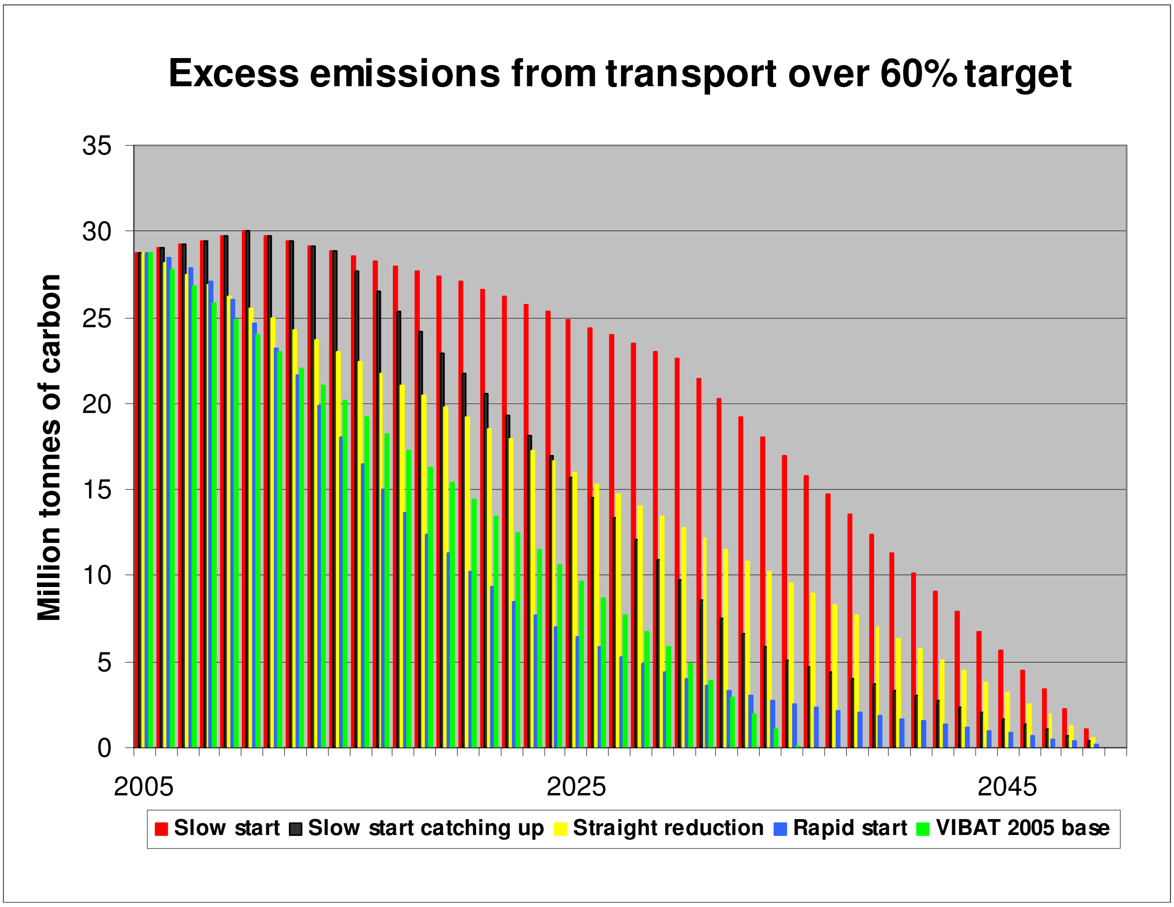
Results from other reduction scenarios: VIBAT

The first example set out here is the research published in January 2006 entitled “Visioning and Backcasting for UK Transport Policy” (**VIBAT**), sponsored by the Department for Transport, and undertaken by University College and Halcrow [34]. This looked at combinations of strategic transport and land use policies which might achieve the 60% emissions reduction target by 2030 rather than 2050.

VIBAT used a straight line achievement rate and this has been added to the chart below for comparative purposes. VIBAT assumed a 1990 start date so this was adjusted to 2005, with an end date of 2035, to allow a more realistic comparison. The original VIBAT total, assuming policies had begun to take effect earlier than 2005, is included in the Table.

In addition, another profile has been created. For this, the DEFRA estimates used for Figure 1 have been adjusted from 2015 onwards to achieve significantly greater reductions. The aim was to create a profile, using DEFRA for the early years, that would emit the same total amount between now and 2050 as that achieved by the straight line rate of progress. This was done to give an idea of how great the challenge might be if the start is too slow. This is set out in Figure 3.2 below.

Figure 3.2



Three important points emerge from this analysis.

The first is that it is not really practicable for a slow start to achieve the same overall emissions as the "rapid start" without unrealistically high annual rates of reduction. Even in the case where the "straight line" total reduction is achieved, extremely rapid progress would have to be made between 2015 and 2035, given the slow start.

The message here is that delay is the equivalent of not achieving the proper target. Including these two new scenarios illustrates the value of looking at the annual profiles of carbon emissions as well as distant targets.

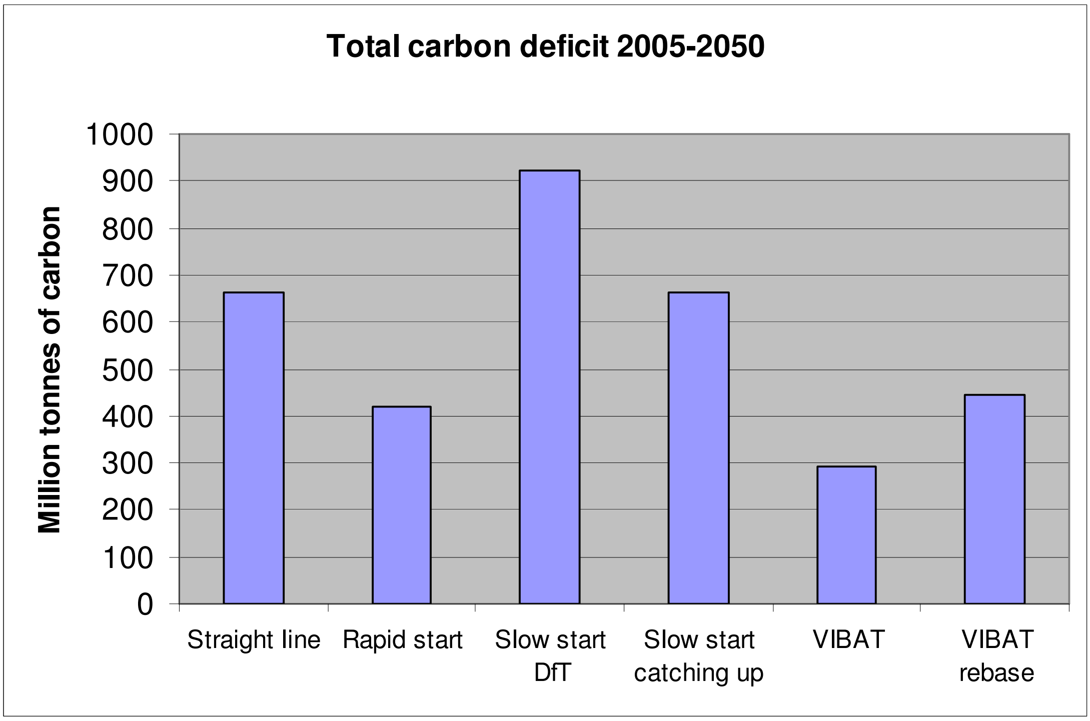
Secondly, it is clear that the rapid start scenario slows down its rate of reduction in the latter half of the 50 year period and moves more gradually towards the target. This can be viewed in two ways. The first is that it is a reasonable representation of technological change not going too much beyond what we know is possible today. The second is that there is bound to be further improvement and thus that progress should continue, effectively moving beyond the 60% target by 2050. Again, this would be an advantage – in terms of climate change any improvement over target is worthwhile.

The third key point, which the inclusion of VIBAT illustrates, is the value of achieving the same target (60% reduction) significantly earlier. This becomes very clear when the total amount of carbon in excess of the desired level over the 50 years is calculated as in Table 1 and Figure 3 below.

Table 1: Total carbon deficit 2005 – 2050
(defined as the carbon emitted in excess of the target level)
million tonnes of carbon equivalent

Straight line reduction	Rapid start	Slow start (Future of Transport)	Slow start catching up	VIBAT	VIBAT rebased to 2005
662	421	921	662	290	446

Figure 3



Overall, the analysis highlights the crucial nature of making early progress. This in turn illustrates the requirement for regular monitoring (probably annually). The key point is that the monitoring must be sufficiently frequent to allow for policy adjustment.

It is also an important motivating factor behind this project's phase two work. This will seek to prepare a UK transport policy package to address climate change which provides the necessary rapid start. This is bound to involve both an acceleration in the adoption of existing technologies and a faster, and deeper, implementation of policies which affect travel choice. It will seek to go beyond the strategic impacts to indicate what specific policies could achieve the desired reduction profile.

Results from other reduction scenarios: California

While many policy packages do not have detailed targets for each year between now and 2050, the choice of even a few interim targets can create a profile which can be analysed. For all the charts except "rapid start" a simple straight line between targets has been used to create annual profiles and allow comparisons to be made.

The example considered next is the new state law in California, Assembly Bill (AB) 32. This was approved in September 2006 and authorised for action by Governor Schwarzenegger in October [35]. Interestingly, it included specific co-operation with the UK. The targets are to return to 2000 carbon emission levels by 2010, to 1990 levels by 2020 (about 15% reduction on today) and to achieve an 80% reduction on 1990 levels by 2050. The profile assumed by this report draws a straight line between the above targets and is **not** part of the legislation.

The targets themselves are to be achieved by means of regulation, in the first instance specifying both vehicle efficiency standards and fuel carbon content [36, 37].

The latter is a flexible standard – it does not specify whether biofuels are to be used, or whether other means such as electric or hybrid power sources reduce the effective carbon emissions per unit of power. All sources will have to complete a full "well to wheel" inventory so that all the emissions from producing and transporting fuel are included. They draw attention to the fact that biofuels from corn which are made out of state probably do not save any emissions compared to current petroleum. Locally produced biofuel using waste products would show significant savings.

The State legislation specifically excludes the use of taxes. Thus the Californian approach is very much technology led in the early stages rather than changing patterns of travel. However, the whole policy is underpinned by the enforceable caps on carbon emissions. For example, manufacturers may have to stop selling vehicles which produce a lot of carbon if they have not sold a large enough number of those which produce a below average amount. The Californian Air Resources Board is currently working on a more detailed implementation plan for AB32.

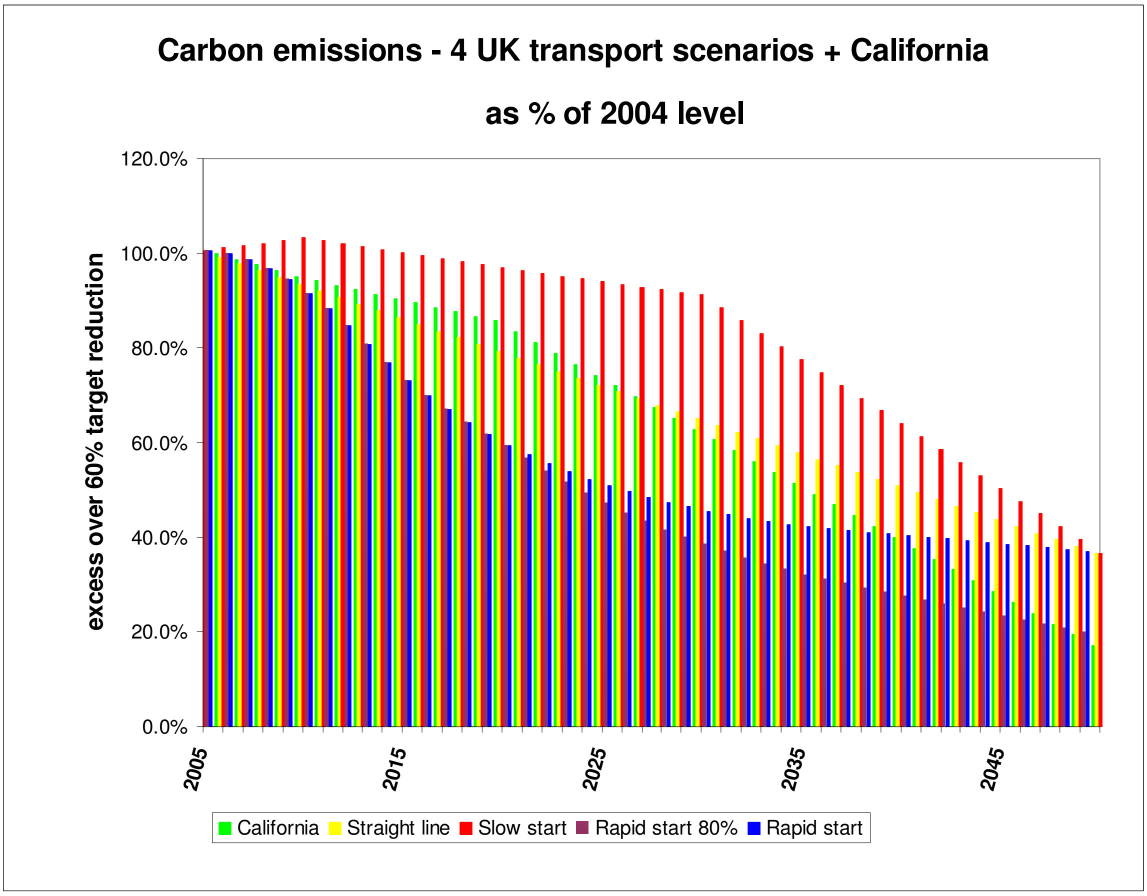
The cap makes it substantially different from policies which reduce a vehicle's carbon emissions per kilometre without setting a total emissions target. This appears to be the national US Government position, as in the most recent State of the Union speech.

Beyond technology, there is some discussion over behavioural change coming on stream, particularly in relation to transferring freight from road to rail, better land use planning, and smart growth [38]. The latter would include UK policies such as accessibility and company travel planning.

California and UK profiles

In order to allow comparison with the rate of achievement of UK scenarios, the Californian profile, as expressed in the targets for 2010, 2020 and 2050, is shown in Figure 3.4 below in percentage terms, with a base year of 2005.

Figure 3.4



The Californian profile outperforms the current profile predicted for the UK, mainly due to the tough early targets for 2010 and 2020. Progress then accelerates slightly to 2050. The 2050 target is also tougher than the UK target and this helps to reduce the total emissions over the whole period. Its overall achievement is close to the rapid start scenario which this project favours.

Conclusions on targets and rates of achievement

1. In relation to climate change it is the total amount of greenhouse gas emitted from now until the target date which should guide short as well as longer term policies.

2. This highlights the need for more frequent interim targets and annual monitoring, and this is very relevant in the context of the proposed UK Climate Change Bill.

3. Other studies, one from the UK, and the other based on California's new legislation, suggest that transport in the UK could make a much more significant contribution to tackling climate change than currently planned.

4. The importance of making an early start to carbon reductions suggests that the achievement of a rapid start is the preferred approach to the formulation of transport policy which addresses climate change. This will be reflected in the policy development undertaken during Phase 2 of this project.

4 Targets, sectors and markets

Introduction

Before any attempt to define transport policies which would achieve a reduction in greenhouse gas emissions it is essential to get to grips with the issue of how overall targets relate to targets for specific sectors such as transport. It is also important to understand how in turn, sector targets relate to the use of carbon "markets". Before considering these two topics it is also important to note that the rate of reduction, set as an annual target or as reduction profile, influences what the level and timing of the target needs to be.

Targets and rates of progress

In relation to targets and reduction profiles, it is the total amount of greenhouse gas emitted during a ten, twenty or fifty year period which counts, rather than getting to a desirable level at one point in time far in the future. This is now recognised, at least in part, by the draft Climate Change Bill. This suggests a succession of five year periods, from 2008 to 2023 in the first instance. Slow progress towards a target, followed by a period of rapid catch up, is equivalent to not achieving the objective of reducing the GHG in the atmosphere, which is what lay behind the setting of the original target.

This was explored in some detail in Section 3, by calculating the total emissions for a fifty year period under different assumptions about the pattern of reductions year by year. These charts include profiles based on:

- the current Government profile (no progress initially, then gradual progress, then assumed very rapid progress);
- equal progress towards the target every year (straight line); and
- rapid early achievement followed by more gradual progress – the most desirable in terms of climate change.

It is clear from the calculations, that in terms of excess carbon (the amount by which emissions exceed the target level of 60% less than 1990), the Government profile emits almost twice as much as the rapid start. In this instance, there would have to be tightening of the target beyond the 60% level in order to "catch up". It should be noted that the 60% level is, in any case, probably too modest, and may need to be strengthened to around 80%. Some policymakers have already accepted this, for example the State of California [34].

Sector swapping and the true cost of reducing emissions from transport

The second area where clarity is needed is the issue of whether all sectors of activity have to achieve the same target. Thus, the argument goes, it may be that power stations can have their emissions reduced so much, or people can improve their home insulation so much, that transport doesn't need to reduce its emissions to the target level. This is related to, but the not the same as, the issue of creating a "carbon market".

Some of the justification for this stems from the estimated costs of reducing carbon emissions from transport. These can be found in work by DEFRA [39] and by the National Audit Office [40].

The DEFRA report suggests that transport reductions cost £160 per tonne of carbon equivalent (tCe). In fact, this calculation contains two important policy elements. The first is the fuel duty increase which was imposed between 1992 and 1999. This is still acting to contain traffic growth and does not have a cost of £160 per tCe, but a benefit of £250. This makes it one of the most cost effective carbon reductions of any sector.

The second element is a “package” which contains the voluntary manufacturers’ agreement to improve vehicle efficiency, VED increases and company car tax. This package is claimed to cost £365 per tCe, and is what causes transport to appear expensive for carbon reductions.

However, this is only part of the picture. The main reason for the package itself performing badly is that the improved efficiency leads to more car travel and this in turn causes congestion and worse air quality. It is these latter two factors which cause almost half the costs. Thus, if traffic increases could be avoided, the cost would fall dramatically. Indeed, in this case, the overall impact of transport as reported by DEFRA would move from negative to positive. [41]

The final cost element is that of manufacturing more efficient vehicles. There is a failure here to report the different costs of add-on technology, such as switching off conventional engines when the vehicle is stationary, and built-in technology, such as the various options for hybrids or the use of lighter materials. In the long run, vehicles and their engines are always being redesigned in the light of technological change, and it becomes very difficult to discern any real long run resource cost. For example, do manufacturers claim that vehicle performance improvements have artificially raised the cost of new cars? There is a fundamental difference between a short term transitional cost and the bringing in to mass production of improved design. This argues for a long term commitment by Government, rather than short term voluntary “agreements”. It should be noted that there is no apparent mechanism to penalise anyone for failing to meet their targets, as is now the case.

Creating carbon markets

More accurately, the latter is a market in permissions to emit greenhouse gas. This would, if implemented across all sectors with no barriers, allow transport to buy the right not to meet the target, as long as someone, somewhere, had more than met it.

There are many problems with such pseudo-markets, and, as Stern observes, one is that they must be kept in a state of shortage if they are to achieve their objectives. These are obviously to reduce emissions, but also to do so at the least cost. It is also the case that a market mechanism should be able to stimulate the private sector to create innovative solutions, although this is influenced by the market power of large companies. However, this all depends on a consistent, long term, high price for carbon. Conceptually this requires all participants in the artificial market to be given not quite enough permissions to emit in the first year, with the amount reducing in every subsequent year. Obviously, every potential member must also agree to join in the market.

The realism of getting polluters to sign up to this is illustrated by the current EU Trading Scheme [42]. Countries produce National Allocation Plans (NAPs) which set the emissions permitted for a specific type of producer for a specific period. Countries then divide their NAP and give it out to individual companies ("installations"). The first set of allocations aimed to get as many member states as possible to agree the permissions and runs out in 2008. A new set of NAPs is being agreed for 2008-2012 and these will have lower national levels of permissions to emit CO2.

To summarise the position, this did not meet the Stern shortage requirement by some considerable way. The result is that, on the date the Review was published (30th October 2006), carbon dioxide was effectively valued at €10.80, rather than the social cost value used by Stern of about €70. By Spring 2007 this had fallen to around one euro. When asked to set future permission levels by the EU Commission, only one country, the UK, was deemed to have put forward an acceptable proposal. The others have been adjusted by the Commission and are in various states of negotiation.

Trading schemes have a theoretical attraction and are often supported by individual companies. Perhaps the most important practical observation is that this support is because their impact is perceived as low. If trading schemes were to have the same effect as, for example, a carbon tax, they would have to reduce the initial permissions to emit very significantly, and have a much higher "fine" price for failure to purchase permits or reduce emissions.

There are a range of other problems with global markets which need to be addressed but are not considered here. They will form part of the later work on implementation. There are however, two issues which are relevant to the sectoral argument. One is the relationship between offsetting schemes and potential global emission trading schemes, the other is the timescale for setting up such fully operational carbon markets.

Offsetting in distant locations

Offsetting is now being advertised as a way of making international travel carbon neutral. For example, flying across the Atlantic is currently being offset in one scheme mainly by giving low energy light bulbs to homes and schools in South Africa, Kazakhstan and the Marshall Islands.

While this is extremely worthwhile in terms of increasing local incomes as well as climate change, it is hard to see how this can really be additional to what would need to be done in any case. The issue of "whose carbon reduction is it?" comes in here, although such trading is part of the Kyoto protocol. It is also the case that many such schemes are actually very small in their overall impact and completely reliant on not too many people reaching for the offset button when they book their flights. For comparison, this method values carbon dioxide at about €11 per tonne (Climatecare, April 2007).

How fast and how effective could carbon markets be?

In terms of timescale there are two issues to be resolved. The first is whether the market mechanism is, even in theory, the most efficient way of achieving the aim of reducing emissions at the least cost. This involves addressing the short term nature of markets, the economic imperfections of artificially created markets and the social and environmental imperfections of such markets.

The second is the political reality of creating pseudo-markets in permissions to pollute. Stern is well aware of some of the problems, and even quotes the classic "prisoner's dilemma" as part of his short list of problems to be resolved. Participants will always be seeking advantage and opportunities are created because the system itself is not a true market. Even real markets are often politically incomprehensible. UK Governments from the 1980s to date have tried to create plausible markets in health and education and, whether or not they are acceptable politically, neither have been able to win public confidence (or prove that they have worked).

Even if it were to be accepted that a market basis were the theoretically ideal solution, it is not one which will be fully operational for many years. Rather like road pricing, a global carbon market always seems at least 10 to 15 years away. Ironically, sectoral markets may have a chance of evolving, allowing trade offs between, for example, flying or driving. However, even these will always be subject to ability to pay. When Antony Crosland, in his Transport White Paper in 1976, coined the phrase "pulling the ladder up behind them" [43] in order to condemn people who thought that car use should cost more, he could have been foretelling the problems of carbon trading.

The important point is that any such arrangements are unlikely to be agreed at a European level let alone at international level unless other measures are introduced first. International sea and air travel are outside the Kyoto protocol because they have their own international agreements. Fortunately there are less theoretically elegant, but more practical approaches such as end use carbon pricing (taxing a product according to how much GHG has been used to produce and transport it) which can be pursued. These would influence international trade indirectly and could stimulate a move towards more direct methods. For domestic air travel, scrapping the fixed passenger levy and instead applying the same fuel tax as for coach and car travel is an obvious first step. Rail should be included and this would mode competition more equal and transparent. If an air travel carbon market were to evolve in Europe (as favoured by some airlines), this could take over when it was working properly.

The most important benefit would be that such measures would make a start on tackling the problem. The search for a perfect solution should not stand in the way of taking practical steps which make an early impact. This is the implication of the analysis on how different rates of reduction can change whether we meet the real objectives. These are to control climate change and to allow for sustainable development.

In relation to the UK transport system, there are a wide range of policies which can be applied in the short term. It is a common misconception that behavioural change is long term, this is only true in a time horizon which is short, such as most transport plans (around 10-15 years). Technological change, particularly vehicle efficiency, takes even longer, for example cars typically last for around 12-15 years. Both types of change can be started now, and indeed they need to be. Nor does this interfere with the eventual development of the perfect market solution. As the Eddington report [44] says, tax policy now can prepare the ground for congestion pricing later.

Transport and lock in

The criticisms of market based systems for long term planning are of course the rationale behind the Government's cost benefit approach, for example to road building. This also frequently requires compulsory purchase (i.e. not paying the individual price or accepting non-sellers). One problem with this is that, being long term, it fails to respond quickly to major developments in the real world, in this case climate change. This is in itself an interesting comment on current transport infrastructure spending which, even to the lay observer, seems strangely out of tune with emerging policy.

The long term costs of investing in systems which are carbon dependent will be very high unless there is an as yet unknown and dramatic change in transport technology. The creation of travel habits based on carbon dependent forms of transport will also make behavioural change increasingly difficult. The phrase which is now being used is "lock in" and is essential that this is avoided. In economic terms, it is creating huge future costs. In political terms it knowingly creates the need for draconian measures later.

It is for these reasons that a prudent approach to transport, or any sector, is to take the common aim of a national target, combined with a sensible rate of achievement, and apply it to that sector.

Transport and social justice

There is one further aspect to the transport "escape clause" on GHG emissions which needs to be included here. Carbon taxes or trading which involves significant increases in the cost of domestic power, such as heating and lighting homes, will tend to hit the less well off who have few options to avoid such spending. This is because such costs are a much higher proportion of their expenditure. Conversely, transport carbon use increases with income and this is just as true in rural as in urban areas.

The approach for this note, as for the whole project, is to treat any GHG emission levy as a zero tax. In other words its objective is to raise nothing, but instead to reduce damaging emissions. If it raises money, this must be returned to those affected. Interestingly, doing this by giving an equal tax free lump sum to every adult and child resident in the UK which returns **all** the “green tax” will actually benefit the least well off [45]. One of the reasons for this is that the proportion of household expenditure spent on transport rises strongly with income [46].

Business taxes can be returned to businesses and these too can target smaller companies or be given as a reduction in national insurance. There are a range of options with different economic and social impacts.

Transport has greater opportunities for such smart environmental charging than other sectors, making it more attractive for the application of financial incentives to reduce emissions. The principles behind such charges adopted for the project will need to be respected:

- The main objectives must be individually identified and clearly stated. *(Rational).*
- It must be clear to those who are affected how the mechanism relates to the objective. *(Transparent).*
- It must be clear to those who reduce their travel by one mode, or incur additional cost, there is an alternative available or that there is a feasible course of action which will avoid the additional cost (*Equitable).*
- Any revenue raised as part of transport policies to address climate change must be returned directly to those affected in a way which does not undermine the objectives *(revenue and policy neutral)*

Conclusions

The task of meeting the overall reduction target at a desirable rate of progress is so great that there can be no “sectoral let out” for transport. Previously some have argued that if it is cheaper to clean up power stations, or reduce domestic power needs, over and above the national target, this could compensate for people driving or flying at the same levels as today. For the time being the prudent approach must be to assume the overall 60% target will be applied in the transport sector. Indeed, it is likely that the overall target itself will have to be tightened in future.

Present policy is in fact moving in the opposite direction. By 2020, DEFRA estimates that transport emissions will be 17% higher than the base year (1990), even excluding international aviation. The rest of the UK’s emissions will be 27% lower. This means that the Climate Change Bill targets could be met, if transport meets its fair share, rather than being allowed to significantly increase its emissions. If transport were to continue to increase its emissions, other sectors would have to reduce their 2020 figure by a further 15%. Achieving this in sectors such as business, agriculture and energy supply, which are already aiming to reduce their emissions by over a quarter, is simply not credible.

A second issue is that economic growth has previously always resulted in transport growth. Thus to reach a 60% target implies that the improvements in the transport field will have to go further if the economy grows. This target is not a relative measure, such as reducing GHG emissions by 60% of whatever travel demand may be. It is an absolute reduction and thus the real challenge is to decouple economic growth and quality of life improvement from growth in emissions. This will require significant changes in travel behaviour, as well as improvements in vehicle efficiency.

Transport offers a wide range of existing opportunities for zero revenue environmental charges, for example with a green “cash back”. These have fewer social justice issues than raising the cost of home heating or lighting and in fact are likely to be positive.

UK based transport (including domestic air) also offers a range of known instruments which work, and can be applied quickly, to produce lower carbon travel patterns. This suggests transport should be a pathfinder sector for carbon reduction strategies.

The final point is that if transport or other sectors perform well, and there is any overall reduction which goes beyond the current target, it will further reduce the risks of damage from climate change. The current target does not restore atmospheric concentration of greenhouse gas to their long term normal levels, just to a level at which many scientists believe the damage won’t be catastrophic. In this sense there is a fundamental difference between greenhouse gas emissions and many other public policy targets. For most conceivable levels of reduction over the next 50 years, the greater and the more rapid the reduction the better.

5 The cost and price of greenhouse gas – the economic debate

Introduction

It is very clear that, even if action is taken soon, the world is heading towards a doubling of GHG in the atmosphere. Scientists' current best guess is that we are several decades and maybe a century away from the most damaging impacts, but we are already experiencing discomfort. To address this, humanity is going to have to take a view of the world which goes beyond the needs of one generation. Fortunately, living beyond the immediate and doing something difficult now to ensure a better future is one of the defining human qualities.

In this context the aim is to bring human activities back into some sort of balance with the climate. The activity which is the focus of this report is transport, although most of the conclusions are of far wider significance. One of the keys to restoring the balance is for the climate impacts of individual actions to be reflected in people's choices. There are two basic approaches to doing this: the first is to create laws and regulations, the second is to use financial means to encourage climate friendly choices. They are not mutually exclusive and may differ between different activities.

An example of the first would be to set an annual GHG allowance for every person on the planet and once this has been used up, no more greenhouse causing activities can be undertaken that year. If you didn't use your allowance you could sell it or save it up for a big trip next year. People's allowances could start higher in places where carbon intensity is high (most of the developed world) and gradually be brought into line with the level at which the risk to the climate from humanity is reduced or virtually eliminated. Such a process is often referred as "contract and converge" [21].

However, financial policies could work towards the same result, for example using fuel tax, efficiency rebates, grants to insulate homes or provide solar heating, and a sales tax which is set according to how much GHG is emitted during the production and transport of everything we buy. The latter would certainly have to extend to all imports, addressing the issue of how much GHG has been "exported". The developing world is becoming less and less industrialised as it becomes richer, and so the emissions to make the things we buy occur in the new manufacturing countries such as China. This is one of the main reasons their emissions are growing so fast.

Both approaches can be combined and made mutually supportive. For example, issuing permits to pollute and then reducing the level permitted year by year is a regulatory approach, but the transition can be made easier, and less costly, using a financial mechanism. This works on the assumption that some people will find it so cheap to reduce their emissions that they don't need all their permits to pollute. Instead they can sell some of them to another polluter who finds it very difficult and costly to make an improvement.

This is the principle behind the European Trading Scheme (ETS) which sets national permitted levels for some high emitting industries (such as power stations and cement). The first period of trading is just finishing, and while the electronic trading system worked, it produced an erratic and rather low carbon price [47]. This was almost certainly due to giving out too high a level of permits and illustrates one of the key problems with such a system. The second round is slightly tougher and the ETS scheme, which is the subject of international interest, is discussed in more detail later in the report.

This initial discussion on carbon price leads into one of the most hotly debated questions in the economics of climate change.

What is the cost of carbon and what is its price?

Underlying all the arguments about which policies should be applied to combating climate change is a profound split on the economics of charging for the emission of greenhouse gas. This is separate from the arguments over whether carbon “markets”, which trade in permissions to pollute, are a suitable mechanism for achieving change.

Before any trading can take place there needs to be some assessment of what the charge should be for emitting too much greenhouse gas. In the ETS scheme it takes the form of a fixed fine (€40 per tonne CO2 up to 2008, €100 per tonne 2008-12). This in turn is related to how much we should pay now to avoid emitting carbon in the future.

There are essentially two different approaches. The first tries to create a value in present day prices for future damage caused by climate change. This is often referred to as the social cost of carbon. The second seeks to set the price in order to achieve the desired reduction. In this case the revenue can simply be returned to people through rebates and many argue that the only real costs are one off transition costs. These may, of course, be quite significant, such as building wind farms or tidal power for renewable power generation. On the other hand there may be long term benefits, in the case of renewable energy, stable and low long term costs and security of supply.

The social cost of carbon and the level of carbon tax

In the first approach it is possible to use established cost benefit techniques which could be attached to greenhouse gas. The Stern Report uses such methods at least in part, trying to calculate the cost of future damage to the world economy. Even assuming that this damage figure is correct, the problem arises of how to translate the future costs into current prices. Economists usually do this by “discounting” the future, although this in itself can be very complex. A simple version is used to discount future benefits from road schemes over their life, taken as 60 years. In this case a pound 60 years from now is reduced in value by 3.5% every year until the present day. The same is done to pounds in year 59, 58, and so on. The results are how ever, easy to understand.

In the case of climate change, the key effect of discounting is that damage in future years is of low value in today's terms and tends not to influence our decisions.

This is quite plainly not appropriate where the desired benefits are focussed in the future and have major consequences which people have extremely strong reasons to avoid. Thus, in the case of climate change, discounting the future creates a moral dilemma. It is that people today will knowingly leave it to future generations to deal with a known and serious problem to which their actions now make a major contribution. This is often called the need for "intergenerational" or "intertemporal" equity. The use of discounting tends to give low social costs for greenhouse gas emissions in the present, insufficient to change behaviour significantly.

The counter argument to this is that future generations will be so much richer that the cost of sorting out climate change impacts in the future will be cheaper relative to their income. This also leads to discounting (though in a slightly different way).

The Stern Review comes up with a simple, and understandable, solution. There is very little pure discounting (strictly speaking the discount rate is close to zero). He also applies a fairly low rate to allow for future wealth. Thus the future costs of climate change are represented today at levels much closer to their full value. This leads to social costs for carbon in Stern's report which are significantly greater than previous studies, particularly in the present day.

The Review uses a cut off point because it is assumed that climate change stops happening by about 2200. In addition, Stern has attempted to introduce the value of avoiding risk, another difficult issue because this has to be quantified and costed. He explains and explores this further in the section on ethics and economics (Stern, Chapter 2).

His description of the different economic models which try to value climate change, and why they differ, is summarised in Chapter 6, especially Figure 6.3. He argues that modelling to date has only dealt in a limited way with elements such as:

- the risk of major step change in the climate;
- non-market effects such as human health and the natural environment;
- effects such as mass migration and any resulting conflicts
- equity implications – damage to the poor countries counts for less in the model because their GDP is low.

Understandably, the introduction of an ethical dimension, the inclusion of distant but severe risk, and the full present day value placed on future damage, has caused a great deal of discussion amongst economists[48, 49]. The cut off point is also important in determining costs. If there is low discounting, any amount of future damage can be added to give a higher present day value. Calculating costs to 2200 is quite speculative enough, but some critics have pointed out that much of the high cost occurs after 2100.

One of the best known commentators, whose modelling Stern quotes, is Professor William Nordhaus from Yale. He has issued a response[50] and is critical of Stern's modelling assumptions, although he welcomes the report's contribution to the debate as a whole. His current modelling suggests a social cost of $17 per tonne of carbon (tC), whereas Stern suggests $311 (in the report expressed as $85 per tonne of CO2). This huge difference is largely explained by the way in which future costs are reduced by different approaches to discounting.

Nordhaus draws attention to why this is important for policymakers. The previous social cost models imply that action should start slowly and then rise in future years as the damage gets closer. The same modelling that produced $17 tC today, produces rising values for carbon of $84/tC by 2050 and $270/tC by 2100. He describes this as the "climate policy ramp" and the logic behind it as follows,

"As societies become richer in the coming decades, it becomes efficient to shift investments toward policies that intensify the pace of emissions reductions and otherwise slow GHG emissions."

However, he immediately qualifies this by saying,

"The exact mix and timing of emissions reductions depends upon details of costs, damages, and the extent to which climate change and damages are irreversible."

These comments come to the heart of the matter. Stern is attempting to represent some very real factors within a social cost benefit framework which is not really designed to handle them. He is in fact led by a higher level objective than defining the right social cost for carbon which is the need to "prevent dangerous anthropogenic interference with the climate system" (Article 2 of the UN Framework Convention on Climate Change). Nordhaus fully recognises this, quotes Article 2, and goes on to say,

"If that is the reason, why not impose the limit directly? Instead of using the near zero social discount rate as an analytic subterfuge to slow climate change, why not simply adopt policies that will directly keep climate change below the dangerous threshold? Limiting climate change directly is more efficient as well as more transparent."

This quote leads into a discussion of the second avenue to achieving carbon targets through fiscal means – restructuring tax and charges to influence behaviour.

Putting a price on carbon to influence behaviour

A different price based approach to applying a general carbon tax based on social cost asks the question "how much does it cost to influence behaviour?". There are many examples where the effect of price on use is regularly calculated and used in policy formulation. In economic terms, there are established price elasticities for such items such as fuel cost and traffic (distance travelled)[51]. These can be used to design policies which are likely to influence behaviour.

For example, the short term impact of fuel duty between 1994 and 1999 was for every 10% increase in cost, a 3% decrease in fuel used. This in turn was split approximately equally between more efficient driving and less distance travelled. In the longer term the impact (elasticity) tends to be significantly higher. There tends to be a lower effect on the number of journeys – in other words distance is reduced by making journeys shorter. This is particularly the case for heavy goods vehicles.

Such so called "environmental taxes" are often combined with the idea of redistributing revenues, broadly to the people from whom they are collected. Thus an additional fuel duty which had the purpose of changing travel patterns (for example encouraging walking and cycling), and encouraging more efficient cars, could be recycled broadly as follows. The amount raised from personal travel would go back to the population as and the amount raised from business (who would pay the duty on fuel used by commercial vehicles) would go back to individual businesses.

The way in which this is distributed will have different effects. For example, a lump sum paid annually to every UK resident would probably have a slight negative impact on GDP, but be of positive help to the least well off and child welfare. If the fuel duty (or any other environmental tax or levy) came back in the form of a reduction in income tax or national insurance it would probably be positive in GDP terms but favour people who are better off.

Parallel to this, business costs would be increased by higher road fuel costs and this could come back as employer national insurance reductions, or rate rebates, either as a lump sum or graduated according to size or turnover. Again, lump sums would favour smaller, more marginal businesses and this may well be the preferred option to support small business creation and the role of local shops [52].

The idea of stimulating markets to work in a particular direction is not new. In relation to climate change in general, and transport in particular, there are several examples.

Examples of influencing behaviour through price – a mixed picture

The new car market

In the car market, recent changes to company car tax and annual vehicle excise duty (VED), which penalise the least efficient cars, have been introduced. Unfortunately this has led to a major switch away from traditional company car purchase to other ways of subsidising car use by employees rather than ownership. In this case they are free to buy a car privately. Thus, in recent years, company cars have become more efficient, but often this has been because those who want larger models have taken the private purchase route instead. HM Treasury has lost more revenue than expected because of this effect [53]. Meanwhile, private purchases have not been much affected and are now, on average, less efficient than company cars – the opposite of ten years ago.

This illustrates the importance of having an integrated approach to applying such policies. In fact, there are clear and more direct pathways to improved vehicle efficiency using sales tax and fuel duty. Voluntary agreements with manufacturers aimed for specific improvements by 2008 which will not be met by some considerable way. The position could be recovered through a fiscal approach and a proposal is set out in detail later in Section 8 of this report.

Aviation

In aviation the per capita Air Passenger Tax (recently increased) is said to be an environmental tax. How far it influences behaviour is not clear, nor is it well related to the carbon emitted by the actual flights. It is not at all apparent why, at least for domestic flights, a fuel duty is not applied instead. This is specifically permitted by the EU and a consultation document including such an option has been produced by the Conservative Party [54]. For EU flights, a Europe-wide agreement on some form of carbon tax or trading scheme is being actively discussed. A proposal for a carbon tax for domestic flights is being prepared as a supplement to this report.

Assessment

In infrastructure assessment, the example of the price of a road death is well known. This is set at a deliberately high level at which it will always be worth saving. It is a policy based value.

Guidance for infrastructure assessment now includes a spreadsheet which costs carbon emissions and should be included as part of the appraisal process. These are based on earlier DEFRA research [55] which chose £70 per tonne from a range of studies. This report raised many of the relevant social cost issues which were later to be considered in Stern.

Avoiding cost through adaptation

While most predictions of the impacts of climate change are negative, there are some who argue that there will be mitigation, at least in part, by the benefits of a temperature rise in colder parts of the world. These arguments include both technological change (such as building design or materials) and some short term increases in agricultural production. There is not, however, a comprehensive vision of an “adapted” future which can be compared to the results from the international climate models. Such results reflect the difficulties caused by such rapid change in the climate and the severe damage caused to equatorial regions should temperatures rise. More locally, EU predictions of winners and losers, have recently been published [56], showing severe droughts in the Mediterranean region, with extreme temperature events more common. Crop gains in Northern Europe are balanced by serious losses in the South, raising issues of equity and large scale migration.

Undoubtedly there will be some adaptation, but to suggest it has any significant impact in reducing costs, particularly at the global scale, appears speculative. It remains important to distinguish between the relatively small scale beneficial adaptations and the larger expenditure undertaken to avoid the consequences of climate change (defensive adaptation). An example of this would be flood defence programmes (both for rivers and as a result of sea level rise). Already costs are being incurred to adapt to future warming.

Conclusions

The arguments over how to calculate social costs, and how to derive a carbon tax value from them, make this a very difficult path for policymakers to follow. It is clear that the usual formats and models work for only part of the real world objectives and there is no agreed methodology for dealing with key areas such as health, forced migration, or the balance between rich and poor. Nevertheless, climate change is an area where the application of agreed goals for reduction can be illuminated by such models – indeed they have provided an important way in which these issues can be teased out and addressed.

For this reason, while continuing to use the resources offered by the economic models, the basic approach for this report is for the financial framework to be led by the objective of stabilising GHG at a safe level. It is not entirely clear what this is - but we have a reasonable approximation and thus it is possible to make progress of the right sort of scale while it is being finalised. Even the social cost models suggest that the social cost of carbon is rising quite significantly all the time. For most people this makes waiting for the final answers a very poor policy choice.

As set out in the previous Sections, this will require a series of interim targets which lead to rapid progress. This contrasts strongly with the "climate ramp" approach and some of the risks were illustrated in Section 2. This leads to the recommendation of a rapid, rather than a slow start to reducing GHG.

This could be achieved by an integrated approach using enforceable targets and new financial measures. These will have to operate as efficiently as possible in a manner which is clearly related to the objective and transparent to those affected.

As a prelude to Phase 2 of this project, an example of a specific current transport policy and how it needs to reformed is given in Section 8. Before doing so, this report addresses two final relevant issues for transport in relation to land use for agriculture. The first is the capture of carbon dioxide through plant growth, in particular offsetting emissions through planting trees. The second is the growing of crops for bio fuels (such as biodiesel or ethanol) for transport.

6 Capturing carbon through afforestation and growing crops for biofuels

Could we absorb our carbon emissions by growing a lot more trees?

If plants are good at capturing carbon in their leaves, stems, trunks and roots, one approach to reducing carbon dioxide would be to grow more of them. In fact this is already happening, with some American electricity generators planting or re-planting forests in the US and elsewhere in the world [57]. This is done to "offset" the burning of fossil fuels by these US companies.

There are many calculations of how far trees (or other plants) absorb carbon and of course this depends on the variety, the soil, the climate they are grown in and the water supply. Fast growing willows in Florida may absorb 20 times the carbon of a pine tree in Canada in any single year. Poplars are another example of fast growing tress which are suitable for temperate climates [58]. However, these trees often need a lot of water do not live as long as other hardwoods. Root structures are also very different. Trying to assess this is very difficult but broad estimates can be made. For example, hardwood forests in a temperate climate should be able to absorb about 2 tonnes of carbon per year per hectare. Poplars and willows are also seen as a fast growing feedstock for the production of bio-ethanol (to replace petrol).

To put this in perspective, an average family car in the UK doing the average mileage would need about a hectare of continuously managed native forest to absorb the carbon it emits [59]. There are 29 million cars and vans in the UK, so this would require the same number of hectares. Nothing approaching this is available, at the moment the total area of agricultural land in the UK is only 18.5 million hectares [60] and the total land area of the UK is about 24.3 million. It may be possible to improve on this rate of absorption, but even doubling the effectiveness of carbon capture by trees would still require almost three quarters of existing agricultural land to be given up to forest.

The offset trap

In complete contrast to this is the claim made by some websites that compensating for annual driving emissions would only require the planting of, for example, 10 trees. Over the lifetime of the trees it is correct to say that they might absorb sufficient carbon dioxide but this is profoundly misleading.

The first problem is that the "offset" of one year's carbon dioxide won't start until the saplings are a few years old. Thus in the first year all the carbon dioxide from your driving goes into the atmosphere as before with no compensating absorption. Over the course of your lifetime (and probably beyond), the first year's driving emissions are slowly absorbed. This could be 40 to 100 years depending on what type of tree is planted. From the climate change viewpoint this is exactly the wrong way round. What is needed is urgent remedial action rather than compensation which finishes after some of the worst impacts of climate change will already be with us.

Obviously this planting of a smaller number of trees must take place every year that the person drives, again difficult to guarantee and leading to the odd situation that someone aged 30 could finish paying back their carbon debt from car driving as late as 2150.

It would also have to be a condition that the trees, once felled at the end of their life, are never burned while there is a greenhouse gas excess in the atmosphere. How a private company can guarantee this for a period starting many decades in the future is not clear. The trees would have to be used for construction, furniture or other, hopefully useful, forms of permanent storage.

It is also the case that the trees will have to be managed and cared for over their lifetime - this could be 40 to 100 years depending on variety. Schemes should be vetted to ensure that arrangements are in place and funded by the original purchase.

There is another important condition that must be met. All the trees must be newly planted and genuinely additional to current or planned tree stocks - they would not have been planted unless the individual pays for them. Sponsoring or "adopting" an existing tree or trees will make no difference to climate change. Schemes should be audited to ensure that this is the case and, to be fair, the best ones should have no problems in passing this test already.

Competition for land

The final issues are outside the criticism of the methods of calculating how many trees are needed. The first relates to the competition for land which is needed for food crops, wildlife, environmental quality and landscape. The second relates to the planting of trees in places distant from where the carbon is emitted. In other words, a form of arborial imperialism where developing countries find tracts of their land is being purchased to be given over to forestry on behalf of foreign companies. In fact, done well, local afforestation schemes can be very beneficial to local communities and sustainable in the longer term. The question is one of speed and scale if developed countries want to offset their high carbon emissions as soon as possible. This issue will arise again when the question of whether plants could be grown and converted into bio-petrol (ethanol) or bio-diesel is considered.

The true role of forests in reducing climate change

While the odd accounting may mislead people into thinking they are actually becoming zero emitters, the principle of planting trees, particularly where there is little vegetation at present, is sound. This is despite a recent scare that trees produce methane, a process thought impossible until very recently. The researchers who discovered this interesting process have themselves made the point that it is extremely small, weakening the carbon benefit from trees by less than 4%[61]. Problems may also occur if trees were to be grown in areas of snow cover, where they may stop the reflection of sunlight and thus absorb more heat. The most effective area for planting on this basis is in the tropics [62].

Tree planting can also fulfil a wide range of functions such as windbreaks and reusing contaminated land. From earlier sections it is also clear that preserving existing forests should be a key priority for climate change policy.

The issues therefore must be to ensure that tree planting does not require excessive inputs, in particular water and fertilizer, nor should it interfere with local communities far distant from the carbon emitters, who bear little responsibility for the problem which is being addressed. They could be faced by the large scale purchase and conversion to forest of their local landscape. The long term political acceptability could not be guaranteed and this would be required for many decades if planting is to succeed. At the other extreme there are places where forests have been destroyed and their restoration would be welcomed locally as well as globally.

Conclusions on the role of trees

The first and most important conclusion is that the existing carbon stored in mature forests should not be released by burning them. Pressure on the world's forests comes from many directions (including climate change itself) such as land clearance for food crops. If the world sought to replace fossil fuels (coal or petroleum) with biofuels, the pressure would be on to cut down even more forests, increase water demands, and use more fertilizers and pesticides which themselves release greenhouse gas.

The next point is that tree planting, and reforestation, is a very simple and valuable way of soaking up some of the carbon we produce. Paying into responsible schemes to plant trees should be continued within a range of policies to avoid climate change. However, the claims made that the levels of planting currently suggested for offsetting transport emissions are enough to cancel them out are misleading in the extreme. What is needed is for emissions to be countered in the year in which they are produced, not a century later. To the extent that such claims create any complacency about people's transport they may delay or prevent the real policy changes which are required.

Can't we use the so called bio-fuels?

Linked to the idea of large scale of tree planting to absorb carbon is the production of bio fuels to replace fossil fuels. Fossil fuels are of course simply bio fuel which has been stored and compressed over millions of years, derived from plants or simple life forms such as algae.

There are two main types. The first is biodiesel from oils (including familiar foods such as soy, oil seed rape, sunflowers and various nuts and seeds. The second is bioethanol which is made by fermentation of plant materials, such as sugar beet or cane and corn.

There are very significant disagreements about the value of biofuels, usually related to two main sources. The first is how much external energy is required to grow the plants, and how much other greenhouse gas may be given off, particularly through the use of chemical fertilizers. The second is the energy needed to harvest the crop and then transform into usable biofuel. There are also issues about the transport of biofuel if it is not produced where it is consumed. For example there would be a huge difference between farmers producing biofuel for their own food production and a tropical date palm based producer who would send their product to be consumed in Northern Europe. This would also have to use tankers in a similar way to those used for current oil supply and produce similar GHG emissions.

Producing a modest proportion of UK demand with biofuel grown in the UK is possible, for example a project at the University of Strathclyde [63] estimated that using all the setaside land in the UK could produce about 3-4% of vehicle fuel consumption. Producing the whole amount of fuel required nationally would take virtually all of the land area of the UK, according to their assessment. This is in line with other estimates for current biofuels, although next generation fuels using more woody crops could be more productive, probably 2 to 3 times better than sugar cane, the current most effective option for bioethanol [64]. The challenge for producing these “advanced” biofuels is producing enzymes which can break down the crop material.

One further issue which is frequently ignored is how far transferring land from one sort of production to another has serious implications and not just for carbon capture. Clearly the land which is best for producing biofuel is likely to be the best for food. This is so complex an issue, involving the whole question of populations, food and its distribution, it is hard to fit it into the more precise calculations for carbon capture versus biofuel. It must be addressed, even if only in a qualitative way. It can be summarised in the question of whether people should find it acceptable to transform food crops into fuel for cars and lorries while people go hungry. This will be an interesting new issue for local transport plans.

The current US growth in producing corn based ethanol is already raising these issues. The international price of corn has reached new heights [65] and led to protests in Mexico over tortilla prices [66].

Considering the alternative use of land within a climate stabilisation plan is a little easier. If productive land (i.e. plenty of water and nutrients in the soil) and which is currently unused were an unlimited resource this would not arise. Clearly these conditions are not met. A basic idea of the problem can be gained by asking a simple question. Would it be better for the climate to plant land for biofuels or to plant trees and carry on burning oil?

The somewhat surprising answer is that in many cases it is probably better to focus on planting for carbon capture. The reason is that the associated GHG emitting processes to produce the biofuel from the crop, and then transport it, can more than compensate for the slightly slower rate of carbon absorption of trees. Much of this is captured in the soil and thus even grasslands can sequester carbon [67]. At the very least, the benefit of using of land for biofuel should be compared to using it for carbon capture. This would radically alter the savings claimed.

However, this conclusion depends very much on the land which is being used. For example, land which is not suitable for tree planting or food but which can sustain crops for biofuel can provide a genuine benefit in terms of climate change. In reality things are not this clear cut, but examples such as the Jatropha plantings on unproductive land in Africa and India [68] show how a reformed agriculture can produce energy feedstock and support rather than replace food crops. Much of this will, of course, not be used for transport in the developed world, but used locally. This has the major additional advantage of not consuming energy to transport the crop or the fuel. Such projects at least hold the key to more sustainable development in deprived rural areas.

Current interest in biofuel production has centred not on the use of poor or contaminated soil but the incorporation of biofuel as part of the developed world's agricultural system. Soy beans and particularly corn in the USA, sugar cane in Brazil, and oil seed rape or sugar beet in Europe are examples. In these cases the planting is seen as part of the range of crops to be produced in a commercial market. It is also possible to encourage biofuel production on non-agricultural grounds such as avoiding climate change, or reducing dependence on imported oil and thus improving national security. It is possible that some large scale agricultural producers support such an approach, at least in part, as a way of subsidising their operations without conflicting with international trade agreements.

Such non-climate related explanations are encouraged by the poor performance of biofuels grown in the same way as industrialised agriculture. Emissions of nitrous oxides in the field from artificial fertilizers as well as the energy inputs to produce them detract from the benefits. The basic issue still remains - the crops are transformed into biofuel and then burnt. The emissions at the exhaust pipe are very similar (probably slightly cleaner). The only difference is the absorption of carbon when the fuel is produced. If the field of soy beans could absorb more or the same amount of carbon then there is no benefit. If making the biofuel uses the same as, or more energy than, oil production, there is no benefit.

The additional danger is of course that forest will actually be cleared, particularly in tropical areas, to grow biofuel crops, for example date palms. Sir Peter Crane, retiring director at Kew, said in September 2006, [69]

"We're going to have to get biofuels off land that's already degraded, perhaps land that's not useful for other purposes, for conservation or agriculture. And we've got to do it without creating other problems with the kinds of inputs that in the past have gone into intensive agriculture."

Of course in the long term there may be new developments such as algae which produce oil at rates far in excess of conventional crops, or nanotechnology filters which would produce biofuel direct from vegetable oil. These are nowhere near being tested for large scale production and there are already obstacles to be overcome, especially the by-products. Some of these will always be useful (such as organic material for fertilizer), some may be useful to a certain extent, such as glycerol, but the scale on which this will be produced will massively exceed current demand. Others may simply provide a new disposal problem, such as residues from the production process. For the time being reliance on an unproven technology does not seem like the most prudent approach given the need for rapid action in the short term.

Agriculture can make a contribution either through offsetting or biofuel, but this will depend on careful scheme by scheme design rather than offering a universal panacea.

7 Targets for more efficient cars

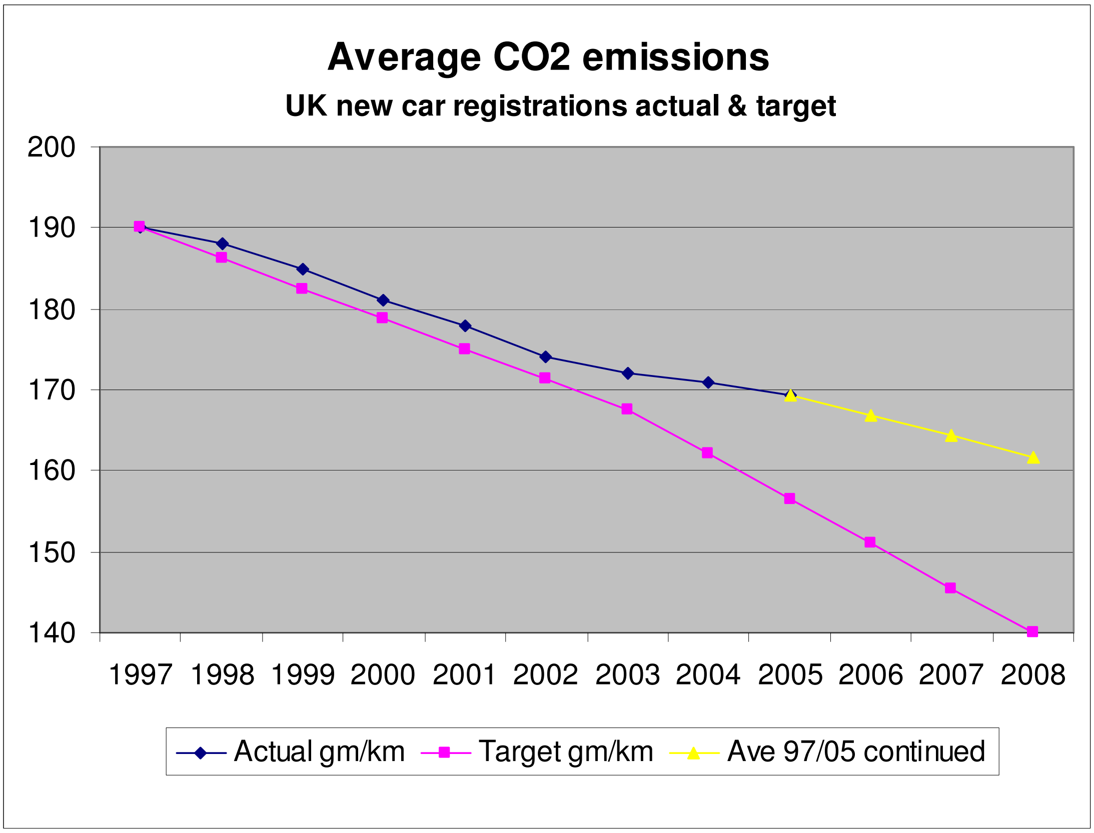
The current road transport target

While biofuels are gaining interest, the current centrepiece of Government policy for road transport and climate change is the voluntary manufacturers' agreement to reduce the average carbon emissions from new cars sold. Similar policies are in place in Europe, Japan and Korea. The European target was to reduce emissions from 190 gms of carbon produced per kilometre to 140 by 2008.

The most recent Commission proposal has suggested a level of 130gm by 2012, but to be a mandatory standard. This proposal is discussed further in Section 8. It also states that the shortfall will be met by increasing use of bio-fuels. While these can make a contribution to reducing carbon emissions, this depends completely on which crop is used, whether crops have to be imported, how the fuel is made (and thus how much energy is used for this purpose), and how much carbon is emitted by the transport which is involved.

The near certainty of the UK failing to meet its target was highlighted by MTRU last year (2005). Since then a further year's figures have been published and show a slightly worsening position. This is illustrated in an MTRU spreadsheet which was published for discussion on the net [70] (www.transportclimate.org). A chart illustrating how continuing the current trend will miss the target by over 20 gms by 2008 is shown below.

Figure 7.1



Source: SMMT published data

It should be noted that much of the carbon reduction in the early years is due to a switch to diesel. While this reduces carbon dioxide emissions, it can increase certain air pollutants, especially particulates and nitrous oxides, compared to equivalent petrol engines. European standards are tightening but, for example, no current diesel car currently meets the stringent Californian Air Resources Board limits for such pollutants and cannot be sold in the 5 US states which have adopted them.

Is it the right target?

The real objective of the voluntary agreement is to improve the efficiency of the UK car fleet and thus reduce carbon emissions. However, the voluntary target for new vehicles is only indirectly related to overall emissions and there is a serious weakness which undermines its validity.

Because the target is expressed in terms of the average fuel consumption of new cars sold, it is perfectly possible for the target to be achieved while the total carbon production of the UK car fleet goes up. For example, if many more new cars are sold, and these are second, third or fourth cars in a household, they are likely to be smaller than the first household car. If a large number of smaller, more efficient, cars are sold, the average fuel efficiency of new cars as a whole will improve. This would happen even if the absolute number of larger, higher fuel consuming cars stayed the same. The smaller cars would represent an increase in car ownership and thus an increase in use. Overall, this would result in an increase in the amount of greenhouse gas produced, at the same time as apparently meeting the Government's key target.

Not only is the target failing to be met, it was inadequately constructed in the first place and is quite likely to be misleading. The fact that it is voluntary and there are no clear mechanisms for the manufacturers to work together to achieve them has been another shortcoming.

Working with the existing data from SMMT and the DfT it is possible to estimate what the voluntary agreement was trying to achieve in terms of overall efficiency of cars in the UK. The policies which follow seek to achieve this in a more secure and effective manner. The voluntary agreement targets will then be achieved, even though the agreement itself is incapable of delivering them.

A new approach to car registration targets

It is not unreasonable to seek an efficiency target for the manufacture of new vehicles, in addition to those needed for their use. Use is, of course, far more important than efficiency and policies dealing with this should be the cornerstone of future transport policy. However, in this particular case a far more sensible target would be to reduce the total carbon producing capacity of the cars owned in the UK. This is defined as the total number of cars multiplied by their potential to produce carbon, (their gms per km).

This would lead to policies which would strongly encourage the sale of much more efficient vehicles and for manufacturers the target for new vehicles should include the total carbon producing capacity of the cars sold. This is just as easy to calculate as the existing measure.

At the same time, the fuel consumption figures used should be adjusted to reflect the actual vehicle sold. This is important because equipment such as air conditioning can significantly alter fuel consumption (by 5-10%). Its inclusion would encourage the use of the most efficient systems and give a more accurate picture of the likely total of emissions.

Leading the market

One of the key objectives is to encourage more efficient cars but this cannot happen unless manufacturers plan to produce enough of them in time to meet the target. This requires clear tax signals (on purchase as well as use) which move consistently in the direction of carbon reduction over a reasonable period of time. It should be noted that simple tax rebates for one technology (such as the previous hybrid rebate in the US) are not recommended. Hybrid power is used in many American models to achieve increased performance at the same or marginally lower fuel consumption. Setting targets in terms of emissions rather than favouring specific technologies also allows manufacturers to exploit the widest possible range of options, from weight reductions to semi-hybrids.

European models such as the diesel hybrid Peugeot/Citroen have been built as prototypes and could be available in the next 2-3 years [71]. They offer 90gms/km of carbon emissions in a mid sized car. It is a true hybrid in that the electric motor and the diesel engine can work separately or at the same time. The issues are how quickly will manufacturers introduce such vehicles and how many will they plan to produce.

There are also many interim technologies less complex than the true hybrid which can reduce fuel use and are simpler to introduce. Examples are switching the engine off when the car is stopped (available already in some models), and using an electric motor for low speeds and switching to conventional fuel as speed increases. In this simpler version the electric and conventional power units are used for different types of driving, rather than also being capable of working together (as in true hybrids like the current Toyota Prius [72]).

Given the long time scales over which people replace their cars and the necessity for rapid action, the voluntary approach is uncertain and has proved completely ineffective. A clear taxation framework for purchase and use is required to give manufacturers the impetus to get the new vehicles into the market in sufficient quantities. The aim would be to place no extra burden on the purchase of a best performing vehicle and only penalise the less efficient.

Carbon tax versus congestion charging

Proposals for the national congestion charge scheme target congestion but are also seen as helping to reduce greenhouse gas. At the moment this is reasonable because in congested conditions cars tend to use more fuel. However, newer technologies will seriously weaken this relationship because they often produce less carbon in congested conditions than in free flow on motorways.

Hybrids, for example, use their electric motors in congested conditions and use the braking system to charge the battery. Most current hybrids are more efficient in stop start conditions than in free flow. Current proposals for congestion charging may be justified in terms of saving business users' time or avoiding the need for road building. However they will be less effective in reducing carbon as vehicle technology changes. They will only contribute if they cause a significant reduction in car use, rather than re-routeing or retiming journeys. Thus if people divert to A roads from congested motorways, their hybrids will consume more fuel than driving round city centres. An indication of this is shown in the US Environmental Protection Agency fuel consumption figures for hybrids shown in Table 7.1.

Table 7.1
Hybrids available in the US market
Urban and free flow fuel consumption

Honda Insight:	City 61	Highway 68
Toyota Prius:	City 60	Highway 51
Honda Civic:	City 50	Highway 50
Toyota Camry:	City 43	Highway 37
Honda Accord:	City 30	Highway 37
Ford Escape (2wd):	City 36	Highway 31
Ford Escape (4wd):	City 33	Highway 29
Mercury Mariner:	City 33	Highway 29
Toyota Highlander (2wd):	City 33	Highway 28
Toyota Highlander (4wd):	City 31	Highway 27
Lexus RX 400h:	City 31	Highway 27
Lexus GS 450h:	City 25	Highway 28

These figures represent EPA test numbers, which are commonly 10 - 20 percent higher than real-world fuel economy for hybrid and conventional vehicles.
Source: hybridcars.com
EPA is the US Environmental Protection Agency

For private cars, increasing fuel duty is simpler than electronic road pricing, and could be introduced immediately. It would directly support achieving the objective which is to reduce carbon emissions. As was seen in Section 5, it is one of the most cost effective ways of emissions across all sectors. The next Section gives an example of the approach to be used in Part Two of the project by setting out an integrated way of achieving real improvements in fuel efficiency, while avoiding the risk of increased congestion and pollution.

8 Environmental duties to encourage more efficient cars

Introduction

UK transport policy in relation to reducing greenhouse gas is guided by the target of 60% reduction on 1990 levels by 2050. As the 2004 transport White Paper [14] says, “real progress” should be made by 2020 and this is now in tune with the draft Climate Change Bill. Policies for promoting sustainable travel and demand management are intended to support this. Overall it is expected that transport carbon emissions will rise by 10% between 2000 and 2010, and then start falling by about 1% per year. This depends upon improved fuel efficiency.

The UK Government, the European Union, and the Japanese and Korean car manufacturers, are all agreed about targets for more efficient cars, at least until 2008 [7]. In the previous Section, the failure to achieve the target and the flaws in its design were set out, and thus alternatives must be sought. There are two possibilities: the first is some form of regulation and rationing by Government of vehicle manufacture or fuel use. The second is to lead the market in a new direction by pricing policy. Given the problems with the first, the focus in this paper is on pricing. In any case, pricing will strongly support the achievement of any mandatory standards.

Clear objectives

For the purposes of formulating policy, there are a few basic criteria which pricing mechanisms for environmental purposes (as opposed to general taxation) should follow.

- The main objectives must be individually identified and clearly stated. *(Rational).*
- It must be clear to those who are affected how the mechanism relates to the objective. *(Transparent).*
- It must be clear to those who are affected that there is a feasible course of action which will avoid the additional cost. *(Avoidable – a zero cost option is available).*

In this case the underlying overall objective is to reduce the greenhouse gas emissions from transport. The timescale and pattern of this reduction is the subject of another discussion note.

The specific objective, in this case, is to improve the efficiency of the UK car fleet. Commercial vehicles would be considered separately.

There are two important constraints to the specific objective. The first is that making vehicles more efficient should not produce more travel and thus fail to achieve the overall objective. In fact, national traffic forecasts currently assume that at least part of the predicted increase in traffic is due to motoring costs falling. At least half of this is due to an assumed increase in car efficiency making driving cheaper, and thus encouraging more of it.

The second constraint is that increasing the rate of manufacture, in order to replace existing cars with more efficient models, would cause a serious increase in carbon produced. About 15-20% of the total carbon emitted during a car's lifetime is from its manufacture.

Integrated approach

Thus the financial structure proposed here covers the two main factors influencing purchase – the initial cost and the ongoing fixed cost (Vehicle Excise Duty). This is matched with an increase in fuel duty such that the efficiency gains do not result in a cheaper cost per mile for driving. Such gains would inevitably generate more traffic and undermine any reduction in emissions.

Large scale inducements to scrap older cars which consume a lot of fuel were considered but have their own problems. Apart from distorting the second hand car market, early scrapping means that extra carbon will have to be used to manufacture more new cars.

However, there is some merit in having a scrap value in terms of carbon emission and it would be useful for other purposes. For example some cars are sold at the absolute margins of safety and efficiency at very low prices. This would tend to be reduced if owners could receive a modest sum which would also cover the removal of a vehicle.

Thus the main thrust of the proposals is a new car sales levy, which does not apply to the most efficient vehicles, together with a phased increase in fuel duty and a revised annual VED.

The inclusion of the sales levy is for the simple reason that it applies directly to the purchase decision. To do the same through VED would require much more draconian increases. This is because people would tend to discount the value of the VED in future years – a principle which is widely accepted in all financial appraisal. In addition an emphasis on VED would do little to discourage use.

This illustrates a further important benefit in adopting an integrated approach. Using one mechanism to achieve significant change means the level at which it is applied will have to very strong, and the risk of failure, for example through unforeseen side effects, is high. A basket of policies which support each other will mean each can be applied at a more moderate level and the risks are reduced.

Thus the sales tax is supplemented with the fuel duty increase and VED reform. A guaranteed scrap value is not central but is considered to be beneficial. A summary of the new charges is shown in Figure 1 below and each new charge is considered in more detail in the following sections.

Figure 8.1 National policies for improving vehicle efficiency

	New emissions based sales levy	*Annual Vehicle Excise Duty (VED) reform*	*Fuel duty increase*	*Scrappage payment*
New car market	**Impact: direct.** Supports purchase of efficient cars, phased in to allow sufficient availability of suitable vehicles. Levy avoided completely on vehicles with agreed lower level of gms/km.	**Impact: indirect.** Annual standing cost particularly influences low mileage purchasers (e.g. second or third car owners in a household). May influence depreciation rates which in turn affect new car purchase.	**Impact: indirect.** Will influence high mileage and generally cost aware, and/or environmentally motivated purchasers, most.	**Impact: very low**
Pre-owned car market	**Impact: indirect** Impact will depend on how the levy affects depreciation rates, thus some uncertainty. Volume of sales not predicted to change significantly except for cheapest cars (see scrappage).	**Impact: indirect.** Stronger effect than on new car market because annual costs greater proportion of total costs. Likely to be greater depreciation on inefficient vehicles to compensate for VED (and fuel duty).	**Impact: indirect.** Stronger effect than on new car market because annual costs greater proportion of total costs, and greater than VED. Likely to be greater depreciation on inefficient vehicles to compensate.	**Impact: indirect.** Supply of very cheapest cars reduced slightly. These tend to be the least mechanically sound and most polluting and sold "on-street". Thus amenity and safety benefit. Supports recycling.
Vehicle use	**Impact: direct** More efficient vehicles may reduce cost per mile of use and thus encourage more car driving (but see fuel duty).	**No predicted impact.**	**Impact: direct** Reasonably clear relationship between fuel used and distance travelled. Congestion, road costs and safety benefits.	**Impact: indirect.** There will be a small reduction of use because very cheap, marginally usable vehicles will be less available. There should be a safety benefit.

All the proposals have a recognisably common structure in their approach to taxing carbon emissions. This is important to achieve the transparency requirements of any new charges. They all include low or zero rates for the most efficient vehicles. The definition of the most efficient vehicle changes over time to reflect the introduction of new technologies. The time horizon given here is up to 2020 and the level of efficiency proposed is within existing capabilities of the major car manufacturers. The key aim is to give them certainty to plan the production of more of the efficient vehicles. Ironically, this should result in the achievement of the voluntary target.

This improvement in vehicle efficiency is only part of the package needed to reduce carbon emissions from transport. This will not be achieved simply by making vehicles more efficient, but would be assisted by it.

Car sales levy

Information on the price sensitivity of car buyers is difficult to obtain because of commercial confidentiality. However, it is clear that there is some evidence from the taxation treatment of company car purchase [52]. Company cars represent 56% of all new car purchases.

Ten years ago newly bought company cars had engines about 10% larger than private cars [73] (the precise grams of carbon per kilometre figures were not available then). The picture today is very different – newly bought company cars are about 3% more efficient than those bought privately. One of the reasons for this is the rapid switch to diesel cars, 44% for new company cars compared to 27% for private buyers. This is despite a small diesel surcharge in the company car tax system.

One of the key reasons for this is the introduction of a CO2 based tax on company cars in 2002. A taxable benefit is calculated, based on the cost of the car, adjusted according to how efficient it is. The percentage of the car's cost which is taxable ranges from 15% to 35% and cars which emit less than 120 gms/km will go down to 10% in the 2008/9 tax year. The percentage increase is fairly smooth, rising by 1% for every 5 gms of extra carbon produced. There is an added complication, in that higher rate tax payers pay more since the taxable benefit of having a company car, calculated as above, is treated as though it is income. Employers are charged as well as employees through national insurance contributions, and there is the additional issue of employees paying tax on free fuel. For this, and other reasons it is difficult to establish a clear formula for how the level of price influences the choice of efficiency. However, the principles are there, and the approach has proved to be effective.

Thus the proposal set out in this document adheres to the principles set out earlier, that it should be rational, transparent and avoidable. In addition, the experience of the company car system has been used in the creation of the general level of the charge. Clearly the impact would have to be closely monitored over the first few years to adjust the level of charge. There has also been some interplay between people giving up company cars, receiving a mileage allowance instead, and then buying a large car privately. Having the two systems more in tune with each other would avoid such market distortions.

Two options were considered for a sales levy, one as a percentage of the new car value, the other as a cost per extra gram of carbon emitted. The latter is preferred in terms of the rationale and transparency of the new charge. Thus the proposal has no banding and applies a constant charge per gm/km (£50) over a reasonably efficient present day car (140 gm/km). Below this level it has a zero additional charge. Rebates for more efficient cars have not been proposed because this would undermine other policies to reduce car use. The definition of an efficient car gets tighter over time. In principle, there should be no ceiling, in other words every extra gram counts the same. Some further work is needed to decide whether an interim ceiling should be used to allow more time for the high consumption market to adjust. This has been included in the chart below.

Relationship with EU targets

It should be noted that the starting point for the tax charge is co-ordinated with the long standing EU target for 2012 of 120gm/km as the average emission rate for new cars. The most recent Commission proposal [74] has suggested a compromise level of 130gm but to be a mandatory standard. It also states that the shortfall will be met by increasing use of bio-fuels. While these can make a contribution to reducing carbon emissions, this depends completely on which crop is used, whether crops have to be imported, how the fuel is made and how much energy is used for this purpose, and how much carbon is emitted by the transport which is involved. The contribution of bio fuels needs to be considered separately and is not nearly as clear cut as improving vehicle efficiency.

In view of the need to make as great reductions as possible, as quickly as possible, there is no reason to change the charge levels in this proposal. These will create market mechanisms to encourage achievement of the efficiency targets. A mandatory 130gm level, and a tax regime which applies a charge only on the least efficient vehicles, are mutually supportive.

There are also EU proposals to remove all car sales taxes in the long term, and to relate them to carbon emissions in the short term. The proposal here is that sales tax should be zero at the target efficiency level and is believed to be consistent with this proposal.

EU studies [75, 76] of the additional costs of manufacturing efficient vehicles vary but achievement of the 120gm standard may cost about £1000, translating into about £1600 in the showroom. Again the scale of the car sales levy proposed is at or around the level needed to encourage manufacturers to apply the available technological solutions, and to develop them further.

Table 8.1 Draft car purchase levy
Preferred option

New car carbon levy @ £50 per gm per km over target average		2007/8	2008/9	2016/17	2020/21
Actual charge 2007/8 at lowest in band	Actual charge 2020/21 at lowest in band				
0		Under 140	Under 135	Under 90	
0	£50	140-144	135-139	90-94	
0	£300	145-149	140-144	95-99	
0	£550	150-154	145-149	100-104	Under 90
0	£800	155-159	150-154	105-109	90-94
0	£1050	160-164	155-159	110-114	95-99
0	£1300	165-169	160-164	115-119	100-104
£50	£1550	170-174	165-169	120-124	105-109
£300	£1800	175-179	170-174	125-129	110-114
£550	£2050	180-184	175-179	130-134	115-119
£800	£2300	185-189	180-184	135-139	120-124
£1050	£2550	190-194	185-189	140-144	125-129
£1300	£2800	195-199	190-194	145-149	130-134
£1550	£3050	200-204	195-199	150-154	135-139
£1800	£3300	205-209	200-204	155-159	140-144
£2050	£3550	210-214	205-209	160-164	145-149
£2300	£3800	215-219	210-214	165-169	150-154
£2550	£4050	220-224	215-219	170-174	155-159
£2800	£4300	225-229	220-224	175-179	160-164
£3050	£4550	230-234	225-229	180-184	165-169
£3300	£4800	235-239	230-234	185-189	170-174
£3550	£5050	240 & over	235-239	190-194	175-179
	£5550		240-249	195-204	180-189
	£6050	Note. Charging could be extended if required to cover all cars, or ceiling slowly raised as in this table.	250 & over	205-214	190-199
	£6550			215-224	200-209
	£7050			225-234	210-219
	£7550			235-239	220-229
	£8050			240-249	230-239
	£8550			250-259	240-249
	£9050			260-269	250-259
	£9550			270-279	260-269
	£10050			280-289	270-279
	£10550			290-299	280-289
	£11050			300-309	290-299
	£11550				300-309
	£12050				310-319

For comparison:
In 2006/7 a £50,000 company car emitting 240 gms/km would incur a tax charge of £7,000 for a higher rate taxpayer plus about £900 to the employer.

Draft fuel duty increases

The targeted increase in fuel efficiency of the average car is 62.5% between 2006 and 2020. This results in the total vehicle stock in the UK achieving an efficiency increase of 42.2%. The fuel duty increases in the Table below have been designed to match this (including the addition of VAT) so that there is no overall incentive to increase travel by car. The less efficient the car, the greater will be the incentive to its owner to use it less. This is consistent with the overall policy objective.

In revenue terms, if motorists drive the same distance as today in their more efficient vehicles, the revenue from fuel duty will stay the same and their fuel costs per mile will stay the same. It should be noted that all the figures are in 2006 prices (no allowance made for inflation).

Thus this proposal is not the same as the fuel escalator, where increases used a fixed percentage increase in duty every year. The introduction is phased, to allow more time for new cars to enter the fleet, but this must be accompanied with a clear commitment to follow the pattern through until 2020. This will enable car owners to make secure long term choices.

Table 8.2 Changes in fuel duty to balance fuel efficiency

Year	Additional fuel duty in p/litre	Base price in p/litre	New price in p/litre	% increase in total price on base year	% increase in total price on previous year
2007	1	89	90	1.3%	1.3%
2008	2	89	91	2.6%	1.3%
2009	3	89	93	4.0%	1.3%
2010	5	89	95	6.6%	2.5%
2011	7	89	97	9.2%	2.5%
2012	9	89	100	11.9%	2.4%
2013	11	89	102	14.5%	2.4%
2014	14	89	105	18.5%	3.5%
2015	17	89	109	22.4%	3.3%
2016	20	89	113	26.4%	3.2%
2017	23	89	116	30.4%	3.1%
2018	26	89	120	34.3%	3.0%
2019	29	89	123	38.3%	2.9%
2020	32	89	127	42.2%	2.9%

Notes
The above duty increases have been increased by VAT @ 17.5% to provide the new prices and % increase figures.
Fuel duty is currently 47.1p per litre.
If the fuel duty escalator had continued in place at 6%, the total duty would now be 83.9p per litre (Treasury Written Answer 13/09/2006)

Annual ownership charges (Vehicle Excise Duty)

The current system of annual duty is based on carbon emissions but in a small number of bands. These are different in size and charge most per gram (£2) at the most efficient end of the spectrum. All cars over 226 gms/km pay the same so there is a zero charge for extra carbon produced. There are two other sets of VED rates for older cars. As the Society for Motor Manufacturers and Traders (SMMT) point out [7], such mixed systems, the tapering of the carbon value and differences between systems, lead to confusion and mixed messages.

While VED is a secondary signal to new car purchase and car replacement, it needs to be consistent with other charges. Although reforming it yet again may be confusing, there needs to be a firm basis on which it will go forward within the time horizon of these proposals (to 2020).

The level of VED should not be used as the key to influencing behaviour because it only indirectly influences the decisions which determine carbon emissions. These two important decisions are:

- efficiency of the vehicle at the point of purchase
- how much to use it to fulfil travel requirements.

Altering both the structure and the rates of VED very significantly for new cars without retrospective changes for existing vehicles could cause people to hold on to older less efficient vehicles. The increased fuel duty would help to avoid this and there is some merit in people maintaining older cars if their mileage is very low. This is because the carbon cost of manufacturing a new one is avoided.

For these reasons the proposal here is to reform VED by applying a single rate per gm/km of £2 to all cars above the reference level used for purchase. This would not be retrospective. The lowest charge would be £20. This results in a small but positive change for the most efficient cars and a small but more noticeable increase for the least efficient vehicles. The average car sold today would pay slightly less than under the current system. A vehicle emitting 300 gms would pay £400 instead of £210. Taken together with fuel duty, this represents on average a move towards charging more for use. Again there is the zero cost option of owning an efficient vehicle.

One area for further discussion is how this proposal is far less draconian than some proposals for VED reform on carbon emission grounds. The key reasons are that an impact is sought first at the point of purchase and secondly on vehicle use. This appears at first sight to be both more efficient and more equitable.

Conclusions from this example

The application of the principles outlined at the start of this report have led to this new approach. The use of fuel duty could be extended for other reasons, for example as a substitute for national congestion charging. It would also, in this case, have a beneficial impact in terms of reducing the average length of haul for inland freight transport [43]. Phase 2 of the project will deal with this and the detailed aspects of repaying any environmental duties to those affected.

Sources and References

[1] Stern Review index page, which includes new material published since the original report in November 2006:
http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

[2] *Draft Climate Change Bill*, Consultation, DEFRA, March 2007
http://www.defra.gov.uk/corporate/consult/climatechange-bill/consultation.pdf

[3] *Climate Change 2007: The Physical Science Basis, Summary for Policymakers,* February 2007
http://www.ipcc.ch/SPM2feb07.pdf

[4] The UK's Hadley Centre is a major resource for all climate change research and provides further discussion of the greenhouse basics. For a general description of the greenhouse effect see:
http://www.metoffice.gov.uk/research/hadleycentre/models/climate_system.html

[5] IPCC 3rd Report, 2001, Chapters 4 and 6.
http://www.grida.no/climate/ipcc_tar/wg1/index.htm

[6] For example see the climatecare/British Airways site at:
http://www.climatecare.org/britishairways/index.cfm

[7] *UK New Car Registrations by CO2 Performance,* Society of Motor Manufacturers and Traders, April 2006 (2005 data).

[8] *Eight glacial cycles from an Antarctic ice core,* Nature, Vol. 429, June 2004

[9] Ocean decadal variability in HADCM3, Met Office website at:
http://www.metoffice.gov.uk/research/ocean/climate/decadal.html

[10] IPCC 3rd Report, Figure 2.20:
http://www.grida.no/climate/ipcc_tar/wg1/fig2-20.htm

[11] Monthly mean Central England Temperature (includes annual average) at:
http://www.hadobs.org/

[12] Parker, D.E., T.P. Legg, and C.K. Folland. 1992. A new daily Central England Temperature Series, *1772-1991. Int. J. Clim.,* ***Vol 12****, p317-342*

[13] For a summary of this phenomenon see: *Thermohaline Ocean Circulation*, Rahmstorf, Encyclopaedia of Quaternary Sciences, 2006

[14] *Future of Transport* White Paper, CM6234, October 2004
http://www.dft.gov.uk/pgr/strategy/whitepapers/fot/

[15] Action Today to Protect Tomorrow - The Mayor's Climate Change Action Plan, February 2007
http://www.london.gov.uk/mayor/environment/climate-change/docs/ccap_fullreport.pdf

[16] United Nations Framework Convention on Climate Change, text at:
http://unfccc.int/resource/docs/convkp/conveng.pdf

[17] for an overview of the carbon cycle and how it is included in modelling see:
http://www.metoffice.gov.uk/research/hadleycentre/models/carbon_cycle/index.html

[18] *Methane emissions from rice fields*, Neue, H. 1993, in *BioScience 43* (7); 466-73

[19] For example 15% of India's net GHG emissions are from this source, see the Initial National Communication to UNFCCC, 2004, Table 2.1 on: http://unfccc.int/resource/docs/natc/indnc1.pdf

Analysis from the US Environmental Protection Agency is on: http://www.epa.gov/methane/reports/06-enteric.pdf

[20] *World Population Prospects: The 2006 Revision,* UN 2006, http://esa.un.org/unpp/

[21] *The World Factbook,* CIA, 2006, 2007. https://www.cia.gov/cia/publications/factbook/ and for China specifically, see: https://www.cia.gov/cia/publications/factbook/print/ch.html

[22] The World Bank, China Key Economic Ratios http://www.worldbank.org/reference/

[23] CDIAC: carbon dioxide information analysis centre (US Dept of Energy) http://cdiac.ornl.gov/

[24] *The Essentials of Contraction and Convergence*, Global Commons Institute, 2002, website: http://www.gci.org.uk

[25] The Energy and Resources Institute (TERI) has many projects in India, see: http://www.teriin.org/projectsmain.php

[26] Kyoto protocol at UNFCCC site: http://unfccc.int/kyoto_protocol/items/2830.php

[27] UNFCCC ratification as of November 2006 at: http://unfccc.int/files/essential_background/convention/status_of_ratification/application/pdf/unfccc_ratification_22.11.06.pdf

[28] Data published by the World Resources Institute in its CAIT database can be found on: http://cait.wri.org/

[29] Further details can be found in: *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, *Chapter 12, Transport,* Baumert, Herzog & Pershing, WRI 2005 http://pdf.wri.org/navigating_numbers_chapter12.pdf

[30] Greenhouse Gas Emissions from Transport, ONS, 2004 http://www.statistics.gov.uk/downloads/theme_environment/transport_report.pdf

[31] Greenhouse gas emissions using IPCC categories from DEFRA e-digest of environmental statistics at: http://www.defra.gov.uk/environment/statistics/globatmos/download/xls/gatb05.xls

[32] Transport predictions and the impact of current policies are described in *Climate Change – The UK Programme 2006,* DEFRA, CM6764, March 2006 http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/ukccp/pdf/ukccp06-all.pdf

[33] **Common s*ources and assumptions for all the tables and charts in Section 3***

Carbon deficit for the UK is defined as amount produced in excess of the long term target level of 16.5 million tonnes of carbon equivalent (60% reduction on 1990 levels)

Totals are for all surface transport (no international air travel or deep sea shipping)

Greenhouse gas emissions from UK transport are from "Climate Change - The UK Programme 2006" DEFRA http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/ukccp/pdf/ukccp06-all.pdf

UK Department for Transport assumptions on traffic growth and vehicle efficiency are at:
http://www.dft.gov.uk/foi/responses/2005/mar/trafficgrowthforecasts/futureoftransportassumptions
http://www.dft.gov.uk/foi/responses/2005/mar/trafficgrowthforecasts/futureoftransporttrafficsummary

Californian estimates are sourced from baseline assumptions for State Bill AB32, in the Climate Action Team Report, March 2006, see reference 30 below.

Except for "rapid start" scenarios, intermediate years are calculated using straight line assumptions between given target years

Californian transport estimates for all years are produced by using a fixed proportion of 41.2% of total emissions (current figure)

[34] *VIBAT Final Report*, UCL, 2006. Available on: http://www.ucl.ac.uk/~ucft696/vibat2.html

[35] Californian estimates are sourced from baseline assumptions for State Bill AB32, in the Climate Action Team Report, March 2006
http://www.climatechange.ca.gov/climate_action_team/reports/2006-04-03_FINAL_CAT_REPORT.PDF
http://gov.ca.gov/index.php?/press-release/4111/

[36] California expert briefing on the low carbon fuels standard
http://gov.ca.gov/index.php?/speech/5249/

[37] State of California Executive Order on low carbon fuels, 18th January 2007
http://gov.ca.gov/executive-order/5172/

[38] For example see: *Smarter Choices – Changing the Way We Travel,* Goodwin et al, DfT 2004
http://www.dft.gov.uk/pgr/sustainable/smarterchoices/ctwwt/chapter1introduction

[39] *Synthesis of Climate Change Policy Evaluations*, DEFRA, April 2006
http://www.defra.gov.uk/environment/climatechange/uk/ukccp/pdf/synthesisccpolicy-evaluations.pdf

[40] *Cost Effectiveness Analysis in the 2006 Climate Change Programme Review*, National Audit Office, January 2007
http://www.nao.org.uk/publications/nao_reports/06-07/Climate_Change_analysis.pdf

[41] See Reference 37 above, Figure 2, and Section 1.199 (page 69).

[42] Home page for the European Emissions Trading Scheme:
http://ec.europa.eu/environment/climat/emission.htm

[43] *Transport Policy, A Consultation Document*, Volume 1, Chapter 13, HMSO, April 1976

[44] *The Eddington Transport Study*, HMSO December 2006

[45] *Equity and Ecotax Reform in the EU: Achieving a 10 per cent Reduction in CO2 Emissions Using Excise Duties*, Barker and Kohler, Fiscal Studies, Vol 19, No.4, 1998

[46] *Family Spending 2005/6 Edition*, ONS 2007. See Annex A, Table 7.

[47] EU carbon trading price can be found at the ECX carbon exchange:
www.pointcarbon.com

[48] Stern debate at Yale (streaming video of the day's discussion available)
http://www.yale.edu/opa/newsr/07-02-21-05.all.html

[49] Martin Weitzman's comments on Stern, work in progress
http://www.economics.harvard.edu/faculty/Weitzman/papers/JELSternReport.pdf

[50] Professor Nordhaus comments on Stern:
http://nordhaus.econ.yale.edu/SternReviewD2.pdf

[51] *Review of income and price elasticities of demand for traffic, Final Report,* Graham and Glaister, Imperial College, July 2002

[52] MTRU work on weight distance taxes for heavy vehicles, 1996 to 2006.

[53] *Report on the Evaluation of the Company Car Tax Reform Stage 2,* HM Revenue & Customs, 2006
http://www.hmrc.gov.uk/budget2006/company-car-evaluation.pdf

[54] *Greener skies: A consultation on the environmental taxation of aviation*, The Conservative Party, March 2007
http://www.conservatives.com/pdf/greenerskiesconsultation.pdf

[55] Government Economic Service Working Paper 140, Estimating the Social Cost of Carbon Emissions, HM Treasury & DEFRA, 2002
http://www.hm-treasury.gov.uk/media/209/60/SCC.pdf

[56] *Accompanying document to the Communication from the Commission, COM(2007) 2final,* January 2007 http://ec.europa.eu/environment/climat/pdf/ia_sec_8.pdf

[57] As reported in the US Government's Energy Information Administration's *Voluntary Reporting of Greenhouse Gases 2004,* Chapter 4
http://www.eia.doe.gov/oiaf/1605/vr04data/chapter4.html

[58] *Inside Agriforestry*, Newsletter of the USDA National Agriforestry Center, for practical discussion of different tree crops and biomass uses see:
http://www.unl.edu/nac/insideagroforestry/2000fallwinter.pdf
http://www.unl.edu/nac/insideagroforestry/vol15issue3.pdf

[59] There are major differences in the rates of absorption according to climate, water availability, type of tree and soil. Another key factor is the age of the tree. This is illustrated in the carbon sequestration tables used for official offsetting schemes, for example see:
Iowa Farm Bureau Carbon Credit Program, Forestry Offsets From Tree Plantings & Reforestation, Chicago Carbon Exchange application, 2003 to 2011, Tables 9.3 and 9.3B2
Greenhouse Gas Reductions and Credits Through Biodiversity Conservation Projects, State of Ontario, June 2000: http://www.ene.gov.on.ca/envision/air/climatechange/greenhouse.pdf

[60] e-digest of statistics, DEFRA, on:
http://www.defra.gov.uk/environment/statistics/land/kf/ldkf05.htm

[61] *Global Warming - The Blame Is not with the Plants,* Press Release, Max Planck Institute, January 2006

[62] *Combined climate and carbon-cycle effects of large-scale deforestation,* Bala, Caldeira, et al, Proceedings of the US National Academy of Sciences, April 2007

[63] *Biofuels for transport*, MSc Energy project, University of Strathclyde, see
http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/quant_bioethanol.htm
http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/quant_biodiesel.htm

[64] For example see *Frontiers: The BP magazine of technology and innovation, Issue 18*

[65] *Corn has deep economic roots as high prices create ripple effect*, US Today, 24th January 2007 http://www.usatoday.com/money/industries/food/2007-01-24-corn_x.htm

[66] *Mexico leader in tortilla pledge,* BBC News, 12th January 2007: http://news.bbc.co.uk/1/hi/world/americas/6255781.stm

[67] *Soil carbon sequestration for improved land management*, Food & Agriculture Organisation of the UN, 2001: ftp://ftp.fao.org/agl/agll/docs/wsrr96e.pdf

[68] *BP & TERI undertake India's biggest Biofuels Production project,* Press Release, TERI, February 2006, for this and other projects see: http://www.teriin.org

[69] *World must wake up to dangers of biofuels, head of Kew Gardens warns,* The Independent Newspaper, 9th September 2006

[70] www.transportclimate.org

[71] Peugeot-Citroen information pack: http://www.psa-peugeot-citroen.com/document/presse_dossier/DP_Hybride_HDi_EN1138701208.pdf

[72] http://www.toyota.co.uk

[73] *Vital Travel Statistics*, Potter, S, Landor, 1997

[74] European voluntary agreement to 2008 and aspiration for 2012 are in: http://ec.europa.eu/environment/co2/99125/en.pdf

[75] *Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2 emissions from passenger cars,* TNO, 2006 http://forum.europa.eu.int/Public/irc/env/eccp_2/library?l=/light-duty_vehicles/task_a/report_2006_31pdf/_EN_1.0_&a=d

[76] *Fiscal Measures to reduce CO2 emissions from passenger cars,* COWI, 2002 http://ec.europa.eu/taxation_customs/resources/documents/co2_cars_study_25-02-2002.pdf