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Stockholm Environment Institute, Project Report - 2010

Towards a Zero Carbon Vision for UK Transport

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Cover Photo: © Robert Hextall

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ACKNOWLEDGEMENTS

We would like to thank the Greenpeace Environmental Trust for giving us the opportunity to undertake an interesting and timely study. In particular, we are grateful to Doug Parr, Anita Goldsmith, Emma Gibson and Vicky Wyatt at Greenpeace for all their feedback and support. A number of transport experts reviewed our scenario assumptions and provided advice. We thank Jillian Anable, Kieth Buchan, Simon Davies, Phil Goodwin, Steve Norris, Simon Reddy and John Stewart for their expert insights.

Finally, we are grateful to Richard Clay and Erik Willis for producing this final report.

LIST OF ACRONYMS AND ABBREVIATIONS

ACS	Air cavity system
APU	Auxiliary power unit
AQMA	Air Quality Management Areas
ATM	Air transport movements
ATOC	Association of Train Operating Companies
BAU	Business-as-usual
BERR	Department for Business, Enterprise and Regulatory Reform
CAA	Civil Aviation Authority
CAEP	Committee on Aviation and Environmental Protection
CCC	UK Committee on Climate Change
CCS	Carbon capture and storage
CCT	Company car tax
CH_4	Methane
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalents
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EC	European Commission
EST	Environmentally sustainable transport
ETS	Emission Trading System
EU	European Union
EV	Electric vehicle
FPE	Fuel price escalator
FTK	Freight tonne kilometres
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigatonnes
Gt CO_2	Gigatonnes of carbon dioxide
GTP	Global temperature potential
GWP	Global warming potential
HGV	Heavy goods vehicle
HOV	High occupancy vehicle
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	Internal combustion engine
ICT	Information and communication technologies
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
ITIF	Information Technology and Innovation Foundation
LDV	Light goods vehicle
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LTP	Local transport plan
MARPOL	International Convention for the Prevention of Pollution from Ships
MI	Maximum Impact
Mppa	Million passengers per annum
mph	Miles per hour
Mt CO_2	Megatonnes (millions of tonnes) of carbon dioxide
NICE	National Institute for Clinical Excellence
OECD	Organisation for Economic Cooperation and Development
NO_X	Nitrogen oxides ($NO + NO_2$)
N_2O	Nitrous oxide
NAIGT	New Automotive Innovation Growth Team
NETCEN	National Atmospheric Emission Inventory
NHS	National Health Service
NTM	National Transport Model
OECD	Organisation for Economic Cooperation and Development
pa	Per annum
PEV	Plug-in electric vehicles
PM	Particulate matter
RF	Radiative forcing
RFI	Radiative forcing index
RTFO	Renewable Transport Fuel Obligation
SARS	Severe acute respiratory syndrome
SEI	Stockholm Environment Institute
TEU	Twenty-foot equivalent units
TSGB	Transport Statistics Great Britain
UK	United Kingdom
UKERC	UK Energy Research Centre
UNFCC	United Nations Framework on Climate Change
VA	Voluntary agreement
VED	Vehicle excise duty
VKT	Vehicle kilometres travelled
WBCSD	World Business Council for Sustainable Development

EXECUTIVE SUMMARY

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level. The dominant factor in the warming of the climate in the industrial era is the increasing concentration of various greenhouse gases (GHG) in the atmosphere.

In 2006, the transport sector accounted for approximately 24 per cent (130 million tonnes) of the UK's domestic emissions of carbon dioxide (CO_2) the majority of these emissions (92 per cent) coming from road transport. The 2008 Climate Change Act, commits the UK to reducing GHG emissions across the economy by at least 80 per cent (in comparison to 1990 levels) by 2050.

In its recently published Carbon Reduction Strategy for Transport, the Department of Transport (DfT) recognises that effective decarbonisation of the transport sector will play a large role in achieving this goal. This DfT strategy document also recognises that complete decarbonisation is unlikely to be possible for aviation and shipping due to the greater technical challenges although by 2050 "these modes will have seen a transformative improvement in efficiency".

Despite the difficulties envisaged by the DfT study in decarbonising the UK transport sector, it is possible to make significant progress towards the desirable future of a zero carbon transport system by 2050. There are no technical, financial, organisational or other obstacles that would put this objective out of reach though a willingness to move boldly and decisively in this direction has yet to be demonstrated.

A zero carbon road transport system has enormous potential to deliver post-Kyoto GHG reductions and to embed the transport sector firmly within a wider process of societal change that can move beyond rhetoric and target setting and deliver a decarbonised future. Indeed, without a clear and robust low carbon transport system in place reinforcing all other sectoral and lifestyle contributions to carbon reduction, it is highly unlikely that CO_2 emission reductions of the scale required across the UK or the European Union (EU) can actually be achieved.

A zero carbon transport future will provide better access for more people to more things than is currently the case. Traffic congestion and time wasted stuck in jams will be a thing of the past and time currently wasted on commuter trips will be spent on rewarding and enriching activities.

By 2050 all urban and rural areas will have significantly enhanced public transport and cycling facilities bringing high quality and low-cost transport choices within everyone's reach. Those who opt not to use a car will save thousands of pounds a year by avoiding the fixed and variable costs of car ownership and use, and will also avoid the uncertainties and potential disruption of oil price shocks as the world adjusts to shortages of supply and increased demand from developing countries. Individuals and families will have much improved air quality, reduced noise and stress from traffic and much improved community life stimulated by reduced levels of motorised traffic and reduced traffic on streets and through villages.

The aim of this study is to quantify and assess the contributions that different CO_2 emission reduction measures can make in assisting the UK to move towards a zero carbon transport sector by 2050. Existing published reports, academic papers and official statistical data have been used to estimate CO_2 emissions from the transport sector in 2050 according to two scenarios: a Business-as-usual (BAU) scenario and a Maximum Impact (MI) Scenario in which all feasible interventions for achieving a 'near zero carbon' UK transport sector are applied.

Much of the baseline and trend data used are derived from other modelling initiatives such as the DfT's National Transport Model (NTM). Therefore, the BAU Scenario estimates are necessarily constrained by these assumptions (e.g. the NTM's future fuel price increase assumptions).

In addition to reducing GHG emissions, moving towards a zero carbon transport system will lead to a number of social, environmental and economic benefits. These co-benefits will improve the quality of life for social groups of widely differing lifestyles and transport needs. The measures outlined in the MI Scenario will deliver the transition towards a zero carbon transport system which in turn, will produce knock-on beneficial effects in the following key areas: environmental quality, social exclusion, mobility and accessibility.

Moving towards a zero carbon transport Britain will affect diverse lifestyle groups in different ways. By 2050 Britain is expected a have an older population, where people aged over 50 will represent 30 per cent of the population. Many older people will remain fit and active into later life where mobility will be a key factor in determining their quality of life. The study compares the current lifestyles of typical families with those likely to be led by their equivalent counterparts in 2050 under assumptions made in the MI Scenario.

The study focuses solely on 'tailpipe' CO_2 emissions. It should be noted that in the future, the carbon intensity of fossil fuels (the 'well-to-wheel' emissions) is likely to increase as fossil fuels become more difficult to locate and extract. An exception to this general approach applies when the role of plug-in electric vehicles (PEV) is considered in the MI Scenario as clearly the concept of 'tailpipe emissions' becomes meaningless for these vehicles. Also, it is beyond the scope of this study to enter into cost-benefit analyses of the various CO_2 emissions reduction measures which have been included in the MI Scenario.

There are two key future challenges which necessitate the reduction of oil use within transport, and the consequent CO_2 emissions, to an absolute minimum. Firstly, transport is extremely dependent on oil and there is a likelihood that there will not be much oil left in 2050, compared with today. Gilbert and Perl (2008) argue that we have to embrace a new transport revolution based on "moving people and freight without oil". It is clear, therefore, that transport systems have to change. Secondly, climate change raises important issues around re-engineering transport systems so that they are less vulnerable to the damaging consequences of climate change and play a full proportionate role in mitigation i.e. reducing GHG emissions.

The climate change problem has a strong ethical dimension through its differentially serious impacts on the poor and the vulnerable. Transport developments based on year-on-year growth in GHG emissions actively contribute to the generation of unethical outcomes. Transport is also the fastest growing source of GHG emissions and shows little sign of seriously addressing the need for carbon reduction.

The BAU Scenario is an estimate of a particular end-state in a chosen year based on the continuation of present trends and policies to 2050. The BAU is one of two scenarios examined in this study to explore future scenarios for a zero carbon transport sector in the UK. The base year for each mode may differ due to the availability of studies and projects using different data.

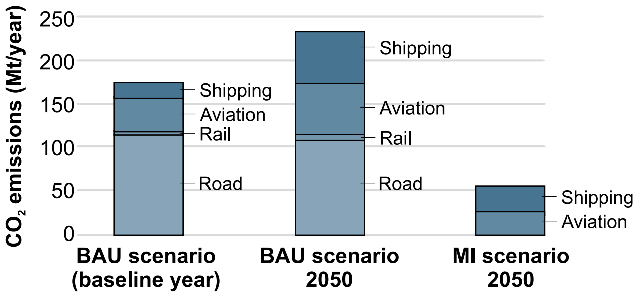
The baseline BAU CO_2 emission estimates are compared with a number of recent UK studies on low carbon transport. The estimates for road and rail transport are generally in line with these studies. Estimates for aviation vary depending on whether or not international aviation is included. Emissions from shipping include those from domestic and international shipping and are considerably higher than reported elsewhere because of the methodology used to allocate emissions to countries. For shipping this is based on freight tonne kilometres as this better represents UK economic activity.

The MI Scenario represents a radically different Britain by 2050, where the UK transport sector emits close to zero CO_2. A wide range of measures known to reduce CO_2 emissions from transport were examined to see the extent to which these measures can have a maximum impact on the transport sector and realise the vision of a zero carbon transport sector in the UK.

These measures are grouped into in four categories (Spatial planning, Fiscal, Behavioural and Technology) and the impacts of each assessed separately in order to allow their relative efficacy to be assessed. For passenger and freight railways, a single technological intervention only is applied: complete electrification of the UK rail network. Biofuels are assumed to have only a minimal role given they are usually considered to be far from 'carbon neutral' and have been associated with adverse land-use issues and other drawbacks identified in the Gallagher review (Renewable Fuels Agency, 2008).

Under the MI Scenario assumptions, road transport will be completely carbon neutral by 2050 due to a combination of reduced demand (approximately 75 per cent from spatial, fiscal and behavioural measures) and a whole-scale shift in technology to PEVs and hydrogen fuel cell vehicles, both of which will utilise decarbonised UK electricity supply. Clearly, a carbon neutral electricity supply would be much more likely to be able meet the increased needs of a road transport sector almost entirely composed of PEVs and/or hydrogen fuel cell vehicles if total demand is also drastically reduced. The measure causing the greatest reduction in demand is the annual increase in fuel costs due to the re-introduction of a fuel price escalator.

Emissions of CO_2 from aviation have been reduced by 56 per cent when the 2050 MI Scenario is compared with the 2050 BAU. CO_2 emissions in 2050 under the MI Scenario are also 11.2 million tonnes less than the baseline 2005 figure. This represents significant progress in bringing aviation into line with the implications of the UK national commitment to an 80 per cent reduction by 2050 on a 1990 base. The



Summary of CO_2 emissions for BAU and Maximum Impact (MI) Scenarios

scale of reduction achieved is still not enough but it has been produced by the full application of all available measures. It is clear that a combination of those measures that reduce demand such as air fare increases, no additional runways, modal shift to railways (including High Speed Rail) and video substitution would deliver a considerably greater reduction than could be achieved by advances in aircraft technology and air traffic management alone. It follows that a reduction in CO_2 emissions from aviation of this scale could not be delivered by a policy that encouraged technological solutions alone whilst allowing demand to continue o grow. Any expansion of airport capacity through building new runways would have the effect of supporting year-on-year increases in demand and therefore does not form part of this MI Scenario. Indeed, there would be no need for any new runways under a policy designed to maximise CO_2 emissions reductions from aviation through a demand-led reduction strategy as assumed in this MI Scenario.

Published evidence that CO_2 emissions from shipping can be reduced by 49 per cent through changes in ship size, routeing, fuel, speed and a number of other promising technologies have been assumed. No change in prices for shipping bulk products or 'twenty-foot equivalent units' (TEUs) have been factored in the analysis because of the lack of published information on robust relationships between shipping prices and the physical quantity of goods shipped or the distance over which they have been moved.

Although road and rail transport could both achieve the zero CO_2 emission target by 2050, emissions from aviation and shipping are problematic. For the 2050 MI Scenario, the net result for the entire UK transport sector is a 76 per cent reduction in CO_2 emissions compared with the 2050 BAU Scenario (or a 68 per cent reduction on the BAU baseline year emissions). While this reduction is a considerable achievement in the transport sector it still falls short of the zero carbon target. The 24 per cent short-fall is entirely due to the remaining CO_2 emissions from aviation and shipping. To improve on this 76 per cent CO_2 emissions reduction would require much more radical interventions or technological innovations for these two sectors than those envisaged

Summary of BAU versus Maximum Impact (MI) Scenario

Category	Baseline emissions (Mt CO_2) [and Year]	BAU emissions (Mt CO_2) 2050	MI emissions – Combined measures (Mt CO_2) 2050	Reduction in CO_2 emissions relative to 2050 BAU
Road	116.2 [2003]	110.2	0	100%
Rail	3.4 [2006/7]	4.6	0	100%
Aviation	37.5 [2005]	59.9	26.3	56%
Shipping	18.9 [2005]	59.9	30.4	49%
All transport	176.0 [composite year]	234.6	56.7	76%

in the present study. This will require fundamental changes in globalisation and patterns of international trade and mobility if aviation and shipping is to make a larger contribution to the zero carbon target.

It must also be emphasised the MI Scenario for road and rail transport depends on the decarbonisation of the electricity supply system. A detailed analysis of policy pathways leading to such a decarbonised electricity supply in the UK is outside the scope of this study. However, if the electrical power sector decarbonisation by 2050 is less than 100 per cent, CO_2 emissions from road and rail transport will be substantially higher than projected for the MI Scenario.

Cycle hire scheme, La Rochelle, France - © Spixey/flickr

1 INTRODUCTION

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPPC, 2007). The dominant factor in the warming of climate in the industrial era is the increasing concentration of various greenhouse gases (GHG) in the atmosphere (Soloman *et al.*, 2007). Several of the major GHG, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) occur naturally. However, current concentrations of atmospheric CO_2 and CH_4 far exceed pre-industrial values found in Polar ice-core records of atmospheric composition dating back 650,000 years, and multiple lines of evidence confirm that increases in their atmospheric concentrations over the last 250 years are due largely to human activities (Soloman *et al.*, 2007).

The GHG contributing most to human-induced climate change is CO_2, global average atmospheric CO_2 concentrations having risen from 280 ppm at the start of the industrial revolution (ca. 1750) to a global monthly mean of 386 ppm in 2009 (Tans, 2009). Anthropogenic CO_2 emissions come mainly from fossil fuel combustion and globally, amounted to 26.1 Gigatonnes of CO_2 (Gt CO_2) in 2004 (Sims *et al.*, 2007) of which the transport sector was responsible for 6.3 Gt CO_2 (Kahn Ribeiro *et al.*, 2007). Over the past decade, global transport GHG emissions have increased at a faster rate than any other energy using sector and will continue to increase in the future as economic growth fuels transport demand and the availability of transport drives development (Kahn Ribeiro, 2007).

Global anthropogenic CO_2 emissions are growing and, according to the International Energy Agency's "Business-as-usual" scenario, are set to rise by 130 per cent by 2050 (IEA, 2008). The Intergovernmental Panel on Climate Change (IPCC) considers a rise of this magnitude could raise global temperatures by 6°C (eventual stabilisation level), perhaps more. This would lead to many adverse consequences including impacts on freshwater resources (increased droughts and flooding, less water stored in glaciers and snow), ecosystems (increased species extinction, reduced biodiversity), increased coastal erosion and flooding (due to sea level rise and increased storm frequency) and negative effects on human health, especially in developing countries (Parry *et al.*, 2007). Mankind faces an urgent need to reduce GHG emissions in order to avert dangerous levels of climate warming.

In 2006, the transport sector accounted for approximately 24 per cent (130 million tonnes) of the UK's domestic emissions of CO_2 the majority of these emissions (92 per cent) coming from road transport (DfT, 2008a). The 2008 Climate Change Act, commits the UK to a reduction in GHG emissions across the economy by at least 80 per cent (in comparison to 1990 levels) by 2050. In its Carbon Reduction Strategy for Transport, the Department of Transport (DfT) recognises that effective decarbonisation[1] of the transport sector will play a large role in achieving this goal (DfT, 2009a). This DfT strategy document also recognises that complete decarbonisation is unlikely to be possible for aviation and shipping due to the greater technical challenges although by 2050 "these modes will have seen a transformative improvement in efficiency".

Despite the difficulties envisaged by the DfT study in decarbonising the UK transport sector, it is possible to make significant progress towards the desirable future of a zero carbon transport system by 2050. There are no technical, financial, organisational or other obstacles that would put this objective out of reach though a willingness to move boldly and decisively in this direction has yet to be demonstrated. A zero carbon road transport system has enormous potential to deliver post-Kyoto GHG reductions and to embed the transport sector firmly within a wider process of societal change that can move beyond rhetoric and target setting and deliver a decarbonised future. Indeed, without a clear and robust low carbon transport system in place reinforcing all other sectoral and lifestyle contributions to carbon reduction, it is highly unlikely that CO_2 emission reductions of the scale required across the UK or the European Union (EU) can actually be achieved.

There is an urgent need to reduce CO_2 emissions and to act now to implement the necessary measures to move the UK transport towards zero emissions. Elements of a zero-carbon road transport system already exists in the sense that enormous progress has been made in different places and at different times to re-shape the transport system so that it delivers societal objectives at a much lower carbon penalty than is currently the case in the United Kingdom (UK). If it were possible to combine

1 The word 'carbon' within commonly used terms such as 'decarbonisation', 'low-carbon' and 'zero-carbon' and 'reduced carbon' is short hand for, and synonymous with, 'carbon dioxide (CO_2) emissions'.

just a small number of elements from UK and European Union (EU) best practice (see box 1.1) and introduce them into the UK planning and transport system with the necessary funding, decisions on transport infrastructure, business and governmental delivery systems and supporting fiscal and taxation regimes then the UK would be well on the way towards the zero carbon transport target over the next forty years.

1.1 AIM OF THE STUDY

The aim of this study is to quantify and assess the contributions that different CO_2 emission reduction measures can make in assisting the UK to move towards a zero carbon transport sector by 2050. Existing published reports, academic papers and official statistical data have been used to estimate CO_2 emissions from the transport sector in 2050 according to two scenarios: a Business-as-usual (BAU) scenario and a Maximum Impact (MI) Scenario in which all feasible interventions for achieving a 'near zero carbon' UK transport sector are applied. Much of the baseline and trend data are derived from other modelling initiatives such as the DfT's National Transport Model (NTM). Therefore, the BAU Scenario estimates are necessarily constrained by these assumptions (e.g. the NTM's future fuel price increase assumptions).

Transport-related CO_2 emissions are not restricted to vehicle exhaust emissions. Emissions of CO_2 are also produced by the energy consumed in the extraction, processing and distribution of fuels (i.e. 'well-to-wheel' emissions) as well as 'embodied energy' CO_2 emissions from the manufacture of vehicles, and construction of roads and other components of the transport infrastructure. However, it is beyond the scope of this study to include 'embodied energy' and 'well-to-wheel' GHG emissions. The study focuses solely on 'tailpipe' CO_2 emissions. It should be noted that in the future, the carbon intensity of fossil fuels (the 'well-to-wheel' emissions) is likely to increase as fossil fuels become more difficult to find and extract. An exception to this general approach applies when the role of plug-in electric vehicles is considered in the MI Scenario as clearly the concept of 'tailpipe emissions' becomes meaningless for these vehicles. Also, it is beyond the scope of this study to enter into cost-benefit analyses of the various CO_2 emissions reduction measures which have been included in the MI Scenario.

Box 1.1: Towards a zero carbon transport system

If the UK is to move towards a zero carbon transport system then every urban area with a population of more than 50,000 would develop and implement a:

- Cycle network similar to Copenhagen (Denmark), Groningen (The Netherlands) and Muenster (Germany) where each day 30 per cent of all trips are undertaken by bike compared the two per cent in large British cities.
- Travel plans similar to the one adopted by York University (UK) where 25 per cent of all trips to the site are by bicycle. This would apply to all major businesses which have over 500 employees.
- Integrated public transport and cycling system similar to that in Basel (Switzerland) which has achieved a modal split of 17 per cent for car use (i.e. only 17 per cent of all trips made every day are by car and 83 per cent by foot, bike and public transport).
- Urban logistics similar to those used in German cities which reduce the number of lorries in urban areas by 60 per cent. This is already in place at the Broadmeads shopping centre in Bristol and Heathrow Airport.

Every rural area in the UK would develop and implement:

- A Swiss style rural transport solution with highly connected and integrated public transport services (bus and rail) to small villages, seven days a week including holidays.
- The German style "citizen's bus" adopted in North Rhine Westphalia to serve rural areas not well connected to the already high quality public transport services available in rural area.
- The Friesland (Netherlands) fully integrated rural public transport network which relates directly to local population sizes.
- The switch to local management and control of some rural railway lines e.g. the Durener Kreisbahn and Regiobahn in North Rhine Westphalia (Germany) which has produced dramatic increases in passenger numbers.
- High quality fully segregated cycle paths besides main roads connecting villages and regional centres in Denmark.
- Anytime, anywhere demand-responsive transport in Limburg and North Brabant, the Netherlands.

2 A VISION OF A ZERO CARBON TRANSPORT FUTURE

Visioning desirable futures has been examined in studies such as The Great Transitions (Raskin *et al.*, 2002), which envisions sustainable and desirable futures emerging from new values, a revised model of development and the active engagement of civil society. Also, the OECD's Environmentally Sustainable Transport (EST) project examines how desirable futures can be attained. It demonstrates what strategies might look like to achieve EST, as well as considering their economic, environmental and social impacts. The present study provides a vision of a desirable future for one important sector of the economy. It provides an examination of how we might deliver the desirable future of a zero carbon transport system in the UK by 2050.

2.1 THE VISION

A zero carbon transport future will provide better access for more people to more things than is currently the case. Traffic congestion and time wasted stuck in jams will be a thing of the past and time currently wasted on commuter trips will be spent on rewarding and enriching activities. By 2050 all urban and rural areas will have significantly enhanced public transport and cycling facilities bringing high quality and low-cost transport choices within everyone's reach. Those who opt not to use a car will save thousands of pounds a year by avoiding the fixed and variable costs of car ownership and use, and will also avoid the uncertainties and potential disruption of oil price shocks as the world adjusts to shortages of supply and increased demand from developing countries and the rapidly growing economies of China and India. Individuals and families will have much improved air quality, reduced noise and stress from traffic and much improved community life stimulated by reduced levels of motorised traffic and reduced traffic on streets and through villages.

The shift to bike, foot and public transport will increase the spending of people in their local areas. This will result in a local renaissance with shops and newly created jobs in local communities serving the increased level of local spending that previously leaked out to global oil and car-making sectors of the economy. Those that have given up individual car ownership will benefit by an average of £4,000 per annum which will be available to spend on local goods and services giving a further boost to local economies (AA, 2010).

The passenger car will still exist and be used by those who have limited transport alternatives but fuel prices will rise to cover the full costs of supporting motorisation (the polluter pays principle) and parking will be recognised as a valuable asset that must be charged for at market rates. Speeds will be limited to a maximum of 20mph/30kph in all residential areas and through villages to support the rapid take up of walking and cycling and to create high quality living environments. Speeds on motorways and dual carriageways will be limited to 60mph to reduce CO_2 emissions and to encourage the take-up of eco-driving techniques. Cars will be either plug-in electric vehicles (PEVs) or powered by hydrogen fuel cells. The electricity required, both for re-charging the PEVs and for producing the hydrogen, will come from a decarbonised electricity supply system largely based on renewable energy and micro-generation in all businesses, homes, schools and health care facilities.

Businesses of all kinds will find ways to introduce flexible working, videoconferencing, more family and child friendly working practices and will actively promote the end of the long commute. Links between businesses, businesses and customers and workers at home or in local "area offices" will be facilitated by a large number of electronic methods. Deliveries of raw materials and goods to manufacturing sites will exploit the advantages of canals, inland waterways, estuaries and the UK's excellent network of 300 ports as well as making better use of the rail network e.g. as in the German "Rollende Landstrasse" system where whole lorries go on trains for sections of their journeys. Lorries will operate in ways that avoid cities, avoid long trunk-haul routes on motorways and are powered by alternatives to diesel that significantly reduce CO_2 emissions.

Tourism in 2050 will still be important but a combination of higher fares and air traffic delays will reduce the demand for flying and increase the number of holidays taken in the UK. There is evidence that holidays involving personal development, child-centred activities, outdoor activities and artistic activities are already on the increase and this process will accelerate putting more emphasis on what is done rather than on where it is done. Holidays in the EU will still be popular and will be accessible by much improved train services, including overnight trains, which provide a journey experience that is also part of the holiday and will steadily supplant air travel.

The aviation industry will still be important but no larger than in 2005 and airlines and companies owning airports will be far more profitable and successful as they diversify into all kinds of communication and mobility activities and services. There will be significant job gains across all sectors of the aviation, rail and bus industries.

The health of all citizens will improve in a low carbon transport future. There will be more lively local economies making jobs available in the community. There will be more social interaction giving everyone the health generating social context of living in a supportive community. There will be less noise and air pollution with attendant health benefits and much more physical activity contributing to a reduction in rates of obesity and heart disease.

The demands on public finance and spending will be reduced. There will be no need for new roads, bypasses and motorway widening at current prices. A healthier and more supportive population and community will reduce National Health Service (NHS) costs e.g. the predicted £50 billion per annum costs of obesity by 2050 (Foresight, 2007).

Local communities will be far more resilient in the sense that a larger proportion of jobs, food and other items of consumption will be sourced locally. This will reduce the risks of disruption that are likely to be associated with long distance sourcing in the future such as oil price hikes, interruption in supply as transport infrastructure succumbs to damage from extreme weather events and shortfalls in fuel availability.

Cities will change so that there is far more green space and woodland and a higher number of homes and employment opportunities than is currently the case in low density developments. Land for eco-efficient, car-free housing can be released from car parks that will now be surplus to requirements and the projected need for new homes therefore, can be met without taking away valuable rural land that will be needed for increased food production.

Cities will be far more friendly and supportive of children and the elderly with calmer environments, reduced traffic and increased feelings of confidence and security. The shift away from the car will increase the amount of walking and cycling and the degree of mutual, friendly "surveillance" making everyone feel safer. Children will rediscover the delights of independent mobility, the joys of getting to and from school and visiting friends and local swimming pools under their own steam. The elderly will find it much easier to cross roads, hold conversations on the street and engage with neighbours in ways that ends social isolation and its related health damaging consequences

Urban and rural residents alike will be happier in this zero carbon future. Layard (2006) has shown that happiness can be measured and that the objective of public policy is to increase the amount of happiness and/or the number of people reporting that they are happy. He shows that in many societies happiness has declined as indices of material welfare have gone up raising the intriguing possibility that a society or culture moving at a slightly slower pace with more opportunities for social, interaction and less noise and pollution might be warmly welcomed. A low carbon future delivers such a society.

A much improved local environmental quality linked to higher levels of integration with local food production, heightened involvement with neighbours and community activities and a greater feeling of security and comfort from a more resilient society will all contribute to increased happiness and to higher levels of social cohesion.

The transformation of society from having a rather one-dimensional emphasis on economic growth to one based on community growth, increased happiness, reduced pollution, improved health and the creation of jobs that are far more evenly distributed and resilient to potential shocks, will bring enormous benefits to all. Examples of community growth would include more social interaction as people meet each other in a much more pleasant public realm as they walk and cycle. A decline in traffic levels is associated with more friends and acquaintances at the level of an individual street (Appleyard, 1981) and more friends and acquaintances are associated with higher self-reported happiness.

This transformed society, combined with increases in transport choice and improvement in safety and security, all point to the absence of "losers" in the zero carbon world. Society will be much fairer with much improved access for everyone, much fewer demands on those with constrained budgets through the elimination of the need to own a car as a default option and the availability of many more transport choices.

2.2 MOVING TOWARDS A ZERO CARBON TRANSPORT FUTURE

There are two key future challenges which necessitate the need to reduce fossil fuel use by the transport system down to an absolute minimum. Firstly, transport is extremely dependent on oil and there is a likelihood that there will not be much oil left in 2050, compared with today. Gilbert and Perl (2008) point out that we have to embrace a new transport revolution based on "moving people and freight without oil". Secondly, climate change raises important issues around transforming transport systems so that they play a full and proportionate role in mitigating GHG emissions as well as becoming less vulnerable to the damaging consequences of climate change in the future. The climate change problem also has a strong ethical dimension through its differentially serious impact on the poor and the vulnerable. Transport developments based on year-on-year growth in GHG emissions actively contribute to the generation of unethical outcomes. Transport is also the fastest growing source of GHG emissions and shows little sign of seriously addressing the need for carbon reduction

Figure 2.1 presents the actual and estimated consumption and production of petroleum liquids for the period 1990 to 2030 based on International Energy Agency data (Gilbert and Perl, 2008). By 2030 production will be considerably less than forecast demand. It would therefore be prudent to reduce the size of this gap and implement a low carbon transport system. The decline of oil availability and the rise in global demand is referred to as the "peak oil" problem and, whilst there is a debate about the exact timing of the tipping point when oil availability declines (and the rate of that decline), there is a considerable measure of

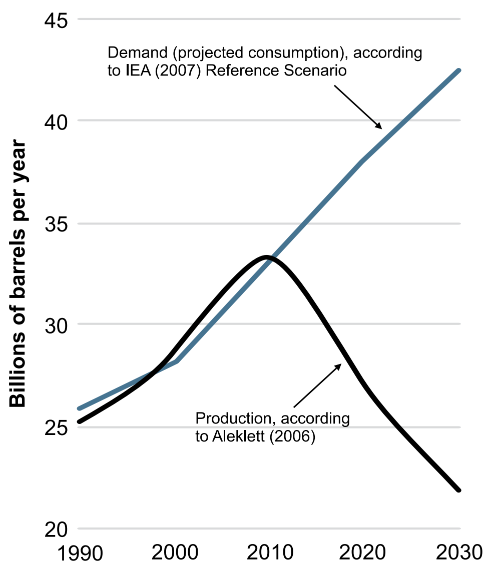


Figure 2.1: Actual and estimated consumption and production of petroleum liquids, 1990-2030
Source: Gilbert and Perl (2008)

agreement that the phenomenon itself is real and has to be dealt with.

The peak oil problem is acknowledged by the oil industry, for example, in the Shell (2008) energy scenarios to 2050. Administrations as widely spread as the Swedish government and the city of San Francisco have examined the peak oil issue, found it to be real and designed policies to cope with the lack of availability of cheap oil. The San Francisco report on peak oil (San Francisco Peak Oil Preparedness Task Force, 2009) has adopted many of the recommendations that are included in this report and these are now under discussion by the city and the State of California. At the national level Sweden has committed to an oil free policy by 2020 (Commission on Oil Independence, 2006) which is much sooner than the present study's target year of 2050. Transport figures strongly in their vision and the policy document makes seven recommendations relating to this sector:

- Encourage a more energy efficient fleet of cars.
- Improve the efficiency of goods transport and reduce its share on the roads.
- Increase the share of fuels from agriculture and forestry.
- Make public transport cheaper and more attractive.
- Strengthen the role of the train.
- Promote alternatives to air travel especially information and communication technologies (ICT) and high speed rail.
- Use ICT and flexible working to encourage different forms of working that reduce work commuter trips.

In terms of climate change the urgency of dealing with GHG emissions is recognised by the UK government's commitment to reduce these by 80 per cent by 2050. However, this target is considered not to go far enough and a generalised target does not deal with the importance of transport and the potential of transport emissions to de-rail an overall target. The Tällberg Declaration sets a more demanding target saying that atmospheric levels of CO_2 must be brought down to 350 parts per million (ppm). This cannot be done unless transport is restructured to play its full proportionate role in a wider community of interest delivering carbon reduction.

The Tällberg declaration sets out the case for an urgent return to 350 ppm from the current 387 ppm. The ethics are clear and the morality is compelling. Significant changes in the current way of life are necessary if the aim for less than 350 ppm within a century is to be achieved. Future generations will benefit for the efforts made today (Ekman *et al.*, 2008). Moving towards a zero carbon transport future makes a significant contribution to those objectives.

Electric car - Lotus Elise - © Harry nl/flickr

3 BUSINESS-AS-USUAL SCENARIO

In line with other major scenario exercises the BAU Scenario can be seen as an estimate of a particular end-state in a chosen year based on the continuation of present trends and policies. The World Business Council on Sustainable Development (WBCSD) (2004) defines BAU as the continuation of present trends which implies:

- "mainstream" projects of economic and population growth are realised;
- the general trajectory of technological development and its incorporation into transportation systems and services continues much as it has over the past several decades; and
- policies currently in place continue to be implemented but no major new initiatives are launched.

This chapter outlines the methodology and assumptions in developing the BAU Scenario to calculate CO_2 emissions from the UK transport sector to 2050. The BAU is one of two scenarios examined here to explore future scenarios for a zero carbon transport sector in the UK. The base year for each mode may differ due to the availability of studies and projects using different data.

3.1 ROAD TRANSPORT

Figure 3.1 summarises the methodology used to estimate the BAU Scenario CO_2 emissions for road transport. The CO_2 emissions were estimated by major vehicle category as used in the National Atmospheric Emissions Inventory NETCEN UK Fleet Composition Projections (NETCEN, 2003) but with the addition of motorcycles:

- petrol car
- diesel car
- petrol Light Duty Vehicle (LDVs)
- diesel LDV
- rigid Heavy Duty Vehicles (HDVs)
- artic HGVs
- buses
- motorcycles.

These categories were further subdivided by Euro emission standard (e.g. for cars: Pre-Euro I, Euro I, Euro II, Euro III, Euro IV) and road type (urban, rural and motorway).

Vehicle kilometres travelled (VKT) for the base year (2003) for the major vehicle categories (cars, LDVs, HGVs, buses and motorcycles) were taken from the DfT Traffic Statistics Great Britain (TSGB) (DfT, 2008b). These distances travelled were further subdivided by fuel type and Euro standard (according to NETCEN, 2003) and road category (DfT, 2004). For motorcycles, CO_2 emissions were then calculated from the total fuel consumption for 2003 reported by DfT (2008c) multiplied by an emission factor of 3,180 g CO_2 kg-1 fuel. For all other vehicle categories, speed dependent CO_2 (ultimate) emission factors (in g/km) for Euro standards up to Euro II were derived from NETCEN (2003) and, for post-Euro II, from DfT (2005).

For the BAU Scenarios projections to 2010, 2015 and 2025, the percentage change (over baseline 2003 levels) of VKT by major vehicle category for England from the DfT's National Transport Model (NTM) were used (presented in DfT, 2008d) and it was assumed these applied to the UK as a whole. Projected changes in distribution of these kilometres travelled between road type (rural, urban or motorway) were derived from the percentage changes given in the DfT's Road Transport Forecasts 2008 (DfT, 2008e).

BAU assumptions

Transport measures incorporated into the NTM forecasts include graduated vehicle excise duty (VED), company car tax (CCT), fuel duty, the Renewable Transport Fuels Obligation (RTFO), the voluntary agreements on new car fuel economy (VAs) (DfT, 2008e). The bulk of these (VED, CCT, fuel duty

2 The validity of some of these assumptions, especially when applied to our 2050 BAU Scenario, may be open to question. In particular, it might be argued that these fuel cost projections are unrealistically low, especially given that 'peak oil' production may have already been exceeded. However, the methodology used in this study has been to produce an analysis based on existing published forecasts rather than undertaking new modelling.

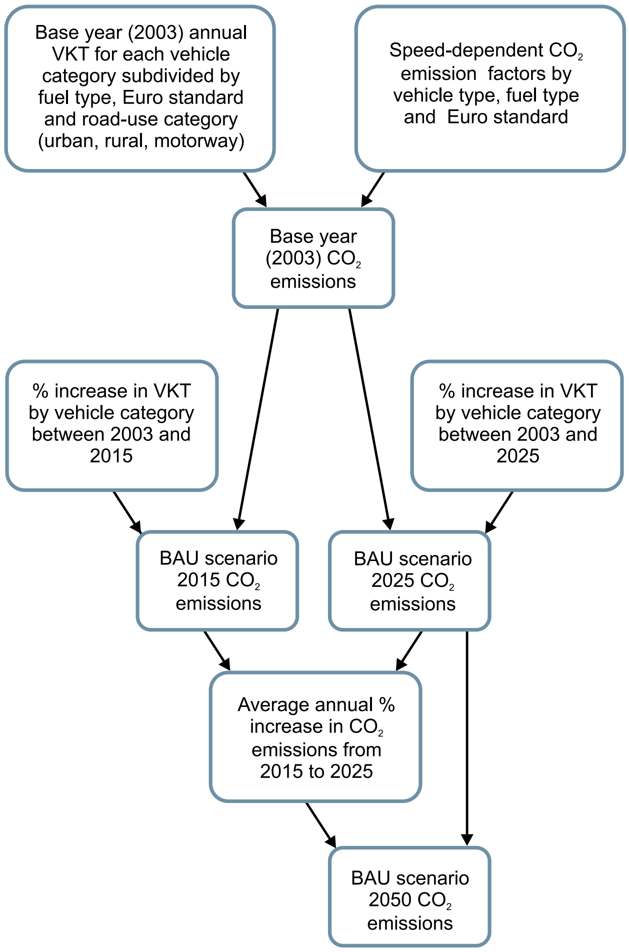


Figure 3.1: Flow chart of methodology used for BAU Scenario CO_2 estimates for road transport

and the VAs) all work to reduce road transport CO_2 by encouraging improvements in fuel economy. The other measure aimed at cutting CO_2 emissions is the RTFO which places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales are made up of biofuels.

The key drivers of traffic growth in the NTM are changes in income, employment, population and falling running or travel costs, as a result of fuel economy improvements. Unfortunately, detailed traffic growth forecasts (by vehicle and road type) are only provided for England and Wales and only up to 2025. It was therefore assumed that rates of change for England also apply to the UK as whole and that the annual percentage increases in traffic for each vehicle category between 2015 and 2025 continue unchanged to 2050. The NTM assumptions for motorcycles and LPG-fuelled vehicles are not stated and are therefore kept constant in the BAU Scenario (2015, 2025 and 2050). The changes in traffic volume adopted in the BAU Scenario are taken from DfT (2008d) and include the assumptions used within the NTM (see box 3.1). For the 2050 BAU Scenario, annual average rates of change in traffic volume between 2015 and 2025 were assumed to continue unchanged up to 2050. Thus, continuation of the above assumptions up to 2050 is implicit in the BAU projections.

Fuel Economy - Improved fuel economy lowers CO_2 emissions. Following the EU negotiations on compulsory targets for new car emissions, the NTM assumes average new car CO_2 emissions reach 130 g/km by 2015 and assumes that improvements in new car fuel economy will continue at an average rate for the recent past of 1.15 per cent per annum for gasoline and 1.35 per cent for diesel through to 2025 (DfT, 2008a). It has been assumed these same rates of improvement apply to LDVs but from an EU agreed target of 160 g/km by 2015 whilst for HGVs the improvement is only 0.8 per cent per annum (DfT, 2008a). For the BAU 2050 scenario, it is assumed the same annual rate of improvement in fuel economy is maintained.

Renewable Transport Fuels Obligation (RTFO) - From April 2008, the RTFO places an obligation on fuel suppliers to ensure that a specified percentage of their aggregate sales are made up of biofuels. The specified amount was 2.56 per cent in 2008/09 and rises each year to a maximum of 5.26 per cent by 2013/14 (Renewable Fuels Agency, 2008).

In addition, the European Commission's (EC) Renewable Energy Directive (RED), which came into force in June 2009, obliges all member states to ensure that 10 per cent of final consumption of energy in all forms of transport is renewable by 2020. This includes renewable energy used to produce electricity used in electric vehicles, including trains, weighted at 2.5 x the energy content of the renewable energy input. Thus the actual per cent biofuel required by 2020 under this directive depends on the extent of electricity supply decarbonisation and, to meet the target, there may need to be an increase in biofuel use above five per cent by 2020. However, for the purposes of the BAU Scenario the NTM assumption of a five per cent biofuel component of all road fuel in 2025 and 2050 has been adopted. Following the NTM methodology, the impact of the RTFO is calculated on an IPPC inventory basis. That is, road transport hydrocarbon fuel sales will fall by five per cent and so total CO_2 emissions will also reduce by five per cent compared with what they would have been. In reality, biofuels production, processing and transport will add to CO_2 (and other GHGs) emissions but these are not included. The actual CO_2 emissions saved depends on the source and type of biofuel and can be estimated by use of for example, the Renewable Fuels Agency carbon calculator.[3]

Box 3.1: NTM Assumptions on population, demographic change, economic growth and fuel costs for road transport

- Population is assumed to rise by 14.5 per cent between 2003 and 2025.
- The over 65 population is forecast to grow from around 20 per cent of the population in 2000 to over 25 per cent by 2025.
- Employment is projected to increase by around 10 per cent over the same period.
- Economic trend growth is assumed to be around 2.5 per cent per annum over the forecast period with Gross Domestic Product (GDP) per capita growing by 2.1 per cent per annum;
- Fuel costs: central projection for 2025 of $72.5 per barrel in 2007 prices. (The projections also include scenarios with a 'high' being $100 and 'low' $45.)[2]
- Constant real prices of cars and non-fuel operating costs.

BAU CO_2 emissions estimates for road transport

Table 3.1 presents CO_2 emissions estimates for UK road transport in the baseline year (2003) and the scenario years (2015, 2025 and 2050). The baseline year emissions of 116 Mt CO_2 compares with the official National Atmospheric Emissions Inventory (NAEI) value of 118 Mt for 2003 (reported in DfT, 2008b). The reasons for the small difference may relate to the use of different CO_2 emission factors or different average speeds assumed for urban, rural and motorway driving. The BAU 2050 scenario estimate of 110 Mt CO_2 is 5.2 per cent lower than the baseline estimate for 2003 (see table 3.1). This is in spite of the increase in traffic projected by 2050 (e.g. 76 per cent increase in passenger car VKT) and is largely a result of the continuous year-on-year improvement in average fuel economy assumed in the BAU Scenario.

3.2 RAIL TRANSPORT

For CO_2 emissions from rail transport, data on diesel and electricity consumed by both passenger and freight rail transport published by Association of Train Operating Companies (ATOC, 2007) were used for a 2006/07 baseline. Due to differences between the ATOC and the DfT's Carbon Pathways Analysis baseline emissions estimates (DfT, 2008a), especially for rail freight, it was decided to use the more detailed ATOC data. Emissions were then estimated according to the percentage increases in CO_2 given by DfT's 'Business as planned scenario', minimum up-take projections (see table 3.2). BAU projections to 2025 and 2050 (see table 3.3) assume a continuation of the average annual percentage increases in CO_2 emissions given in the DfT Carbon Pathways Analysis for the period 2020 to 2022 (i.e. 0.39, 0.65 and 0.85 per cent for diesel passenger, electric passenger and diesel freight respectively).

The DfT's 'Business as planned scenario' takes account of CO_2 saving initiatives that are either planned or that are expected to take place. Projections are expressed as a range bounded by maximum and minimum anticipated levels of saving. The BAU

3 See: www.renewablefuelsagency.org/carboncalculator.cfm

Table 3.1: Business-as-usual baseline (2003) and scenario (2015, 2025, 2050) CO_2 emissions estimates for road transport

Vehicle Type	Baseline (2003) CO_2 emissions (Mt)	CO_2 emissions in 2015 (Mt)	CO_2 emissions in 2025 (Mt)	CO_2 emissions in 2050 (Mt)	Annual % increase in VKT from 2015 to 2025, and applied to 2025 to 2050	Total % change in CO_2 emissions by 2050 over 2003 emissions
Passenger cars	66.4	58.1	57.9	59.6	1.23%	-10.2
Light Duty Vehicles	14.0	14.7	15.5	18.8	2.13%	34.4
Rigid HGVs	9.9	9.1	8.5	7.6	0.37%	-22.7
Artic HGVs	20.8	18.4	18.9	20.6	1.17%	-0.8
Buses and coaches	4.3	3.6	3.2	2.6	0.00%	-38.6
Motorcycles	0.5	0.5	0.5	0.5	0.00%	-5.0
LPG vehicles	0.3	0.3	0.3	0.3	0.00%	0.0
Total:	**116.2**	**104.6**	**104.8**	**110.2**		**-5.2**

projections are based on the minimum values (see box 3.2).

BAU CO_2 emissions estimates for rail transport

Table 3.3 presents BAU emissions estimates for UK rail transport in the baseline year (2006/7) and the scenario years (2015, 2025 and 2050). The baseline year emissions are 3.44 Mt. For the BAU 2050 scenario, the estimate is 34.3 per cent higher than CO_2 emissions in 2006/7).

3.3 AVIATION

The DfT's CO_2 passenger demand and CO_2 forecasts were used to develop the BAU Scenario for aviation (DfT, 2009b). The DfT forecasts passenger demand and CO_2 emissions over two time-periods (2005–2030 and 2030–2050) and use detailed models related to passenger airport choice and projections of economic growth, trade, exchange rates and fares, for the period 2005-2030. It then uses a 'central case' trend in passenger demand and fuel efficiency as well as available airport capacity to project CO_2 emissions for 2050.

In general, the DfT model forecasts the number air transport movements (ATMs) at each airport depending on available capacity which are then combined with projections of average flight distance (depending on type of flight e.g. long-haul, short-haul, domestic etc.) to obtain seat-kilometre projections by airport. These are then combined with a projection of the fleet fuel efficiency taking into account different aircraft type and configurations. There are a number of assumptions made within the DfT forecasts. Box 3.3 highlights the key assumptions in the BAU Scenario.

Under the assumption that airport capacity is not constrained, the DfT forcast that air travel demand at UK airports will grow strongly (under their central case scenario), from 241 million passengers per annum (mppa) in 2007 to 465 mppa in 2030 (within the range 415-500 mppa). This will lead to a growth in UK aviation CO_2 emissions (covering both domestic and international aviation) from 37.5 Mt CO_2 in 2005 to 58.4 Mt CO_2 in 2030, within the range 51.8 Mt CO_2 to 61.6 Mt CO_2. After 2030, the growth in aviation emissions is projected to slow, partly due to market maturity, limits to improvements in aircraft efficiency and capacity constraints slowing demand growth. By 2050 aviation emissions are projected to have stabilised, at 59.9 Mt CO_2 within the range 53.0 Mt CO_2 to 65.0 Mt CO_2 (see table 3.4).

These DfT figures have been used in the BAU Scenario however, it is important to mention that aviation emissions contribute more to climate change than do

Box 3.2: Assumptions of the DfT's 'Business as planned scenario' for rail transport

- Rail growth occurs in line with the High Level Output specification (HLOS)/Freight Route Utilisation Strategy estimates and is accommodated through additional trains to maintain crowding at constant levels and running additional freight services;
- the electricity generating mix becomes cleaner over time based on the Department for Business, Enterprise and Regulatory Reform (BERR) projections;
- regenerative braking is in place across the electrified network;
- new trains coming into service reflect an increased emphasis on energy efficiency compared with recent designs;
- rail uses a five per cent biofuel mix from 2010; and
- introduction of a range of energy saving initiatives e.g.: driver training, improved idling and stabling policies.

Table 3.2: UK CO_2 emissions (tonnes, '000) under a 'business as planned' maximum and minimum take up of measures. source: dft

Year	2008		2014		2020		2022	
	Max	Min	Max	Min	Max	Min	Max	Min
Passenger Rail	2,696	2,704	2,730	2,895	2,988	3,136	3,018	3,168
Of which –Electric trains	1,425	1,432	1,450	1,540	1,584	1,665	1,596	1,678
Diesel trains	1,271	1,273	1,280	1,355	1,404	1,472	1,422	1,491
Freight rail (all diesel)	644	644	569	600	607	640	618	651
Total rail:	**3,340**	**3,349**	**3,298**	**3,495**	**3,594**	**3,776**	**3,636**	**3,819**

Table 3.3: Business-as-usual baseline (2006/7) and scenario (2025 and 2050) CO_2 emissions for rail transport

Vehicle Type	Baseline (2006/7) CO_2 emissions (Mt)	CO_2 emissions in 2022 (Mt)	CO_2 emissions in 2025 (Mt)	CO_2 emissions in 2050 (Mt)	Annual % increase in CO_2 emissions used for 2025 and 2050 estimates	Total % change in CO_2 emissions by 2050 over 2006/7 emissions
Diesel passenger rail	**1.24**	**1.45**	**1.47**	**1.62**	**0.39%**	**30.6**
Diesel freigh rail	**0.76**	**0.77**	**0.49**	**0.98**	**0.86%**	**28.5**
Electric passenger rail	**1.44**	**1.69**	**1.73**	**2.03**	**0.65%**	**40.5**
Electric freight rail	**0.0**	**0.0**	**0.0**	**0.0**	**0.0%**	
Total:	**3.44**	**3.91**	**3.98**	**4.62**		**34.3**

Box 3.3: Assumptions of the DfT BAU Scenario for aviation

Financial

*Oil Price: u*nder the BAU there a number of financial assumptions which affect ticket price. Regarding fuel cost, there is an assumption about the relationship between aviation fuel consumption and oil prices. The price of oil is assumed to move in line with the BERR central oil price projection (2007 prices \$73 - \$68 per barrel in 2015) however in 2008 oil prices were around \$100 per barrel. This could be a continuing trend if the current economic situation continues. Also in the future the price of oil may be much higher as stocks are depleted and extraction gets harder. This will affect demand as the cost could be passed on to the passenger through higher ticket prices. DfT predictions show that using a slightly higher 2030 oil price of just \$80 a barrel in its forecasts would lower demand by 15 million passengers a year. Higher oil prices could even lead to air services ceasing as the cost of running air fleets becomes too expensive for some airlines.

Air Passenger Duty/Carbon cost: the BAU assumes that Air Passenger Duty (APD) will increase in 2009 and 2010 and will continue in real terms thereafter. An Carbon Tax may also be applied in addition to the APD. Whilst this tax has only been mooted at the moment it is probable that ticket prices will include a component attributable to the carbon impact of flying. This tax will also reflect both direct carbon emissions and other warming-effects of non-carbon emissions into the atmosphere.

European Emission Trading Scheme (EU ETS) starting in 2012 aviation will be included in the EU Emission Trading Scheme. This means that the industry will be allocated a certain number of carbon credits based on average emission figures for (2004-2006) otherwise know as the 'cap'. Under the operating rules of the ETS, if passenger numbers (air traffic movements) increase then the aviation industry would either have to reduce emissions through improvement in efficiency (engine technology, airspace management etc.) or purchase carbon credits from other airline companies if the ETS is operating under a 'closed' system or with companies in other sectors if operating in an 'open' system. If they have to buy more credits then this cost could be passed onto the passengers. If the price per tonne of carbon rises significantly because of the need to buy the additional credits then the ticket price becomes too expensive for passengers and this leads to a reduction in demand.

Exchange rate: one further factor affecting demand for air travel, especially in leisure and tourism markets, is fluctuating exchange rates. In terms of European travel, there might be a shift towards more domestic vacations. A shift in people's decision to visit long haul destinations to take advantage of better exchange rates may also occur. However, the DfT methodology assumes this remains constant over the period.

Technology

Engine Efficiency: under the BAU there will be an overall improvement in the fuel efficiency of the aircraft fleet. More efficient aircraft types will replace older aircraft and those not replaced will be retro-fitted with new technology. The model assumes the industry will make technological gains consistent with the manufacturers' ACARE target for fuel efficiency such that a proportion of aircraft coming into service in 2020 are 40 per cent more fuel efficient than those in service in 2000. These targets are voluntary and therefore there is no guarantee that they will be attained. Also, there is a long product life-cycle involved in designing and implementing new technology in aviation. Under more stringent economic conditions existing fleets may be used for longer. Fuel efficiency improvements within both the BAU and the MI Scenarios do not include biofuels/hydrogen as their uptake is too uncertain.

Behavioural: under the BAU it is not foreseen that there will be a significant shift away from air travel through direct behaviour change. The air-ticket price will be the deciding factor on which most people choose to fly. However, the cost of businesses travel will have little effect on demand.

emissions from other transport modes due to non-CO_2 warming effects. An 'uplift factor' or multiplier is often applied to CO_2 from aviation to account for the fact the aircraft emit other greenhouse gases into the stratosphere, mainly nitrogen oxide and water vapour which have the potential for causing global warming (there is also the potential for some cooling as well, but to a lesser extent). The value used for the multiplier is based on the Radiative Forcing Index (RFI) which is the ratio of total radiative forcing (RF) of all GHGs to RF from CO_2 emissions alone (IPCC, 1999). The extent to which these contribute to climate change is much debated and a range of values is given in the literature, typically between one and four. For example, the IPCC report (1999) Aviation and the Global Atmosphere estimated it to be 2.7 (with an uncertainty of ± 1.5). However, following work by Sausen *et al.* (2006), this has been revised to take into account the uncertainty in

Table 3.4: DfT Business-as-usual baseline (2005) and scenario (2030 and 2050) CO_2 emissions estimates for aviation

Scenario	Baseline (2005) CO_2 emissions (Mt)	CO_2 emissions in 2030 (Mt)	CO_2 emissions in 2050 (Mt)	Total % increase by 2050 over 2005 emissions
Low	37.5	51.8	53	41%
Central	37.5	58.4	59.9	60%
High	37.5	61.6	65	73%

Source: DfT (2009)

the global warming effect from cirrus clouds and the DfT report (DfT, 2009b) uses an uplift factor of 1.9. Also, the Stockholm Environment Institute (SEI, 2009) suggest that a multiplier of "at least 2" is required to capture aviation's climate change impact. Therefore, in light of the uplift factor used by DfT and that suggested by SEI, a reasonable estimate of the full total CO_2 emissions including non-CO_2 warming impacts from UK aviation would be effectively doubled (74 Mt CO_2eq) in 2005.[4]

No attempt has been made to develop an alternative model for aviation. The BAU Scenario assumptions are designed to be in agreement with those of the DfT. However, Stanton and Ackerman (2008) have commented on the assumptions used by the DfT and suggest that the net economic benefits that can be gained from the increase in passenger numbers following the introduction of a third runway at Heathrow are over-inflated. A similar view is adopted in this study. The case made by government for the growth of aviation, or its role in supporting the national economy or its presumed benefits in terms of jobs created or international competitiveness is not accepted. These are wider issues than estimating the end-point for the growth of aviation on BAU assumptions and the DfT view of this end point is accepted.

BAU CO_2 emissions estimates for aviation

Table 3.4 presents the DfT's BAU emissions estimates for UK aviation in the baseline year (2005) and the scenario years (2030 and 2050). The baseline year (2005) emissions are 37.5 Mt. For our BAU 2050 scenario, we have chosen the central DfT estimate of 59.9 Mt CO_2 which is 60 per cent higher than CO_2 emissions for aviation in 2005.

4 For a more detailed review of the use of the 'uplift factor' see http://www.CO$_2$offsetresearch.org/aviation/index.html

3.4 SHIPPING

Shipping is an international activity responsible for the mass movement of cargo and freight over long distances. It is largely controlled by the International Maritime Organisation (IMO) which has the responsibility for controlling and regulating air pollution from shipping under the MARPOL ("MARine POLlution") convention 73/78. One hundred and fifty countries are signatories to the convention which covers 98.7 per cent of all shipping.

An IMO GHG Study found that in 1996, shipping accounted for 1.8 per cent of world's total CO_2 emissions. However, a more recent estimate undertaken in 2007 put this figure at 2.7 per cent or 843 Mt CO_2. This difference is explained by improvements in a more detailed methodology which takes into account shipping activity rates and fuel consumption. The study also forecasted future global emissions using IPCC scenarios and by 2050, in the absence of any regulations, emissions were predicted to rise by 2.4 to 3.0 times (MEPC, 2008). Emissions in 2050 could be between 2.4 and 3.6 Gt CO_2 representing 10 - 15 per cent of global CO_2 emissions according to the UK Committee on Climate Change (CCC) scenarios.

Global emissions from shipping are greater than those from aviation and global growth rates are reflected in UK growth rates. Since the early 1990s, UK port container traffic has increased from approximately 3.5 million twenty-foot equivalent units (TEU) in 1990 to nearly nine million TEU in 2007 (DfT, 2007). Such levels of growth are clearly at odds with other emission reduction targets.

The calculation of emissions from shipping is relatively easy where energy consumption is directly proportional to the quantity of fuel that is used which in turn is proportional to CO_2 emissions. The allocation of global shipping emissions to the UK is problematic due to a number of different methodologies that could be used. This is partly due to ship ownership and operational differences but also governance overseeing legislation and emission controls. With regard to adjusting UK GHG targets the CCC states: "It is not clear what methodology for estimating the UK's international shipping emissions should be used as the basis for such an adjustment." (CCC, p 329). The four main emission allocation options are those based on:

- bunkers sales/bunker consumption;
- freight tonne kilometres;
- country of departure/destination;
- zone of emissions within radius of coastline (12 miles/200 miles).

Shipping has been left out of the Kyoto Protocol due to the difficulties of estimating emissions and the methodology by which they are assigned to different nations. Under the United Nations Framework Convention on Climate Change (UNFCCC), countries are not required to produce a GHG emissions inventory for shipping as they do for other sectors. However, they do have to provide an inventory for fuel bunker sales which is reported as a footnote. This reported figure does not give an accurate picture of the fuel consumed by UK ship operators. Since 1998 there has been a decrease of 23 per cent in emissions from UK shipping bunkers, although there was a 1.5 per cent increase from 2006 to 2007. This is related to the fact that UK operators purchase most of their fuel outside the UK either because it is cheaper or for operational reasons. When ships stop en-route to refuel in other countries, these bunker fuel sales, and associated CO_2 emissions, are then attributable to the host country where fuel is uploaded not to the country where the ship is registered or to the country where the ships cargo is off-loaded. The other confounding issue is the use of flags of convenience or 'flagging out' of ship fleets. This practice switches the ship's registration to another country, with the purpose of minimising operational costs as well as a way to avoid regulatory requirements. The implication is that it is difficult to identify who is the legal authority required to regulate for pollution or environmental damage. Furthermore, if emissions are allocated on the basis of freight tonnes kilometres then there is a problem as the vessel may stop-off at a number of ports en-route dropping-off/picking up cargo. It is difficult to calculate the emissions on freight moved and to

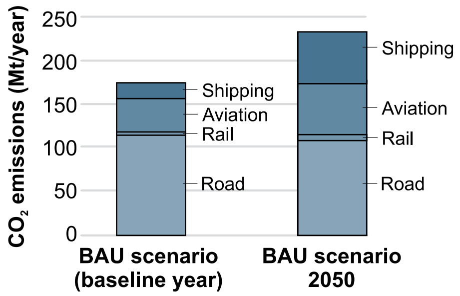


Figure 3.2: Baseline and BAU 2050 scenario estimates of UK transport CO_2 emissions used for this study (as Mt CO_2 yr^{-1})

keep track of who should be responsible on the basis of territory/ship owner for the emissions along each segment of the journey.

A wide range of published estimates for current baseline levels of CO_2 emissions exist. Future projections are then based on a set of key drivers for growth:

- economic activity (GDP and value of imports and exports);
- trade activity (tonnes and tonne / kilometres);
- fuel usage (sales and estimates); and
- installed power.

However, uncertainties in these estimates increase significantly when projecting emissions to future years.

The BAU shipping scenario is based on the annual growth rate of 2.6 per cent per annum as suggested by Entec (2008). Entec project emissions between 2000 and 2020 and these are assumed to continue up to 2050 at a 2.6 per cent per annum increase. This growth rate can be applied for any of the allocation methods. However, we are only considering emissions allocated to freight tonne kilometres (FTK) as this avoids the problem of ships refuelling elsewhere or operating under countries' flags. FTK is a measure of economic activity and so essentially this is an allocation of responsibility, i.e. who is making the economic returns from the transport of the cargo.

BAU CO_2 emissions estimates for shipping

Table 3.5 presents BAU emissions estimates for UK shipping in the baseline year (2005) and the scenario years (2030 and 2050). By 2050, CO_2 emissions from shipping are projected to increase by over 200 per cent.

Table 3.5: Business-as-usual baseline (2005) and CO_2 emissions estimates (2030 and 2050) for shipping based on freight tonne kilometres

Baseline (2005) CO_2 emissions (Mt)	CO_2 emissions in 2030 (Mt)	CO_2 emissions in 2050 (Mt)	Total % increase by 2050 over 2005 emissions
18.87	35.85	59.91	217%

3.5 SUMMARY OF BAU EMISSION ESTIMATES

Table 3.6 compares the baseline BAU CO_2 emission estimates with those reported in a number of recent UK studies on low carbon transport. The estimates for road and rail transport are generally in line with these studies. Estimates for aviation vary depending on whether or not international aviation is included. Emissions from shipping include those from domestic and international shipping and are considerably higher than reported elsewhere because of the methodology used to allocate emissions to countries. For shipping this is based on FTKs as this better represents UK economic activity.

Freiburg - Vauban © kaffeeeinstein/flickr

Table 3.6: Baseline and BAU Scenario estimates of UK transport CO_2 emissions (as Mt CO_2 yr-1) compared to other studies

This Study	Category	Baseline value (year)	2020	2025	2030	2050	Per cent increase (+ve) or decrease (-ve) in 2050 compared with baseline
Towards a Zero Carbon Vision for UK Transport	Total transport	176 (composite year)		199		235	+34%
	Road	116 (2003)		105		110	-5.2%
	Rail	3.4 (2006/7)		4.0		4.6	+34%
	Aviation (Dom and Intern)	38 (2005)			58	60	+60%
	Shipping (Dom and Intern)	19 (2005)			36	60	+217%
Other Studies							
COCC - Committee on Climate Change Building a Low-carbon Economy (2008)	Total transport	169 (2006)					
	Domestic transport	130 (2006)					
	Aviation (Dom and Intern)	38 (2006)					
	Shipping	9 (2000)					
DfT - Carbon Pathway Analysis: Informing Development of a Carbon Reduction Strategy for the Transport Sector (2008)	Total transport	131 (2006)	129				
	Road	120 (2006)	116				
	Rail	3.3 (2006/07)	3.6 - 3.8				
	Aviation (Dom)	2.3 (2006)	2.9				
	Shipping (Dom)	5.5 (2006)	6.2				
VIBAT - Visioning and Backcasting for UK Transport Policy (2007) [Note: these values have been converted from values originally expressed in MtC rounded to the nearest whole number.	Total transport	150 (2000)			191		
	Road	139 (2000)			180		
	Railways	7 (2000)			4		
	Aviation (Dom)	4 (2000)			4		
	Shipping	4 (2000)			4		

4 MAXIMUM IMPACT SCENARIO

The Maximum Impact (MI) Scenario outlines different policy pathways that will move the UK towards achieving a zero carbon transport system by 2050. There are three precursors to the MI Scenario:

- the OECD Environmentally Sustainable Transport (EST) study (OECD, 2002);
- the Visioning and Backcasting for UK Transport Policy (VIBAT) (Hickman and Banister, 2007);
- the Campaign for Better Transport study on A Low Carbon Transport Policy for the UK (Buchan, 2008).

4.1 PREVIOUS LOW CARBON TRANSPORT STUDIES

OECD EST study

The OECD's EST study used a backcasting exercise to define a desirable future for transport that looked beyond just CO_2 emissions. It demonstrated the feasibility of reductions in transport activity by the year 2030 compared to a BAU Scenario in 2030. In a backcasting exercise, goals are set and there is a working backwards – backcasting - to determine what must be done to reach them. Policy development is based on forecasting results in an attempt to change projected trends to avoid an undesirable future. Policy development based on backcasting results in doing what is necessary to achieve a desired future (See figure 4.1). The EST study proposed a range of policy instruments which included regulations (emission and CO_2 standards and limit values), economic instruments (such as fuel and road pricing and fiscal incentives and disincentives) and changes in infrastructure investment policies and land-use planning. Information dissemination and education to raise public awareness about the problems and possible solutions and alternatives also play key roles in the proposed strategies. The study concluded that although environmentally sustainable transport is attainable, this will only be achieved with a broad-based and concerted commitment. Key challenges lie in the acceptability of the strategies and their component instruments rather than in the effectiveness of the instruments themselves. The study recommends that issues of acceptability are best addressed by careful phasing of the application of instruments across the whole implementation period until 2030. Issues of effectiveness are best addressed by careful monitoring of the effects of instruments and appropriate adjustment of the vigour of their implementation (OECD, 2002).

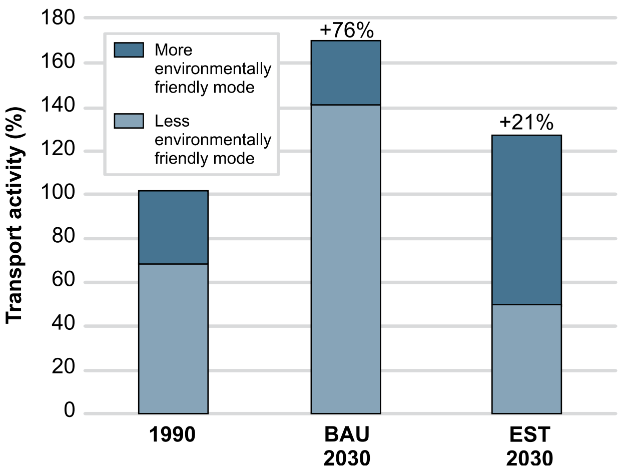


Figure 4.1: OECD Environmentally Sustainable Transport (EST) project results comparing the baseline situation (1990) with the BAU (2030) and the preferred scenario in 2030 (aviation excluded)

VIBAT study

The VIBAT study, funded by the DfT Horizons Research programme, does not include international aviation or shipping. This study produced 123 individual "measures" that would produce a 60 per cent reduction in CO_2 emissions by 2030 and these were assembled into eleven policy packages. It concludes that a 60 per cent reduction in domestic transport by 2030 is possible with some important qualifications:

> *"But it is travel behaviour that the real change must take place, and this should be implemented at the earliest possible occasion. Changes in the built environment will be effective in the medium term (over 10-15 years), whilst the major contribution of technological innovation will be effective after 2020. However, it is not possible to achieve the 60% CO_2 reduction target (in 2030), with the expected growth in travel, as the increase in CO_2 emissions from the growth outweighs many of the possible savings from behavioural change and technological innovation. "*

Low Carbon Transport Policy study

The 'Low Carbon Transport Policy for the UK' study, produced for the Campaign for Better Transport (Buchan, 2008), undertook an analysis and made policy recommendations to show that it is possible to reduce:

- overall CO_2 emissions from transport by 26 per cent by 2020 compared to 2006 figures;
- passenger travel emissions by 32 per cent;
- freight emissions by up to 19 per cent;
- fuel use by 25 per cent by making cars more fuel efficient;
- car traffic by 15 per cent;
- domestic aviation emissions by 30 per cent.

The policy package outlined includes a range of quick-win measures on business travel, including commuting and freight, and funding to switch local car journeys to walking and cycling. Longer-term measures include a new national travel card, parking controls in new developments, changes in planning guidance and tax changes to reward low-carbon travel. The study identifies a number of different policy packages that will reduce CO_2 emissions in aviation, freight and passenger transport. It demonstrates that a 26 per cent reduction in CO_2 is possible by 2020 and that:

> *"These reductions would be in line with those required for the UK generally to achieve 80 per cent reduction in emissions by 2050."*

Towards a Zero Carbon Vision for UK Transport study

The approach used in developing the MI Scenario for the present study takes the form of a backcasting exercise similar to that used in the OECD and VIBAT studies and examines future scenarios for CO_2 emissions from the transport sector in the UK (see figure 4.2). This MI Scenario envisions a radically different Britain by 2050, where the UK transport sector emits close to zero CO_2. A wide range of measures known to reduce CO_2 emissions from transport were examined to see the extent to which these measures can have a maximum impact on the transport sector and realise the vision of a zero carbon transport sector in the UK. These measures are grouped into in four categories (Spatial planning, Fiscal, Behavioural and Technology) and the impacts of each assessed separately in order to allow their relative efficacy to be assessed. For passenger and freight railways, a single technological intervention only is applied: complete electrification of the UK rail network. Biofuels are assumed to have only a minimal role given they are usually considered to be far from 'carbon neutral' and have been associated with adverse land-use issues and other drawbacks identified in the Gallagher review (Renewable Fuels Agency, 2008).

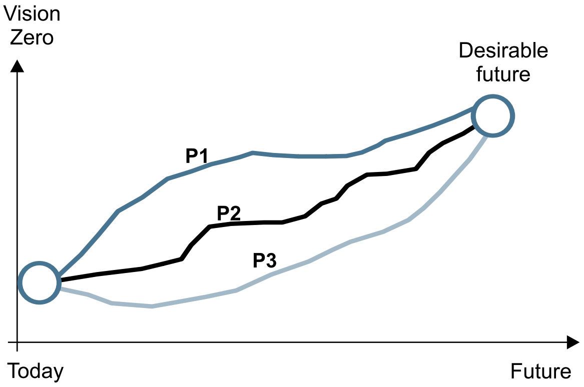


Figure 4.2: A backcasting approach

A transport system in which plug-in electric vehicles (PEVs) or hydrogen (H) fuel cell vehicles predominate, combined with a carbon-neutral electricity supply, is seen as probably the only way that a near zero CO_2 emission transport sector can be achieved in 2050. This was also the view of the King review (HM Treasury, 2007) in which it is stated that:

> *"In the long-term (possibly by 2050 in the developed world), almost complete decarbonisation of road transport is a possibility. If substantial progress can be made in solving electric vehicle technology challenges and critically, the power-sector can be decarbonised and expanded to supply a large proportion of road transport demand, around 90 per cent reduction per kilometre emissions would be achieved across the fleet."*

This is also a view reflected in the DfT's Carbon Reduction Strategy for Transport (DfT, 2009a) which envisages that by 2050, road and rail transport will be largely decarbonised and powered by clean electricity. The UK Energy Research Centre (UKERC) has explored scenarios for the possible development of the UK energy system to achieve the UK Government's Climate Change Act target of 80 per cent CO_2 reduction by 2050 (UKERC, 2009). Under UKERC's low-carbon core scenario, electricity generation would undergo progressive decarbonisation to produce a 93 per cent reduction in CO_2 emissions by 2050 compared with their reference scenario. Under the UKERC 'super ambition' (CSAM) scenario, almost complete decarbonisation of UK electricity supply is envisaged by 2050. It has therefore been assumed that, for the purposes of the present analysis, a carbon-neutral UK electrical power supply could be achieved by 2050, although undoubtedly this would represent a huge challenge.

For aviation and shipping, the options for reducing emissions are more limited but nevertheless a full range of technology and operational measures that can be implemented over the next forty years have been applied. Biofuels are also not considered a viable fuel replacement for aviation or shipping. There is also the assumption that the EU emissions trading system (ETS) will lead to efficiency improvements in both sectors as well as possible price effects in the case of aviation.

The following methodology was used to avoid overestimating the combined effect of more than one measure applied to the same category. Clearly, two measures each reducing CO_2 emissions by 50 per cent when applied separately, would not give 100 per cent emissions reduction in combination. The 50 per cent reduction of the second measure would only apply to the 50 per cent remaining after the first measure, the total reduction being 75 per cent. The same logic applies to combining the effect of any number of measures. For example, if there are three measures to be combined and measure M1 alone reduces CO_2 emissions by x%, measure M2 alone reduces emissions by y% and measure M3 alone reduces emissions by z%, the combined effect of all three (Mcomb) is calculated as:

$$M_{Comb} = 100 - (1-x/100) \times (1-y/100) \times (1-z/100) \times 100\%$$

(Equation 1)

The order in which the measures are arranged in the equation is irrelevant as the result is the same. The same approach is used when applying a particular reduction measure annually over several years as we have done for air fare increases and the road fuel price escalator (FPE). If the annual decrease in emissions is x % and the period of time over which it takes place is T years then the total reduction M is calculated as:

$$M = 100 - (1 - x/100)^T \times 100\%$$

(Equation 2)

The following sections outline the assumptions used and CO_2 reduction achieved from different transport modes when a range of spatial planning, fiscal, behavioural and technology measures are applied.

4.2 ROAD TRANSPORT

Spatial planning

This category covers aspects of spatial planning that are known to support sustainable transport. It mainly focuses on urban planning, encouraging walking by pedestrian-oriented design (ease of access to shops and other amenities), reallocating road space (to pedestrian only streets, cycle tracks, bus lanes, grass verges etc.) and high occupancy only vehicle (HOV) lanes. There is clear evidence that high density cities that avoid urban sprawl, and have good quality accessibility policies to deliver services locally, produce significant reductions in VKT (e.g. Kenworthy and Laube, 1999). Also, it is easier to serve more densely populated areas with attractive and efficient public transport systems compared with lightly populated areas. Thus the development of compact cities could significantly reduce urban CO_2 emissions. This category also includes the effect of implementing a 'Regional co-operation model for HGVs'. The regional co-operation model for reducing road freight transport has been advanced by Holzapfel (1995) and is based on an analysis of the potential for substituting regional supply chain linkages for longer distance linkages and reducing the kilometres driven by HGVs by up to 67 per cent.

MI Scenario assumptions for spatial planning:

- **Pedestrian-oriented design**: urban car VKT reduced by 10 per cent (Dierker *et al.*, 2005).
- **Road space reallocation**: urban car CO_2 emissions reduced by 11 per cent (Cairns *et al.*, 1998).
- **High occupancy only vehicle (HOV) lanes**: urban car VKT reduced by 1.4 per cent (VTPI/TDM 2008).
- **Compact development**: for cities >100K population, all traffic VKT reduced by 30 per cent (Reid Ewing, 2008).[5]
- **Regional co-operation model for HGVs**: assume 50 per cent reduction in total VKT (Holzapfel, 1995).

Table 4.1 presents the reduction in CO_2 emissions in 2050 from spatial planning measures used in the MI Scenario.

5 In order to avoid double-counting, the 30 per cent value is assumed to include the impacts of the first three assumptions (Pedestrian-oriented design, Road space reallocation and HOV lanes) which, therefore, are not applied to urban traffic in cities with a population > 100,000 in addition to the 30 per cent.

Fiscal

Financial incentives and disincentives in the form of charges, tax increases, fare subsidies (for public transport) can have a powerful effect on people's transport choices from the type of car they purchase (if at all) through to choice of transport mode for each individual journey. This category covers road user charges and charging for parking spaces which can also shift car users to other, more sustainable, forms of transport.

The Fuel Price Escalator (FPE) is the practice of automatically increasing hydrocarbon oil duty (i.e. 'fuel tax') in the UK by more than inflation. It was first introduced by a Conservative government in 1993 when it was set at an annual increase of three per cent, later rising to five per cent, and then continued by the Labour government in 1997 at a higher rate of six per cent per year. The FPE was abandoned after the UK fuel protests of 2000. For fuel price, it is assumed there will be a re-introduction of the FPE at five per cent per annum above inflation in 2010 and maintained through to 2050. This will result in a seven-fold (i.e. 600 per cent) increase in the cost of fossil-fuel derived hydrocarbons (e.g. gasoline, diesel, LPG) for all road vehicles by the end of the 40 year period. The escalator would not apply to electricity used to charge PEVs or to produce hydrogen for hydrogen fuel cell vehicles and hence produce a progressively stronger incentive to choose these cleaner alternatives.

The vehicle excise duty (VED), sometimes termed a 'circulation tax', is a recurrent charge levied by the government on vehicles used on the public road. It can be linked to fuel efficiency or engine size and so influence CO_2 emissions through altered vehicle purchase choice.

Vehicle purchase taxes are levied when vehicles are purchased and can be specifically aimed at reducing CO_2 emissions as, for example, in so-called 'feebate' tax structures that offer buyers rebates for choosing low CO_2 emitting vehicles and penalties for buying high CO_2 emitting vehicles. Other financial incentives include subsidising public transport fares to encourage up-take of these more CO_2 efficient modes.

MI Scenario assumptions for Fiscal:

- Road user charges: three per cent reduction in all traffic (Kollamthodi, 2005).
- Workplace car parking charges: CO_2 emissions from commuting by car reduced by 12 per cent (Shoup, 2007). Thus, assuming 25 per cent of total car CO_2 emissions are due to commuting (DfT, 2008a; 2008e) this equates to a three per cent reduction in total passenger car CO_2 emissions.

Table 4.1: The impact of the MI Scenario 'spatial planning' measures on CO_2 emissions in 2050

Vehcile Type	Baseline (2003) CO_2 emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions due to MI Spatial measures (%)
Passenger cars	66.4	59.6	48.2	-19+-
Light Duty Vehicles	14.0	18.8	17.8	-5
Rigid HGVs	9.9	7.6	3.7	-52
Artic HGVs	20.8	20.6	10.2	-51
Buses and coaches	4.3	2.6	2.4	-9
Motorcycles	0.5	0.5	0.4	-14
LPG vehicles	0.3	0.3	0.3	0
Total:	**116.2**	**110.2**	**83.0**	**-25**

- Urban, non-commuting car parking charges: A 13 per cent reduction in urban car VKT assuming: (a) VKT elasticity factor of -0.07 (average quoted for predominantly urban areas by Litman (2009); (b) 75 per cent of car CO_2 emissions are for non-commuting purposes (DfT, 2008a; 2008e) assuming that this also applies to urban car use; and (c) average parking charges increase in real terms by 10 per cent per annum from 2010 to 2030, to give a 570 per cent final increase.

- Fuel price: A five per cent per annum fuel price escalator is introduced from 2010 onwards producing a 600 per cent fuel price increase by 2050 for all road vehicles. A short-term elasticity factor of -0.25 for fuel consumption (Goodwin *et al.*, 2004) applied annually results in a 40 per cent reduction in CO_2 emissions for all fossil fuel powered road vehicles by 2050. (An implicit assumption here is that there will be progressive availability of non-CO_2 emitting alternatives such as electric vehicles powered by carbon neutral electricity, and carbon neutral public transport systems).

- VED circulation tax: Increased differentiation reduces VKT for all cars by 4.8 per cent (COWI, 2002).

- Car purchase tax and 'Feebate' systems based on fuel consumption: Reduces VKT for all cars by four per cent (Anable and Bristow citing Van den Brink and Van Wee, 2001).

- Public transport fares subsidy: a 30 per cent reduction in fares will reduce CO_2 emissions for all cars by two per cent (UKERC, 2009b).

Table 4.2 presents reduction in CO_2 emissions in 2050 from fiscal measures used in the MI Scenario.

Behavioural change

Although fiscal measures and spatial planning will usually reduce transport related CO_2 emissions through their effect on peoples' behaviour, some measures can be regarded as 'purely' behavioural and these are included here. 'Ecological driving' can reduce fuel use by means of information campaigns, better vehicle maintenance (including correct tyre pressures), in-car information systems and courses on driving style (smoother driving etc.). Vehicle CO_2 emissions vary with speed and can be minimised if the vehicles are made to keep to lower speeds, especially on motorways. Car sharing increases vehicle occupancy and reduces the number of vehicle journeys needed so reducing CO_2 emissions. Much freight that is currently hauled by road could be transported by rail, inland waterways and coastal shipping, all these alternatives being much less carbon intensive per tonne-kilometre moved. There is also a variety of mainly behavioural measures, termed 'Smarter choices' by

Table 4.2: The impact of the MI Scenario fiscal measures on CO_2 emissions in 2050

Vehcile Type	Baseline (2003) CO_2 emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions due to MI Fiscal measures (%)
Passenger cars	66.4	59.6	19.9	-67
Light Duty Vehicles	14.0	18.8	8.9	-53
Rigid HGVs	9.9	7.6	3.6	-53
Artic HGVs	20.8	20.6	9.8	-53
Buses and coaches	4.3	2.6	1.5	-41
Motorcycles	0.5	0.5	0.3	-41
LPG vehicles	0.3	0.3	0.3	0
Total:	**116.2**	**110.2**	**44.3**	**-60**

Cairns *et al.* (2004), including workplace travel plans, home working and teleworking, travel awareness and education, public transport information and marketing, personal travel plans, local collection points, school travel plans, home shopping and car clubs. Although these measures can make an important contribution to CO_2 emission reduction from road transport, there is considerable overlap with both spatial measures (e.g. compact development) and fiscal measures (e.g. parking charges) already dealt with above. Therefore, to avoid the danger of double-counting, 'Smarter choices' have been omitted for the purposes of the current analysis. Thus estimates of the emissions reduction potential of the 'behavioural change' category used here can be considered to be conservative estimates.

MI Scenario assumptions for behavioural:

- Ecological driving: eight per cent reduction in car CO_2 emissions (DEFRA, 2007; King 2008).
- Reducing motorway speed limit to 60 mph and enforcing it: 10 per cent reduction in motorway CO_2 emissions (Commission for Integrated Transport, 2005).
- Car share: reduction in car VKT for urban (8.3 per cent) and rural (3.6 per cent) driving (VTPI/TDM 2008).
- Modal shift for road freight: 20 per cent reduction in CO_2 emissions from HGVs (Whitelegg, 1995).

Table 4.3 presents reduction in CO_2 emissions in 2050 from behavioural measures used in the MI Scenario.

Technology

The internal combustion engine (ICE) has been the predominant form of propulsion for road vehicles for over 100 years and continued increases in ICE engine efficiency, as assumed for the BAU Scenario, will deliver substantial CO_2 emission savings. Further savings could be achieved through a large-scale shift to highly efficient, smaller diesel engines. However, in the likely absence of large-scale availability of sustainable biofuel substitutes for all fossil fuels currently used in transport, a radical shift to other technologies will be required in order to achieve a near zero carbon emission target for this sector by 2050. The New Automotive Innovation and Growth Team (NAIGT) has set out a roadmap, agreed by UK industry, that shows how automotive technology will need to develop to 2050 in order to tackle the CO_2 challenge (See figure 4.3). Although innovations in ICE vehicles and different types of electric hybrids will play a role in the intervening years, by 2050 road transport will have to be largely made up of some combination of PEVs and hydrogen fuel cell vehicles, depending on technology breakthroughs. Of course this technology shift would only deliver a low carbon future if the electricity required to charge the PEVs, or to produce the hydrogen for the fuel cells, comes from carbon-neutral sources such as renewables, fossil fuel combustion with carbon capture and storage (CCS), or nuclear energy. ICE passenger cars, vans and motorcycles would become obsolete in this low carbon future. Lighter HGVs up to 12 tonnes would also be fully electric (DfT, 2009a) although heavier HGVs would need to be powered by hydrogen fuel cells or sustainable biofuels (as described by Baker *et al.*, 2009) in order to achieve carbon neutrality.

MI Scenario assumptions for Technology:

- All passenger cars, LDVs, motorcycles and HGVs/buses less than 12 tonnes in weight to be PEV using 100 per cent renewable electricity or hydrogen fuel cell powered (using carbon neutral sourced hydrogen).
- Heavier HGVs and buses/coaches (>12 tonnes) to be powered by either H fuel cells (with carbon neutral sourced hydrogen) or sustainable biofuel.
- Liquefied petroleum gas (LPG) vehicles completely phased out.

The assumptions in the MI Technology package are different from the first three in that they comprise desired technology end-points rather than a set of policy interventions per se. These technology end-points could arise simply as a result of the spatial, fiscal and behavioural measures described earlier. In particular, the fiscal measures alone may render petrol/diesel powered vehicles prohibitively expensive compared with say, PEVs. Alternatively, a society being adversely affected by climate change in forty years time may reasonably decide to ban any remaining petrol/diesel vehicles completely. In this case the technology assumptions would in a sense, also represent policy interventions. Of course, significant policy interventions would be required to produce the carbon neutral UK electricity power generation sector on which the above assumptions are based, but a detailed analysis of these is beyond the scope of this study.

Table 4.4 presents reduction in CO_2 emissions in 2050 from technology assumptions used in the MI Scenario. Clearly, with 100 per cent carbon neutral electricity, the CO_2 emissions from road transport are also reduced by 100 per cent under these assumptions.

Table 4.3: The impact of the MI Scenario behavioural measures on CO_2 emissions in 2050

Vehcile Type	Baseline (2003) CO_2 emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions due to MI Behavioural measures (%)
Passenger cars	66.4	59.6	48.4	-18.7
Light Duty Vehicles	14.0	18.8	18.1	-3.8
Rigid HGVs	9.9	7.6	5.8	-23.5
Artic HGVs	20.8	20.6	15.3	-25.7
Buses and coaches	4.3	2.6	2.6	-2.2
Motorcycles	0.5	0.5	0.5	-1.5
LPG vehicles	0.3	0.3	0.3	0.0
Total:	**116.2**	**110.2**	**91.1**	**-17.3**

Combined measures

Table 4.5 presents reductions in CO_2 emissions in 2050 from all four categories of road transport measures used in the MI Scenario, both when applied separately and when combined. Each package of measures is first of all considered in isolation so, for example, Spatial planning alone reduces the BAU 2050 total from 110.2 Mt CO_2 to 83.0 Mt CO_2, a reduction of 27.2 Mt CO_2 or 25 per cent. This same calculation is then repeated for each other package of measures so that each row shows their impact on CO_2 emissions in isolation. The final row uses the methodology described in Section 4.1 (using Equation 1 extended to four

Table 4.4: The impact of the MI Scenario technology measures on CO_2 emissions in 2050

Vehcile Type	Baseline (2003) CO_2 emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions due to MI Technology measures (%)
Passenger cars	66.4	59.6	0.0	-100
Light Duty Vehicles	14.0	18.8	0.0	-100
Rigid HGVs	9.9	7.6	0.0	-100
Artic HGVs	20.8	20.6	0.0	-100
Buses and coaches	4.3	2.6	0.0	-100
Motorcycles	0.5	0.5	0.0	-100
LPG vehicles	0.3	0.3	0.0	-100
Total:	**116.2**	**110.2**	**0.0**	**-100**

Note: The effect of measures when combined is somewhat less that the sum of the effects of each separate measure due to the use of a method (explained fully in Section 4.1) that avoids overestimating the effect of combining measures.

Table 4.5: The impact on road transport CO_2 emissions by 2050 of all MI Scenario measures applied both in isolation and when combined

	2005	2050	Reduction in CO_2 emissions (Mt CO_2) relative to	Per cent change in CO_2 emissions relative to
	Emissions (Mt CO_2)		2050 BAU	2050 BAU
BAU Total	**116.2**	**110.2**		
MI measures separately: **Spatial planning**		83.0	27.2	-25%
Fiscal		44.3	65.9	-60%
Behavioural		91.1	19.1	-17%
Technical		0.0	110.2	-100%
The three non-technical MI measures combined		28.0	82.2	-75%
All four MI measures combined		**0.0**	**110.2**	**-100**

terms) to combine all four packages (spatial, fiscal, behavioural and technology); the final result being a 100 per cent reduction in CO_2 emissions due to the fact that technology alone produces 100 per cent reduction. However, as referred to above, the technology assumptions run in parallel with the others so that, for example, the 40 per cent reduction in fuel consumption by 2050 due to the FPE would most likely depend on non-CO_2 emitting transport alternatives such as PEVs being available. For this reason, the combined impact of the three non-technology MI categories only (also calculated using Equation 1) are also shown in table 4.5 in order to indicate what their total effect on CO_2 emissions would be in the absence of a complete switch to carbon neutral technologies. It can be seen

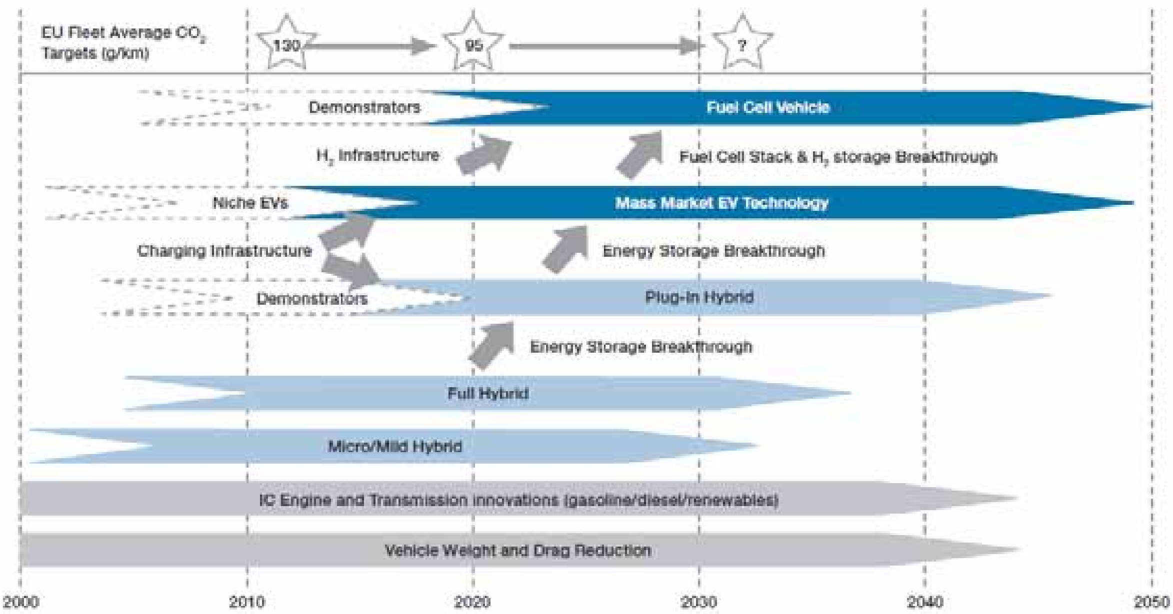


Figure 4.3: High-level technology roadmap for the UK's decarbonisation of road transport

Source: NAIGT (2009)

that together, these non-technical measures would achieve a 75 per cent reduction in CO_2 emissions relative to the BAU 2050 scenario.

In addition to the impact of technology changes, reducing the demand for road transport is also clearly very important. Spatial re-engineering interventions and behavioural change can help to do this but the largest impact on demand comes from fiscal interventions, in particular the FPE. Any remaining demand for private motorised transport can then be met by PEVs or other technologies based on electric power and storage. In assessing the effect of these technological changes, it is assumed that an electricity supply system that is 100 per cent decarbonised will be in place by 2050. The final result is a road transport system that is 100 per cent decarbonised

4.3 RAIL TRANSPORT

Electric trains emit 20 to 35 per cent less carbon per seat-kilometre than diesel equivalents on the basis of the current electricity generation mix (Rail Safety and Standards Board, 2007). This advantage will increase over time as our electricity generation mix becomes less carbon intensive. It is therefore assumed the railway network will be completely electrified by 2050 and that the electricity used will be carbon neutral (i.e. from renewable sources, fossil fuel with carbon capture and storage or nuclear). This is in line with the DfT's Carbon Reduction Strategy for Transport (DfT, 2009a) which envisages that by 2050, rail transport will be largely decarbonised and powered by clean electricity. Hence the MI Scenario assumes that CO_2 emissions from both passenger and freight rail will be zero by 2050.

MI Scenario assumption for railways:

- All passenger and freight rail to be powered by electricity that is 100 per cent carbon neutral.

4.4 AVIATION

The aviation BAU Scenario included changes expected over the next 40-50 years. The DfT's (2009) Low Carbon Transport report recognises that, even in the longer-term, the decarbonisation of aviation (and shipping) and the use of alternative fuel sources will be more challenging than for road and rail modes.

The International Air Transport Association (IATA) (2009) has developed a roadmap towards carbon neutral growth (no increase in emissions as demand continues to grow). The IATA roadmap includes setting emissions standards, use of biofuel and improvement in air traffic management. In the short to mid-term (to 2020) a 1.5 per cent per annum improvement in fuel efficiency is expected. Within this timeframe, the industry is also expected to achieve carbon neutral growth. By 2050, emissions will have reduced by 50 per cent compared to 2005 according to the IATA roadmap; clearly a long way off from zero carbon transport.

The Sustainable Aviation Group (2008) presents a more optimistic future where demand increases threefold by 2050 but emissions from aircraft manage to return to 2000 levels. They suggest that this can be achieved through a combination of new technologies and operational efficiency gains and with ten per cent reduction by using biofuels.

The main way to reduce aviation emissions which is considered in our MI Scenario, is a reduction in flying activity and distance travelled. The MI Scenario sees the need for people to adapt their lifestyles by taking fewer long-haul holidays, international business trips and overall travelling less by air. UK internal flights could be eradicated through substitution of transportation modes that are less GHG intensive than aircraft. In particular, information technology plays a key role in reducing domestic and international air travel in the business sector.

In terms of fiscal measures, the BAU Scenario already incorporates the introduction of the EU ETS which will affect ticket prices and thereby demand. In the MI Scenario there will be higher ticket prices due to a rise in the price of oil and with the introduction of some form of carbon tax. Aviation growth will continue, albeit at an increasingly slower rate, and a general "greening" of attitudes and behaviour will gradually smooth out growth rates in the latter half of the projection. In the MI Scenario no major institutional changes in the aviation industry over the next 40 years are expected. Improvements in airspace management will mean there is a coordinated approach to flight planning and this will be augmented by better communication due to technological developments.

Constraining capacity

The BAU Scenario is based on DfT forecasts for aviation emissions in 2050. These forecasts are based on a scenario[6] which includes additional capacity at Stansted and a third runway at Heathrow. Due to some of the other measures in the MI Scenario, additional capacity will not be required as there will be fewer domestic and international air traffic movements. Therefore, in the MI Scenario the policy that sanctioned the additional runways has been reversed (as subsequently occurred under the 2010 Con-Lib government with respect to the third runway at Heathrow airport). However, growth at airports in terms of air traffic movements and passenger numbers will continue at expected rates using existing airport capacity. This is modelled in the DfT CO_2 forecasts (table G15, pg 148) and shows that in 2050 CO_2 emissions reduce from 59.9 Mt CO_2 under their 's12s2' scenario to 54 Mt CO_2 under their s02 - "maximum use" scenario. Therefore, as a consequence of this intervention measure to constrain demand, we will see a 10 per cent reduction in aviation emissions under our MI Scenario (see table 4.6).

Technology

In this section we evaluate opportunities for technological change that go beyond the technology assumptions already considered in the BAU Scenario. The MI Scenario does not foresee a radical shift in aircraft design or major switch to alternative fuel. It is assumed aircraft manufacturers meet their ACARE objectives to improve fuel efficiency in new aircraft by 2030. After this, additional improvements to the design of existing aircraft, making smaller improvements in efficiency, will be retrofitted in the current fleet. ACARE suggests that from 2021, 0.5 per cent per annum increase in efficiency is feasible with further developments in lightweight materials and turbomachinery (e.g. turbines and compressors) efficiencies. Whilst the technology exists conceptually to produce more efficient aircraft, such as use of blended wing bodied aircraft, airlines retain their existing aircraft fleets for longer (20-30 years) so that even by 2050 the aircraft fleets are based on current designs. In the MI Scenario there will be a replacement of the whole fleet of aircraft by 2050 by scrapping or re-engineering the oldest and most fuel intensive aircraft.

However, one significant development in engine design in the future could be the use of the propfan (or open-rotor/inducted jet) which is a hybrid between a turbofan and a turboprop engine. This type of engine has an open rotor (like a turboprop) with thin, highly swept blades which improves aerodynamic performance at higher speeds. The advantages of this type of engine are speeds comparable to turbojets and reduction in fuel intensity between 51 and 55 per cent compared with conventional engines (Peeters Advies, 2000). These aircraft could be used on short haul flights.

Biofuels will only replace a small proportion of fossil fuel as there is only limited production capacity and it certainly will not be able to be used as a substitute for the whole fleet. Also, there are complex issues and uncertainties regarding using biofuel including the amount of land required to produce feedstock, issues relate to food security and the potential loss of biodiversity that could occur through deforestation and other land-use change.

Predominantly, aviation will still use carbon-based fuels as hydrogen-based propulsion systems are not yet technically feasible. For long-haul flights, there is a design problem with hydrogen because of its low density and therefore to store enough fuel on board would require a much larger aircraft. Once again, this carries with it a number of issues including airport infrastructure requirements. The second and more environmentally sensitive aspect is the need for these aircraft to fly at lower altitudes and releasing water vapour (a greenhouse gas) into the atmosphere. Therefore, a precautionary approach for using hydrogen is taken so as not to detract from the potential for reducing carbon emissions made elsewhere. Finally, synthetic kerosene is another potential substitute fuel which could be produced. However, the production process for synthetic kerosene could lead to even more GHG emissions (CAEP, 2007).

Airlines could also optimise load factors and aircraft configurations especially as in the MI Scenario there will be fewer business passengers. Carriers with large business class cabins have higher emission levels per passenger than those that carry a larger number of economy passengers in the same aircraft type. According to EUROCONTROL (2008) scenarios, the number of seats per aircraft is expected to increase by approximately one per cent per year until 2030.

As a result of the technological improvements but not including radical new technology such as blended-wing aircraft, CO_2 emissions from aviation in the MI Scenario are reduced by 14 per cent in 2050 (table 4.7). This is consistent with the scale of reduction suggested by the Sustainable Aviation Group (2008).

6 In the DfT forecasts this is called the s12s2 scenario

Table 4.6: Reduction in CO_2 emissions in 2050 from constraining demand (no new runways at Heathrow and Stansted) used in the MI Scenario

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Constrained Demand	37.5	59.9	54.0	-10%

Note of Explanation
DfT forecasts for air travel include a new runway at Heathrow. The definition of constrained demand used in this study is no additional runway capacity at any London airport and the effect of removing additional runway capacity is a 10 per cent reduction in demand when the Maximum Impact Scenario is compared with the Business-as-usual Scenario

Operational efficiencies

With regard to air transport management (ATM), there is the potential for reducing aircraft emissions in the air through efficient management of airspace and optimised flight-planning and on the ground through better aircraft handling procedures. The Civil Air Navigation Services Organisation (CANSO) has assessed the long-term potential for efficiency improvements in global air traffic management. They foresee only an additional four per cent improvement above what has been achieved up until 2005 (Stollery, 2008). However, inefficiencies in European airspace enable far greater reductions in CO_2. For example the UK National Air Traffic Service (NATS) plans to cut by an average of 10 per cent of ATM-related CO_2 emitted per flight by aircraft in UK controlled airspace by 2020 (NATS, 2008).

Air traffic control can ensure that emissions are minimised by creating flight plans which have more direct routes and with flexibility to take advantage of tailwinds. These plans will also see aircraft flying at those altitudes that cause the least climate change in relation to global warming potential (GWP). Each GHG has a different capacity to cause global warming depending on its radiative forcing properties, its molecular weight and its lifetime in the atmosphere which taken together determine its GWP. (GWP is defined as the warming influence over a set time period of a gas relative to that of CO_2).

In addition to CO_2, GHGs such as water vapour and nitric oxide, together with nitrogen oxides which are major precursors of ozone (another GHG), are released by aircraft at high altitude (6 - 10 km). Also released are other ozone precursors such as hydrocarbons and carbon monoxide as well as particulate matter (soot, nitrate and sulphate particles), some of which reduce and some of which increase aviation's total climate impacts.

Contrails formed when water vapour freezes at high altitudes, can lead to the formation of cirrus clouds. These are considered to contribute to global warming however their overall effect is highly uncertain (IPPC, 1999). Nonetheless by taking into account weather conditions at high altitudes then aircraft could fly at lower altitudes where appropriate to minimise contrail formation.

Telematics can play an important role in improving operational efficiencies especially through improved

Table 4.7: The impact of the MI Scenario aircraft technology measures on CO_2 emissions in 2050

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Aircraft Technology	37.5	59.9	51.8	-14%

Note of Explanation
The BAU Scenario includes technology changes that were anticipated by the DfT in its scenario work. The technology impacts that have been included in the MI calculations in this table are additional to any BAU technology assumptions.

communication between the aircraft and the ground. Satellite technology such as the European EGNOS/ GALILEO system (a global navigation satellite system or GNSS) can assist navigation and re-routing to avoid difficult or dangerous weather. These can be used for all flight phases (take off/cruise/landing) and mean that the stacking of aircraft over certain parts of the country can be avoided. This arises as aircraft are usually allocated a particular time-slot to land and when they miss their slot by arriving late or because there is congestion on the ground then they need to fly in a holding pattern until a slot becomes available. This extra fuel used leads to increased carbon emissions.

Another area where improvements in airspace management can lead to reduced amounts of fuel consumption and lower carbon emissions is the utilisation of airspace restricted to military operations. This would see greater co-operation between military and civil air traffic control such as proposed under the SESAR programme (EC, 2009) and would see the abolition of fixed military airspace.

There is also the potential for ground-based reductions in carbon emissions associated with aviation. The assumption in the MI Scenario is that electric vehicles (using a renewable energy supply) will be used on all airside operations. Better communication between aircraft, ground vehicles and terminal facilities such as baggage handling will reduce delays. The use of Auxiliary Power Units on-board aircraft for air-conditioning and lighting whilst at departure gates can also be replaced by ensuring aircraft plug-in to a renewable energy supply. The overall effect of improving air transport management both in the air and on the ground including the use of military airspace will reduce CO_2 emissions by 13 per cent in 2050 (see table 4.8).

Fiscal

The price of air fares plays an important role in the demand for aviation, the net effect depending on the price elasticity of demand. Several factors contribute to the price of air fares such as route, distance flown, seat availability and class of seat. Also, additional expenses of the airlines related to CO_2 emissions, noise and security charges and price of oil will be passed onto the customers by increased fares. Changes in fares generally have an inverse effect on the demand (e.g. higher prices lead to less demand) the scale of the effect determined by its price elasticity.

An analysis by Cairns and Newson (2006) of studies on price elasticities for air travel suggest that they ranged between -0.5 and -1.5. Therefore, a 10 per cent increase in fares would yield a demand reduction in 5 - 15 per cent. However, this tends only to be the case for short-haul and budget flights. Elasticities for business flying and long haul flights tend to be lower. The DfT (DfT, 2008a) concludes that while the price elasticity for leisure travel was -0.3, no significant price effect is found for business travel. Cairns and Newson (2006) also highlight the fact the business flights and long haul are generally not affected by price increases.

Some key fiscal policy interventions, such as the inclusion of aviation in the EU ETS in 2012, are already take into account under the BAU Scenario (see box 3.3). However,there are other factors that will affect ticket prices including:

- taxation of aviation fuel (a massive subsidy enjoyed by the industry, see next section);
- VAT on air tickets;
- airport slot auctions;

Table 4.8: The reduction in CO_2 emissions in 2050 from air traffic management measures used in the MI Scenario

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Air Traffic Management	37.5	59.9	52.4	-13%

Note of Explanation
It is assumed that the contribution of de-militarised air space is 3% and the remaining 10 % refers to all the other measures. The DfT has reported that four per cent of the delays in EU air space are the result of military activity. Three per cent has been selected as a conservative estimate on the basis that it is unlikely that all delays attributable to military activity can be stripped out of the system (DfT, 2001).

Boeing 787 Dreamliner © Dave Sizer

- raising airport landing charges;
- emissions charging.

These differ in the way they are applied. In general, they cannot be done unilaterally by the UK Government and some, such as aviation fuel taxation, can only be done through lengthy international processes.

The option used in the MI Scenario (also considered feasible at the EU level) is en-route emission charging of flights within and between European countries. Here the emission charge would include the full climate change effect of aircraft emissions taking into account the 'uplift factor' based on the RF potential of emissions at high altitude (see Section 3.3).

In addition to these price effects, the MI Scenario includes an assessment of the impact on air fares if the industry was not subsidised by the Government in the form of zero fuel tax, VAT exemption and other measures. The Aviation Environment Federation (Sewill, 2005) calculates the revenue lost by the Treasury as a result of the exemption from fuel tax and VAT, and tax free sales, amounted to £9.2 billion when income from air passenger duty of £0.9 billion is factored in. If air travel was taxed the same as car travel then:

- the rate of growth would be halved;
- the climate change impact would be much reduced;
- an extra £9 billion a year would be available for improving public services or cutting taxes.

Fuel taxation is one of the most cited examples of how the aviation industry benefits significantly compared to other industries. Due to international agreement (the Chicago Convention of 1944) aviation fuel is tax exempt. ICAO, the industry body responsible for international agreements including fuel tax, is strongly against countries imposing taxes unilaterally. There would be major legal hurdles to face if the UK Government imposes a tax itself. Even if it managed to implement such a tax, airlines would simply refuel in countries where the tax was exempt.

For the MI Scenario it is assumed that a package of fiscal measures which increase ticket prices may include emission charging based on full climate change impact applied at the European level as well as including external costs such as noise and local air pollution. The MI Scenario also includes the removal of any domestically applied subsidies but not a fuel tax. In the scenario, UK aviation Air Passenger Duty is assumed to remain at current levels from 2012 onwards.

As a consequence of these fiscal measures in the MI Scenario, air fares will increase by six per cent per annum over the next 40 years (2010-2050) to produce a nine-fold final price increase. These annual increases represent a strong enough price signal over a long time period to bring about a change in behaviour that is large enough to make a contribution to demand reduction and carbon reduction without economic disruption. An increase in the cost of carbon from £80 to £200 per tonne in 2050 as suggested by the Committee on Climate Change (2009) is unlikely to have a significant effect on demand as the carbon cost is only a small fraction of the overall ticket price. The discussion around price signals and their application over a long time period has been advanced by (amongst others) Weizsaecker and Jesinghaus (1992) and Kohlhaas (2000). Both authors argue that the rate of taxation should not be so great as to create perturbations in the economy that cause difficult problems of adjustment. They take the view that the exact value of the initial rate of taxation is not as important as the year-on-year cumulative effect and its impact on behaviour. That is also our view.

In the MI Scenario, we have used the mean price elasticity value of -1.146 derived by Brons *et al.* (2002) from a meta-analysis of elasticities based on a set of 204 observations. Short haul flights account for approximately 30 per cent of air traffic movements in the UK (including domestic flights). Therefore using the elasticity value of -1.146, it is estimated (using Equation 2 in Section 4.1) that an increase in fares due to emission charging and other fiscal measure reduces CO_2 emissions from short haul flights by 94 per cent by 2050. Table 4.9 shows that the effect of increasing prices alone could reduce total (short haul plus long haul) aircraft CO_2 emissions by 27 per cent by 2050.

In this report a direct increase in fares charged to passengers has been selected. There are several ways this can be achieved through regulation and governmental intervention and a carbon tax as recommended in CCC (2009) is one of them. Another method would be to assess the full range of externalities associated with aviation including nose and air quality and use conventional methods of evaluation to put a monetary value on the externalities and through government regulation internalise them (i.e. fully recoup the costs through a charge related to emissions or noise and directly impacting on the actual fare paid by the passenger). The feasibility, practicality and effectiveness of different methods of “making the polluter pay” have not investigated . It is noted that it is EU and UK government policy to make the polluter pay and to internalise external costs. It is also noted that the aviation industry is complex and has many strategies available to it to minimise or mitigate a carbon tax or an emissions charge and ensure that the full weight of the monetary value of that charge or tax does not bear down on the passenger. This will reduce the impact of the tax or charge on passenger demand so that demand reduction does not take place or is much lower than it could be. A direct and transparent method is preferred whereby the fares rise in the way we have specified in the MI Scenario and cannot be diluted or mitigated by industry strategies to fuel extra demand through lower fares.

Creaton (2005) shows how one low cost airline (Ryanair) produces low fares by very impressive cost cutting and by robust negotiation to produce, for example, a 50 per cent reduction in landing charges at Stansted. Any carbon taxation or emissions charging regime would be severely compromised by the ability and willingness of local authorities and airports to grow the demand for flying by finding ways of delivering financial inducements to airlines which then negate wholly or partially the impact of the tax or charge. This study has set out to avoid this.

Behaviour

In terms of behavioural change, the MI Scenario assumes that there is a continued drive by the Government towards a low-carbon economy and that this is reflected in changes in behaviour of businesses, tourists and the ways in which business to business contacts and family contacts are initiated and maintained. Stringent regulation of behaviour in the form of carbon rationing or personal carbon allowances is not envisaged in the MI Scenario. However, people will tend to travel shorter distances and there will be greater use of railways for domestic travel as a result of improved services and lower fares. People will still take long haul flights but less frequently.

Other factors may also lead to a change in travel behaviour patterns. For instance, the global impact of climate change will affect leisure and tourism travel. Under IPCC climate change predictions many destinations face risks from climate change in the form of coastal inundation, erosion, saline contamination and loss of beach. Some small island states will be submerged in water due to rising sea-level (Mimura *et al.*, 2007). Increases in sea surface temperature of approximately one to three degrees C are expected to result in more frequent coral bleaching events and widespread coral mortality. Southern Europe will simply become too hot for holidaymakers and there will be a shift in demand for tourism to countries in more northern latitudes including the UK. This is

Table 4.9: The impact of fiscal measures on CO_2 emissions in the MI Scenario

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Fiscal Measures	37.5	59.9	43.5	-27%

highlighted in Eurocontrol's "Challenges for Growth" report (2008):

"Within 10-20 years parts of the Mediterranean are forecast to become so hot during mid summer that this could cause a decline in the tourism economy during July and August."

Therefore, more domestic holidays could be taken in the UK which would also mean an increase in road traffic and domestic aviation. The UK may become a more popular holiday destination taking holidaymakers away from Mediterranean resorts.

Climate-sensitive diseases, including morbidity and mortality from extreme weather events, certain vector-borne diseases, and food- and water-borne diseases could increase under a warming climate. The perception of the risk to human health to diseases such as swine flu and severe acute respiratory syndrome (SARS) could result in changes in demand for air travel and flight patterns. The Mexican swine flu pandemic of 2009 saw airlines reducing services at least over the short-term. These events are difficult to predict and not explicitly modelled here but rather highlighted as potenetial consequences of climate change which will affect demand.

Substitution of information technology

Technology will play an important role in reducing air travel and in particular business travel which accounts for 14 per cent of the market (UK and Foreign together). The extent to which this situation will actually materialise is difficult to predict as it will require both a shift in organisational behaviour as well as significant investment in infrastructure to provide high quality video-conferencing and associated secure electronic data transfer. The next generation of broadband and more extensive wireless connectivity could mean both business and households will require less travel. There is a body of evidence to show that companies are beginning to substitute technology for travel. Joint research by ETNO and WWF (Pamlin and Szomolányi, 2008) suggests that (see figure 4.4):

> *"If all European companies were to cut their business travel by 20% and use video or audio-conferencing instead, we would save 22 million tonnes of CO_2 each year, equivalent to taking one third of the UK's cars off the road."*

Myoshi and Mason (2009) suggest that 10 to 20 per cent of business travel could be saved by either replacing the travel with alternative forms of communication or by simply stopping unnecessary travel. Therefore, if this 20 per cent saving in business related air travel can be achieved then this will lead to a significant reduction in carbon emissions.

A report from the WWF-UK (Pamlin and Szomolányi, 2008) entitled 'Travelling Light' suggests that many UK businesses have a "green" corporate policy which aims to reduce their carbon emissions and that they are willing to use technology to replace travel. However, they also point out that the quality of the experience needs to be better and the equipment has to be user-friendly with good inter-operability across different systems. This relates to the provision of high quality broadband to replace current broadband provision which is of much lower

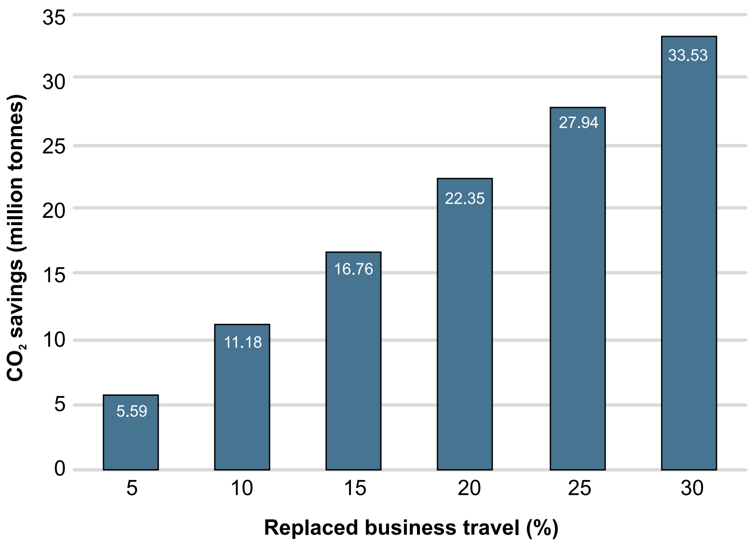


Figure 4.4: CO_2 Savings in Europe from use of video-conferencing
Source: Pamlin and Szomolányi (2008)

quality (speed, performance and availability). Most of the companies surveyed believe that investment in videoconferencing should be encouraged by the government. This could have additional benefits to the UK economy. However, there needs to be willingness on both the business community and the Government to achieve this. This will require incentives and other policy interventions to change current business travel behaviour

Ackerman (2005) presented a range of different scenarios for aviation up to 2050 and sees information technology as one of the key driving forces for reducing emissions though substitution. The reduction in short haul flights has also been driven by the availability and relative cost of quality high-speed rail links within Europe.

In the MI Scenario, aviation business travel activity is assumed to have fallen by 20 per cent by 2050. This has the potential to reduce emissions by 1.7 Mt CO_2 (2.8 per cent). Table 4.10 shows the reduction in CO_2 emissions in 2050 from video conferencing assumed for the MI Scenario.

Substitution of air travel by rail travel

In the absence of a national plan aimed at re-localising economic activity, it is assumed that high speed rail will be the preferred option for replacing physical travel in order to reduce domestic and short haul aviation in UK. This will require four strands of intervention:

- Government subsidy to reduce the price of rail travel. This would be affordable if revenue from Air Passenger Duty was used.
- Upgrade of existing rail lines to accommodate high speed trains as well as improvements in service (networks and schedules) and e-ticketing.
- Investment in rail termini. These are needed to connect both major urban areas and main points of international embarkation/disembarkation (sea ports and airports).
- High speed rail links to Europe extended.

Within Europe it is foreseen that the expansion of the network of high-speed rail will attract more passengers travelling shorter distances. This development will reduce aviation passenger demand by 0.3-0.5 million flights in 2030 in particular those short-haul fights within Europe for which the train can be time-competitive (up to approximately 500 km) (EUROCONTROL, 2008). However, if the UK's high-speed rail network connects with mainland Europe then there is even more potential for replacing short-haul flights especially within Northern Europe (Belgium, Holland, France and Germany). This accounts for approximately 10 per cent of UK arrivals and departures in 2007. The MI Scenario applies a 50 per cent reduction to statistics for France and Germany to recognise the size of the country and that high-speed train substitution is less likely (DfT, TSGB, 2008b).

Under the MI Scenario there will be complete rail substitution for domestic air travel by 2030 (given a 10 year high-speed train investment plan). This means there is a potential saving of approximately 3.5 Mt CO_2 per year. It is assumed this substitution is made by rail transport powered by renewable energy sources. It is also assumed a feasible reduction in short haul flights from nearby Europe by 10 per cent. This would mean a further 1.4 Mt CO_2 (approximately one per cent aviation emissions) by 2050. This represents approximately eight per cent of total aviation emissions (see table 4.11).

Summary of all measures

Table 4.12 shows the impact of each of the measures used in the MI Scenario for aviation. Each measure is first of all considered in isolation so, for example, 'constrained demand' reduces the BAU 2050 total from 59.9 Mt CO_2 to 54.0 Mt CO_2, a reduction of 5.9 Mt CO_2 or 10 per cent. This same calculation is then repeated for each measure so that each row shows the

Table 4.10: The impact of the MI Scenario video conferencing measures on CO_2 emissions

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Video Conferencing	37.5	59.9	58.2	-2.8%

impact in isolation of each of measure in reducing the BAU total. The final row uses the methodology described in Section 4.1 (using an extended version of Equation 1) to combine all six measures so that the final result is a reduction of 33.6 Mt CO_2 which brings down the BAU 2050 total of 59.9 Mt CO_2 to a new total of 26.3 Mt CO_2. This is a reduction of 56 per cent. It can be seen that the combined reduction is somewhat lower than the value obtained by adding up the six separate reductions (whether as Mt CO_2 or percentage). This is because the combined reduction was calculated using a methodology (see Section 4.1) that avoids erroneously overestimating the combined effect of more than one measure.

It is clear that by 2050, aviation is a long way from decarbonising under the MI Scenario. The MI Scenario has taken into account the fact that there are already a number of policies assumed within the BAU Scenario including fuel efficiency improvements related to aircraft engine technology and air traffic management. It also includes the participation of aviation in the EU ETS. However, it can be seen from table 4.12 that fiscal measures (27 per cent) and aircraft technology (14 per cent) make the largest reductions in emissions. Railway and video substitution have a smaller impact largely because the measures do not affect the whole market. For example, railways substitution only affects the domestic market which is only a relatively small percentage of total emissions. It is can be seen that taken together, those measures that reduce demand (constrained demand, fiscal measures, railway substitution and video substitution) would deliver considerably greater reductions than could be achieved by simply focussing on improvements in aircraft technology and air traffic management.

Table 4.11: The impact of rail substitution on aviation CO_2 emissions assumed in the MI Scenario

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Rail Substitution	37.5	59.9	55.0	-8.2%

Table 4.12: Summary of all measures taken in the aviation industry in the MI Scenario

	2005	2050	Reduction in CO_2 emissions (Mt CO_2) relative to 2050 BAU	Per cent change in CO_2 emissions relative to 2050 BAU
	Emissions (Mt CO_2)			
BAU Total	**37.5**	**59.9**		
MI measures separately:				
Constrained Demand		54.0	5.9	-10%
Aircraft Technology		51.8	8.1	-14%
Air Traffic Management		52.1	7.8	-13%
Fiscal Measures		43.5	16.4	-27%
Railway Substitution		55.0	4.9	-8.2%
Video Substitution		58.2	1.7	-2.8%
All MI measures combined		**26.3**	**33.6**	**-56%**

Note of Explanation. The effect of all measures combined is somewhat less that the sum of the effects of each measure implemented separately. This is intentional because the method used is designed to avoid overestimating the combined effect of measures for which information is only available concerning their effects when applied individually. (See text for more details.)

4.5 SHIPPING

The Government has outlined its options for dealing with shipping emissions in its "Low Carbon Transport: A Greener Future" report (DfT, 2009a) although shipping was left out of the 2006 Climate Change Bill. The UK Government does not foresee that shipping, like aviation, can be fully decarbonised. However, it suggests there will be major step changes in efficiency through technology and operations (DfT, 2009a). In addition, it considers the International Maritime Organisation (IMO) as the main body to enforce regulation for emissions at global levels. However, the Government envisages that the implementation of such regulation, or setting a cap on emissions, will be a very slow process and suggests instead that shipping be included within an EU Emissions Trading System. Shipping emissions could be offset by reductions in other sectors operating in the scheme. However, this has a number of potential problems related to the allocation of carbon permits. If this is done on the basis of a freight-tonne kilometres (FTK) then there needs to be some kind of apportionment according to journey segment. Secondly, if it is done on bunker sales a certain amount of carbon is not accounted for as ship operators will bunker fuel where it is cheapest or where it most convenient on route.

In the MI Scenario, emissions for shipping are derived from the allocation method based on FTK as this is a better reflection of UK economic activity and methods are also fairly well-established for allocating emissions on journey segment. It is apparent that using bunker fuel sales would severely under-estimate UK shipping emissions.

An AEA Technology study (AEA Technology, 2008) examined the possibilities of reducing CO_2 from shipping including technological, operational, fuel technology and global carbon price. The implications of their study are that, under a high carbon price scenario, emissions from shipping in 2050 could be double current levels. A number of assumptions about the likely operational, technological and design improvements in ships over the next forty years are included within their scenario. These are summarised as follows:

Operational

- a shift to larger ships, or operating ships at slower speeds;
- optimal hull maintenance and upgrades to propellers and engines;
- improved on-board operations such as better energy management and voyage optimisation.

Technological and design

- improved hull and propeller designs to reduce resistance and increase propulsive efficiency;
- propellers designed to recover energy;
- improvement in the overall body design to reduce air and wind resistance.

The CCC sees the potential for carbon reductions as follows:

- potential to reduce CO_2 emissions from existing ships by approximately 10 per cent through operational measures and by retrofitting various technical measures, while a state-of-the-art ship built in 2008 could emit 27-32 per cent fewer emissions compared to a baseline 2008 typical in-service ship;
- a 2022 state-of-the-art ship might emit 32–35 per cent fewer emissions than a 2008 typical in-service ship.

The European Technology Platform, "Waterborne" in its "Vision 2020" considers different technological improvements in ship design which will contribute to carbon reductions. This will be through the development of clean propulsion systems and economic retrofit-packages for existing ships as well as non-fossil based propulsion solutions for economic application on large ships and highly sophisticated ICT as well as improved ports handling and operations. Improved engine efficiency could reduce fuel consumption by up to 30 per cent.

The MI Scenario assumes there will be a number of operational, technological and design improvements in ships over the next forty years which could lead to a reduction in shipping emissions.

Speed

Ships travelling at slow speeds have been found to be far more efficient and less polluting (Harrould-Kolieb, 2008). The IMO suggests that slower speeds applied across the whole fleet could reduce emissions by 23 per cent. Further measures through voyage optimisation can also lead to improved fuel efficiency. Voyage optimisation is where ship operators take various measures to reduce fuel consumption. These are made by operating within the constraints that are imposed by logistics, scheduling, contractual arrangements and other constraints. These measures include (IMO, 2009):

Table 4.13: The impact of the speed reduction and voyage optimisation measures on CO_2

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Slower Speeds / Voyage Optimisation	18.9	59.9	46.1	-23%

- selection of optimal routes with respect to weather and currents in order to minimize energy consumption (weather routeing);
- just-in-time arrival, considering tides, queues, and arrival windows taking into account penalties and safety;
- ballast optimization – avoiding unnecessary ballast;
- trim optimization – finding and operating at the correct trim.

Table 4.13 presents reduction in CO_2 emissions from speed reduction and voyage optimisation. The MI Scenario uses value suggested by the IMO to reduce carbon emissions by 23 per cent and amounts to approximately 14 Mt CO_2 in 2050.

New technology

In the past ships used sails to harness the power of wind and kite sails are now being suggested as a novel means of reducing fuel costs and also for reducing carbon emissions. A kite's shape is aerodynamically more efficient than a standard spinnaker on traditional ships; the kites fly up to 1,000 feet above the sea surface where winds are much stronger. Using sails under optimal wind conditions, fuel consumption can be reduced by up to 50 per cent. However, these conditions are usually only temporary. According to Skysails (2009) 10-35 per cent fuel savings are likely but only for 30-50 per cent of the time the vessel is at sea. Improved weather-tracking using satellite and radar systems could enable the ships to alter its route to seek out the stronger winds. The technology is being used on cargo vessels already and there are no real barriers to retro-fitting the whole fleet.

Another more radical ship design uses technology known as an Air Cavity System (ACS). This development by the DK Group[7] could reduce emissions by 15 per cent. This technology is still a prototype and involves injecting air into specially designed hulls which reduces the frictional resistance of the hull surface against the water. This means that the ship requires less engine power and consequently less fuel and as a result, carbon emissions are reduced.

As in the case of aircraft, the speed of implementing this technology is again, fairly slow. Therefore, carbon reductions will be constrained by the ability of ship-yards to meet demand and by the rate of fleet turnover. Ships have a long service life and so replacement of ships may take some time. There can be accelerated development in new technology possibly through incentives scheme by building new fleets and retrofitting.

In the MI Scenario the introduction of new technology will lead to an average 30 per cent reduction in ship emissions by 2050 with the assumption that the fleet is either replaced with new ships or retrofitted (see table 4.14).

Cleaner fuels

Ships can reduce CO_2 emissions by 4-5 per cent by switching to "cleaner" fuels where marine diesel oil is used instead of residual oil. Residual (heavy) oil is much cheaper for shipping lines but requires more processing on board. A by-product of this is sludge which is then burnt on-board releasing a variety of particles (sulphates, black carbon). Cleaner fuels are processed at refineries and so there are potentially life-cycle carbon emissions to consider and the net effect might only be two to five per cent reduction. Therefore, in the MI Scenario a conservative four per cent reduction in emissions is used.

As in the case of aviation, the use of biofuels is not considered an option. The IMO's (2009) summation of the potential of using first or second generation biofuels is given below:

"In summary, the present potential for reducing emissions of CO_2 from shipping through the use of biofuels is limited. This is caused not only by technology issues but by cost, by lack of availability and by other factors related to the production of

7 See: www.dkgroup.eu

Modern ship - MV Emma Maersk © tidewater muse/flickr

biofuels and their use. Additionally, the biofuels are, at present, significantly more expensive than petroleum fuels." (IMO, 2009)

An alternative to biofuels is Liquefied Natural Gas (LNG) which has a number of additional benefits such as low levels of emissions of nitrogen oxides, sulphur oxides and particulate matter. Unfortunately, there are associated increases in emissions of methane, a more powerful GHG than CO_2. Another option for shipping is to use nuclear reactors onboard although this is not likely for obvious environmental, political and security reasons. Table 4.15 presents the reduction in CO_2 emissions from ships using cleaner fuels.

Shore-side measures

Other measures within the MI Scenario include portside measures such as cold-ironing. This is where ships, whilst docked in port, shut off their propulsion engines and use auxiliary engines to power on-board

Table 4.14: The impact emissions of CO_2 from shipping using new technology

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Technology	18.9	59.9	41.9	-30%

refrigeration, lights, pumps and other equipment. These auxiliary engines tend to be powered by high-sulphur marine heavy fuel oil or in some cases by low-sulphur marine gas oil, resulting in significant emissions of air pollutants. Therefore, an alternative measure to reduce emissions from the ships whilst docked is to connect to shore-side electricity generated from renewable sources. It is often possible to reduce energy consumption on board ships by using equipment more efficiently and using optimal settings for heating ventilation and air conditioning. The IMO states that up to a two per cent reduction in fuel consumption could be made. This figure is used in the MI Scenario and shown in table 4.16. Solar panels on-board the ship could also be used although only as a source of complementary energy and it use therefore will have little overall effect on emissions.

Summary of all measures

Table 4.17 presents reductions in CO_2 emissions in 2050 from all shipping measures used in the MI Scenario, both when applied separately and when combined. Each measure is first of all considered in isolation so, for example, new technology reduces the BAU 2050 total from 59.9 Mt CO_2 to 41.9 Mt CO_2, a reduction of 18 Mt CO_2 or 30 per cent. This same calculation is then repeated for each measure so that each row shows the impact in isolation of other measures in reducing the BAU total. The final row uses the methodology described in Section 4.1 to combine all the measures so that the final result is a reduction of 29.5 Mt CO_2 which brings down the BAU 2050 total of 59.9 Mt CO_2 to a new total of 30.4 Mt CO_2. This is a reduction of 49 per cent. Unlike the situation for aviation, it can be seen that emissions in the 2050 MI Scenario are still significantly higher than those in the BAU baseline year of 2005. This is due to the overall growth in shipping expected in the next forty years.

4.6 SUMMARY OF MI EMISSION ESTIMATES

Table 4.18 and figure 4.5 provide a summary of the CO_2 emission reductions achieved by implementing the package of measured discussed in the MI Scenario. Road transport will be completely carbon neutral by 2050 due to a combination of reduced demand (approximately 75 per cent from spatial, fiscal and behavioural measures) and a whole-scale shift in technology to PEVs and H-fuel cell vehicles, both of which will utilise decarbonised UK electricity supply. Clearly, a carbon neutral electricity supply would be much more likely to be able meet the increased needs of a road transport sector almost entirely composed of PEVs and/or H-fuel cell vehicles if total demand is also drastically reduced. As for road transport, rail passenger and rail freight CO_2 emissions will be cut to zero due to being 100 per cent powered by a decarbonised electricity supply.

Emissions of CO_2 from aviation in the 2050 MI Scenario have been reduced by 56 per cent when compared with the 2050 BAU emission as well as being 11.2 Mt less than the baseline 2005 figure. This represents significant progress in bringing aviation into line with the implications of the UK national commitment to an 80 per cent reduction by 2050 on a 1990 base. The scale of reduction achieved

Table 4.15: The impact on emissions of CO_2 from shipping using cleaner fuels

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Cleaner Fuels	18.9	59.9	57.5	-4%

Table 4.16: The impact on emissions of CO_2 from shipping following the implementation of shore-side measures

Measure	Baseline (2005) CO_2 Emissions (Mt)	BAU CO_2 emissions in 2050 (Mt)	MI CO_2 emissions in 2050 (Mt)	Change in CO_2 emissions over 2050 BAU emissions
Shore Side Measures	18.9	59.9	58.7	-2%

Table 4.17: The impact of all shipping measures on CO_2 emissions in the MI Scenario

	2005	2050	Reduction in CO_2 emissions (Mt CO_2) relative to	Per cent change in CO_2 emissions relative to
	Emissions (Mt CO_2)		2050 BAU	2050 BAU
BAU Total	18.9	59.9		
MI measures separately:				
New technology		41.9	18.0	-30%
Speed /Voyage Optimisation		46.1	13.8	-23%
Cleaner Fuels		57.5	2.2	-4%
Shore Side Measures		58.7	1.2	-2%
All MI measures combined		**30.4**	**29.5**	**-49%**

Note: As in table 4.12, the effect of all measures combined is somewhat less that the sum of the effects of each separate measure due to the use of a method (explained fully in Section 4.1) that avoids overestimating the effect of combining measures.

is still not enough but it has been produced by the full application of all available measures. It is clear that a combination of those measures that reduce demand such as air fare increases, no additional runways, modal shift to railways (including High Speed Rail) and video substitution would deliver a considerably greater reduction than could be achieved by advances in aircraft technology and air traffic management alone. It follows that a reduction in CO_2 emissions from aviation of this scale could not be delivered by a policy that encouraged technological solutions but allowed demand to continue to grow. As in road transport, technology alone cannot solve these problems and first and foremost, measures are required that substantially reduce demand. Any expansion of airport capacity through building new runways would have the effect of supporting year-on-year increases in demand and therefore does not form part of this MI Scenario. Indeed, there would be no need for any new runways under a policy designed to maximise CO_2 emissions reductions from aviation through a demand-led reduction strategy as assumed in this MI Scenario.

Published evidence leads to the conclusion that CO_2 emissions from shipping can be reduced by 49 per cent through changes in ship size, routeing, fuel, speed and a number of other promising technologies. No change in prices for shipping bulk products or 'twenty-foot equivalent units' (TEUs) have been factored in the analysis because of the lack of published information on robust relationships between shipping prices and the physical quantity of goods shipped or the distance over which they have been moved.

Although road and rail transport could both achieve the zero CO_2 emission target by 2050, emissions from aviation and shipping are problematic. For the 2050 MI Scenario, the net result for the entire UK transport sector is a 76 per cent reduction in CO_2 emissions compared with the 2050 BAU Scenario (or a 68 per cent reduction on the BAU baseline year emissions). This falls short of the zero carbon target for UK transport as a whole by 2050. The 24 per cent shortfall is entirely due to the remaining CO_2 emissions from aviation and shipping. However, the reductions achieved in this study are still significantly greater than other studies examined and reflects a 100 per cent decarbonisation of road transport which is responsible

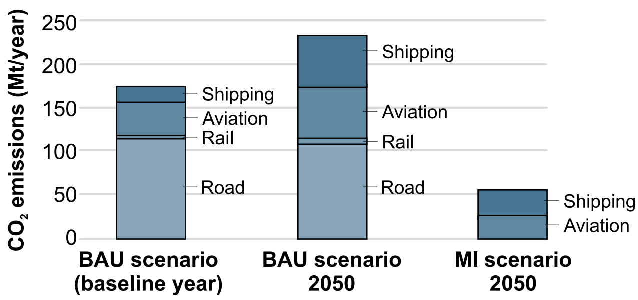


Figure 4.5: Summary of CO_2 emissions for BAU and Maximum Impact (MI) Scenarios

Table 4.18: Summary of BAU versus MI Scenario

Category	Baseline emissions (Mt CO_2) [and Year]	BAU emissions (Mt CO_2) 2050	MI emissions – Combined measures (Mt CO_2) 2050	Reduction in CO_2 emissions relative to 2050 BAU
Road	116.2 [2003]	110.2	0	100%
Rail	3.4 [2006/7]	4.6	0	100%
Aviation	37.5 [2005]	59.9	26.3	56%
Shipping	18.9 [2005]	59.9	30.4	49%
All transport	**176.0 [composite year]**	**234.6**	**56.7**	**76%**

for 66 per cent of baseline transport CO_2 emissions. In addition, it achieves a 49 per cent reduction in CO_2 from shipping and a 56 per cent reduction for aviation. To improve on the overall CO_2 emissions reduction for transport would require much more radical interventions or technological innovations for these two sectors than those envisaged in the present study.

Panorama in Freiburg-Vauban - © Matthew Wyneken

5 LIFE IN A ZERO CARBON TRANSPORT BRITAIN

In addition to reducing GHG emissions, moving towards a zero carbon transport system will lead to a number of social, environmental and economic benefits. These co-benefits will improve the quality of life for social groups of widely differing lifestyles and transport needs. The measures outlined in the MI Scenario will deliver the transition towards a zero carbon transport system which in turn, will produce knock-on beneficial effects in the following key areas:

- environmental quality;
- social exclusion and mobility;
- accessibility.

Environmental quality

Motor vehicles are an important source of nitrogen oxide and particulate matter (PM) pollutant emissions. Nitrogen oxides are acidic gases and ozone precursors and can affect human health and vegetation. Airborne particulate matter (usually measured as PM10) consists of fine particles that can be carried into the lungs and have been linked to premature deaths among those with pre-existing lung and heart disease. Annual average particulate matter levels have been steadily decreasing. However, there has been an upward trend in background urban ozone levels due to the reduction in urban emissions of nitrogen oxides, which destroy ozone close to their emission source. Ground level ozone occurs naturally but levels can be increased as a result of reactions between nitrogen oxides, oxygen and volatile organic compounds in the presence of sunlight. Once formed, ozone can persist for several days and can be transported long distances. In addition to being a powerful greenhouse gas, ozone can cause irritation to the eyes and nose and exceptionally the airway lining (when levels are very high), and can also damage plants and crops.

The UK has a serious air quality problem in its cities with over 150 declared Air Quality Management Areas (AQMA) where air quality exceeds thresholds designed to protect human health. Most of the AQMAs are traffic related and are the subject of Air Quality Action Plans that are largely ineffective. AQMAs have been in place for over 10 years and very few have been "signed off" in the sense that an Air Quality Action Plan has been successful and air quality problems have been resolved. Over 16,000 people die in the UK each year as a result of vehicle-related poor air quality. The phasing-in of PEVs to replace petrol fuelled vehicles and an increase in the use of public transport, cycling and walking will eliminate traffic-related air quality problems bringing a significant public health gain as a co-benefit of reducing CO_2 emissions

In addition, there will be a reduction in vehicle related noise pollution due to a decrease in the number of vehicles used and the gradual substitution of electric vehicles for internal combustion engines produces less noise. Transport noise can cause sleep disturbance, cardiovascular disease, elevated hormone levels, psychological problems and even premature death. Studies on children have identified cognitive impairment, worsened behaviour and diminished quality of life (EEA, 2009).

Social exclusion and mobility

Transport provision in the UK has evolved in a way that excludes many groups from playing a full role in a modern society. They exhibit a lack of mobility often compounded by a lack of accessibility that excludes them from work, leisure, educational and other opportunities (Solomon, 2003). Four main types of transport social exclusion have been identified by the UK government and discussed in Solomon (2003). They are:

- spatial - where people simply cannot get to the location they wish to access (e.g. there is no transport to or from a particular settlement, for example the home of a relative);
- temporal - where they cannot get there at an appropriate time (for example no buses catering for shift working patterns no transport available for young people to return from town in the evening);
- financial - where they cannot afford to get there (when the sacrifice of, for example, food for fares, is not realistic);
- personal - when they lack the mental or physical equipment to handle the available means of mobility (they cannot comprehend the system, or they cannot physically use what transport is available).

Problems of social exclusion and lack of mobility have a differential impact on key identifiable groups and sub-groups in society:

- the unemployed;

- families with young children;
- the young;
- those on low income;
- the elderly;
- those living in rural areas.

Moving towards a zero carbon transport system is associated with the reduction of the need to travel, much improved levels of service and quality for bus, bike and pedestrian journeys and the closer physical proximity of destinations that are routinely accessed. The quality of life for all those without access to a car will improve as the transport system adjusts to prioritise the needs of those who rely on alternatives to the car. These groups are dominated by women, the elderly, those on low income and young people. A zero carbon transport system provides a remedy for the long-standing problem of transport, social exclusion and mobility.

Reduced traffic levels also contribute to improved road safety, the reduction of death and injury and the attractiveness of walking and cycling as transport choices especially for women and children. This improvement in road safety is of direct benefit to low income groups and ethnic minorities who experience a higher level of death and injury on the roads than other groups.

Accessibility

Accessibility is indivisible from the consideration of social exclusion and creating a transport system that rewards all users rather than those relying on private car ownership. The distinctive dimension of accessibility is its emphasis on the ways in which society provides destinations that can be easily accessed for routine everyday purposes. To give a very clear example, a policy that seeks to close 3,000 post offices in urban England is a policy aimed at reducing accessibility and depriving socially excluded groups of easy access to a basic service and ensuring that more car trips are made to the remaining post offices which are now fewer and hence on average further away than they used to be. Post offices are important in a consideration of accessibility but the principle applies to local shops, dentists, doctor's surgeries, workplaces and a large number of leisure and education facilities. A prioritisation of accessibility in public policy would seek to enrich the density of provision of these facilities within a given range of where people live e.g. provide more local swimming pools. This is exactly the policy objective adopted in the MI Scenario where spatial planning and "densification" have been used to reduce the need to travel and put many more destinations within easy reach of homes. A zero carbon transport system is a system that maximizes accessibility.

Lifestyles

Moving towards a zero carbon transport Britain will affect diverse lifestyle groups in different ways. By 2050 Britain is expected a have an older population, where people aged over 50 will represent 30 per cent of the population compared to approximately 20 per cent in 2006 (See table 5.1) (GAD, 2007) . Many older people will remain fit and active into later life where mobility will be a key factor in determining their quality of life. The following narratives compare the current lifestyles of typical families with those likely to be led by their equivalent counterparts in 2050 under assumptions made in the MI Scenario.

Table 5.1: Population forecasts

	2006	2051
Percentages		
0-14	17.6	16.3
15-29	19.6	17.1
30-44	22.0	19.1
45-59	19.4	17.2
60-74	13.7	15.7
75 and over	7.7	14.5
All ages	**100.0**	**100.0**

NARRATIVES

Retired couple

Ron and Mary's transport needs involve using rail and coach to visit family and distant relations and friends. They use public transport mainly for city centre shopping, medical visits and leisure activities. They take a couple of major holidays a year and enjoy the advantages of off-peak European package holidays and cruises.

In 2050 Britain older people like Ron and Mary will enjoy the benefits of much improved public transport services. They will notice this through increased frequencies of bus services, bus services that run from early in the morning until late at night and at weekends and on bank holidays. These services will link residential areas with a range of important destinations and the rural retired will notice a dramatic increase in bus service provision and frequency. Bus use will continue to be free for this group as is currently the case but car ownership will be rendered almost totally unnecessary as a result of the dramatic increase in bus service density.

Rural areas will also benefit from so-called "demand responsive transport" where buses, given enough notice, will deviate from a set route and call at the home of the person requesting the service. Transport options will also include car share clubs where retired people can access cars for any journey that would still be difficult by the much-improved public transport.

Retired people will still have the option of taking holidays abroad but air travel will be more expensive so less frequently used and sea transport will figure much more as a transport choice.

Young family

Nick has a company car and works from home one day a week. Claire runs a small car and drives to her clients after dropping their child at the child-minder. They are located just outside the main urban area on a new estate built on a green field site which has a bus service every 20 minutes. However, neither Nick nor Claire has ever used it. They go to the out-of-town shopping centre at the weekends for the weekly supermarket shop and for leisure activities (cinema/ten-pin bowling). Nick plays sport twice a week and Claire goes to the gym three times a week. Both of these take place in the city. They also socialise with friends in the city rather than on their estate. They go on a package holiday once a year and take day-trips to the seaside at other times of the year. They visit grandparents on an alternate weekly basis. They usually go out for a pub lunch in the countryside.

In 2050 Nick's company have upgraded their fleet of hybrids with electric vehicles. Claire's counterpart works in her own salon on a new eco-development serving the surrounding estates. This development encourages people to walk or cycle through a local incentive scheme so she does not need a car. Doing without a second car saves a great deal of money and increases their disposable income.

The new eco-development is powered by micro-generated renewable energy. The development also includes gym and sports fields meaning the Nick and Claire's 2050 counterparts travel less into the city by themselves. However, at the weekend they go into the city as a family for cultural activities and to meet friends and family. This is now much easier and cheaper because there are more buses and buses have a "family day ticket" which produces an 80 per cent reduction in fares compared to the old system of charging every adult and child for the bus trip.

Nick and Claire's counterparts also holiday with their family in the UK however they take the train rather than drive. Trains now include on-board entertainment, generous space, windows you can see out of, child compartments, high quality food and drink and ample luggage space including a luggage van on routes that could benefit from this service. This is important with a family with three small children.

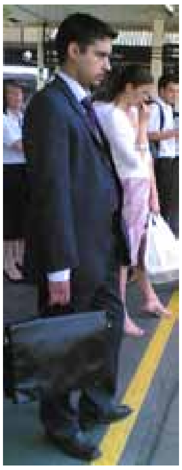
Trains are cheaper and they can purchase a family ticket in advance so there is guaranteed seats for all the family. These trains are state-of the-art. Journey times are quick, toilets are clean and do not malfunction and taxi services at the destination are built in as part of the service and meet the family for the final leg of the trip by road.

Married professionals with children

Greg and Deidre have cars and use them for commuting to work, the school-run and for ferrying children to after-school activities. They also take part in local community activities including the parent-teacher association and church. They tend to eat out as a family at the weekend. They have at least two holidays a year usually a package holiday destination in the summer and a camping trip in the spring

In 2050, overall changes in logistics for families like Greg and Deidre's have helped create more quality time which is spent locally. Greg's 2050 counterpart runs an electric vehicle purchased under a Government car scrappage scheme. He has reduced his business mileage through using technology – he uses video-conferencing from his office to speak to clients he has already met and uses software for more efficient meeting and journey planning. Deidre's 2050 counterpart does not have her own car but car shares to work with her colleague. This saves a great deal of money and boosts the family budget. As active members of the church they help to operate an electrically-powered mini-bus which picks up parishioners who are either too old or less mobile. They invite friends and relatives for lunch or dinner at the weekend instead of going out to eat. They have an allotment and make their own bread. They still take two, sometimes three holidays a year however, these are usually activity holidays in the UK. They take their children on weekend breaks to European cities (Paris, Berlin, Bruges) by rail as they can check-in from their local underground station all the way to their destination due to standardised ticketing which operates across Europe.

Semi-rural professionals



Richard commutes to London by train during the week – Monday and Thursday. He also travels abroad frequently for business purposes. Richard uses a computer/internet for work i.e. logging onto the company intranet. However, he relies on the IT support desk to ensure his equipment works. His wife, Valerie does a lot of outside activities including golf (twice a week) and riding (once a week) and she also drives a relatively new 4 x 4 Volvo X90 which she needs for driving to the stables. Richard does not do any other exercise and suffers from diabetes and hyper-tension due to his stressful lifestyle.

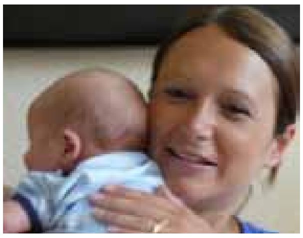
Richard's 2050 counterpart spends less time flying and so has more time to spend playing golf and being with his wife. He is also able to spend more time in the region where he lives as his company has installed a fast broadband home office enabling him to conduct his business at home. He also drives less than his 2010 counterpart as he also uses video-conferencing office suites at a number of locations across the UK. This means he can rent a fully-equipped tele-presence office suite (including fair-trade tea and coffee) by the hour. Valerie's 2050 counterpart plays golf four times a week, is able to go out horse-riding more often and drives a much smaller, plug-in electric vehicle. At the weekend they cycle to the local pubs for lunch. Richard's 2050 counterpart lives a much less stressful life and his blood-pressure is within the normal range.

Young couple

Danny and Stacy own one car which is nine years old. They are reliant on this for going to work Danny drops Stacy at her work and usually picks her up. They also use it for driving out to the shopping mall. They use public transport and taxis during the evening. They go on self-catering holidays in the UK. They go by car to a caravan at the coast. Except for a local convenience store, the estate where they live is too far from the main shopping centre and poorly served by public transport and so they drive out to the local retail park. Danny watches his local football team regularly and also plays for his local pub football team. Stacy visits her mum every Sunday for lunch – she takes the bus there and taxi back. She goes out night-clubbing with her work colleagues every Friday and either takes the night bus home or shares a lift.

Danny and Stacy's 2050 counterparts have a small but stylish plug-in electric car which they share with friends. They enjoy the freedom of not having children and so also have a hectic social life. However, they do all their shopping on the internet so that they can maximise their socialising time at the weekends. They use the much improved bus service for most of their non-work related travel and still mainly go on self-catering holidays in the UK.

Single parent



Mary relies on the bus for all her travel. Her estate is a long way from the city centre and cannot afford a car or taxis. However, due to poor lighting, and poor access and other anti-social problems buses do not stop near her estate anymore. The most direct route for her to walk passes through an unlit recreation park and so she avoids this making her journey times longer. She uses local services for all her needs apart from the local health centre which was recently set on fire and so has to take her son who is asthmatic to the District Hospital on the other side of the city. She also has to go into the city to go to the Job Centre. Mary has not had a holiday or left her home city for about 10 years. She had a bike but it was stolen.

Mary's 2050 counterpart is also unemployed but her quality of life is much better. Her son has no health problems with his lungs as air quality is much improved due to the fact that all vehicles in the city are either electric or have very low air pollutant emissions. Due to a healthy routes initiative based on smarter choices which incorporates a pedestrian/ cycleway, the local authority has invested in street lighting with a text and web-based 'lights-out' reporting facility. Each street-light location is recorded spatially and given a unique code identification number. Residents are able to text or email and also locate on an on-line map the position of the street light that has gone out. This is the chosen route for Mary's counterpart to go to local shops and school.

Public transport is now much cheaper than it used to be and connects Mary's counterpart with most destinations she needs to reach. This has saved money and also made her access to training and education much easier so she is improving her skill levels and qualifications which she expects will lead to a well-paid job.

A Community Regeneration scheme has led to a number of improvements to the local facilities and services. The local streets have also been made safer through improvements in the road layout and other traffic-calming measure. As a consequence bus services actually stop nearby. The money she has saved has meant she has been able to go on several day trips during the school holiday.

Cycling - Holland © Dietmut Teijgeman-Hansen

6 POLICY PATHWAYS

In this Chapter, the policy changes and pathways that need to be introduced into the UK to deliver the carbon reductions reported for road, rail, shipping and aviation will be examined. These will be described and located within a delivery timetable so that all the measures and interventions work synergistically to move towards the desirable future of a zero carbon transport system in 2050. Before examining the policy components in more detail we first of all discuss the rebound effect.

The rebound effect

A rebound effect takes place when an environmental policy designed to reduce fossil fuel consumption (for example) produces an effect that is less than predicted because of changes in consumer or producer behaviour that consume some of the "gain" in more consumption. A frequently quoted example is that of a driver who benefits from more fuel efficient vehicles through a reduction in fuel costs and chooses to drive more miles each year because he/she can do so as a result of lower costs. Another example is energy efficiency in the home and the observation that loft insulation or double glazing produces reductions in energy costs which are then (partly) consumed by turning up the thermostat and enjoying a warmer environment. Recent research (UKERC, 2007) has confirmed that the rebound effect is real and can account for 30 per cent of the savings i.e. it can eliminate 30 per cent of the benefits of the energy efficiency measure. The research also confirms that the rebound effect is complex and difficult to predict in practice. The rebound effect is not evaluated in the context of this report. The existence of the effect has influenced the identification and selection of measures so that (for example) the internalisation of external costs and fiscal measures generally are designed to make sure that price signals reinforce physical measures and avoid the car-driver rebound effect identified above. The approach adopted has been to construct multiple, synergistic reinforcing measures around demand reduction, spatial re-engineering and fiscal measures so that the result in terms of travel choices and behaviour are "locked-in" and not diluted by rebound effects of any kind.

Spatial planning

Most of the policy framework for spatial planning is already in place in the UK Planning Policy Guidance 13 (PPG13)[8] and in Regional Spatial Strategies and policy pronouncements on accessibility. The problem is that on the ground things move in the opposite direction e.g. closure of 3,000 post offices and loss of small shops/ local retailing. The following measures/interventions are needed:

A clear duty has to be imposed on local authorities by central government to increase the number of local facilities so that people are nearer to the things that they need to travel to. This would be associated with a similar duty imposed on all NHS, education and other public services and also Post Office Services.

- A clear duty should be imposed on every local authority to double the urban density from approximately 40 people per hectare to 80 people per hectare. This doubling of density would reduce urban car travel measured in VKT by 37 per cent (pers. comm. Kenworthy, 15 June 2009).

- Local Transport Plan (LTP) funding (LTP3 and LTP4) should be linked directly to outcomes especially the reduction of VKT and reduction of CO_2. The current system of funding capital and revenue bids and funding roads, trams etc, should be scrapped. Local authorities would be able to draw down funds in direct proportion to the degree to which those funds would reduce distance travelled and emissions. This would then shift funding into high quality cycle routes, improved bus services and much improved pedestrian environment.

- Changes need to be made to the planning system to require independent verification of the impact of the proposed development on CO_2 emissions. The independent verification body would work along similar lines to the National Institute for Clinical Excellence (NICE). There would be a presumption that those developments adding to CO_2 emissions would not gain permission unless there was an overwhelming national case demonstrating that (a) the development should proceed even though it adds to the CO_2 inventory and (b) there are no alterative options/plans or proposals that could achieve the same objectives at a lower CO_2 total.

- All new housing areas above 500 homes should be designed and developed within a totally integrated package in which the ways in which people will move around and access services has

8 PPG13 sets out the objectives to integrate planning and transport at the national, regional, strategic and local level and to promote more sustainable transport choices both for carrying people and for moving freight..

been anticipated and structured to deliver CO_2 reductions. This will be based on the example of Vauban in Freiburg (Germany) and other successful housing developments in the EU.

Fiscal

- Road fuel taxation should be increased annually through the re-introduction of a fuel price escalator to send strong market signals to car users to make changes to their behaviour that will reduce VKT. The increases will be large enough to deliver the reduction in CO_2 based on elasticity information in the MI Scenario and will also contribute to security and other policy objectives as we seek to reduce our dependence on fossil fuels.

- Parking cash-out (Shoup, 2007) should be introduced in every workplace and on the basis of international evidence this will reduce VKT by 12 per cent which translates directly as a 12 per cent reduction in CO_2. This reduction will apply only to the totality of VKT of car trips for the journey to work.

- Parking space not associated with the workplace (supermarkets, NHS facilities, retailing, tourism, recreational destinations etc) should be charged at a rate that represents the full commercial value of the land. Parking should not be subsidised or cross-subsidised.

- UK governmental spending on walking, cycling, public transport, shared space and urban design should be adjusted to the average prevailing in Austria, Denmark, Germany and Switzerland. Spending should be reported on a per capita basis and the current geographical inequalities in the UK eliminated. Currently, London has £826 public expenditure per capita per year on transport and the Northwest is £309, West Midlands £269, Yorkshire and Humber £239 and Northeast £235.

- All subsidies for road passenger transport, aviation and road freight should be eliminated and full internalisation of external costs implemented taking care to avoid "double penalties" e.g. if fuel taxation and parking charges cover internalisation then there is no need to go further.

Behavioural change

- Best practice in mainland Europe in public transport pricing should be adopted to deliver a much more attractive deal for bus and rail fares (n.b. UK public transport fares are amongst the highest in the EU).

- Large scale 'personalised journey planning' projects should be funded in all urban areas above 100,000 population and should be along the lines of the York Intelligent travel project or the project currently underway in Brisbane (Australia) covering 350,000 people. These projects are to run continuously and not be sporadic and 'one-off'.

- Workplace travel plan along the lines of the new BSI PAS 500 specification for workplace travel plans should be introduced in every workplace in the UK employing more than 100 people. This should be funded by the organisations themselves with appropriate taxation relief and also by public bodies in the same way as the extensive Transport for London workplace travel plan operation.

- There should be a similar programme for every school in the UK to minimise car trips and maximise use of alternatives. Every school travel plan should be fully funded by highway authority through LTP funds and linked directly to local engineering interventions to close roads, install cycle routes or take whatever other measures are needed to create a demonstrably safe and secure travelling experience for all pupils up to the age of eighteen.

- A programme of 'tourism without traffic' projects (along the lines of the East Sussex project) should be introduced so that car trips to tourist destinations can be shifted wherever possible to non-car modes. A duty would be placed on all national parks and areas of outstanding natural beauty to produce such a plan and to draw down funds sufficient to deliver large-scale modal shift and CO_2 reduction.

- All universities and all NHS facilities should adopt high quality travel plans using BSI PAS 500 as the basis. This should be funded by direct government grant and linked to local engineering interventions where appropriate.

- A mandatory default speed limit should be introduced on all residential roads of 20 mph and the police instructed to enforce it. Police authorities should be funded additionally to carry out enforcement.

- Legislation should be introduced to permit all residential roads with evidence of substantial rat-running to close the road to through traffic and restore a sense of "places for people" and a harmonious living space.

Technology

- All buses should be converted to best available technology for reducing air pollution and CO_2. This will be a combination of what is currently done in Helsinki, Stockholm and Bremen.
- All taxis should be similarly converted.
- All passenger cars in use in 2050 should be PEVs or hydrogen fuel cell vehicles, both of which will utilise a 100 per cent decarbonised UK national electricity supply system.
- All passenger and freight railway lines in UK should be electrified.

Table 6.1 outlines a policy implementation framework to move towards a zero carbon transport systems in the UK. However, achieving a near zero annual CO_2 emissions by 2050 is not the only consideration as the speed of implementation is also important. It should be emphasised that the earlier a measure is implemented, the greater will be the cumulative CO_2 emission reduction by 2050 and hence the greater will be its contribution towards mitigating future climate change. For example, by 2050, a reduction measure fully implemented in 2010 will deliver 40 times the total CO_2 emission reduction achieved by the same measure only implemented in 2049 (all other things being equal).

For this reason, it is envisaged that under the MI Scenario, the onset of implementation of most of the spatial, fiscal and behavioural measures listed in table 6.1 is immediate and that for the majority of these, implementation is completed by 2020. Compact development of cities and the technological advances included in the MI Scenario bring about continuous improvements spread over the longer term with complete implementation by 2050 at the latest.

As detailed in Chapter 4, implementation of the MI Scenario measures outlined in this policy pathway could deliver a 76 per cent CO_2 reduction compared with the 2050 BAU Scenario (or a 68 per cent reduction on the BAU baseline year emissions). For road transport, the measure having the greatest effect on reducing demand would be the fuel price escalator.

It should be emphasised that only by implementing the complete package of measures will a carbon neutral road transport sector be delivered by 2050. Reducing demand (from a combination of fiscal, spatial and behavioural measures) in the MI Scenario could achieve a 76 per cent reduction in CO_2 emissions, but this will be much more difficult in the absence of alternative technologies such as PEVs and H-fuel cell vehicles utilizing decarbonised UK electricity supply. Equally, providing technological solutions alone will not deliver the required reductions if people's demand for existing technologies is not curtailed by the fiscal, spatial and behavioural measures as well. Also, a decarbonising UK electricity supply would be unlikely to meet the additional power requirements of PEVs and/ or H-fuel cell vehicles if total demand from road

Groceries by rail - the Stobart express, Scotland © Duncan Brown

Table 6.1: Policy implementation framework

Measure	2010	2020	2030	2040	2050
Road Transport					
Spatial planning					
Pedestrian-oriented design					
Road space reallocation					
High occupancy only vehicle lanes					
Compact development: for cities					
Regional co-operation model for HGVs					
Fiscal					
Road user charges					
Car parking charges					
Fuel price escalator					
VED circulation tax					
Car purchase tax/'Feebate'					
Public Transport Fares					
Behavioural					
Ecological driving					
Motorway speed limit: 60 mph					
Car share					
Modal shift for road freight:					
Technology					
Cars, LDVs, m'cycles and HGVs/buses < 12 t to be PEV or H-fuel cell (using electricity that is 100% C-neutral by 2050)					
HGVs and buses/coaches >12 t to be powered by either H fuel cells (with C-neutral sourced H by 2050) or sustainable biofuel					
LPG vehicles phased out					
Rail					
All passenger and freight rail to be powered by electricity (that is 100% carbon neutral by 2050).					
Shipping					
New technology					
Speed /Voyage Optimisation					
Cleaner Fuels					
Shore Side Measures					
Aviation					
Constrained Demand					
Aircraft Technology					
Air Traffic Management					
Fiscal Measures					
Railway Substitution					
Video Substitution					

Indicates the period over which implementation is phased in (i.e. from when the measure is initiated to when its implementation is complete and has its maximum impact on emissions).

transport is not drastically reduced at the same time. The existence of these synergies means that only the implementation of all measures (fiscal, spatial, behavioural and technological) combined can deliver a decarbonised road transport sector by 2050.

Although road and rail transport could both achieve zero CO_2 emission target, emissions from aviation and shipping are problematic and together account for the 24 per cent short-fall for the transport sector as a whole. To improve on the 76 per cent CO_2 emissions reduction for transport by 2050 therefore, would require radical interventions or technological innovations than those envisioned in the present study for these two sectors.

This report has focussed on evidence-based interventions that have a clear logical sequence between the intervention and the likely results of that intervention. This necessarily excludes other interventions that could make a substantial contribution to achieving a low carbon transport system. An example of such an intervention is a significant prioritisation, above anything currently envisaged, of public health measures (see box 6.1).

It must also be emphasised that additional policy interventions would be required to produce the 100 per cent carbon neutral UK electricity power generation sector on which zero CO_2 emissions for the road and rail transport sectors will totally depend. A detailed analysis of policy pathways leading to such a decarbonised electricity supply in the UK is outside the scope of this study. However, if electrical power sector decarbonisation by 2050 is less than 100 per cent, CO_2 emissions from road and rail transport will be substantially higher than projected for the MI Scenario. It is clear that, for the transport sector of 2050 to even achieve the 76 per cent CO_2 emissions reduction, the introduction of a programme to radically change the way electricity is generated is urgently required.

Box 6.1: The prioritisation of public health measures

The introduction of a new public health regime that actually does protect the health of residents when noise and air quality limits are exceeded. This would apply to all road and airport projects both new infrastructure and existing operations. Clear noise limits published by the World Health Organization exist on what levels should not be exceeded in order to protect public health and as well air quality thresholds developed on the same basis. The problem is that at the moment there is no expectation that they will be enforced in any way. Measures designed to protect public health are not applied in real world situations to protect the health of geographically defined populations. This could be very different and thresholds which presumably should not be exceeded could be made enforceable in the following way.

All local authorities routinely monitor air quality (AQ) through a network of AQ monitoring stations. Under a new AQ regime all exceedances of EU AQ limits would be recorded each day for the main pollutants and work carried out to identify the sources of those pollutants. Local authority AQ officers already know the sources of most pollutants (point sources, traffic, airports etc) so this is not difficult. For each day and part of each day that AQ threshold are exceeded from airport sources (for example) the airport operator would be fined £100,000 and this income would be ring fenced for the improvement of community facilities in the local authority area. For an airport operator there are ways of avoiding fines:

- reduce the number of flights;
- develop a surface access strategy to maximise public transport access and minimise car and taxi use;
- establish a Low Emission Zone and only allow the lowest polluting vans and lorries to enter the site;
- reduce the number of car parking places;
- decommission all plant that currently runs on diesel or fuel oil and switch to electricity.

For the Highways Agency or Highway Authority there are ways of avoiding fine arising from traffic pollution:

- close roads when levels trigger the danger threshold;
- implement serious demand management measures to reduce car use;
- implement serious "urban logistic" strategies to reduce HGV activity;
- switch road freight to rail and inland waterway.

Currently there is no policy connection between AQ standards and the need to improve AQ and the seriousness with which measures can be implemented in the transport sector to reduce pollution. Measures to reduce pollution will reduce greenhouse gases and will contribute to healthy, safe sustainable communities.

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