Institution of Mechanical Engineers
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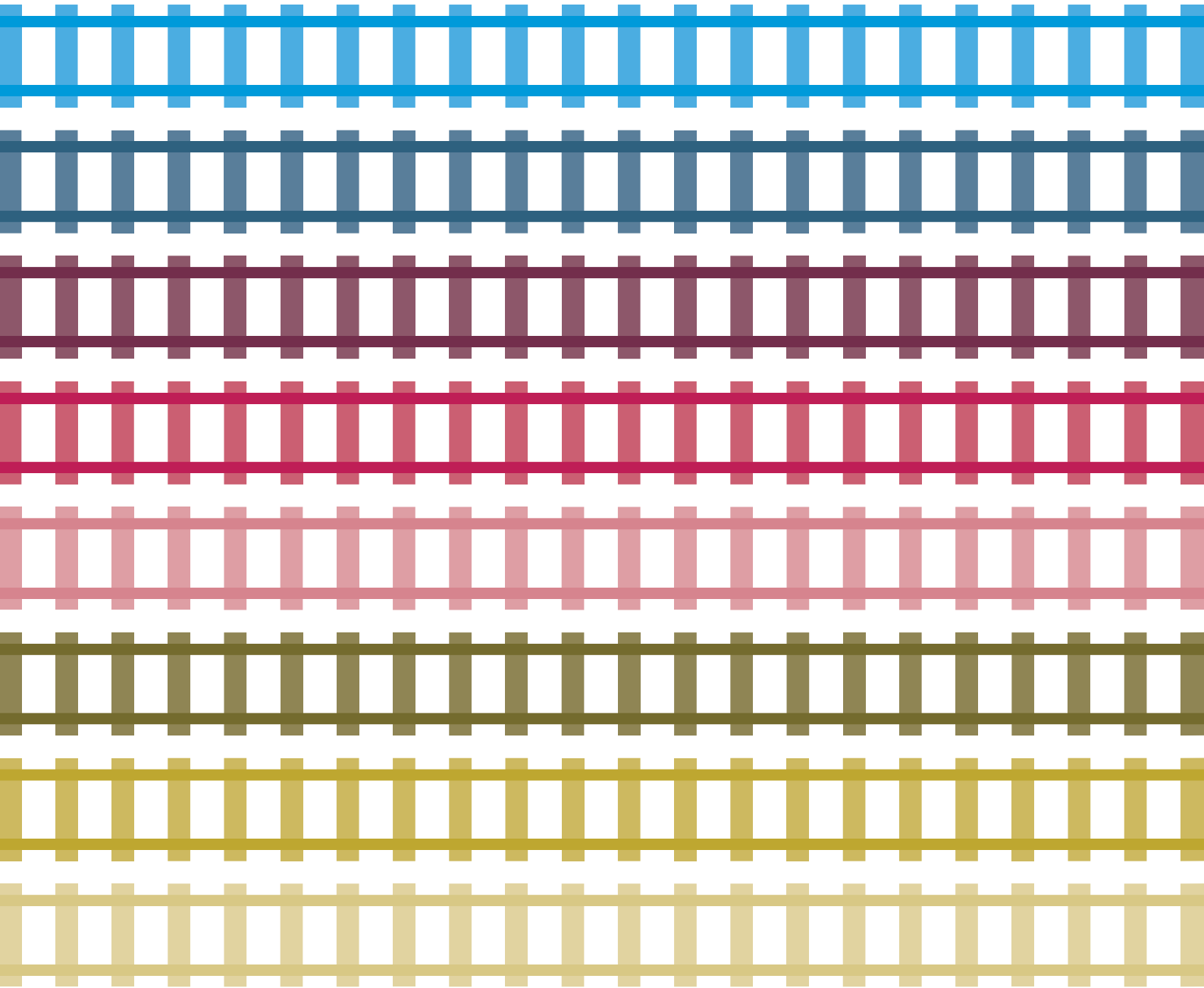
Low-Carbon Mobility: A Sustainable Future for Transport



Executive Summary

Climate change concerns have been the subject of extensive media coverage and it is widely accepted that human-activity carbon emissions are a strong driver of global warming and climate change.

This review focuses primarily on reducing transport-related carbon emissions through innovation, influence and investment. This paper has been produced in the context of the IMechE's strategic themes of Energy, Transport, Education and Environment and its vision of "improving the world through engineering".

The Institution of Mechanical Engineers believe that more can be done to meet Government carbon reduction commitments and that the railway should not only contribute to the development of sustainable mobility but lead the way in providing a vision for low carbon living. Reducing carbon emissions from transport should be high on the Government and public agenda and IMechE is pleased to present this review and its recommendations which, it hopes, will be influential in guiding the Government's policy and investment decisions in the progression towards a low-carbon transport system.

Specifically, this review aims to establish what environmental advantage rail holds over alternative modes of transport, what scope for improvement there is for the environmental performance of the current transport system (i.e. scope for CO_2 emission reduction) and what the most cost effective policy actions are that the UK government could take to reduce transport-related CO_2 emissions.

Key messages from this study include:

Societal Change

- There is a clear relationship between social values, behavioural patterns and people's transport choices. A change in societal values is potentially one of the greatest influencers for environmental awareness and transport carbon emission reduction.
- Today, despite growing awareness, environmental impact is not yet a key influencing factor in passenger transport choices.
- To drive real change, having a substantial carbon footprint will need to become as socially unacceptable as drink driving or smoking in a public place – examples where awareness campaigns, combined with legislation, have successfully changed societal views.

Fiscal Measures

- Transport planning, taxation, pricing structure and public investment policy is, in places, ineffectual and contradictory and undermines environmental objectives to reduce emissions by 60% by 2050.
- The relative price of travel, across rail, air and road, does not reflect the environmental impact of the journey in each case. Rail is still comparatively highly priced and perceived as poor value for money. Pricing structures (particularly pricing of infrastructure) must be revised to ensure the price of travel, across all modes, bears the full environmental (and other external) cost to create pricing that reflects the comparative cost. Information on the comparative carbon cost of a journey (carbon pricing on travel or carbon branding of tickets, to show the emissions associated with each journey) would help differentiate 'greener' modes and induce modal shift to rail.
- Modal shift to rail, from revised rail pricing structures, could have a significant impact on CO_2 emission savings. An increase of 10% market share for rail could potentially save 2.96 million tonnes of CO_2 per year.

Investment in Rail Infrastructure

- The Government has committed £10 billion investment for enhancing rail network capacity. Whilst this improves the productivity of the existing infrastructure, new infrastructure and electrification will be required in the long term to deliver additional capacity.

- There is a fundamental need for a balanced and integrated transport infrastructure investment policy across all modes. Investment in transport infrastructure, for all modes, is at an all-time high. Rail is now receiving equal public investment to road. However, this substantial public funding (£4,400m per year) is generating additional capacity for road traffic, which is in conflict with sustainable transport development. Balanced investment, in line with sustainable transport policy, will be hugely instrumental in improving performance and creating required capacity to generate modal shift to rail and subsequently, a reduction in CO_2 emissions for transport.

Combining Transport and Energy Strategy

- For every 1GW generated by a renewable energy supply, the carbon emissions are 0.7–1.5 million tonnes of CO_2 lower than that produced by conventional fossil fuels.

- The rail industry needs further electrification and to reduce its overall dependency on fossil fuels. A combined long term programme of electrification with the continued increase of the contribution of renewable energies to the UK electricity generation mix would significantly enhance the environmental performance of rail. This case is even stronger with the breakthrough of regenerative braking technology.

Local Authority Transport Planning

- There is a real opportunity to drive environmental and transport planning objectives through devolved responsibility to local authorities which are experiencing a renaissance in transport as a result of local "ownership". Local community partnerships can be set environmental targets and a local carbon emissions trading scheme can allow them to invest in areas which are most effective for their regions; to off-set or trade environmental performance between transport operators or projects whilst keeping up with regional growth.

This report has generated a number of recommendations for cost-effective policy actions which will yield a reduction in CO_2 emissions for transport. These recommendations have been made in the context of an infrastructure investment programme which can deliver current railway capacity and performance and accommodate the predicted future growth. A balanced and integrated transport infrastructure investment policy across all modes will be, in itself, hugely instrumental in generating modal shift to rail, addressing capacity and subsequently providing a reduction in CO_2 emissions for transport.

1. Government campaign to endorse, promote and educate on the environmental impact of travel and 'green' transport choices.

2. A review of rail pricing policy, comparatively with the costs of other modes.

3. Transport environmental duty imposed on all transport modes in accordance with associated carbon emissions.

4. Increase in the proportion of national grid electricity generated from renewable sources and combine upgrade/enhancement of the national grid system with rail network electrification.

Contents

1. Introduction

1.1 BACKGROUND

In today's society, it is difficult to open a newspaper, watch television or go online without experiencing some reference to the environment, climate change and initiatives to reduce environmental impact or develop sustainable solutions for the future. It is the biggest challenge facing our generation and involves all aspects of industry and society on a global scale.

"The railway should not only contribute to the development of sustainable mobility but lead the way in providing a vision for low carbon living"

In July 2007, the UK Government issued a White Paper entitled "Delivering a Sustainable Railway"[1]. This paper acknowledges the achievements to date, and challenges ahead, for the railway industry. It takes a view on the performance of rail and sets out plans for growth and development to unlock the potential of rail as a "green" transport choice for the public. A further paper was issued in October 2007, "Towards a Sustainable Transport System: Supporting Economic Growth in a Low Carbon World[2]". This outlines transport-related investment and policy plans with the aim of ensuring that the UK transport system is well-placed to play its part in the fight against climate change.

In response to these Government papers and growing media coverage of the subject, the Institution of Mechanical Engineers (IMechE) presents this review, "Low-Carbon Mobility: A Sustainable Future for Transport", discussing issues related to carbon emissions from transport, with the hope of capturing the interest and stimulating debate within the general public, as well as IMechE members and the broader engineering community. This paper has been produced in the context of its strategic themes of Energy, Transport, Education and Environment and its vision of "improving the world through engineering".

Transport, and particularly rail, has an important role to play in the development of our economy in a sustainable way and reversing the effects of climate change. Government papers, outlining policy and investment plans, and the Department for Transport's Rail Technical Strategy are welcomed by IMechE. For the first time, the railway has a 5 year plan with committed funding (in the form of the High Level Output Specification (HLOS)). Rail has experienced over 40% growth in the last 10 years and all forecasts expect growth of this magnitude to continue. Recent studies show that rail offers a significant environmental advantage over alternative modes of transport, producing only 2% of the UK's transport CO_2 emissions with a 7% transport market share[3] but IMechE believes that more can be done to meet Government carbon reduction commitments; that the railway should not only contribute to the development of sustainable mobility but lead the way in providing a vision for low carbon living. Rail has the potential to influence how people value their time, combine travel with other activities and, ultimately, make more informed, and greener, transport choices. The development and planning of rail should be used as a primary means to meet overall objectives for reducing transport carbon emissions by treating rail as part of an overall transport, and energy, strategy.

Reducing carbon emissions from transport should be high on the Government and public agenda and IMechE is pleased to present this review and its recommendations which, it hopes, will be influential in guiding the Government's policy and investment decisions in the progression towards a low-carbon transport system.

1.2 OBJECTIVE

This review focuses primarily on reducing transport-related carbon emissions through innovation, influence and investment. In doing so, this paper considers rail as an integral part of the transport network and a major part of the solution.

Specifically, this review aims to:

1. Establish what evidence there is to demonstrate that rail offers an environmental advantage over alternative modes of transport and define the quantified advantage.

2. Understand the scope for improvement for the environmental performance of the current transport system (i.e. scope for CO_2 emission reduction).

3. Discuss issues such as influencing modal shift and energy sources as well as direct initiatives for the railway industry.

4. Present the most cost effective policy actions that could be undertaken by the UK government that would yield the greatest reduction in CO_2 emissions for transport.

1.3 SCOPE

There are many ways in which environmental performance of transport can be improved. This review, Low-Carbon Mobility: A Sustainable Future for Transport, explores various measures that could reduce transport-related CO_2 emissions under the themes of:

- Social values and public behaviour;
- Modal shift;
- Rail network capacity;
- Fiscal measures;
- Railway's carbon footprint.

This review assesses the relative cost-benefit impact of various policy actions on transport CO_2 emissions and cost-effective policy actions that the Government could take to reduce CO_2 emissions from transport. The objective of the study is to present existing research in the context of overall impact on transport emissions and stimulate further discussion and debate. It is not an exhaustive study which encompasses all potential actions to reduce transport-related emissions.

All views provided are consensual and based on existing research and published material referenced within this report. The research methodology is presented in Appendix A.

The IMechE will review the outcomes of this study in 12 months time to assess the development of CO_2 emissions from transport and progress made by government policy to reduce the environmental impact of travel.

2. Why we need a Sustainable Transport Strategy

2.1 CLIMATE CHANGE

Climate change concerns have been the subject of extensive media coverage and it is widely accepted that human-activity carbon emissions are a strong driver of global warming and hence climate change.

Over the past 20 years, the effect of global warming has been more evident. Figure 1 illustrates the global warming trend. The requirement to curb carbon emissions is heightened by the fact that, without intervention activity, emissions are predicted to keep rising sharply over the coming years (for instance, the International Energy Agency (IEA) estimates a 55% increase in global CO_2 emissions related to energy over the period 2004 to 2030[4]). Recent reports show that the effects of climate change are being seen at rates faster than predicted; our consumption of natural resources and production of greenhouse gases is accelerating. This means current lifestyle patterns and behaviours are unsustainable for the future.

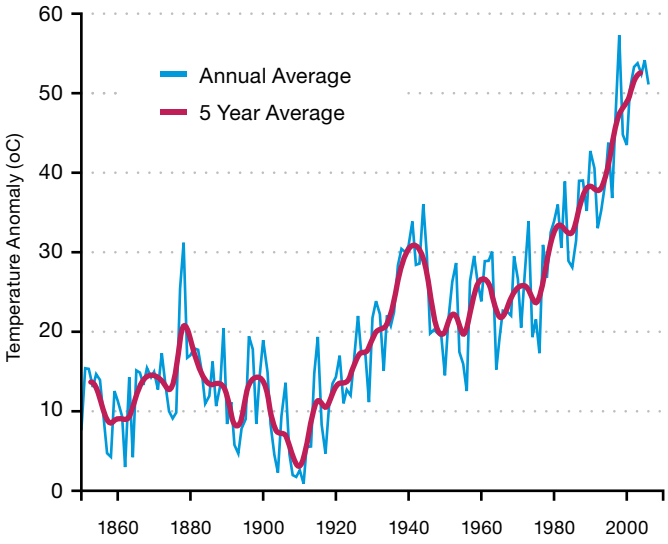


FIGURE 1:
Global Temperatures 1850 to 2005
Source: Climatic Research Unit of Met Office Hadley Centre

The UK is responsible for 2% of global greenhouse gas emissions. In 2005, the UK emitted 567 million tonnes of CO_2. In order to combat the predicted increase in temperature, emission targets have been set both internationally, through the Kyoto agreement, and nationally. Figure 2 shows the current levels of emissions against both targets.

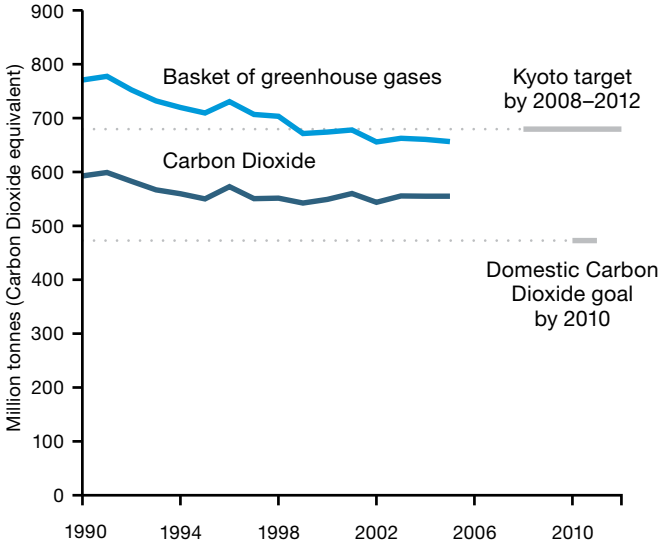


FIGURE 2:
Emissions of greenhouse gases against targets
Source: Draft Climate Change Bill, March 2007

2.2 TRANSPORT EMISSIONS: THE FACTS

The main sources of carbon emissions are power generation, transport, domestic and industrial processing and manufacturing/construction.

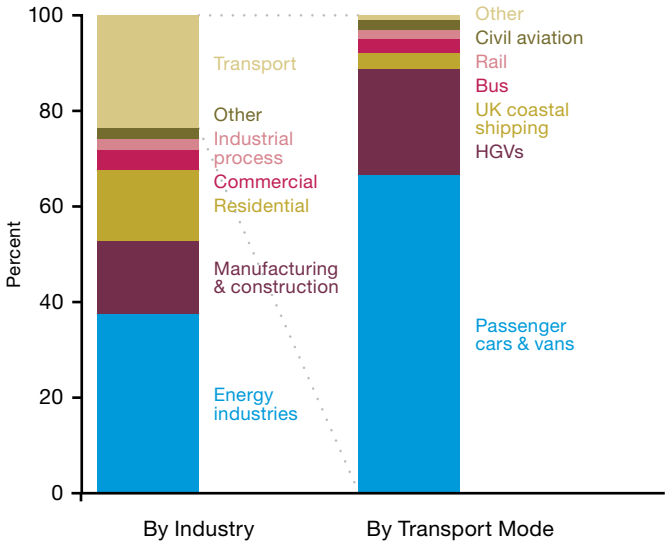


FIGURE 3:
UK Carbon Emissions by industry sector & transport mode
Source: DfT, Delivering a Sustainable Railway, July 2007

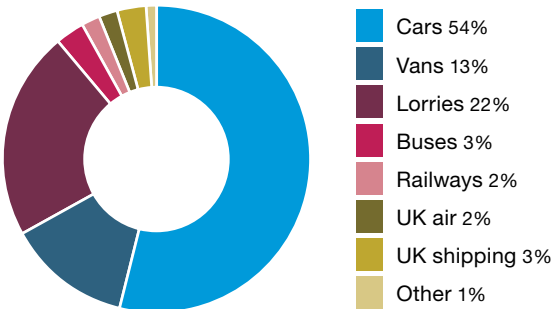


FIGURE 4:
CO_2 emissions by transport mode 2005
Source: CfIT Transport and Climate Change 2007

This shows that transport accounts for almost one quarter of UK CO_2 emissions (accountable for 41.6 MtC in 2005) with rail contributing only 2% to transport-related emissions[5]. In the UK, 795 billion passenger-kms are undertaken each year[6]. Rail accounts for 7% of this market (see Figure 5).

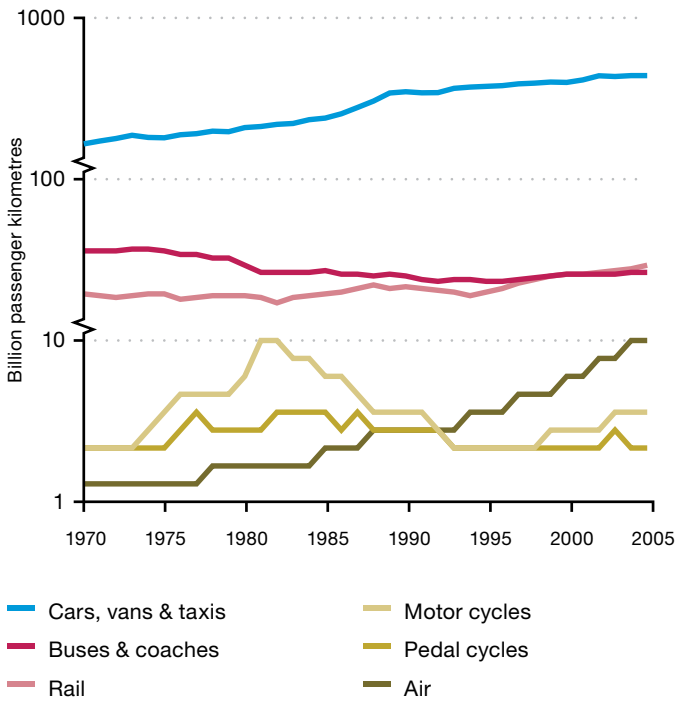


FIGURE 5:
Transport mode market share
Source: DTI National Statistics, Energy Consumption in the UK

With 7% share of the passenger transport market, producing only 2% of transport CO_2 emissions; this illustrates the environmental advantage of rail over other modes. Road traffic accounts for over three quarters of all transport emissions.

At a time where public transport usage is growing in every sector[7] and the UK has the fastest growing railway in Europe[8], transport is an increasingly significant source of emissions and a growing area of concern for climate change developments – emissions from transport are expected to more than double before 2050, making it the second fastest growing sector, after power.

The transport industries are responding and the environmental performance of many modes have improved significantly, driven in some cases by industry sector policy. Rail currently holds the advantage and studies have shown that it is getting greener faster than other industries but it cannot afford to be complacent. As other industries drive substantial changes in environmental performance, and social/political concerns grow over climate change, every area of industry must play its part.

2.3 THE CHALLENGE FOR THE FUTURE

So what will happen if we do nothing? Studies predict a continued rise in global temperatures, causing further melting of the Artic ice caps and causing sea levels to rise, affecting our local weather systems, forests, crop yields, wildlife, water supplies and ecosystems. These will be permanent changes in our climate and landscapes. Britain could be up to 6°C warmer than current conditions.

We need to better understand how we, personally, impact global warming and take action to reduce carbon emissions (our 'carbon footprint') associated with our lifestyles and the products we consume.

To meet the growing demand for transport and other lifestyle needs, and address concerns over climate change and security of energy supply, energy policy has seen a number of developments over recent years. The DTI undertook an energy review in 2002, which led to the publication of an energy white paper in 2003. Its goals included putting the UK on a path to cut CO_2 emissions by some 60% by 2050, with real progress by 2020.

Cutting CO_2 emissions by some 60% by 2050 is ambitious and will require major changes in all industry sectors.

Transport has a key role to play in ensuring that economic growth and access to effective, affordable mobility is preserved whilst working within the constraints that new environmental targets may set.

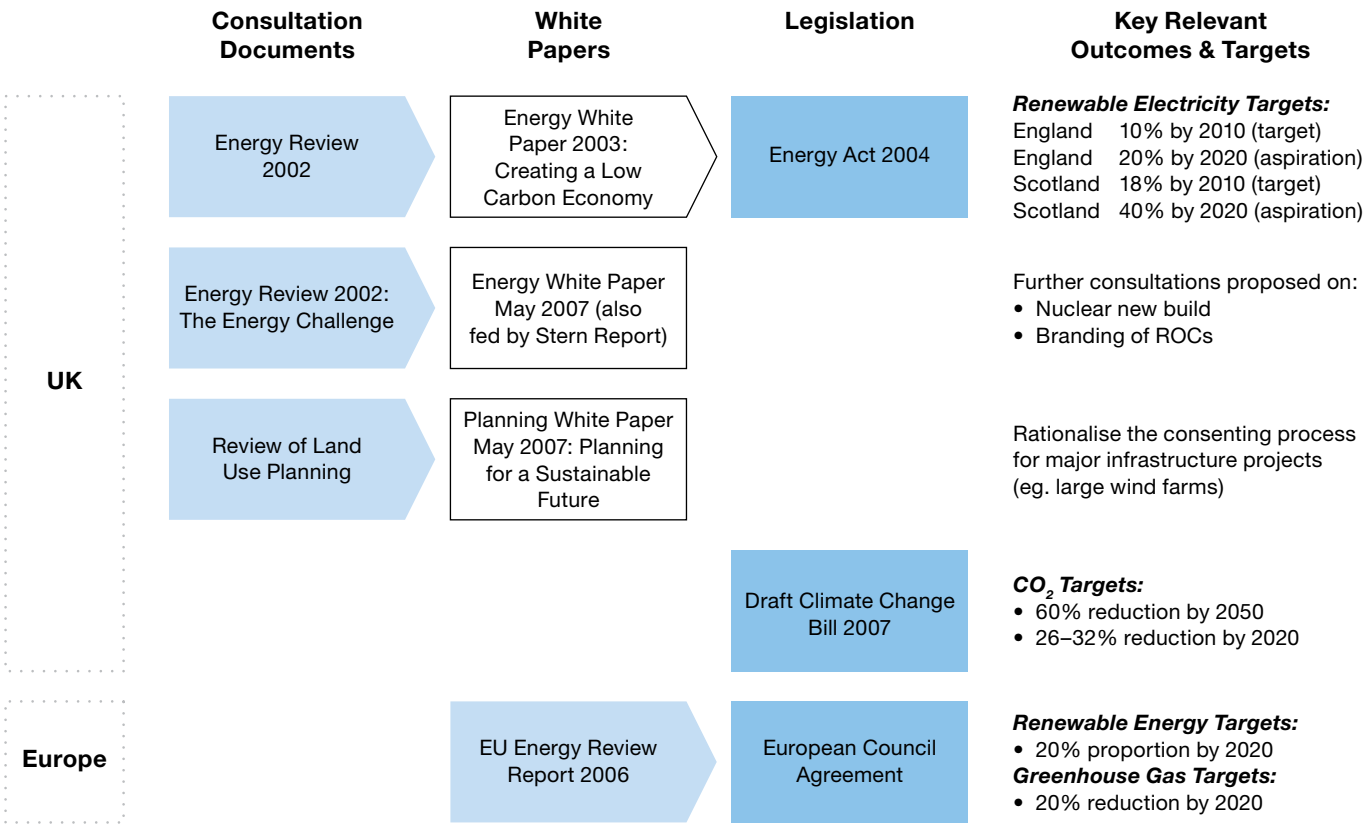


FIGURE 6:
Overview of Recent UK Energy Policy Process

3. Taking steps towards low-carbon mobility

3.1 A CAMPAIGN FOR "GREEN" TRANSPORT

Societal change is potentially one of the greatest influencers for environmental awareness and transport carbon emission reduction. There is a clear relationship between social values, behavioural patterns and people's transport choices. We are already experiencing a rising trend in ethical consumerism and the development of a carbon-conscience culture.

As an example, Tesco (one of the largest retail chains in the UK) has recently become the first supermarket to assign a 'carbon label' to every product it sells[9]. Product labelling for goods, displaying transport mode and energy and emissions rating, is a positive way to raise awareness and educate consumers. Tesco believes the market is ready, that consumers have asked for this information in order to help fight climate change and induce a low-carbon economy. This labelling is predicted to encourage consumers to opt for lower carbon goods, promoting local suppliers and encouraging the supply chain to cut carbon emissions in order to remain competitive.

FIGURE 7:
Examples of a growing carbon-conscience culture

The transport industry is also working hard to promote sustainable initiatives and influence the travelling public. The Stagecoach Group have a fleet of buses trialling biodiesel (consisting of recycled cooking oil and food based by-products). It estimated that this could result in a reduction of 82% in CO_2 emissions[10], giving an annual saving of 960 tonnes of CO_2. Stagecoach are conducting a six month trial where local residents are being encouraged to exchange their waste cooking oil for subsidies on their bus fare. Similarly, the UK rail industry has recently embarked on a number of communication initiatives; with a number of train operators advertising the associated carbon emissions per rail journey compared to other modes and some operators have a "Green Page" or an environmental section within their monthly magazine, promoting current green initiatives and corporate values for sustainable development.

Real societal change will require a large scale communication and a campaign focussed on increasing public awareness of the "green" credentials of their consumer and transport choices. The campaign should be accompanied by appropriate incentives (such as tax relief on 'greener' transport options) and the provision of adequate capacity for real effectiveness.

FIGURE 8:
Examples of corporate social responsibility for the environment within the transport sector

This can be done by a wide range of marketing and policy initiatives:

- A Government campaign which endorses and promotes 'green' transport choices. Campaigns should educate the public on the environmental impact of travel and transport decisions, specifically the carbon cost of travel for various modes.
- Branding of travel tickets to show high/medium/low carbon costs for journeys.
- A central advertising campaign illustrating the environmental initiatives of the rail industry to its target markets (business and leisure passengers).
- Marketing, promotion and the refurbishment of public transport services such as buses, trams and the underground to broaden their appeal through the "it's cool to be green" image.
- Public engagement and consultation through the use of conventional market research tools such as surveys and focus groups to assess the effectiveness of any campaign or policy change and to help target initiatives which the public perceive to be key to changing their mode of transport.

The Government believes that in the future "people will have double today's income and half today's carbon footprint[11]". In order to drive this change, having a substantial carbon footprint will need to become as socially unacceptable as drink driving or smoking in a public place – these are examples where Government campaigns, combined with legislation, have successfully changed societal views and improved our health and safety. Today, despite growing awareness, environmental impact is not yet a key influencing factor in passenger transport choices. We look at two examples below to illustrate the potential of how a transport-focussed carbon footprint campaign could influence views and, subsequently, reduce CO_2 emissions through consumer choice.

Case Study 1: Drink-Driving

The social shame of drinking and driving now ranks alongside sexual abuse and drug dealing, according to recent research[12]. In a poll conducted after the screening of the "SHAME" Anti Drink-Drive campaign, 93% of people viewed drink-driving as extremely shameful, comparable with scores of 98% for sexual abuse and 94% for drug dealing. This campaign was thought to improve social attitudes, making a positive step towards making roads safer. Results of the campaign include:

- 27% increase in drivers (post-campaign) who believe they cannot consume any alcohol without affecting their driving.
- 72% of drivers believe that driving after two drinks is very unacceptable.

Such nationwide campaigns saw arrest figures fall and a reduction of more than 40% in the number of people killed by drink drivers.

Case Study 2: Unleaded Petrol for Cars

Emissions of lead from petrol-engine road vehicles has fallen virtually to zero following reductions in the amount of lead in petrol in the 1980s, the increase in uptake of unleaded petrol in the 1990s and the eventual ban at the end of 1999 of leaded petrol for general sale[13].

Road fuel tax in the UK is an effective tool for changing behaviour and, in this instance, reducing the amount that people use their cars or their choice of fuel in order to protect the environment. It can also be used to raise revenue which can then be used to support sustainable transport projects.

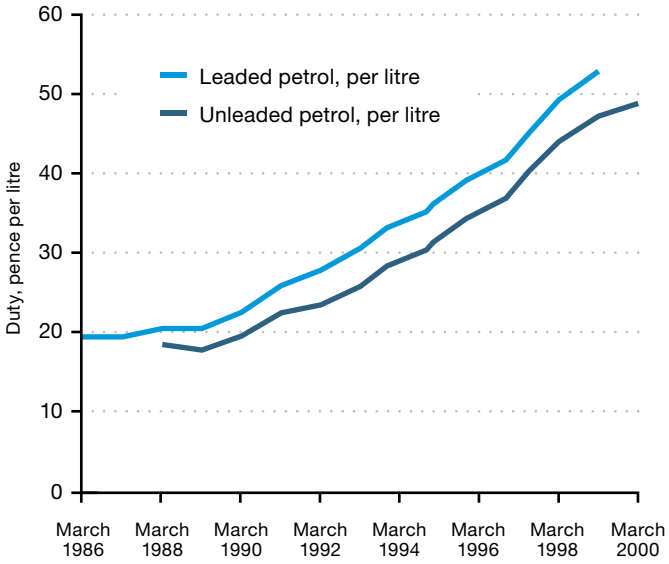


FIGURE 9:
Real Duty on Leaded/Unleaded Petrol
Source: The Petrol Tax Debate by the Institute of Fiscal Studies, July 2000

Although eradicating CO_2 emissions is not as simple as banning it through legislation, the uptake of unleaded petrol in the 1990s is telling and shows how effective educative campaigns can be in influencing consumer choice combined with the use of tax.

Surveys have been undertaken to understand the potential response to increases in road tax/duty and how this would influence peoples choices for 'greener solutions'. 33% of respondents said their choice of car would be influenced if the duty difference was increased by £50 (55% would be influenced for a £150 difference in duty). This equates to a potential saving of 0.3–1.6 MtC by 2020 from road taxation alone (i.e. excluding the potential savings from airline emissions from increased fuel or environmental duty).

Similarly, the drink-driving campaign shows the potential of a consistent message through government and the media on public behaviour.

"Imagine, if 72% of the travelling public believed that a high carbon cost per journey was very unacceptable, what different choices would people make?"

Imagine, if 72% of the travelling public believed they could not travel without directly affecting the environment and that a high carbon cost per journey was very unacceptable, what different choices would people make? Based on the assumption that a similarly structured campaign targeted at transport could influence the public in a similar manner, the resultant savings in carbon emissions could be 3.6 MtC by 2020[14] as travellers opt for lower-carbon modes or reconsider the necessity of their journeys and alter their lifestyles accordingly.

3.2 MODAL SHIFT: GETTING BACK ON TRACK

Rail offers a significant environmental benefit over other transport modes and has significant potential as a key contributor to low-carbon economic growth. Not withstanding demand growth for rail of 40% in the last decade and predicted growth in the next ten years of 30% and the challenge for capacity this sets, the most effective contribution the railway can make to reduce overall transportation carbon emissions is to attract more passengers and freight custom from competing modes such as roads and aviation. The most effective way to do this is to induce modal shift through a combination of incentivising demand for rail services and increasing capacity. A 1% modal shift in transport from road to rail could save 0.117 MtC in a year, 1% shift from air to rail for UK short-haul could save 0.0016 MtC[15].

Inducing modal shift to rail involves measures which make rail the natural choice for the traveller for all types of journeys. Passenger expectations of service quality are rising in line with increases in income and lifestyle patterns. To be competitive, the railway must look to provide more flexible services; moving towards a 24/7 society and an improved service package which allows for a more effective journey time i.e. an ability to work or relax in comfort for the duration of your journey, allowing passengers to make the most of travelling time and consider rail as a more rewarding and enjoyable way to travel, as well as 'greener'. This effective journey time should include service provision at railway stations as well as on-board services, with facilities such as business lounges and wi-fi zones for business travellers and amenities such as supermarkets, childcare nurseries, retail services, such as dry cleaning, banks and post offices for commuters and leisure passengers, encouraging people to integrate regular lifestyle activities with their choice of travel.

Attracting more people to rail will require:

- Better integrated transport systems with key modal interfaces to link journeys and reduce waiting times.
- Journey time reduction (by introducing more 'express services' and utilising technology such as improved signalling systems). More modern signalling will also improve railway network capacity.
- Rail service enhancement with improved frequency, plus the greater provision of business, entertainment and information services.
- Comparable ticket pricing with other competing modes.

To capitalise on opportunities for modal shift and support continued growth, key areas for action are:

- Planning for new rail infrastructure on selected routes to cater for inter-modal shift and ease overcrowding. Government investment in new rail infrastructure should be on the same scale that we have seen in the past for new airports and motorways.
- Use of the latent capacity in rail through yield management techniques. This will enhance load factors that have an important influence on the carbon emissions per passenger kilometre and will further enhance the relative "greenness" of rail travel.
- To facilitate and promote cycle-friendly rail travel. As cycling is a growing mode of transport in the UK and has a strong synergy with rail as a combined environmentally-friendly way to travel, particularly for commuters, more should be done to provide for this market. On-vehicle access, security at stations for bicycle storage and integrated routes in/out of stations and into town centres should be developed. Encouraging this mode of transport will also have a positive affect on health.
- Where 21% of the UK's transport carbon emissions are generated by freight and 79% of the freight market is HGV/road-use, this represents a significant opportunity to re-address the balance and reduce environmental impact in this area by modal shift to rail.
- Building on the potential of HSL1 to extend from London-Paris and London-Brussels the shift from air to rail that has already been achieved with Eurostar services. Further high-speed connections would attract similar modal shift for markets such as Birmingham/ Leeds/Manchester/Sheffield or Glasgow/Edinburgh to Paris/Brussels and London to Amsterdam/Cologne – all of which would involve journey times comparable with those found commonly in inter-city journeys in the UK (e.g. London - Plymouth, Newcastle – Bristol) and the rest of Europe.
- Minimising the extent to which pricing and safety restrictions faced by rail users of Eurotunnel (which compare unfavourably with those faced by road users of the Channel Tunnel or rail users of similar tunnels elsewhere in Europe) act as a barrier to rail movements between the UK and the rest of Europe, for both freight and passenger services.

Incentive programmes such as Spanish rail's Madrid-Seville policy, which offers a refund of the entire ticket cost if there's even a five minute delay on the service, is said to be a success (less than 0.25% of trips have resulted in refund of fares) and the public have responded favourably to a reliable, comfortable high-speed rail line.

There is evidence of direct displacement to rail where a High Speed Line offers an alternative to short-haul intercity destinations. To illustrate the potential impact of modal shift on CO_2 emissions, independent research commissioned by Eurostar concluded that the environmental benefit of the train (London-Paris) versus a flight is a 90% reduction in CO_2 emissions (return trip by plane 244 kg/CO_2, 22 kg/CO_2 by train per passenger). One return journey by air from London to Paris generates the equivalent amount of CO_2 from around eleven return journeys on Eurostar. Calculations are based on actual load factors, fuel consumption and electric power generation mix; it is worth noting that Eurostar has a significantly higher load-factor than some of the UK rail network and higher nuclear energy content in the power supply system. However, the reduction in emissions for rail journeys is still significant and, in light of predicted continued growth in domestic and short-haul international air travel in the future, the case for modal shift driven by rail infrastructure investment in such cases will become increasingly more important.

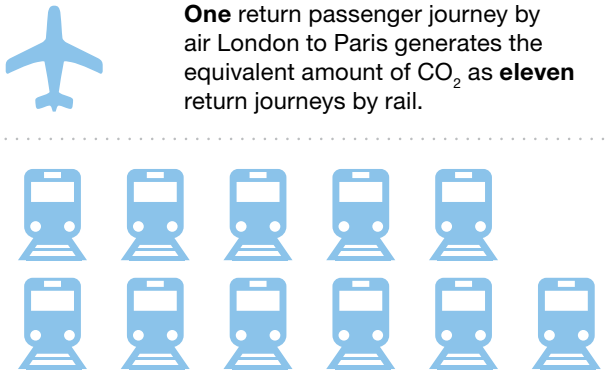


FIGURE 10:
Comparison of CO_2 emissions rail versus air

When asked for their reaction to the difference in CO_2 emissions between flying and going by rail, a separate YouGov poll of over 1000 people in the UK, revealed that four out of ten people (41%) said they are 'much more likely to take the train'.

Studies show as distance increases, the proportion of passengers who travel by air, as opposed to rail, also increases[16] (see Figure 11).

Destination	Distance from London (miles)	Proportion of trps made by:	
		Air	Rail
Aberdeen	524	96%	4%
Glasgow	402	93%	7%
Edinburgh	394	85%	15%
Newcastle	296	52%	48%
Manchester	184	44%	56%

FIGURE 11:
Transport mode market share: Journeys from London
Source: DfT, Delivering a Sustainable Railway, July 2007

As demonstrated by Eurostar, market share for rail grows where high speed lines provide a competitive route against the airline industry (in journey time and cost). With a 19% increase in passengers choosing Eurostar in its opening 3 months, this represents an equivalent saving in carbon of 0.118 MtC/year achieved through modal shift from road and air on the London-Paris route[17]. A new network of high speed lines in the UK would have the same potential for regaining market share from the domestic flight market and the market from the regions to the near continent (e.g. Paris, Brussels, Cologne and Amsterdam). Taking the equivalent displacement of Eurostar services from air to rail, a high speed line from Edinburgh to London could recover as much as 35% market share (taking market share to 50% rail, 50% air - see Figure 11). This is a gain of 1.495 million passengers per year from air to rail or equivalent saving of 0.13 MtC[18] per year. It is acknowledged that significant investment would be required for a high speed rail network and the timescales involved for such an initiative would mean that the benefits would not been seen for at least 10–15 years. However this investment is absolutely necessary to deliver the capacity and growth our transport system needs.

3.3 CAPACITY: TO DRIVE FUTURE RAIL GROWTH

Despite minimal investment in new infrastructure, compared to other modes, the UK railway has delivered record growth (in both passenger and freight journeys) and is predicted to continue to grow at similar rates in the next 30 years. This growth does not take into account the imperative of a modal shift to rail to drive down transport CO_2 emissions. The government has committed an investment of £10 billion between 2009 and 2014 for enhancing the capacity of the rail network for the future with an overall investment of £15 billion[19]. This investment aims to accommodate a 22.5% increase in passenger demand by 2014. The High Level Output Specification defines how this money will be allocated to improve capacity, performance and safety.

A number of measures can be taken to improve existing railway network capacity, including:

- Optimised train configuration planning for services;
- Segregated lines for high speed, regional, commuter and freight traffic;
- In-cab signalling systems for traffic management;
- Commuter interiors made simple – 'metro-style' for greater passenger numbers;
- High speed network;
- Longer trains;
- Additional railway stations on existing routes;
- Operation of a 7 day railway.

Whilst this improves the productivity of the existing infrastructure, in the medium to long term, new infrastructure and electrification of areas of the network will be required to deliver additional capacity.

Although there is an anticipated overall growth of double passenger numbers in 30 years, demand for specific routes and rates of growth of specific regions/cities is difficult to predict. Government investment plans must therefore be flexible and, the Government proposes to assess and qualify plans under the following criteria[20]:

- Deliver capacity and tackle congestion;
- Be affordable and offer value for money;
- Be environmentally sustainable.

New proposals and existing transport services (across all modes) should be reviewed against these criteria. Such a review would generate the necessary action to deliver significant rail capacity enhancements, we believe at levels significantly above those currently committed by Government.

In parallel, whilst the central Government plays a key role in taking strategic national decisions, there is a real opportunity to devolve further transport planning responsibilities to local authorities, build on the success of the Community Rail Development Strategy partnerships and to mirror the achievements of regionally devolved services across much of Europe (and in Scotland) which are experiencing a renaissance in transport as a result of local "ownership". Regional co-operation between communities, local authorities and train operators is an effective way to maximise the potential environmental benefits for public funding and maintain flexibility (allowing redistribution of investment, if required). Sensibly structured alignment of rail franchises to local government areas would also aid regional planning and performance measurement. Local community partnerships can be set environmental targets and a local carbon emissions trading scheme can allow them to invest in areas which are most effective for their regions; to off-set or trade environmental performance between transport operators or projects whilst keeping up with regional growth. Regional authorities and Community Rail Development Strategy partnerships are best placed to propose, review and implement investment programmes which comply with the criteria above. Some examples of projects making a real difference in local transport environmental performance include the Warwickshire Climate Change Strategy whose slogan is "Thinking global, acting local" and Camden's Green Transport Strategy which has achieved a significant reduction in road traffic since 1994 with savings of 23% CO_2 emissions through initiatives such as 'green travel' and public transport plans[21].

3.4 FISCAL MEASURES: INCENTIVES FOR GREEN TRANSPORT CHOICES

If no action is taken, transport will continue to be one of the fastest growing sectors contributing to carbon emissions and climate change. Transport pricing, through policy, taxation and duty initiatives can play a key role in influencing transport choices and inducing modal shift to 'greener' modes. Examples include:

- Carbon pricing through trading and taxation measures. Transport environmental duty ("Green Tax") imposed on all transport modes, valued in accordance with associated environmental performance (CO_2 emissions). This would raise awareness of the environmental impact of transport decisions and give visibility to the relative environmental performance of each mode.

- An appraisal of road pricing policy (car sales, road tax, excise duty, fuel duty) and a revised system which explicitly relates the true cost of vehicle use (including all external costs) to the distance travelled per journey.

- Campaigns to influence driver behavioural change such as congestion charges, tolls and limited road access for single occupancy cars. Both Swiss and French Governments have plans which divert revenue from such charges into further development of other, more sustainable, modes of transport. Such revenue could be used to directly fund investments in improved public transport.

- Mandatory Environmental Impact Assessment on all major transport investment projects to manage environmental risk and drive "green" initiatives and policy.

Road traffic accounts for over three quarters of all transport emissions and continues to grow. Car ownership is increasing; cars are becoming more affordable as incomes rise. Car use is also increasing for a range of journey purposes – it is a convenient method for travel, particularly as our towns and cities experience urban sprawl, with housing and commercial developments further from town/city centres. In addition to environmental impact, road traffic has a number of local effects, for example deaths caused by air pollution (approximately 24,000 people in the UK die each year from air pollution) and road traffic accidents. Policy measures to date, such as traffic management schemes and investment aimed at increasing road capacity to ease congestion, have in fact generated more traffic. The issue of road congestion and associated emissions will require a range of measures such as financial disincentives for car users, road vehicle technology advancements and the provision of real alternatives for drivers to induce modal shift to more environmentally sound modes of transport.

Investment in transport infrastructure, for all modes, is higher than it has ever been[22]. Where investment in road infrastructure has been traditionally, and consistently, high, investment in rail infrastructure is only now, in the past 10 years, beginning to match the same level of investment. Investment in airports is relatively low, and the majority of the investment is privately funded. However the trend shows a substantial increase in overall investment in this area in the past 5 years, reflecting significant growth in domestic and international flights. Rail is catching up on years of under-investment but road continues to receive over £4,400 million worth of public funding per year; a significant contribution to the mode of transport which currently accounts for 85% of transport emissions.

Influencing transport choices and inducing modal shift to 'greener' modes is the most effective way to combat transport emissions and the most influential fiscal measure the Government can take to induce modal shift to rail is to address rail pricing and revise the pricing structure such that rail pricing is comparative with the costs of other modes and seen as good value for money. Despite a growing market share, rail is still perceived to be expensive, particularly for 'walk-on' tickets at peak travel times and, in some areas, rail pricing remains unregulated (i.e. operators are free to set fares) where there are several travel options for passengers – this is a missed opportunity for influencing modal shift to a more carbon-efficient choice of travel. 43% of rail revenue is generated from regulated pricing (i.e. capped prices) but there has been overall an increase in rail prices each year since privatisation.

Walk-on fares in Britain are the most expensive in Europe. Recent research shows that the price is the top thing that passengers would like to change about the railway. Figure 12 below shows results from the National Passenger Survey undertaken by Passenger Focus; price of the ticket is the key concern for passengers, beating punctuality and frequency of service. A survey undertaken by the Chamber of Commerce for business passengers claims 19% of passengers surveyed said fares were the aspect of the railway which needs improving the most[23].

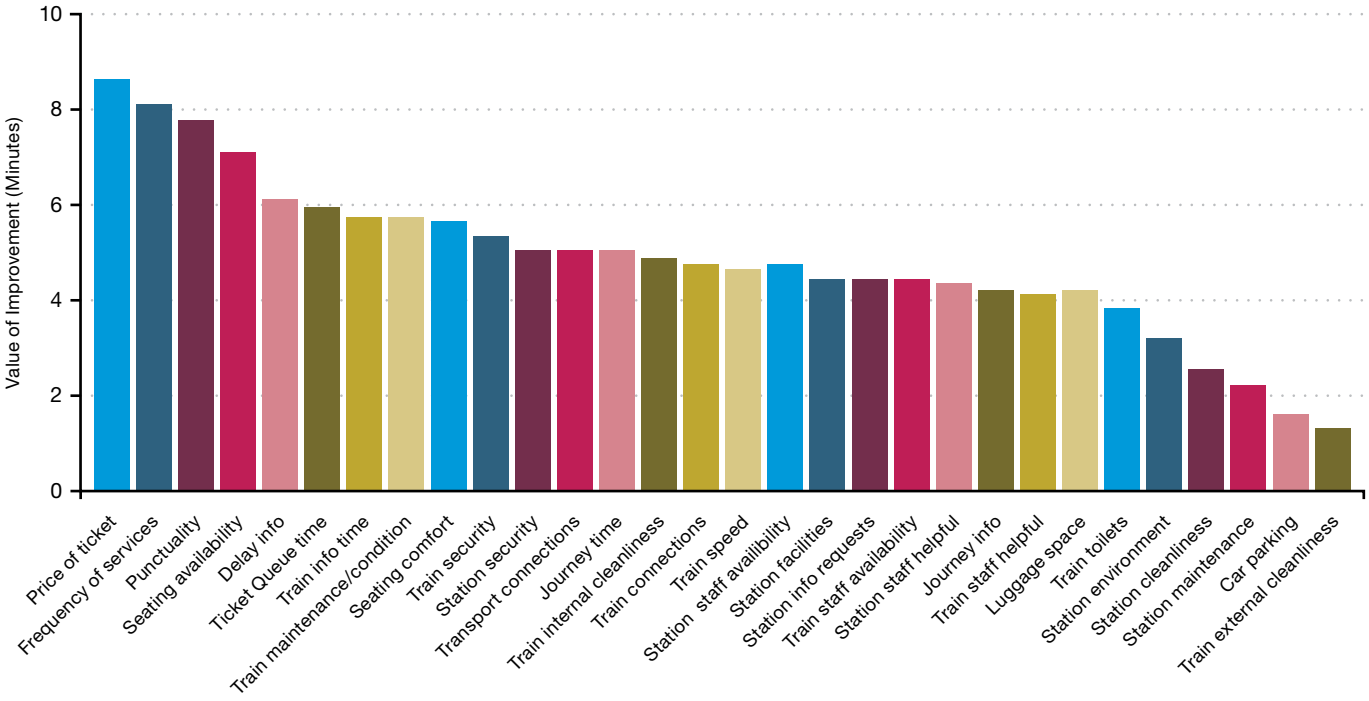


FIGURE 12:
Rail services: passenger improvement areas
Source: DfT, Delivering a Sustainable Railway, July 2007

Looking at the relationship between passenger ticket prices and the environmental cost of the same journey, although a crude comparison, Figure 13 takes typical journeys with the associated quoted fare (for travelling the next day, at the time of writing) with the associated 'carbon cost' of travel for each mode. It is clear from this illustration that rail is comparatively expensive and the relative cost of travel does not reflect the environmental impact of the journey, in each case.

The market for budget airlines offering low-cost fares has seen incredible growth in recent years but with no tax on airline fuel, no VAT on airline tickets and ongoing public investment in airports, such low prices are artificial. Although popular with passengers, as they are perceived to be excellent 'value for money' low-cost air fares are simply not sustainable, in the long term financially or for the environment. As aviation pollutes at high altitudes, its effects are also much greater than ground transport per ton of carbon. Although the message that rail is a 'greener' way to travel is becoming more widely understood by the public, transport pricing policy continues to undermine this message.

		Journey to London from...		
		Glasgow 401 miles	**Manchester** 206 miles	**Paris** 291 miles
By Rail	Ticket cost	£120.00	£109.50	£154.50
	Environmental cost (kg/CO_2 per passenger)	46.8	24	34
By Air	Ticket cost	£67.99	£38.90	£85.23
	Environmental cost (kg/CO_2 per passenger)	133.7	68.7	97
By Road	Ticket cost	£160.40	£82.40	£171.40
	Environmental cost (kg/CO_2 per passenger)	80.2	41.2	58.2

FIGURE 13:
Comparison of cost of journeys by rail, air & road[24]

"Although the message that rail is a 'greener' way to travel is becoming more widely understood by the public, transport pricing policy continues to undermine this message"

In order to generate modal shift to 'greener' modes, costing structures must be revised to ensure the price of travel for all modes bear their full environmental (and other) external costs; that pricing systems more accurately reflect the environmental benefit of modes such as rail and infrastructure costs are allocated in the same way, using the same rationale across all modes. Current Government plans for rail pricing will dampen demand and will tend to induce modal shift away from rail. It will also limit accessibility to rail, as a choice of transport, disadvantaging the underprivileged. Consideration of rail pricing, and its potential to influence modal shift, is a serious shortcoming of current energy and environmental policy for sustainable transport. The question is, 'to what extent will passengers alter their behaviour (to drive less or take fewer short-haul flights, switch to rail) in the face of higher prices for flights and car ownership?' or alternatively, 'be encouraged to take the train (over the car or air) when presented with cheaper tickets?'. Research undertaken by Outlook Research Ltd on behalf of Passenger Focus claims over 80% of leisure passengers and almost 75% of business passengers would travel more on trains if pricing was cheaper. Almost three quarters of leisure passengers have decided not to travel by train at some time due to the price of the tickets and 50% of people were likely to modify their travel plans (e.g. avoid travelling at peak times) when offered 20% reduction in price[25]. Based on this, restructured pricing systems could lead to a substantial increase in market share for rail with associated savings in CO_2 emissions. For example a gain in market share for rail of 10% (from 7% to 17%, an increase of 79 billion passenger/km/year) from road and domestic air gives a carbon saving of 2.96 MtC[26] per year.

3.5 RAILWAY'S CARBON FOOTPRINT: PLAYING ITS PART

A Carbon Footprint is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in units of carbon dioxide. This can consist of primary footprint (a measure of our direct emissions of CO_2 from the burning of fossil fuels including energy consumption and transportation) and secondary footprint (indirect emissions from the whole lifecycle of products we use, for example, their manufacture, transport and disposal). The average UK carbon footprint is 9.4 tonnes per person per year[27] (equivalent to 38 flights from London-Paris, see Figure 10 section 3.2).

Carbon Footprint is a term developed to help individuals and organisations conceptualise their impact in contributing to global warming. In terms of the transport industry this includes:

- Electricity, fuel and water consumption;
- Travel by various modes (and the energy used to support this);
- The amount of waste produced that is not or cannot be recycled.

The industry has a responsibility to measure and report on its direct and indirect carbon emissions, particularly its use of electricity and fuel. Carbon footprint can be better understood and actively reduced by undertaking Life Cycle Assessment (LCA) of products and activities and by implementing an energy management plan to ensure optimisation of energy efficiency.

Although rail is considered to be an environmentally friendly mode of transport, contributing only 2% to transport-related emissions, the railway must play its part in the fight against climate change, taking steps to reduce its own carbon footprint. Public awareness of environmental issues will increase and there will be increasing pressure to determine and reduce environmental impact in all areas of industry and society.

A number of initiatives are already underway within the railway, and wider transport, industry to improve environmental performance:

- Research and development of fuel technologies, such as biodiesel, low-sulphur diesel, hydrogen fuel cells and hybrid engines;
- Implementation of regenerative braking (putting energy back into the power system) on both AC and DC systems;
- The formation of the Sustainable Development Steering Group and the development of rail industry carbon reduction targets in 2008;

- Optimising the balance between the comfort, reliability, weight, accessibility (RVAR compliance) and energy efficiency of rolling stock; initiatives in weight reduction of rolling stock, recycling of materials etc.

Like many other industries, transport has seen a substantial increase in environmental and sustainability policy and the development of corporate social responsibility programmes, outlining how businesses are addressing issues such as energy efficiency, recycling of waste, management of emissions and promotion of organic, fair-trade and ethically produced goods. Many companies within the railway community have issued "green policies", 10-point plans for sustainability or their commitment to the environment. Initiatives within these policies include:

- Recycling of paper, on-board waste and waste on stations and even recycling of materials used for railway infrastructure and railway vehicle components;

- Energy-saving programmes (some with incentives for staff) in office/depot sites and in fleet operations. Fitment of energy metres in rail vehicles to analyse energy usage patterns;

- Journey environmental impact calculators on train operator websites, showing the carbon saved in travelling by train over road for passenger journeys;

- Application of new technologies such as regenerative braking, automatic engine shutdown and solar powered LED signalling;

- Driver training programmes promoting 'eco-driving' techniques.

With many companies such as Siemens Transportation, Network Rail, Eurostar, Virgin Trains, National Express Group, Bombardier Transportation promoting their sustainability policies and 'green' initiatives, the key will be embedding sustainability into the culture of all areas of the transport industry; making policy and initiatives part of the day job.

The sector and Government needs to better publicise and communicate these initiatives to the public to reinforce the image of rail as an environmentally friendly mode of transport and an industry actively taking steps to reduce its own carbon footprint. The development of industry targets for environmental impact and emissions, with clear plans and performance measures, from the industry's Sustainable Development Steering Group, will help drive improvements across the industry.

Research indicates that actions such as disconnecting electric vehicles when stabled could save 0.04 MtC, energy efficient driving could save 0.041 MtC, hybrid engine technology could save 0.032 MtC and reducing train weight by 5% can save 0.013 MtC, all at relatively low cost and short investment pay-back period.

However, for the rail industry, most significant of all is the need for further electrification and to reduce its overall dependency on fossil fuels. Whilst the 'greenness' of the electric railway network is heavily dependant on National Grid Supply composition (i.e. its proportion of electricity generated from renewable or nuclear sources), electric traction allows the original fuel source to be optimised over time. Electric trains are positively perceived as being quieter and cleaner than their diesel counterparts and are recognised throughout the world as the natural choice for high speed and/or high capacity railways. Although, with the current generation mix, the relative carbon efficiencies are similar between electric and diesel, the overall capacity and performance benefit and greater flexibility lies with electric trains - this potential needs to be realised.

The rail network uses 1% of UK energy. Network Rail is the 3rd largest energy consumer in the UK. 39% of the network is electrified while 50% of rail vehicles are electric and, in some cases, diesel trains run on electrified lines. 60% of electric vehicles are capable of regenerative braking but only 15% utilise this (regenerative braking can reduce energy use of vehicles by up to 20% but there are still technical and safety issues which require resolving before it can be fully implemented across the network).

The Government has set challenging targets on increasing the proportion of electricity generated from renewable sources (10% by 2010 and an aspiration towards 20% by 2020 – see Figures 15 and 16) and related reductions in CO_2 emissions against a 1990 baseline (26-32% by 2020 and 60% by 2050). In 2006, 4% of the UK electricity generation mix was produced from renewable energy supplies (see Figure 14). The achievement of these targets would significantly enhance the environmental performance of the electrified rail network and therefore, rail's contribution to the achievement of transport emission objectives. Further electrification would serve many purposes predominantly, increase network capacity and enhance the environmental performance of rail, particularly as the electricity generation mix develops.

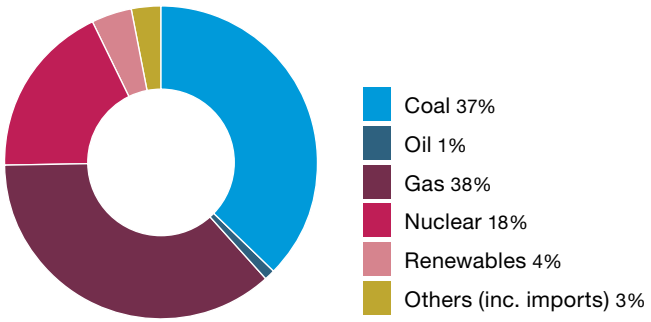


FIGURE 14:
UK Electricity Generation Mix in 2006
Source: White Paper – Meeting the Energy Challenge 2007

The UK national grid transmission and distribution system is fundamentally mismatched to the geographic location of most renewable energy projects (the national grid is a system based on centralised power stations distributing electricity to the more remote regions of the UK, rather than electricity generation in remoter regions, distributing to centralised areas). With the growth of renewable energy supplies, a combined programme to extend electrification of the railway with the upgrade/enhancement of the national grid transmission system would be powerful in combating transport emissions for the future. As well as being the natural choice for high speed or high capacity networks, lower cost electrification may well become appropriate for regional services in areas where sustainable energy sources are available locally. An ongoing long term programme of electrification would benefit significantly from the continued increase of the contribution of renewable energies to the UK electricity generation mix. This case is even stronger with the breakthrough of regenerative braking technology, which could provide additional support to the grid, by returning electricity as the vehicle brakes (as much as 20%).

The UK generated 407,265 GWh of electricity in 2005. Of this transport consumes 2%; while the railway network uses 2,700 GWh for its electric traction[28]. For every 1GW generated by a renewable energy supply, the carbon emissions are 0.7–1.5 MtC lower than that produced by conventional fossil fuels[29]. As the electricity generation contribution of renewable energy grows to its target of 20% in 2020, and fossil fuel sources are progressively displaced, this could lead to savings of up to 0.12 MtC per year[30] for the current rail network electricity demand for traction alone, with the potential for further savings as additional areas of the network are electrified (displacing diesel).

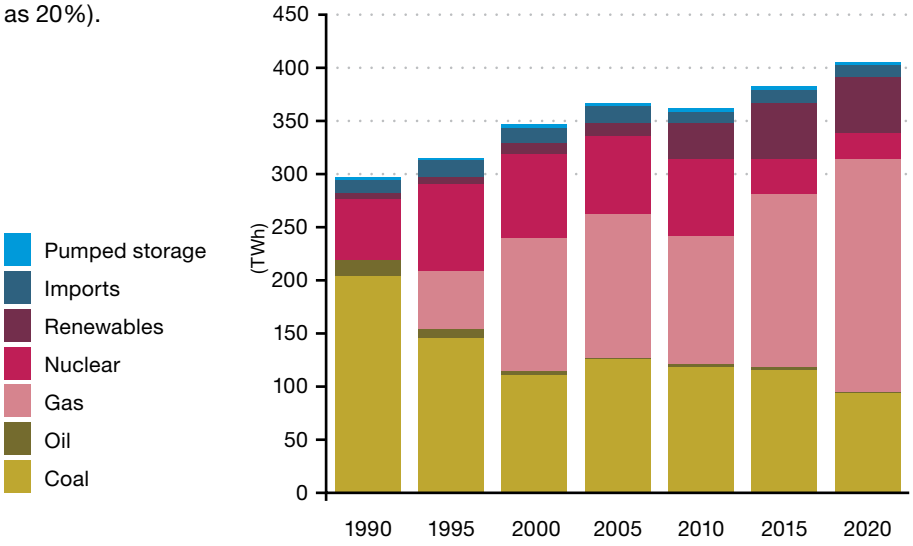


FIGURE 15:
Projection of UK Electricity Generation Mix in 2020
Source: Energy Review 2006 – The Energy Challenge

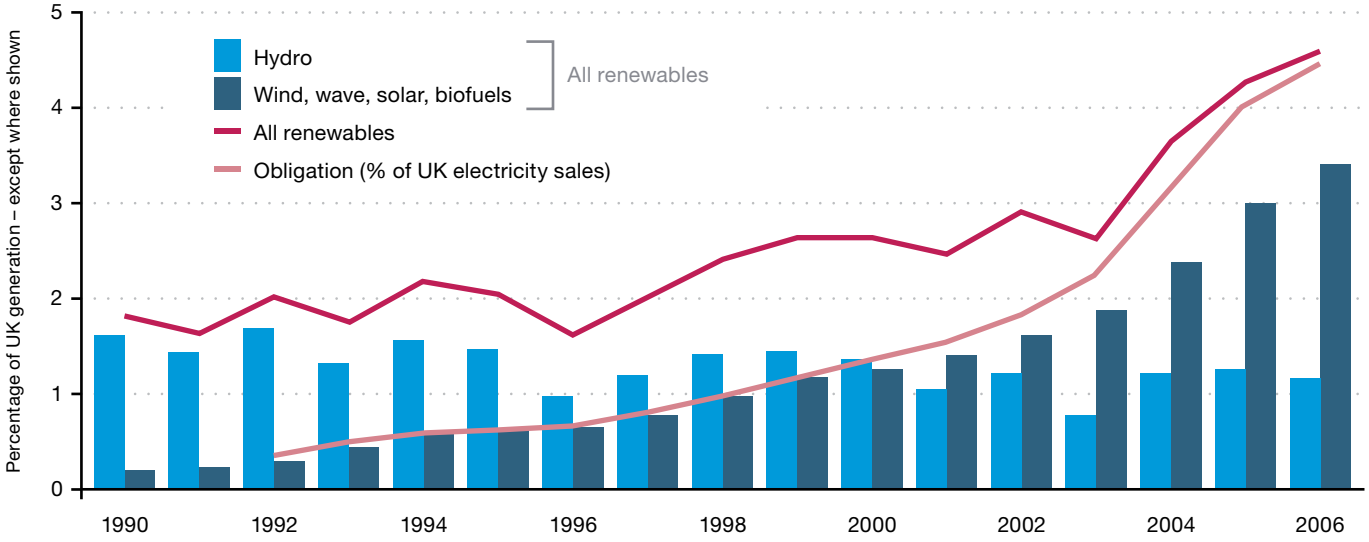


FIGURE 16:
Renewables Electricity Generation Obligation

4. Recommendations for Action

4.1 OUR VISION: LOW CARBON MOBILITY, A SUSTAINABLE FUTURE FOR TRANSPORT

Our world is changing. Where we have taken lifestyle choices on our purchases, our travel and our energy for granted, we must now re-think if we are to preserve similar choices for the future, for ourselves and generations to come.

But cutting carbon and the development of a sustainable way of life is not necessarily synonymous with a constrained or unfulfilling lifestyle. Like any other engineering problem, progression towards low-carbon living should be viewed as an opportunity for:

- A healthier society, where more people walk or cycle and where trends such as obesity and heart disease decline as people become more active;
- Community development, as fewer people use private cars within city/town centres, people interact more on public transport and a revival of local shops and businesses where consumers support local produce and organic goods;
- A flexible and slower society, with changes in work patterns; greater number of people working from home with the aid of technology and peak travel is eased as the traditional 9-5 becomes a thing of the past, people will enjoy flexible working hours. There will be less need for travel for businesses with video-conferencing and virtual meeting tools and people will value their time differently, using travelling time to their benefit.

Many of the changes required to reduce our carbon emissions may, in fact, be life-enhancing. Mobility; getting people from A to B whether it be for work or leisure, will always be a key element to our society for quality life and the economy but shaped in the right way through transport policy will ensure it contributes to a sustainable future.

4.2 RECOMMENDED POLICY ACTIONS

There are many ways in which the environmental performance of transport can be improved:

- **Technical** solutions such as modified fuels, weight saving initiatives, regenerative braking for rail vehicles, aerodynamic design and electrification;
- **Operational** solutions such as ‘eco-driving’ training, improved vehicle configuration planning against demand, integrated public transport and environmental performance measurement with key performance indicators;
- **Behavioural** solutions, changing attitudes and subsequently, people’s transport choices such as campaigns and communication, ticket branding for environmental impact and improved on-board services for more effective journey times;
- **Fiscal** solutions such as taxation, carbon trading schemes, congestion charges, tolls and passenger ticket pricing policy.

This paper has discussed and assessed a range of such initiatives under the themes of:

- Lifestyle trends and social values;
- Modal shift;
- Rail network capacity;
- Fiscal measures;
- Railway’s carbon footprint.

The most effective solutions are those that can deliver a significant reduction in CO_2 emissions at the least cost, within useful timescales. As part of the assessment, the relative cost and timescales for imposing policy measures was established against the associated potential savings in CO_2 emissions. This has generated recommendations for policy actions which are the most cost-effective for reduction in CO_2 emissions for transport. Although these policy actions are relatively low cost measures, government policy and subsequent investment should be consistent with objectives to cut carbon emissions for transport. At this time, road continues to receive over £4,400 million worth of public funding per year which is a significant contribution to the mode of transport which currently accounts for 85% of transport emissions.

Any policy must be supported by a flexible plan to develop the transport infrastructure necessary to deliver current railway capacity and performance and to accommodate predicted future growth. We would anticipate the next HLOS to be greater informed, with firmer commitments made to fully exploit rail as a primary means to meet overall environmental objectives by treating rail as part of an overall transport and energy strategy. There is a fundamental need for a balanced and integrated transport infrastructure investment policy across all modes. This, in itself, will be hugely instrumental in generating modal shift to rail and supporting the need for capacity and subsequently providing a reduction in CO_2 emissions for transport.

From reviewing available literature, published data and research into the costs and environmental benefits for various initiatives, the recommendations below represent the most cost effective policy actions the Government could take to yield the greatest reduction in CO_2 emissions for transport; in order to truly unlock the potential of rail as a major contributor to a sustainable transport plan:

1. Government campaign to endorse, promote and educate on the environmental impact of travel and 'green' transport choices.

2. A review of rail passenger pricing policy, comparatively with the costs of other modes.

3. Transport environmental duty imposed on all transport modes in accordance with associated carbon emissions.

4. Increase in the proportion of national grid electricity generated from renewable sources and combine upgrade/enhancement of the national grid system with rail network electrification.

4.3 ACHIEVING REAL SAVINGS IN CARBON EMISSIONS FROM TRANSPORT

Policy Action	Investment Required	Return (saving in CO_2)
1. Government campaign for "greener" transport choices	No capital investment required. Cost of marketing and communication campaign	3.6 MtC by 2020
2. Revised travel pricing policy	No capital investment required. Administration costs of revised policy and pricing structures.	2.96 MtC per year
3. Transport Environmental Duty	No capital investment required. Administration costs of revised taxation policy.	1.6 MtC by 2020
4. Increased renewables energy supply to National Grid	Commitment for 2020 is already in place under the Renewables Obligation.	0.12 MtC per year in 2020

5. References

	Details	Available from
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15	DfT National Statistics, Transport Statistics Great Britain 2007. Passenger transport per mode 2005 combined with Figure 4: CO_2 emissions by transport mode 2005 (CfIT)	www.dft.gov.uk
16	Department for Transport, Delivering a Sustainable Railway, July 2007	www.dft.gov.uk
17	Passenger number increase of one fifth (1,360,000 passengers) period Jan-June 2004 from same period previous year. Assuming half passenger share gain from air and half from road (680,000 passengers from each) Carbon savings calculated using London-Paris route emissions from Table 12.	www.bbc.co.uk
18	Based on estimated passenger numbers travelling from Edinburgh airport to London Airports (City, Luton, Stanstead, Gatwick, Heathrow) in 2005 of 3.63 million (Ref, House of Commons 23 January 2007)	
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27	http//en.wikepedia.org	http//en.wikepedia.org
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29	DTI, Meeting the Energy Challenge, A White Paper, May 2007	www.dti.gov.uk
30	Calculated assuming railway network operation of 18 hours/day, 330 days/year with a carbon emission saving of 1.5 MtC per 1GW electricity	

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Aviation Environment Federation	Fly now grieve later – compares emissions for different modes of transport	www.aef.org.uk
BBC News	News article 16 Nov 2005 – colour coding of food	www.bbc.co.uk
British Airports Authority	Number of passengers passing through airports	www.baa.co.uk
Center for Clean Air Policy Center for Neighborhood Technology	High Speed Rail and Greenhouse Gas Emissions	www.elpc.org
Collins	Carbon Counter: Calculate your Carbon Footprint	www.collins.co.uk
Commission for Integrated Transport	Trend in UK transport emissions – showing Pie charts graphs etc.	www.cfit.gov.uk
Commission for Integrated Transport	CfIT supporting document – transport and climate change	www.cfit.gov.uk
Commission for Integrated Transport	CO_2 emissions freight transport	www.cfit.gov.uk
Commission for Integrated Transport	Cost effectiveness – governments approach	www.cfit.gov.uk
Commission for Integrated Transport	Road – cfit climate change summary	www.cfit.gov.uk
Commission for Integrated Transport	Cost effective carbon targets by 2020	www.cfit.gov.uk
Commission for Integrated Transport	Summary of methodology to calculate savings	www.cfit.gov.uk
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Department of Transportation	European examples of modal shift	www.dot.gov
Department for Transport	Number of bus journeys	www.dft.gov.uk
Department for Transport	Number of rail journeys	www.dft.gov.uk
Department for Transport	Public Transport Statistics Bulletin GN: 2007 edition	www.dft.gov.uk
Department for Transport	White Paper: Supporting Economic Growth in a Low Carbon World	www.dft.gov.uk
Eurostar	Eurostar v air CO_2 emission comparisons	www.eurostar.com
European local transport	Passenger Transport: The Citizens' Network Urban Passenger Transport Benchmarking Initiative	www.eltis.org
First Group	Public transport operator FirstGroup unveils climate change strategy	www.firstgroup.co.uk
Freight on Rail	The impact of transfer of goods between rail and road (cost of road maintenance)	www.freightonrail.org.uk
Global logistics	Tunnel Vision: Switzerland's AlpTransit Gotthard Tunnel	www.inboundlogistics.com
HM Government	Draft Climate Change Bill	www.defra.gov.uk
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International Herald Tribune	Eurostar's gains are airlines' losses. Quotes growth figures, and punctuality better than air.	www.iht.com
Liberal Democrats	Policies for reducing transport emissions	www.libdems.org.uk
LUAS	Dublin Luas Light Rail Network, Republic of Ireland. States future plans for integration.	www.railway-technology.com
MDS transmodal	Government infrastructure development	www.mdst.cu.uk
MTRU transport consultancy	A methodology for assessing the impact of transfers from road to rail	www.mtru.com
National Air Traffic Services	Number of UK flights	www.nats.co.uk
ORR	Office of rail regulation annual report 06-07	www.rail-reg.gov.uk
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ORR	ORR national rail trends yearbook	www.rail-reg.gov.uk
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Stagecoach	Press release 26/10/07 - Bio Bus	www.stagecoachbus.com
Tesco	Tesco to 'carbon label' its products	www.ft.com
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The Railway Forum	Rail v air comparisons	www.railwaysforum.com
The Scottish Parliament	Scottish Survey: Mode Choice - Car Vs Public Transport	www.scottish.parliament.uk
The University of Dublin	Car dependent cities such as Dublin exacerbate social inequality	www.ucd.ie
Trinity College Dublin	Car dependency and social class. Talks about the shift from car to public transport.	www.tcd.ie
Visit Oslo	Oslo Transport. Shows different modes of transport	www.visitoslo.com
Wikipedia	Channel Tunnel facts and figures. Quotes future growth figures, displacing air journeys.	www.wikipedia.org
Word press	Supermarkets in label wars - Walkers go green	www.wordpress.com

7. Abbreviations

AC	Alternating Current (electrical)
ATOC	Association of Train Operating Companies
CfIT	Commission for Integrated Transport
CO_2	Carbon Dioxide
DC	Direct Current (electrical)
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DTI	Department of Trade and Industry
DUKES	Digest of United Kingdom Energy Statistics
FNC	Frazer-Nash Consultancy
FT	Financial Times
GW	Giga watt
GWh	Giga watt hour
HGV	Heavy Goods Vehicle
HLOS	High Level Output Specification
HSL	High Speed Line
IEA	International Energy Agency
IMechE	Institution of Mechanical Engineers
LED	Light Emitting Diode
MtC	Million tones of Carbon
RSSB	Rail Safety and Standards Board
RVAR	Rail Vehicle Accessibility Regulations
UK	United Kingdom

Appendix A: Research methodology

Map of Existing Research

Much research has already been undertaken (or is underway or planned) within the transport industry relating to sustainability and, more specifically, carbon emissions. As part of this research study, we have developed a 'mind-map' showing the various parties sponsoring research in this area and the topics currently covered (see Appendix B).

Research

An evidence base has been generated through systematic web-based research. We have undertaken a study of research, literature, media articles and publications available, in the public domain, on the subject of sustainable transport and the environmental impact of transport. A bibliography and references can be found in Sections 5 and 6.

Identification and Categorisation of Issues and 'Green' Initiatives

A structured workshop approach has been used to identify a number of the issues and activities/actions which could impact transport-related carbon emissions. This has addressed issues such as influencing modal shift, energy sources and capacity as well as more direct initiatives for the railway industry. The list of options has been compiled by a research team with combined knowledge/experience of the transport industry and transport and energy research.

Issues have then been assessed against key attributes and recorded in a matrix format. This matrix highlights the relative strengths and weaknesses of each of the candidate options, in terms of criteria such as their dominance (potential impact on carbon emission reduction) and ease of influencing. Options are scored against the criteria. Where data is available and appropriate to the analysis, this is entered directly into the model. Where the issue under consideration is based on non-quantifiable data or unavailable data, engineering experience and judgment has been used in order to score the options relative to each other.

Cost-Benefit Assessment

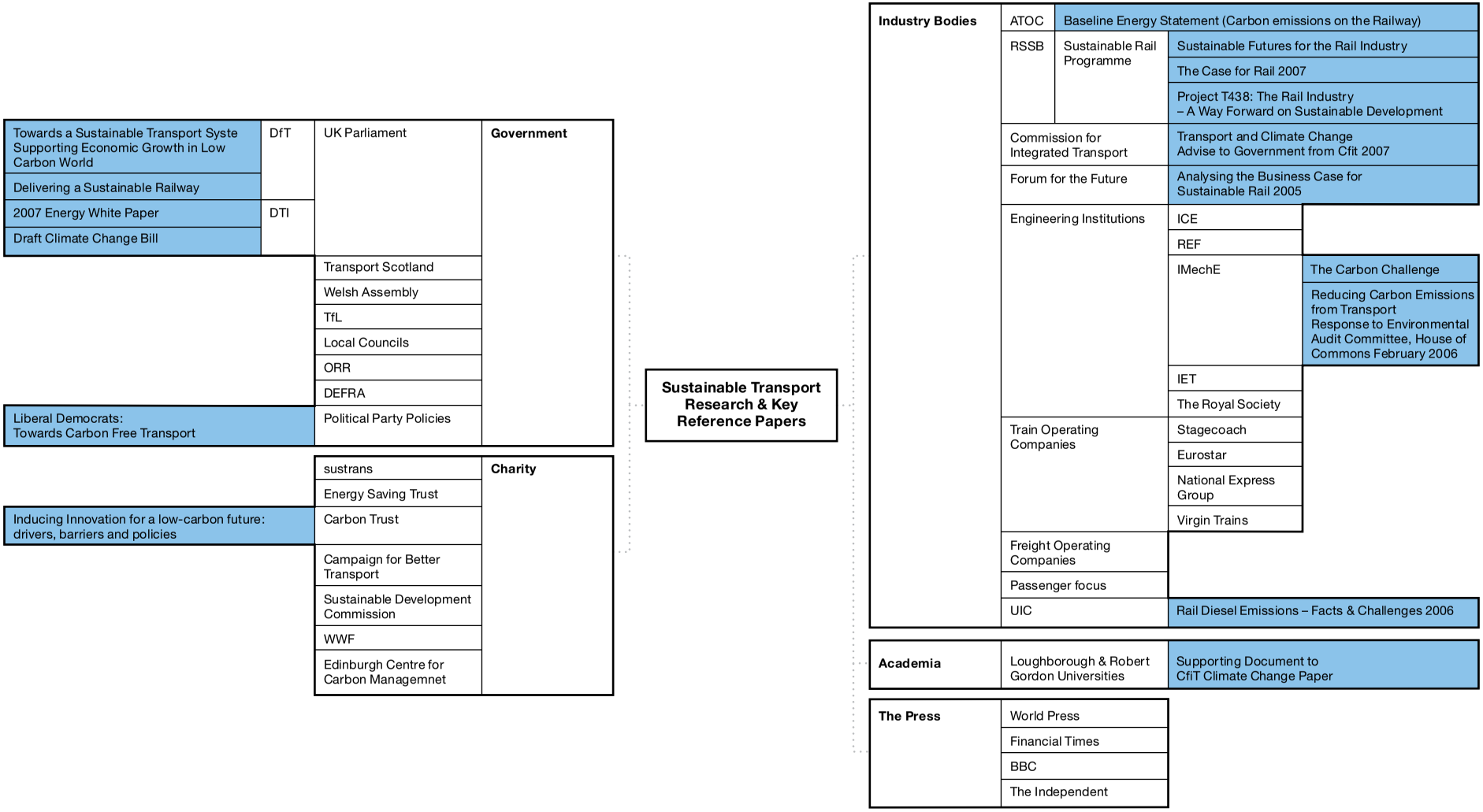
The most highly-scoring options have been subject to further investigation including further research and a cost-benefit assessment.

Recommended Policy Actions

References to research evidence have been provided to support proposed policy recommendations of the most cost-effective initiatives for reducing transport-related carbon emissions.

Appendix B: Transport sustainability – a map of current thinking

NOTE: This mind-map shows all parties involved in research, policy development or reporting on sustainability of transport. Items highlighted with blue indicate key research publications which have been used in the production of this report.



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