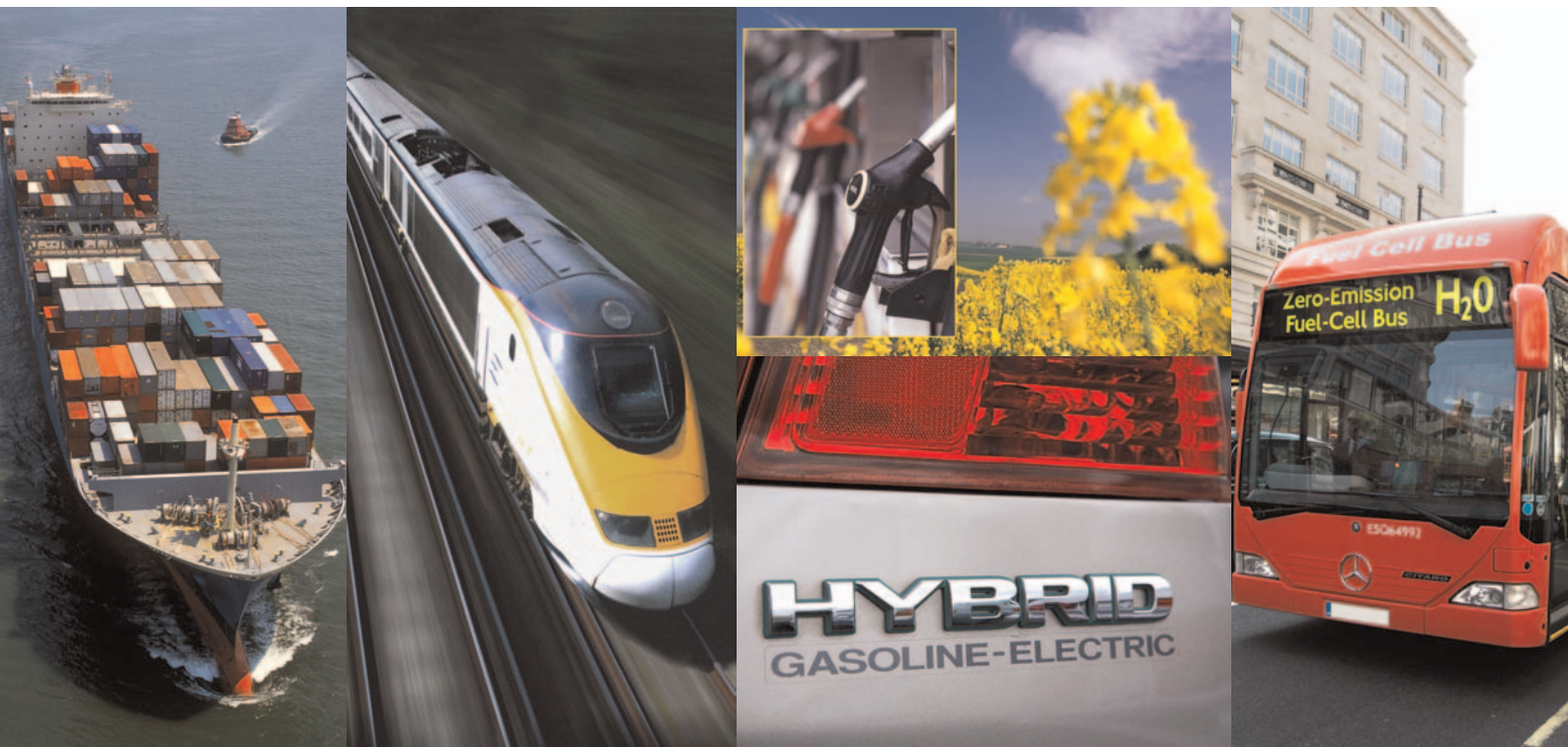


Low Carbon Transport Innovation Strategy



May 2007

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Foreword

Secretary of State for Transport



There is no doubt that the challenge of tackling carbon emissions from the transport sector is a huge one. We all enjoy travelling for leisure purposes and we depend on an effective transport system to deliver the wide range of goods and services on which our prosperity and well-being as a society relies. And as our economy and our population has grown, so has our demand for travel.

Despite the scale of the challenge, we are committed as a Government to addressing climate change both internationally and domestically, and the transport sector must play its part in that process. The Government is developing a wide range of relevant policies in this area. We are investing record sums in our public transport systems and have recently published proposals for a modernised national framework for bus services. We are supporting zero carbon options such as walking and cycling and are putting in place a substantial programme to promote changes towards more sustainable patterns of travel behaviour using a range of measures collectively known as smarter choices. These include workplace, school and personalised travel planning, travel awareness campaigns, car clubs, car sharing and measures to reduce the need to travel such as video-conferencing.

These approaches undoubtedly have significant potential to reduce the carbon footprint of our travel. Equally there is no doubt that new technology will play a major role in the transition to a lower carbon transport system. Development of the Low Carbon Transport Innovation Strategy, a commitment that arose out of the Government's 2006 Energy Review, is a reflection of that.

The Strategy, which we are publishing alongside the Government's Energy White Paper, sets out a comprehensive approach to incentivising new technology development in the transport sector, building on the findings of recent work such as the Stern Review. It highlights the wide range of technologies which can contribute to carbon reduction in each of the major transport modes, road, aviation, rail and shipping – and the major new steps that we are taking to stimulate the research, development and demonstration projects which can make these technologies a reality. It draws out the links between a future low carbon transport system and a future low carbon energy system.

With the right policies and approach, the UK can gain both environmental and economic benefits from leading the way in the development of a lower carbon transport system. We have many companies which are already, or can become, world leaders in the field of lower carbon transport. Our strategy aims to set a framework in which those companies can develop the lower carbon technologies of tomorrow with confidence, and allow the UK to benefit from the growing global market for these technologies which will surely emerge over the coming decades.

A handwritten signature in black ink, appearing to read 'Douglas Alexander', with a stylized, cursive script.

Rt Hon Douglas Alexander, MP

Executive summary

1. The Government announced in the Energy Review last year that it would develop a Low Carbon Transport Innovation Strategy (LCTIS). Development of the strategy reflects the critical role that new technology will play in delivering carbon reductions in the transport sector over the long term.
2. The LCTIS, which is being published at the same time as the Government's Energy White Paper, sets out an overall framework through which the Government will encourage innovation and technology development in lower carbon transport technologies. It also contains specific chapters on the road, aviation, rail and maritime sectors - setting out in detail the technologies that can contribute to lower carbon transport and the steps the Government is taking to encourage them.
3. The Government's approach to low carbon transport innovation recognises that there are a range of market failures and barriers to entry which can impede the development and commercialisation of new technologies in this area. These include the early stage of development of many relevant technologies, limited demand from consumers for lower carbon options, a still evolving regulatory environment and the capital intensive nature of much transport equipment and infrastructure. High capital costs also mean that replacement rates in the transport sector are often slow, manufacturers can be risk averse and the costs and risks of moving from the demonstration phase to full commercialisation for new technologies are high.
4. These conditions justify a range of interventions by Government to help stimulate the development of lower carbon transport technologies at all stages in the innovation chain and for all major modes of transport. Consistent with the Stern Review's recommendations on developing new technologies to address climate change our approach will involve:
 - In dialogue with our EU and international trading partners, considering a range of mechanisms which provide a **carbon price signal** to all major transport modes which are significant emitters of carbon.
 - The utilisation of **other market based or regulatory approaches** to encourage the deployment of lower carbon transport technologies. These may take a wide range of forms including taxation incentives, measures to support lower carbon public procurement or minimum standards regulations.

- Support for **research, development and demonstration** projects in a wide range of lower carbon transport technologies across all major transport modes.
- Providing consumers and travellers with **better information** about the carbon impacts of their choices and the lower carbon options available to them.

We believe that this fourfold approach represents a coherent overall framework for action, which we will continue to develop and refine over time as we are committed to making the UK an attractive environment for developing and deploying lower carbon transport technologies.

Low carbon technologies and the road sector

5. The road sector is the largest source of carbon emissions from transport in the UK. It is also the transport sector with probably the greatest potential to reduce carbon emissions in the coming decades. In developing the LCTIS the Government therefore asked E4tech to examine how the innovation system was functioning for some of the key technologies central to carbon reduction in the road sector.
6. E4tech's study *A Review of the UK Innovation System for Low Carbon Road Transport Technologies* is being published alongside the Government's strategy (and is available in full at www.dft.gov.uk/pgr/scienceresearch/technology/). Their work highlights a range of existing or nearer market technologies that have, in combination, the potential to make a significant contribution to carbon reduction in the road transport sector in the near-medium term - as well as a number of technologies with longer term potential to deliver very large scale carbon reductions.
7. Those technologies with the clearest potential to contribute in the near future include:
 - continued incremental improvements to petrol and diesel engines
 - a range of new and emerging lightweight materials,
 - nearer market hybrid petrol-electric or diesel-electric vehicles,
 - first generation biofuels (bioethanol made from sugar or starch crops and biodiesel made from oil crops and wastes)
8. Those technology options which may become very significant over longer timescales are:
 - "plug-in" hybrids which can be re-charged from the electricity grid
 - fully electric vehicles
 - second generation biofuels, manufactured from a wide range of biomass sources
 - hydrogen powered vehicles and fuel cells.

The key attraction of these latter technologies is the possibility they offer of delivering very substantial carbon reductions from road transport over the longer term – including potentially achieving the almost total de-carbonisation of road transport. However in general they are not yet ready to be applied to mass markets in the road sector, either because costs are prohibitively high and/or significant

technological progress is required to bring down costs and overcome performance issues likely to be important to consumers.

9. E4tech's work suggests that for all technologies, clear and long term policy signals supporting lower carbon road transport are needed to drive all stages of the innovation cycle. This includes a recognition that a range of technology options are likely to be required in order to deliver large scale emissions reductions over time. Their work also suggests some important differences between the support needed for innovation in technologies nearer and further from market, and thus some differences in the nature of the policy responses that are most appropriate from Government. In particular, E4tech suggest that, for nearer market technologies, the most effective intervention from Governments would be a strengthening of policies supporting market deployment of lower carbon vehicles. This may involve further regulatory or taxation measures, as well as the use of public procurement to help the creation of niche markets. For riskier and further from market options, while deployment signals remain essential in providing a stimulus for technology development, there is in addition a stronger case for Government providing targetted financial support for industry and academic led, research, development and demonstration activities.
10. The Government supports the broad conclusions of E4tech's work. We are working at both the European and domestic level to develop new measures and policies aimed at strengthening current and future demand for lower carbon vehicles.
11. At the European level, the European Commission has recently issued a communication which sets out its intention to replace the current CO₂ voluntary agreements between the Commission and automotive manufacturers (which expire in 2008/9) with a new legislative framework to deliver average new car fuel efficiency of 130 grammes of CO₂ per kilometre (gCO₂/km) by 2012. The Communication proposes an overall target of 120g CO₂/km by 2012 with the additional 10g CO₂/km to be delivered through a range of other measures.
12. The Government welcomes the Commission's intention to bring forward a legislative framework and supports a move to demanding mandatory fuel efficiency targets. Subject to understanding how the targets will be implemented and subsequent impact assessment, the Government is supportive of the Commission's proposals. However it is our view that the proposals should also set out a longer term strategy for improving vehicle fuel efficiency. The Government announced in Budget 2007 that its longer term objective is that average new car emissions be reduced to 100 grammes of carbon dioxide per kilometre.
13. The Government is also continuing to act to strengthen policies at the domestic level:
 - We are incentivising the purchase of lower carbon vehicles through the graduated vehicle excise duty regime. Further strengthening of these incentives, including reduced rates for the most fuel efficient vehicles and higher rates for the most polluting, were made in Budget 2007.
 - We are providing new funding of an initial £20m to develop a programme aimed at reducing the barriers faced by companies in moving from prototype demonstra-

tions of lower carbon technologies to full commercialisation. This programme will provide financial support for public procurement of fleet demonstrations of lower carbon vehicles (and where appropriate supporting infrastructure). The programme will seek to build on the model of contractual forward commitments in which commitments to purchase vehicles are linked to the achievement of pre-determined cost and performance criteria. The Government will consult on the detailed operation of this new programme later in 2007 – with a view to supporting the first fleet procurements/demonstrations in 2008.

- We launched a new communications campaign covering eco-driving and purchasing earlier this year. This highlights to consumers that they can contribute to tackling climate change without compromising on the type of car they drive – both by driving in a more fuel efficient way and by purchasing a lower carbon vehicle within a given class.
- We are supporting biofuels through the development of the Renewable Transport Fuel Obligation (RTFO). We launched a consultation in February of this year covering both the detailed implementation of the RTFO over the period 2008/9 to 2010/11 and issues relating to the future evolution of the RTFO after its initial phase. Details of the consultation can be found at www.dft.gov.uk/roads/rtfo

14. As set out in the Stern Review, we also consider that Governments have a clear role to play in supporting research, development & demonstration activities to bring forward lower carbon vehicles. The UK automotive sector remains a significant part of the UK economy and expanding our expertise in lower carbon vehicles is likely to be central to the future competitiveness of that sector. In conjunction with the Technology Strategy Board (TSB), DfT and EPSRC will therefore help finance and develop a new Low Carbon Vehicle Innovation Platform providing critical coordination and up to £30million of support from 2008/09 onwards. The Innovation Platform will bring together key stakeholders in the UK automotive sector and provide new funding for UK industry led demonstration and collaborative R&D projects – focussed on nearer and further from market technologies where the UK has or can develop world leading expertise. We will review the Innovation Platform after its first year of operation with the strong intention of extending the programme to run over a number of years.
15. Separately, the Government is also setting up the Energy Technologies Institute (ETI) with a minimum budget of around £600m over the next decade. The ETI will significantly expand the scale of basic and applied R&D into lower carbon technology development taking place in the UK – including options relevant to lower carbon transport and road vehicles. In order to strengthen ETI's activities in the transport area still further, from 2008 onwards, the Department for Transport will contribute an additional £5m per annum of new money to ETI expenditure on lower carbon transport technologies – supporting a wide variety of technology development relevant to the road sector and other transport modes.
16. In these ways the Government aims to ensure that the UK automotive sector and research base will maintain and develop its strong position in a range of technologies likely to be critical to lower carbon transportation in future decades. Reflecting the

importance of the road sector to transport carbon emissions, the Government has asked Professor Julia King, Vice-Chancellor of Aston University and former Director of Advanced Engineering at Rolls Royce plc, working with Sir Nicholas Stern, to lead a review to examine the vehicle and fuel technologies which over the next 25 years could help to decarbonise road transport. This review will feed into the work of the Energy Technologies Institute.

Low carbon technologies and the aviation sector

17. Globally, carbon dioxide emissions from aviation are responsible for around 1.6% of total greenhouse gas emissions. However, aircraft are also responsible for other climate effects, for example, high-altitude emissions of nitrogen oxides (NO_x), which can lead to the production of ozone, and for the formation of contrails – they are also believed to contribute to the formation of cirrus clouds. While scientific knowledge in this area continues to evolve and remains uncertain the total climate change impact of all aviation emissions is presently estimated to be at least two (and possibly four) times greater than the effects of carbon dioxide alone. Emissions from the aviation sector are also forecast to grow significantly over time. Taking account of both these factors means that aviation could in future represent a significant proportion of total UK greenhouse gas emissions – particularly if efforts to reduce emissions in other sectors are more successful.
18. Aviation is by its very nature an international industry and the Government believes that for action to be most effective in this area it should be taken at an international level. Consequently, the Government's preferred policy approach for addressing the climate impacts of aviation is through a well-designed emissions trading scheme. The UK has taken a lead in arguing for the early introduction of aviation in the EU ETS. In the last year much work has been done to progress the debate internationally, and last December the European Commission published its legislative proposal to include aviation in the EU ETS. The UK welcomed the publication of the Commission's proposal and will continue to lead the debate in Europe on aviation's incorporation into the EU ETS with the aim of ensuring a robust and environmentally efficient scheme is introduced as soon as possible.
19. That said, the Government has made clear that our focus on the EU ETS does not preclude consideration of additional measures to ensure that aviation plays its part in meeting the challenge of climate change. In December of last year we announced that levels of Air Passenger Duty (APD) would be doubled with effect from 1 February of this year. The Government is committed to addressing the climate impacts of aviation through carbon pricing and related regulatory or fiscal measures. Through carbon price signals of this kind, the aviation industry will be appropriately incentivised to pursue cost effective approaches to emissions reduction and to the development of new technology to reduce emissions.
20. There is some potential to reduce emissions from aviation through improved air traffic management. Internationally, the largest gains in this area are likely to arise from more direct routing of aeroplanes and through greater utilisation of measures such as Continuous Descent Approach. Overall, these and other measures have the potential to offer modest improvements to the fuel economy of aviation - potentially

reducing average carbon emissions on a per passenger km basis by around 6-12% over the long term.

- 21.** Larger gains are achievable from improving the fuel economy of the aviation fleet. New aircraft are more fuel efficient than existing older aeroplanes which are still in operation. Historically the aviation industry claims that it has delivered around a 70% improvement in fuel efficiency over the past 40 years. Improvement continues to this day with the newest models developed by both Airbus (the A380) and Boeing (the 787) estimated to be up to around 20% more fuel efficient per passenger km than the current typical average.
- 22.** It is clear that further improvements in the fuel efficiency of aircraft can be achieved over time. The Advisory Council for Aeronautics Research in Europe (ACARE) has set a series of ambitious goals for reducing the environmental impact of aviation. These include reducing carbon dioxide emissions from new aircraft by 50% per passenger km (to be achieved from a combination of more efficient aircraft engines, operations and air traffic management measures), reducing nitrous oxide (NOx) emissions by 80% and noise by 50%, all by 2020 (relative to a 2000 base).
- 23.** The ACARE goals are demanding and large scale research and development funding is being made available to support the development of greener aircraft, both domestically and at European level. Some of the key measures are as follows:
 - In the UK, the National Aerospace Technology Strategy (NATS) is a major partnership between industry, Government and academia to address UK competitiveness in aerospace technology. The aerospace industry bids NATS projects into the DTI led Technology Programme for support. Through this process the Government is providing around £45m per year of civil aviation development funding from the Department of Trade & Industry (DTI), Regional Development Agencies (RDAs) and the Engineering and Physical Sciences Research Council (EPSRC) - to be matched by a similar amount from industry.
 - Many of the programmes in NATS have a direct bearing on environmental issues – most notable amongst these are the Environmentally Friendly Engine (EFE) Technology Validation Programme and the Integrated Wing Aerospace Technology Validation Programme (IWATVP). The 5 year, £95m EFE programme is led by Rolls-Royce, involves a consortium of five UK aerospace companies and six universities. The Integrated Wing programme includes technologies focussed on wing optimisation, flow control and noise reduction, new materials design and manufacturing and advanced fuel and landing gear systems. Phase 1 of this programme is a £34m programme (with £17m from Government) in which there are a total of 17 industrial and academic partners. The lead industrial partner is Airbus.
 - Through the next EU Framework Programme, FP7, which commences this year and will run until 2013, further substantial funding of over €4 billion is available for transport research with about half for collaborative research in aeronautics and air transport. The Commission is also proposing a “Clean Sky” Joint Technology Initiative on more environmentally friendly aeroplane technology as a public private partnership between the Commission and the industry with about €800m of EU funding from the transport programme. “Clean Sky” is a large technology research

programme seeking step changes in the reduction of fuel consumption, emissions and noise of future aircraft. Industry will invest an additional €850m representing around 50% of the Clean Sky programme. Clean Sky aims to assess and validate a range of technological approaches with the potential to deliver step changes in component, system and engine technologies, leading to the earlier introduction of new, greener products that will accelerate the reduction of emissions from aviation and increase the competitiveness of European industry.

24. Achieving in full the stated ACARE goals is unlikely to be delivered solely through incremental evolution of current technology approaches to aeroplane design and operation. More radical aeroplane designs may need to be considered. One such design is the “SAX-40”. This concept was developed as part of the Silent Aircraft Initiative (SAI) – a £2.3m three year collaboration between Cambridge University, the Massachusetts Institute of Technology, Boeing, Rolls-Royce and Nasa – and was unveiled last year at the Royal Aeronautical Society. The SAX-40 design involves a “blended wing” concept in which the fuselage and wings are blended together in a manner comparable to that used in stealth military aircraft. The design team estimate the aircraft could deliver fuel efficiency improvement of around 25% over today’s most efficient aircraft – and with some further potential for reductions beyond that as the design was developed as much with noise reduction in mind as reduced fuel consumption.
25. Biofuels (such as kerosene manufactured from biomass using the Fischer Tropsch process) and hydrogen produced from renewable sources could also be potentially used in commercial aircraft. The aviation industry has announced plans to trial the use of biofuels in aircraft in the near future. There are considerable commercial and technical challenges to be overcome before hydrogen fuelled aircraft could be a reality.
26. The Government will also continue to support relevant domestic academic and industry work in this area. One such initiative, recently launched, is OMEGA (Opportunities for Meeting the Environmental Challenges of Growth in Aviation). The OMEGA project is being supported by £5m of Government funding and is being led by Manchester Metropolitan University while bringing together a wide range of leading UK academic and industrial expertise in the environmental impacts of aviation and opportunities for mitigation of those impacts. OMEGA will consider a 2050 time horizon and support a range of initial research projects focussed on long term and more radical options for addressing the environmental impacts of aviation. Drawing on the UK’s considerable academic and industrial expertise in a wide range of aviation issues, OMEGA aims to place the UK at the forefront of both policy and technological work in this area.

Low carbon technologies and the rail sector

27. Rail’s carbon emissions are relatively low, being responsible for around 1% of total UK carbon emissions. But as with all modes, rail needs to play its part in improving its energy efficiency and carbon emissions profile.

28. Trains and rail infrastructure are long lived assets. So getting technology right at the outset - or building in sufficient flexibility to adapt to developments, for example in traction technology - is important. The DfT is currently leading the Intercity Express Programme (IEP) which sets out to deliver a best overall value solution for train replacement and demand growth on key long distance routes. For both environmental and cost reasons, a key objective will be to ensure that the new high speed train is as fuel efficient as possible. Following on from IEP, the Government will expect all future train procurement exercises to place considerable emphasis on reducing carbon and other environmental impacts.
29. Looking ahead, the Government is committed to working with the rail industry to support and facilitate the introduction of more energy efficient technologies and operational practices. Avenues being explored include optimising the rail network for energy efficiency, trialling hybrid trains combining diesel and battery power, considering the longer term role that hydrogen fuel cells could play and identifying techniques for reducing train mass. The Government's long term rail framework document will be published in summer 2007 and will say more about improving all aspects of rail's environmental performance.

Low carbon technologies and the shipping sector

30. Shipping is a very fuel efficient method of moving bulk freight and remains comfortably the most low carbon method currently available for long distance movement of freight on a per tonne basis. Fuel makes up a relatively high proportion of international shipping costs and marine diesel engines are already efficient. Internationally, there has thus far been only a limited policy or commercial focus on technological options for reducing the carbon footprint of shipping.
31. However, while highly efficient, shipping is a not insignificant source of carbon emissions at a global level – estimated to account for around 1.8-3.5% of worldwide carbon emissions – and movement of goods by ship continues to grow. There is therefore a good case for examining the technological options available for further reducing carbon emissions from shipping over time. With this in mind, the Government commissioned AEA Energy & Environment and Newcastle University to advise on the technology options available in this area and their likely viability. Their report is being published alongside the LCTIS (and is available at www.dft.gov.uk/pgr/scienceresearch/technology/).
32. The study highlights that there are a range of options for further reducing the carbon impacts of shipping – of which the most promising are incremental improvements to existing marine engines, improved fleet management techniques, biofuels and using kites or skysails as a means to supplement the existing propulsions systems of commercial shipping.
33. In order to stimulate interest in the development of more fuel efficient and lower carbon ships, the Government considers that, over time, carbon pricing approaches or related regulations should be extended to the shipping sector as well as other modes of international transport. As with aviation, the shipping industry is an international one and any approach to carbon pricing or other relevant regulations

needs to be developed at an international level to be effective. The UK Government has already put a discussion paper to the International Maritime Organisation (IMO) on emissions trading and the possibilities of extending it to the shipping sector. We will continue to work with the IMO and other relevant international organisations to progress discussions on options for incentivising carbon emissions reductions in the shipping sector. We will also work within the EU Framework Programme and domestically to examine the case for additional R,D&D into technologies for lower carbon shipping.

Key conclusions and next steps

34. Our strategy for stimulating new lower carbon transport technologies has highlighted the important role that Government can play at all stages of the innovation cycle from basic research through to product commercialisation. Consistent with the conclusions of the recent Stern Review, we are adopting an approach which combines the use of carbon pricing mechanisms and supporting regulation in the transport sector with additional Government support for research, development and demonstration projects (R,D&D). In particular we are significantly expanding our support for low carbon R,D&D through the creation of the Energy Technologies Institute, a new Innovation Platform for UK automotive R&D and a new programme of support for public procurement of lower carbon vehicles. At a European level support for relevant R,D&D is also being increased through Framework Programme 7 and we will work to ensure that UK companies and academic groups are active participants in international collaborative projects in these areas.
35. Work on the strategy has also highlighted strong links between lower carbon energy generation and potential lower carbon transport systems of the future. The carbon savings offered by a transport system based around hydrogen fuels or electrically powered transportation would be very largely dependent on the energy source used to make the hydrogen or generate the electricity. Further de-carbonisation of the UK's energy mix would increase the scope for a hydrogen or electricity based transport sector to offer very substantial carbon savings. The impacts on total UK electricity demand could also be substantial.
36. Finally, policy making in this area must be mindful of the considerable uncertainty surrounding the pace and nature of technological developments which can contribute to lower carbon transport. These uncertainties suggest that the Government should as far as possible adopt a technology neutral approach to deployment incentives for new technologies while supporting R&D into a broad range of technological options with the potential to deliver carbon reductions over time. Support for innovation should also be placed within a broader mix of policies for incentivising emissions reduction in the transport sector – including non-technology based approaches. The Government will continue to develop and refine its policies in these areas over time with the objective of providing a commercially attractive environment for innovation and low carbon transport technology development in the UK.

Chapter 1

Introduction

- 1.1** The Government announced in the Energy Review¹, published in July last year, that it would develop a Low Carbon Transport Innovation Strategy (LCTIS). Development of the strategy reflects the important role that new technology will play in delivering carbon reductions in the transport sector over the long term.
- 1.2** In developing this strategy the Government has sought to examine the innovation processes affecting the development of new lower carbon transport technologies, to set out a coherent overall policy framework in this area, and to discuss the steps the Government is taking to help to accelerate the emergence of lower carbon transport technologies in the UK.
- 1.3** The strategy is presented in three main parts. The first part (sections 2-3) considers the importance of low carbon technology innovation in the transport sector and the overall basis for Government intervention to encourage innovation. The case for developing the LCTIS is discussed – as are the factors which may constrain or impact on successful low carbon innovation in transport. Building on the Stern Review, and other relevant work in this area, this section presents an overall framework through which Government will assess and develop its policies for promoting low carbon technological innovation in the transport sector.
- 1.4** The second part of the document (sections 4-7) considers, for each of the major transport modes, the current position in relation to low carbon technology development. Key current and future technologies for each mode are considered, alongside details of a range of actions which the Government is taking to help to stimulate further innovation or accelerate technological development. The largest discussion in this part of the strategy is of the position in the road sector – reflecting the fact that this sector is the largest source of carbon emissions from transport in the UK. In this section we discuss supporting analysis by E4tech on the key technological and policy issues impacting on low carbon innovation for road vehicles. Subsequent sections of the strategy present detailed discussion of the position on low carbon technology development in the aviation, rail and shipping sectors.
- 1.5** The third part of the strategy (sections 8-10) considers a range of cross cutting issues impacting on low carbon technological innovation in the transport sector. In

particular this section of the strategy sets out the full range of existing Government interventions supporting research, development and demonstration (R,D&D) of low carbon transport technologies. It presents a range of actions the Government will take to expand support over time and to bring greater coherence to the Government's approach in this area. This section of the document also discusses the relationship between de-carbonisation of the electricity mix and the achievement of very large scale long term reductions in emissions from the transport sector, as well as considering the impact of technological uncertainty on the development of Government policies in this area.

Chapter 2

The need for a Low Carbon Transport Innovation Strategy

Transport, energy & carbon emissions

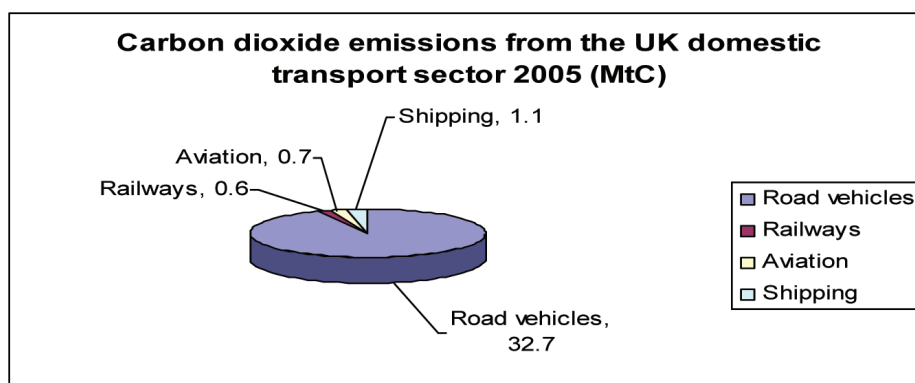
- 2.1** Effective transport systems are an important part of our lives and essential to the health of the UK economy. Our objective in Government is that people and goods can be transported quickly, safely and with as little impact on the environment as possible. The recent Eddington Transport study, published in December of last year, highlighted the importance of an efficient transport infrastructure in sustaining the UK's productivity and competitiveness¹.
- 2.2** However transport is a major energy user and currently the large majority of our transportation needs are met by a fossil fuel, oil. The combustion of oil gives rise to emissions of carbon dioxide, the greenhouse gas responsible for the majority of human induced climate change.
- 2.3** In 2005, the latest year for which figures are available, carbon dioxide emissions from the domestic transport sector in the UK were 35.2 MtC - approximately 23% of total UK carbon emissions - when calculated on a by source basis². This is below the average for OECD countries reflecting the UK's high population density, urbanisation and an extensive public transport network³. The pie chart below shows the breakdown of emissions by the major transport modes on this basis⁴.

1 The Eddington Transport Study is available at http://www.hm-treasury.gov.uk/independent_reviews/eddington_transport_study/eddington_index.cfm

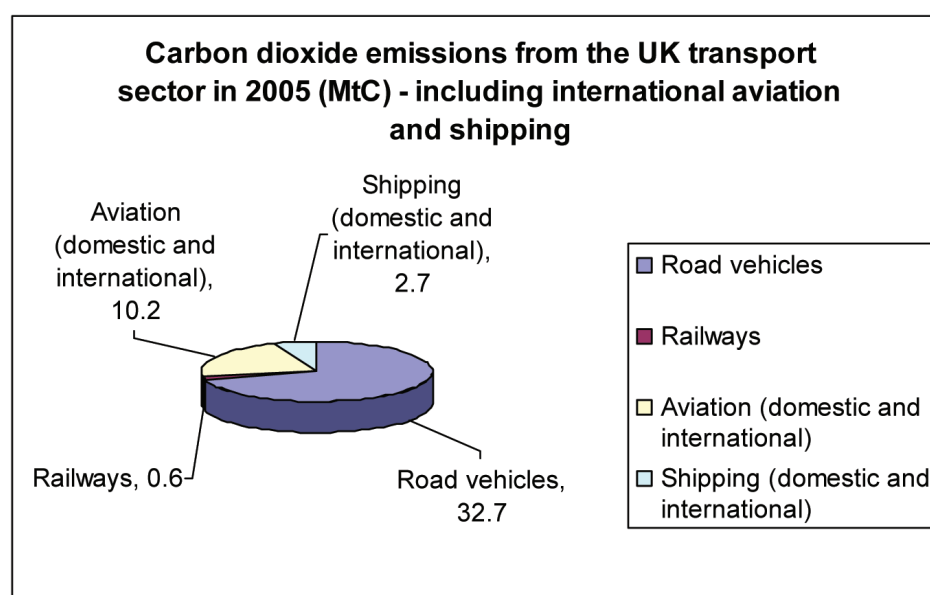
2 Carbon dioxide emissions from transport can also be shown on an end user basis- a method which includes a share of emissions from combustion of fossil fuels at power stations and other fuel processing industries. The full emissions inventory by source and by end user is available on the Department for Environment, Food and Rural Affairs website in Table 5 at: <http://www.defra.gov.uk/environment/statistics/globalatmos/gagccukem.htm>

3 Cutting Transport CO₂ emissions: What Progress? OECD (2007)

4 This and the following pie chart exclude 0.1MtC of emissions from other mobile sources and transport machinery.

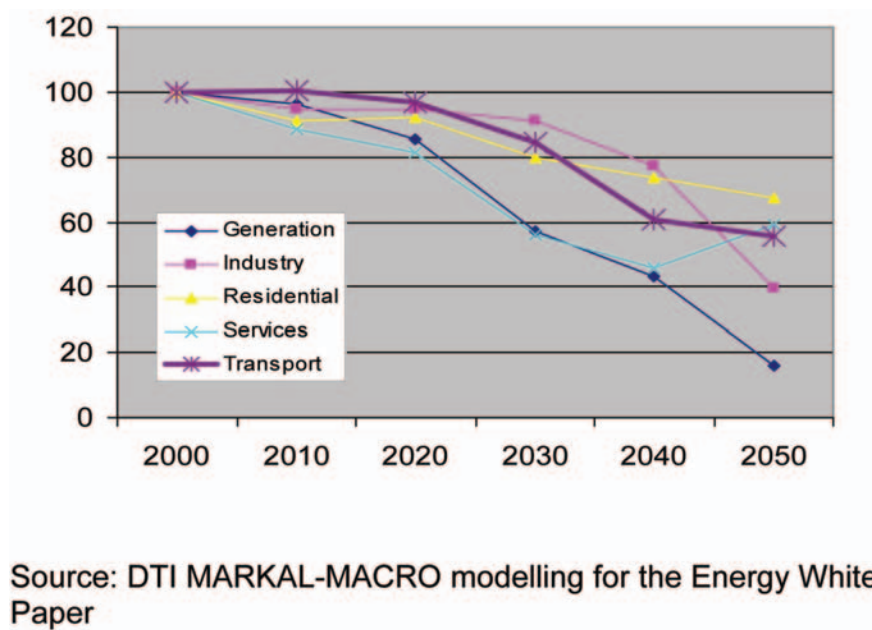


2.4 However these figures are an understatement of total carbon emissions from the UK transport sector as they exclude emissions from international aviation and shipping. There is no international agreement through the Kyoto Protocol on how to assign emissions between countries for international aviation and shipping. Including figures based on sales of aviation and marine fuels for international journeys departing from the UK gives a higher figure for total transport carbon emissions of 46.3MtC in 2005 – approximately 28% of total UK carbon emissions (including international emissions). A breakdown of the major emissions on this basis is shown in the pie cart below:



2.5 Even these figures are likely to be an understatement of the full climate impact of UK related transportation. As noted in section 5, while the scientific evidence remains complex, there are strong grounds for considering that the full climate impact of aviation emissions at high altitudes is greater than that attributable to carbon dioxide emissions alone. Additionally, as discussed in more detail in section 7, rough estimates of UK carbon emissions from international shipping based on the UK's share of global GDP or international trade would suggest figures around 3-4 MtC higher than those based on sales of marine fuels in the UK – reflecting the fact that the UK is not a major refuelling hub for international cargo ships. In summary, carbon emissions from transport represent a significant proportion of total UK carbon emissions which, depending upon the method of calculation, are between around a quarter and a third of total UK emissions.

- 2.6** Carbon emissions from transport are also rising – over the last decade transport has been the fastest growing source of carbon emissions, both in the UK and many other countries. This reflects the impact of increased personal mobility and a growing economy on the demand for goods and services. While forward projections, which are inevitably uncertain, suggest that carbon emissions from domestic transport may begin to plateau out in the following decades, if emissions from international aviation and shipping are included then the overall trend on a business as usual basis remains upwards.
- 2.7** The Government has not set individual carbon reduction targets for different sectors of the economy – as we consider that emissions reduction efforts should be first focussed on the areas in which they are most cost effective. Nonetheless transport policies in the Government’s existing climate change programme are expected to deliver around 6.8MtC of savings in 2010 compared to a business as usual scenario. The Stern Review suggested that in the short term many transport abatement policies may not be cost-effective, but that action is nevertheless required to contain emissions and to bring forward technologies which can deliver more cost-effective carbon reduction in the future⁵.
- 2.8** In the longer run, if lower carbon technologies can be effectively commercialised and their costs reduced, modelling analysis suggests that in a carbon constrained world by 2050 it may be cost effective for domestic transport to abate carbon emissions by around 40-60% relative to 1990 though the least-cost emissions trajectory may be somewhat later than for other sectors, as the graph below shows. This is based on scenario modelling using the MARKAL-MACRO model and is not a forecast of emissions trajectories for transport or other sectors.



- 2.9** There are a wide range of technologies which have the potential to reduce the carbon impacts of transportation. Many of these are already being developed within

⁵ See Annex 7c of the Stern Review for further discussion http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economic-s_climate_change/stern_review_report.cfm.

competitive private sector transport markets. However, many are still at the development or demonstration phase. Some are commercially available but have not achieved significant market penetration. Accelerating the development and deployment of these technologies will play a very important role in reducing the carbon impacts of transport over time.

Scope of the strategy

2.10 The Low Carbon Transport Innovation Strategy considers, for each major transportation mode, the potential of new lower carbon transport technologies to deliver carbon reductions over time. For each mode it examines the current state of technology development and the innovation framework supporting technology development, with a particular focus on research, development and demonstration activities (R,D&D). It sets out the existing policies that the Government has put in place to incentivise carbon reduction and support relevant R,D&D, as well as new measures that will be developed over the coming years.

2.11 The strategy is therefore technology focussed - reflecting the important role that we expect new technology will play in this area. That said, it is important to stress that the strategy is not a reappraisal of all the Government's policies bearing on the climate impacts of transport. For example, while it is not the focus of this document, the Government fully recognises that carbon reduction in the transport sector can also be achieved in a variety of other ways which include:

- encouraging modal shift to lower carbon forms of transport
- encouraging zero carbon options such as walking & cycling
- changed behaviour (eg greater use of car sharing)
- reducing the need to travel – eg through telecommuting

The Government has put in place a substantial programme to promote changes towards more sustainable patterns of travel behaviour. These include encouragement for cycling and walking, workplace, school and personalised travel planning, travel awareness campaigns and marketing, car clubs, car sharing and measures to reduce the need to travel such as video-conferencing. Further detail on these measures is contained in the transport chapter of the Energy White Paper⁶.

2.12 Additionally, the Government also recognises the important role public transport has to play in reducing emissions from transport and is putting record amounts of investment into public transport to give people a real alternative to using their car. As a result, the UK now has the fastest growing railway in Europe and the highest number of rail passengers in 40 years. The government also recently published proposals for a modernised national framework for bus services. Re-energising bus use is important for giving people choice and enabling them to make lower-carbon transport choices. Local and central Government are spending over £2.5 billion a year to provide bus services, up from £1bn in 1996/97.

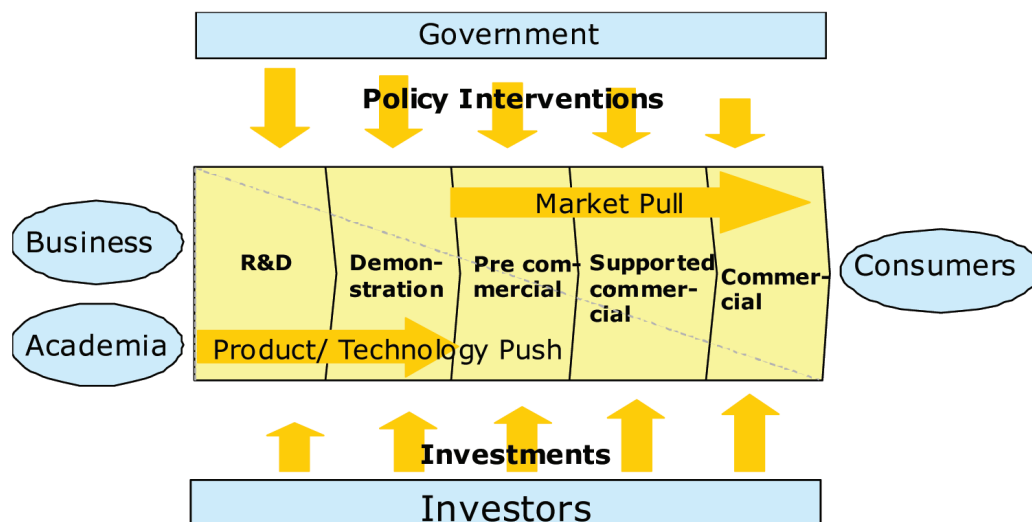
- 2.13** Much can be achieved from such approaches but it is clear that new technology will need to play a very important role if large reductions in carbon emissions from transport are to be achieved over the longer term. The Government's aim is that lower carbon transport technologies will be deployed in the UK – and that the UK will benefit from the growing global market for these technologies over the coming decades.

Chapter 3

Low carbon innovation and the transport sector

The “innovation chain”

3.1 The process of innovation and technology development is often described in terms of a “chain” in which new ideas and technologies pass through a range of phases from early research & development to ultimate commercialisation – as illustrated below¹:



3.2 A brief discussion of what is meant by the different stages of technological maturity shown in the diagram is useful at this stage.

- *Basic and applied R&D* includes both “blue skies” science and engineering/ application focussed research
- *Demonstration* includes early prototypes and is intended to take us to the point where fully functional working devices are utilised, but only in single units or small numbers, and still financed largely through R&D related grants or corporate research programmes.

- *Pre-commercial* is intended to capture a fairly broad stage of development, one where a small number of units of previously demonstration stage technologies are sold in niche markets for the first time.
- *Supported commercial* is the stage where, given generic support measures or regulatory incentives provided by Government, technologies are rolled out in substantial numbers by commercially oriented companies
- *Commercial technologies* can compete un-supported, within the broad regulatory framework set by Governments.

3.3 The above diagram and categorisations are helpful in illustrating how a range of actors impact on the technology development process and how Government policies and regulations can impact on all phases of the innovation chain. That said, it also represents in many senses a simplified picture – as in reality there will be feedback loops and iterations between the stages. Many technologies and innovations will also fail at some stage in the chain, either because of systemic barriers preventing their progression or because they are simply out-competed by more technologically viable or commercially attractive alternatives.

3.4 Moreover, the actual nature of an innovation system will depend significantly on the technologies and markets in question. For example, some markets for new information and communication technologies and supporting software currently exhibit rapid innovation with products moving quickly from demonstration to full commercialisation – a process which reflects relatively lower barriers to entry for new products and is driven by high consumer demand for the technological advances and convenience that such products can offer. On the other hand the innovation system for the development of new drugs, or new energy generation technologies, may look very different, with longer lead times, higher barriers to entry and larger costs and risks attached to new technology development. Where technological advances are rapid, barriers to entry low and consumer demand for new products high, the role for Government may be relatively limited, given that private companies can be expected to bring forward new products of their own accord. Where, however, there are significant impediments to successful innovation, then the case for Government intervention may be higher.

The role for Government in innovation

3.5 The role for Governments in supporting innovation therefore depends significantly on the nature of the sector, the extent of any market failures and the characteristics of the innovation system in question. The Government's approach to innovation is set out in The Science and Innovation Investment Framework 2004-14.² Public sector intervention in support of low carbon innovation has traditionally been justified in terms of two main market failures.-

2

(<http://www.dti.gov.uk/files/files12093.pdf>) and the Government's Investment Framework for Science and Innovation (http://www.hm-treasury.gov.uk/spending_review/spend_sr04/associated_documents/spending_sr04_science.cfm)

- the external cost of carbon – since emitters do not pay the full social cost their carbon emissions impose on society there is less incentive to bring through low carbon innovation than is optimal
- the public good nature of innovation – new knowledge is often easy to copy and therefore it is difficult for an innovator to capture the full value of the innovation. A private market might therefore not produce enough innovation from a societal point of view.

Recent work in this area suggests that an approach focussed on ‘innovation systems’ and ‘innovation systems failure’ provides a broader way to understand the barriers to innovation and the role for the government³. This approach emphasises the role of factors in addition to the above market failures such as the importance of networks and interactions between users, producers and technology developers, the role niche markets can play in technology development and the impact of uncertainty on investment decisions.

- 3.6** The Stern Review published in October 2006 argues that technology policy is one of the three essential elements of any policy framework aiming at reducing greenhouse gas emissions (alongside carbon pricing and removing barriers to behavioural change). Stern observes that effective action on the scale required to tackle climate change requires a widespread shift to new or improved technology in key sectors such as power generation and transport. The Review also argues that most of the development and deployment of new technologies will be undertaken by the private sector; the role of governments is to provide a stable framework of incentives.
- 3.7** Stern suggests that carbon pricing alone will not be sufficient to induce enough innovation. There are other market failures in the innovation sector (e.g. to do with the uncertainty of the long term carbon price and other information asymmetries and network externalities) which justify additional (more direct, technology specific) public sector intervention. Stern argues that policy should aim at bringing a portfolio of low-emission technology options to commercial viability, but that technology-neutral market incentives also need to be complemented by focused incentives supporting technology development and deployment. The review also emphasises the importance of the specific interventions being well-designed and having clear review and exit strategies. Overall the Stern Review recommends that global public energy R&D funding should double and deployment incentives for low-emissions technologies should increase two to five times.

Factors impacting on innovation for lower carbon transport

- 3.8** In considering existing markets for low carbon transport technologies there are a range of considerations which may guide Government intervention. Some of these are common to low carbon technologies in general, and some are more specific to the transport sector.

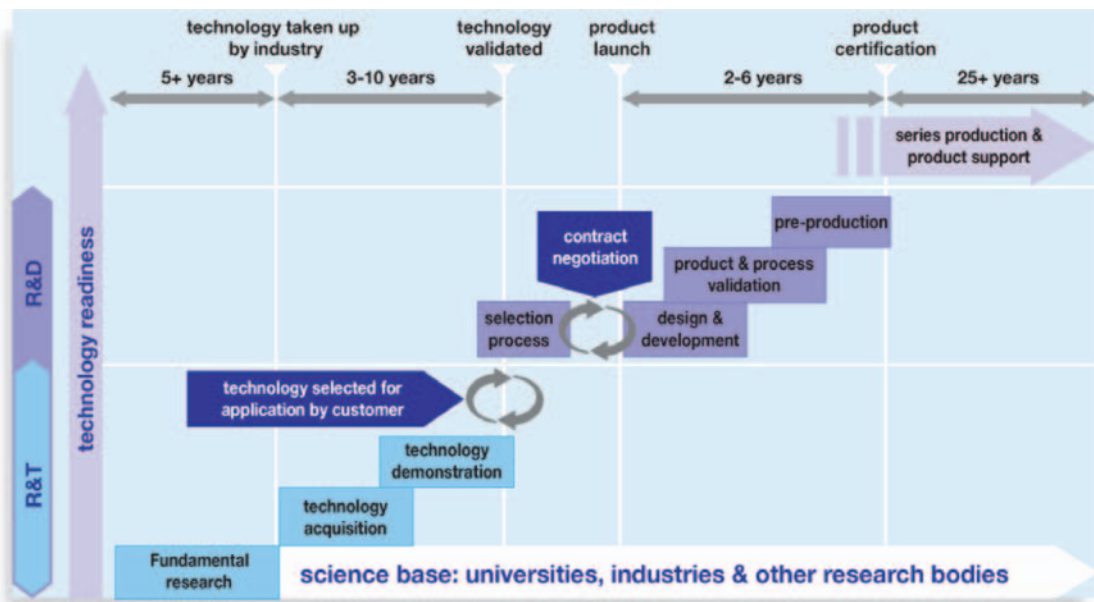
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See for example Timothy J Foxon (2003) Inducing Innovation for a low-carbon future: drivers, barriers and policies, A Report for The Carbon Trust

- 3.9** Firstly, as is discussed in more detail in later sections of this strategy, and in common with many other energy using sectors, many lower carbon transport technology options are *technologically and commercially immature* and are at earlier stages of the innovation chain described above. Current technology costs are often higher, markets are less well developed and improvements in technology performance are frequently required in order to achieve large scale commercialisation.
- 3.10** Secondly, many developers of, and investors in lower carbon transport technologies presently face *carbon pricing uncertainties*. The technical or commercial immaturity of many low carbon alternatives may be less of a barrier to market penetration if there are in place regulatory interventions or market mechanisms which give a value, eg through a carbon price - to the carbon savings offered by low carbon technologies. However, in general, carbon pricing mechanisms have yet to be applied to the transport sector internationally – though it is arguable that fuel duty in the UK already provides a significant carbon price signal in the road sector. Even where they are in operation, carbon pricing mechanisms such as the EU Emissions Trading Scheme (EU ETS) are in their relative infancy. Uncertainties over the scope and strength of future carbon pricing signals in the transport sector remain an inhibitor to investment in lower carbon alternatives.
- 3.11** Thirdly, the nature of the UK's existing transport infrastructure can act as a constraint on the technological options which it is viable or cost-effective to introduce – creating a degree of “*infrastructure lock-in*”. This is perhaps most evident in the road sector where an extensive network of filling stations and refineries has grown up over many years to support road transport based on gasoline and diesel fuels. Replacing this network with one based, for example, on the supply of hydrogen fuels, or numerous re-charging points for electric or part electric vehicles, could be a significant undertaking. Similarly, existing infrastructure impacts to a degree on the scope for new technology development in other transport modes.
- 3.12** Fourthly, while public awareness of climate change and the carbon impacts of individual actions is rising, in general the available evidence suggests that *consumer behaviour* in relation to travel is not yet heavily influenced by climate considerations. Most consumers still make the majority of their travel and transport decisions principally on the basis of criteria of cost, performance and convenience - rather than carbon impacts. There is therefore, as yet, only limited market pull from consumers to drive large scale market penetration of lower carbon options.
- 3.13** Finally, most relevant transport technology is highly *capital intensive* and therefore exhibits slow replacement rates. The average replacement rate for passenger cars and light vehicles is around 10 years. Replacement rates for new trains, aeroplanes, ships and buses are generally considerably longer with timescales which usually run into many decades. Capital intensity and slow replacement rates in the transport sector inhibit low carbon innovation in a number of ways. They make purchasers more risk averse and inclined to opt for proven alternatives over new technologies. They significantly increase the costs of demonstration projects, which are generally an essential phase in the innovation process, prior to commercialisation. They limit the size of the market which is open to new technologies at any moment in time, and

thus the speed at which new lower carbon transport technologies can achieve market penetration, even if other barriers can be overcome. They also increase the challenges associated with raising capital or new finance to support the development and demonstration of new lower carbon options.

3.14 The above factors contribute to a number of features which, in very broad terms, seem to characterise existing innovation processes for lower carbon technologies in a number of transport modes. One such factor is that timescales for the development of new technologies in the transport sector are often long – with a substantial timelag between investment in research & development and that investment bearing fruit in commercial markets. For example, in the aviation sector, which is particularly capital intensive, UK firms are still benefiting directly from Government funded investment in wing aerodynamics and fundamental engine technology made in the late 1950's and 1960's and which fed into the complete range of Airbus and RB211/Trent engine families. The Society of British Aerospace Companies (SBAC) estimates that, in the aviation sector, the timescale between research and implementation of new products can often be as much as 20 years – as shown in the diagram below⁴:



3.15 The long timescales between research and commercialisation which often apply in the transport sector also significantly increase the commercial risks, for private sector companies operating in competitive markets, of funding R,D&D activities. Profits from research activities are distant, uncertain and may be captured by competitors through knowledge transfer. While levels of private sector R&D in some transport modes (notably the automotive and aviation sectors) are substantial, the majority of this tends to be focussed on nearer market and incremental product development as opposed to inevitably riskier further from market options. This feature of relevant markets increases the case for financial contributions from the public sector in support of longer term R,D&D activities which may deliver broader

public goods and bring currently more distant technologies closer to commercialisation.

- 3.16** Thirdly, the capital intensity of projects – along with uncertain demand from consumers – means that moving successfully from the demonstration phase to full scale commercial roll out can be particularly challenging in the transport sector. This phase of the innovation chain – sometimes known as the “valley of death” – is the point at which costs and risks usually rise very substantially for technology developers – and where investors and financiers typically seek firmer assurances about the scale of their likely return. To some extent, in an efficient market, the higher costs and risks of the demonstration phase should act to separate out the most promising technology options from those with less potential. However broader market failures, including uncertainties about the scale of potential markets for such new technologies, or the degree to which they will be supported by carbon pricing or other regulatory interventions, can act as a significant deterrent to further development even for technology options with significant long term commercial potential.
- 3.17** Considered in combination, the above factors would seem to place some quite formidable barriers in the way of the development and deployment of lower carbon transport technology options. This observation is supported by the available evidence from the UK and other major industrialised countries. With few exceptions, in most countries carbon emissions from the transport sector are rising, fossil fuel based transport systems predominate and market penetration of lower carbon technology options remains very limited.

Government position

- 3.18** We consider that the barriers to successful low carbon innovation in the transport sector are considerable and do justify a broad spectrum of interventions by Government. Subsequent sections of this strategy set out in detail a wide range of actions that the Government is already taking in different transport modes, as well as some significant new measures that we will develop following the publication of this strategy.
- 3.19** In broad terms the Government’s approach to creating a stronger incentive framework for lower carbon transport technologies will be fourfold:
- In dialogue with our EU and international trading partners, the Government will continue to consider the application of a range of mechanisms which provide a **carbon price signal** to all major transport modes which are significant emitters of carbon. Our commitment to include aviation in future phases of the EU Emissions Trading Scheme (EU ETS) is an example of this.
 - The Government will continue, on a case by case basis, to utilise and explore the case for **other market based or regulatory approaches** to incentivising the deployment of lower carbon transport technologies – including action at the EU or domestic level.

- The Government will support **research, development and demonstration** projects in a wide range of lower carbon transport technologies across all major transport modes. Section 8 of this strategy discusses in detail the steps the Government is taking to increase the level of support it provides for R,D&D in this area, as well as measures aimed at bringing greater coherence and clarity to existing and future activities.
- The Government will seek to provide consumers and other users and purchasers of transport equipment or services with **better information** about the carbon impacts of their choices and the lower carbon options available to them.

The Government believes that this approach represents a coherent overall framework for guiding Government activity and policy making in this area. It is consistent with the recent Stern Review conclusions on the steps Governments should take to most effectively encourage the development and deployment of lower carbon technologies in a wide range of sectors.

- 3.20** The approach however, will not be adopted in a prescriptive or formulaic way. Decisions on carbon pricing or signals may need to be taken in conjunction with EU and other international partners, and should also take account of any existing regulatory or taxation frameworks. The timings at which carbon price signals are introduced into different transport sectors may also be a relevant consideration – it could for example be counterproductive to introduce a carbon price signal into one sector if it encouraged modal shift of passengers or freight to another form of transport which had higher carbon emissions but was not yet covered by any form of carbon pricing regime.
- 3.21** Similarly, decisions on research, development & demonstration priorities for UK funding within different transport modes should take account of a wide range of considerations including the costs and carbon saving potential of different technological options, the scope and extent of existing R,D&D activity undertaken by the private sector and other countries, areas of UK academic and industrial strength and so on. The levels of global R,D&D necessary to support a widespread international transition to a much lower carbon transport sector are likely to be substantial⁵. Expanding levels of R,D&D will require substantial contributions globally from both the private and public sectors. It is not realistic for the UK Government or UK companies to seek to establish a technology lead or competitive advantage in every major low carbon transport technology area. Equally, the UK considers that it should play its part in supporting relevant domestic and international R,D&D - not least because the UK possesses many companies with a strong competitive position in transport technologies and who stand to benefit if they can maintain leading positions in future markets for lower carbon options.
- 3.22** In short, while the above approach represents the *guiding principles* by which the Government will develop a stronger framework for stimulating lower carbon transport

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The Stern Review noted that global levels of R&D into lower emission energy technologies have fallen significantly since 1980 and recommended that this trend be reversed through a doubling of global levels of public energy R&D (see Chapter 16 of the Stern Review – Accelerating Technological Innovation). Similarly the International Energy Agency's Technology Perspectives 2006 Report also stated that "there is an acute need to stabilise declining budgets for energy-related R&D and then increase them...government funded R&D will remain essential, especially for technologies that are not yet commercial"

technology development, it is necessary to consider the specific circumstances and existing policy measures which apply in different areas of the transport sector before examining the case for additional measures or further Government interventions. Subsequent sections of the strategy examine each of the major transport modes in the UK.

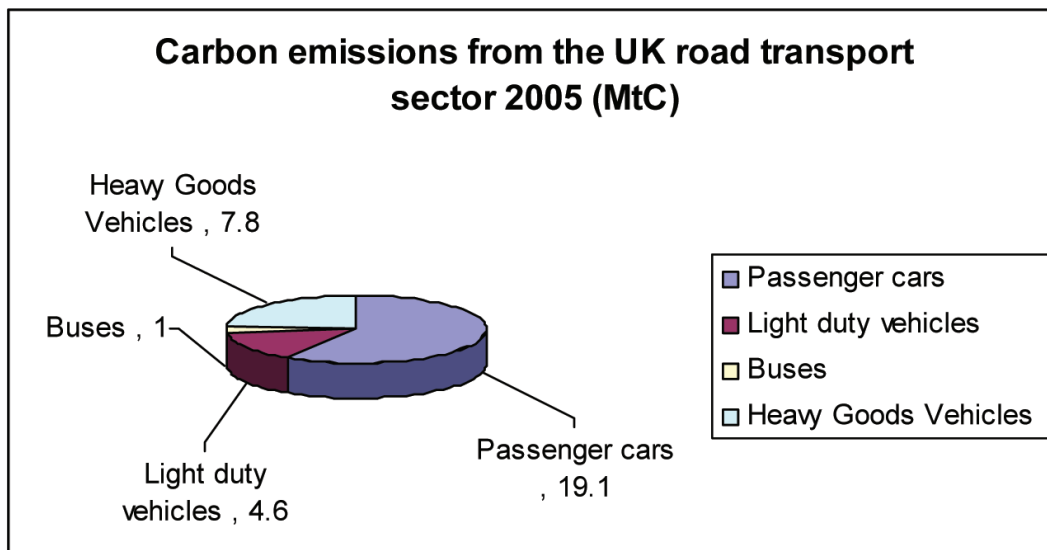
Chapter 4

Low Carbon Technologies and the Road Sector

Carbon emissions from the road sector

4.1 The road sector is the largest source of carbon emissions from transport in the UK.

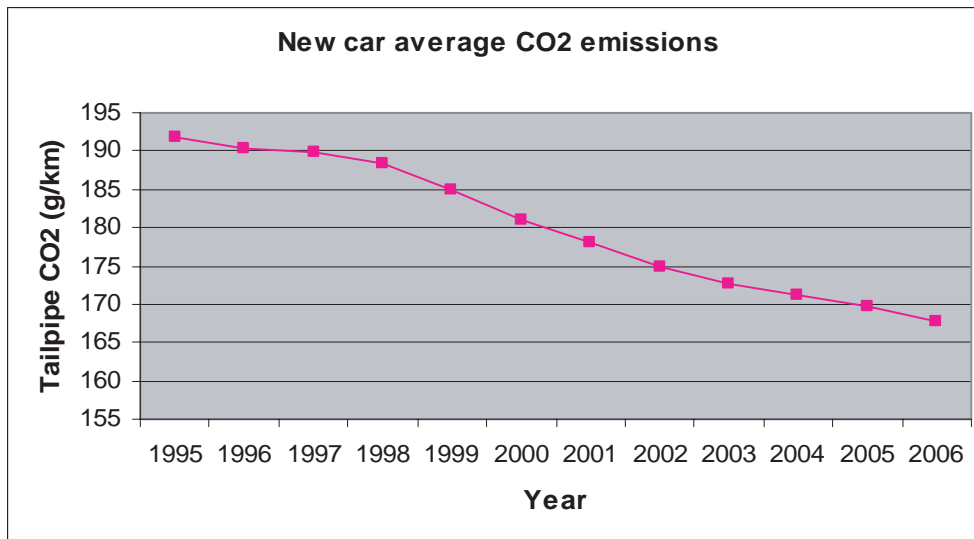
4.2 In 2005 the road sector was responsible for carbon emissions of 32.5MtC measured by source. Passenger cars were responsible for the majority of those emissions, with substantial contributions from heavy goods vehicles (HGV's) and light duty vehicles such as small commercial vans. The pie chart below shows the breakdown for the major sources of emissions:



4.3 Overall, carbon emissions from road transport have been on a moderate upward trend having risen from 30.5 MtC in 1994. Broadly speaking this reflects continued growth of road transport within a growing economy.

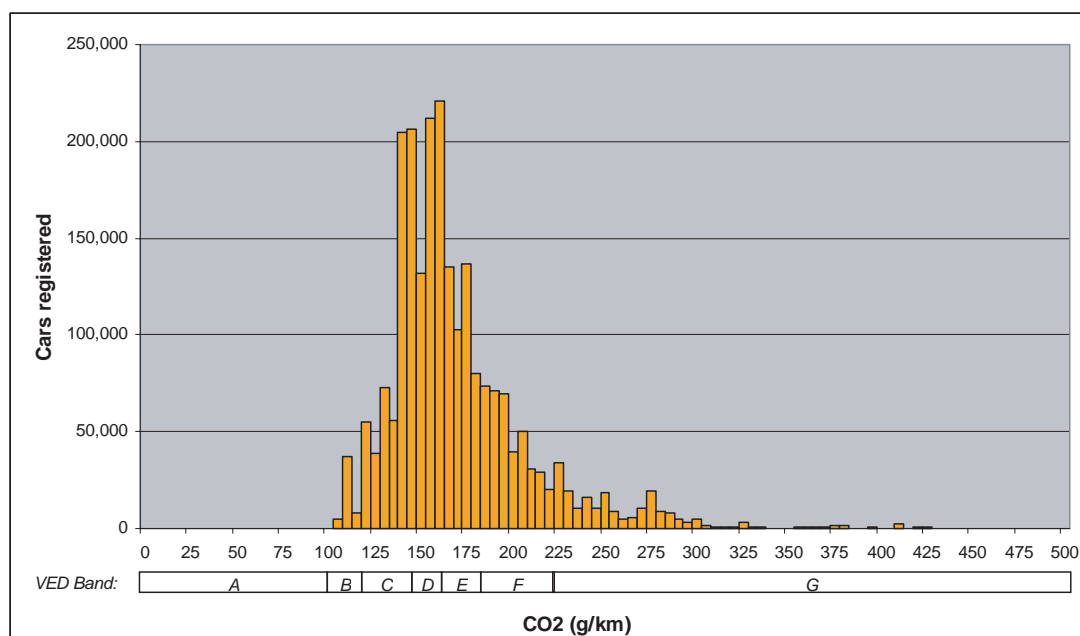
4.4 However within the overall figures there are somewhat different trends. While carbon emissions from HGV's and light duty vehicles are continuing to rise, those from passenger cars have been essentially stable over the past decade. The impact of continued growth in total passenger kilometres travelled by car has been offset by modest but steady progress in improvements in fuel efficiency.

- 4.5** The tailpipe carbon emissions of new cars purchased in the UK is on a slow gradual downward trend, as shown in the graph below¹.



- 4.6** This trend reflects a combination of increased penetration of diesels into the car fleet, continued progress by the automobile industry in achieving incremental improvements in fuel efficiency and the impacts of existing Government and EU policies in this area. In the UK the average CO₂ emissions from new cars sold in the UK in 2006 was 167.7g/km – a fall of around 1.2% from the previous year. However, figures on average fuel efficiency hide substantial variation in the tailpipe carbon emissions from cars sold in the UK – with the most fuel efficient models achieving CO₂ emissions of a little over 100g/km while the least efficient may have emissions of 250g/km or more
- 4.7** The graph below shows the distribution of new car sales by CO₂ emissions for 2006 – as well as the current Vehicle Excise Duty (VED) band into which they fall².

¹ Source: pre-2001 fuel efficiency estimates come from The Society of Motor Manufacturers and Traders (SMMT). Post-2001, estimates are based on new car emissions data collected by the Driver and Vehicle Licensing Agency (DVLA).
² Source – DVLA



It can be seen that the majority of new cars sold in the UK have emissions within the range of 130–190g CO₂/km, though there is also a long tail of cars with higher emissions.³

Existing Government policies

4.8 The Government has in place a range of policies which impact on the development of lower carbon technology options in the road sector. The major policies in this area are set out below. Firstly, there are a number of relevant taxation measures:

- Road fuel duty encourages the purchase of more fuel efficient vehicles by increasing the cost of petrol and diesel.
- Vehicle Excise Duty (VED), which is levied annually, is graduated according to CO₂ emissions.
- Company Car tax rules have been reformed to provide significant incentives to purchase lower CO₂ vehicles
- Biofuels – bioethanol and biodiesel - enjoy preferential tax treatment relative to gasoline and diesel, with a 20p/litre reduction in the duty levied until 2009/10.

4.9 In addition to taxation measures, the Government is also taking a range of other actions at the domestic level:

- The Government is introducing a Renewable Transport Fuel Obligation (RTFO) to incentivise the use of biofuels. The RTFO will be introduced in 2008/9 with the Obligation level rising to 5% by 2010/11. The Government has indicated its intention to raise the Obligation level above 5% subject to a range of cost, standards and sustainability criteria being met.

³ Most studies suggest that the large majority (around 80%) of carbon dioxide emissions arise during the operational phase of a vehicle's life rather than during construction or disposal. The Government therefore considers that, while manufacture and disposal are important, focussing on tailpipe carbon emissions from cars remains an appropriate method of examining and incentivising the market penetration of lower carbon vehicles.

- The Department for Transport (DfT) has a £5m per annum programme of support for industry led low carbon vehicle R&D, as well as providing around £0.5m per annum of grants for the trialing and demonstration of infrastructure for alternative fuels. Both of these programmes are currently managed by the Energy Savings Trust (EST).

There is also significant relevant action at the European level. The EU has a voluntary agreement with automotive manufacturer associations which aims to reduce the average CO₂ emissions of new cars to 140g/km by 2008/9. However, although progress has been made in reducing average emissions of new cars (both in the UK and across the EU) on current trends the 140g/km target is not likely to be achieved.

- 4.10** The EU also supports research and development into lower carbon vehicle technologies within the wider Framework Programmes (FP) which support R&D across the EU. FP7 will run from 2007-2013 and includes a significant transport work programme, within which there will be significant support for lower carbon vehicle research. FP funded projects must involve collaborations between organisations in different member states

Key technologies for a lower carbon road sector

- 4.11** There are a range of different vehicle and fuel technologies with the potential to reduce carbon emissions from the road sector. As part of the preparatory work for the Energy Review the Government commissioned E4tech to assess the carbon reduction potential of a range of technologies in the road transport sector. Their report was published alongside the Energy Review.⁴ Box 1 provides short summaries of some of the key future technologies in this area – further detail can be found in the original E4tech report.
- 4.12** In developing the Low Carbon Transport Innovation Strategy the Government asked E4tech to extend their original analysis to a second stage, and to examine how the innovation system functions for some of the key technologies likely to be central to carbon reduction in the road transport sector and to make broad recommendations for policy options that could strengthen the functioning of that system in a UK context. E4tech's work takes account of the international nature of the automotive and fuels industries, while providing a particular focus on UK actors, policies and expertise.
- 4.13** E4tech's second study *A Review of the UK Innovation System for Low Carbon Road Transport Technologies* is being published alongside this strategy (and is available in full at www.dft.gov.uk/pgr/scienceresearch/technology/). E4tech's work brings out the complexity of innovation systems for low carbon road transport technologies and the many actors – from both the public and private sectors – who are involved. It also highlights that technology categories such as biofuels and hybrids should be seen as broad terms encompassing a range of different component technologies which are often at widely differing stages of development.

4 The report is available at <http://www.dti.gov.uk/files/file31647.pdf>

- 4.14** That said, their conclusions point to a range of existing and closer to market technologies that have, in combination, the potential to make significant contributions to carbon reduction in the relatively near term. These technologies include:

Box 1 –Potential future lower carbon vehicle technologies

Hybrid and Electric Vehicles

Hybrid vehicles can come in many varieties with different levels of cost and complexity. Essentially a hybrid is a vehicle that combines electric power from an on board battery with a standard internal combustion engine (ICE) running on petrol, diesel or biofuels. A “mild hybrid” is one where the engine shuts down when the vehicle is stationary, and where energy from braking is used to charge up the battery, to be re-used later alongside the ICE in acceleration. These both save energy and reduce carbon emissions. A “full hybrid” refers to a vehicle which can run purely on stored electric energy for limited distances, without burning any fuel. The car will run on electric power at low speeds where the efficiency of the ICE is low, and on normal engine power at higher speeds where efficiency is high, thereby maximising the overall efficiency of the car.

For existing hybrids the range of the electric-only mode is limited, while all the energy ultimately comes from the petrol or diesel in the car. If a larger battery is used and is charged from an external source then a vehicle could be used in electric mode for longer distances. This is called a “plug-in hybrid” and could be used for short-medium length journeys purely in electric mode, with longer trips using the ICE and petrol or diesel fuel. Last is a purely-electric vehicle which has a battery large enough to make all its trips in electric only mode and does not use an ICE or liquid fuel. Existing electric only vehicles have limited range due to the constraints of battery technology. The carbon emissions of a plug-in hybrid or fully electric vehicle will of course depend on the sources of electricity used to charge the battery.

Biofuels

Biofuels are liquid fuels derived from many different biological sources which at present include sugar, wheat, corn, rapeseed, soy and palm oils. These materials can be converted into liquid fuels, which can be blended with petrol or diesel or used alone, or gaseous fuels such as biogas. When biofuels are burned, they release into the atmosphere the carbon that they absorbed in the growing process. In this way biofuels can be “carbon neutral” in that they absorb and release the same carbon. However in practice the carbon benefit is lower due to the energy used in the manufacture and transportation of the biofuels. Different biofuels can have very different carbon impacts over the full life cycle, though most offer significant advantages over petrol or diesel.

In the future biofuels may come from a broader range of biomass sources converted in a variety of ways. Such “second generation” biofuels could include “lignocellulosic” biofuels which can use the woody plant matter from a crop (including the tougher stems) as well as wood, waste and other materials which widen the possible sources for fuel beyond food crops. In many cases, through utilising waste materials or more of the crop, and through more efficient processes, these future biofuels have the potential to achieve larger carbon reductions over the life cycle than existing biofuels. Competition for land use could also be reduced through use of these materials and through growing woody crops on land unsuitable for food crops.

Hydrogen and Fuel Cells

Hydrogen can be used to provide energy for transport, through use in a fuel cell vehicle or internal combustion engine. When hydrogen is used, there are zero or very low emissions of air pollutants, with only water and heat as by-products. However hydrogen must be produced using another form of energy. Significant overall carbon savings from using hydrogen in transport can be made only if hydrogen is produced using low carbon sources.

In a fuel cell vehicle the hydrogen is split, and combined with oxygen from the air, to produce electricity to power the vehicle. The fuel cell, which is generally combined with a battery to form a hybrid system, has the potential for high efficiency, and so very low emissions from the system as a whole. However fuel cell vehicles need significant cost reduction and performance improvement before they can reach mass market. Advances in the storage of hydrogen in vehicles, which can be in the form of compressed gas, liquid or within another solid material, are also required.

- a range of technologies offering the scope for further incremental improvements in the fuel efficiency of conventional petrol and diesel internal combustion engines
- a range of lightweight materials with the potential to reduce the weight of future vehicles and thus improve fuel efficiency
- nearer market versions of hybrid vehicles.
- first generation biofuels (bioethanol made from sugar or starch crops, and biodiesel made from oil crops and wastes) and potentially some of the most advanced “second generation” biofuels made from biomass wastes or a range of lignocellulosic non-food crops.

4.15 In general, these technology options offer the potential for continued incremental improvements in the fuel efficiency and carbon footprint of road vehicles, rather than offering the promise of large scale de-carbonisation of the road transport sector. That said, the combined scope for carbon savings offered by these technologies is substantial.

4.16 Technology options which may become widely deployed over somewhat longer timescales include:

- more advanced versions of hybrids, including “plug-in” hybrids in which the battery is re-charged from the electricity grid
- fully electric vehicles (which may expand independently or evolve from plug-in hybrids)
- a broad spectrum of 2nd generation biofuels, manufactured in a variety of ways and from a wide range of biomass sources
- hydrogen fuelled vehicles, whether powered by an internal combustion engine or more likely by a fuel cell.

The key attraction of these technologies is the possibility they offer of delivering very substantial carbon reductions from road transport over the longer term – including potentially achieving the almost total de-carbonisation of road transport - with supplementary benefits for UK energy security and air quality. In general however they are not yet ready to be applied to mass markets in the road transport sector, either because costs are too high for large scale commercial deployment or further technological progress is required to bring down costs and overcome performance issues likely to be important to most consumers.

4.17 E4tech’s work suggests that for all technologies, clear and long term policy signals supporting lower carbon road transport are needed to drive all stages of the innovation cycle. This should include a recognition that a variety of technology options are likely to be required in order to deliver large scale emissions reductions across a broad range of vehicle types over time. Their work also suggests that there are some important differences between the support needed for innovation in technologies nearer and further from market, and thus some differences in the nature of the policy responses that are most appropriate from Government. In particular, E4tech suggest that, for nearer market technologies, the most effective intervention from Governments would be a strengthening of policies supporting market deployment of lower carbon vehicles. This may involve further regulatory or taxation measures, as well as use of public procurement to help the creation of niche markets. For riskier and further from market technologies, while deployment signals remain important in providing a stimulus for technology development, there is in addition a stronger case for Government providing targeted financial support for industry and academic led, R,D&D projects.

4.18 The Government supports the broad conclusions of E4tech’s work. Going forward our policies towards lower carbon road transport technologies will:

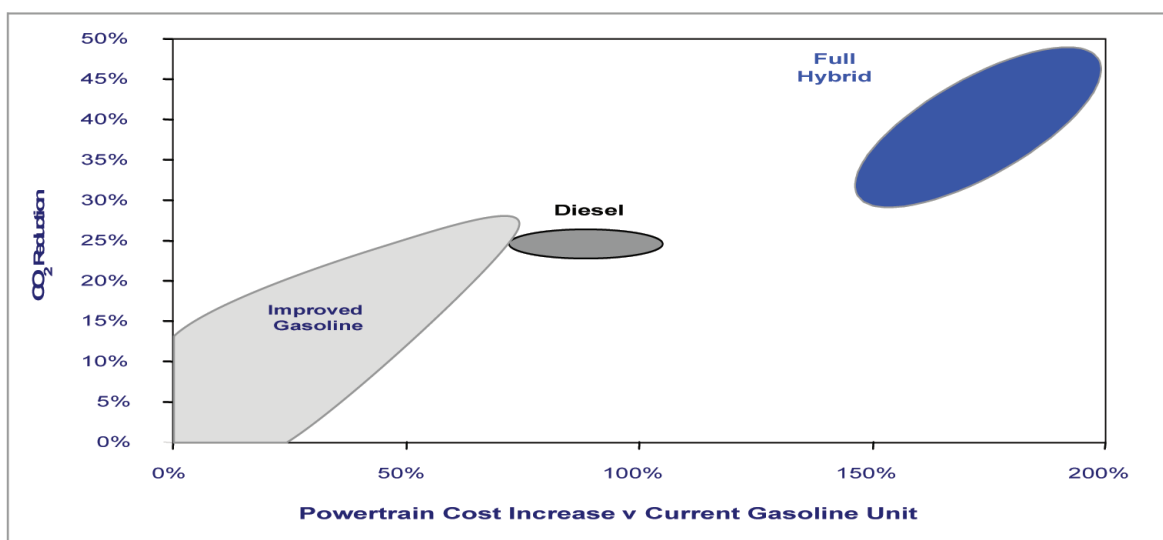
- seek to provide strengthened deployment signals which increase the prospects that cost-effective carbon savings from existing and nearer term technologies are realised in the UK
- provide targeted support for national and international R,D&D efforts to improve the technological and commercial potential of lower carbon options in the road sector

We now discuss in more detail the basis for this approach and the policies we are developing to support it.

Securing cost-effective carbon savings from existing and closer to market technologies

- 4.19** There are a range of strong arguments for placing a high priority on securing carbon emissions savings in the road sector from the range of technologies which are either available now or likely to be available in the near-term.
- 4.20** Firstly, considered in combination, the carbon savings potential of these technologies is substantial. As noted above, there is significant variation in carbon emissions from existing vehicles on the market. This indicates that there is potential to reduce carbon emissions from passenger vehicles simply through influencing consumer behaviour and gradually accelerating purchasing decisions in favour of lower carbon vehicles. This does not necessarily or always mean persuading consumers to purchase smaller cars, as there is quite considerable variation in the fuel efficiency of vehicles even when considering those within the same class or approximate engine size – figures from the Society of Motor Manufacturers and Traders (SMMT) suggest that a reduction of up to 30% in average fleet CO₂ emissions could be achievable if every consumer chose the most fuel efficient vehicle in its category⁵.
- 4.21** Moreover, over the next 10-15 years, E4tech's and other work suggests continued incremental improvements in fuel efficiency can be achieved by the automobile industry through additional refinements, in-particular to petrol and to a lesser extent diesel internal combustion engines. In combination, it is estimated that these technologies could improve internal combustion engine fuel efficiency by of the order of 15-20% compared with today's levels by 2020. Further improvements can also be potentially achieved from a range of lightweight materials (for further detail see sections 4 and 5 of E4tech's report).
- 4.22** Continued evolution and market penetration of current hybrid technology, applied both to petrol-electric and potentially in due course, diesel-electric vehicles, also has the potential to provide additional carbon savings. The graph below, from UK automotive engineering consultants Ricardo, indicates that hybrids could deliver of the order of an additional 20% above improvements to the internal combustion engine alone, though at higher powertrain cost⁶. The current position on hybrid technology and its potential evolution is discussed in more detail in section 6 of E4tech's report.

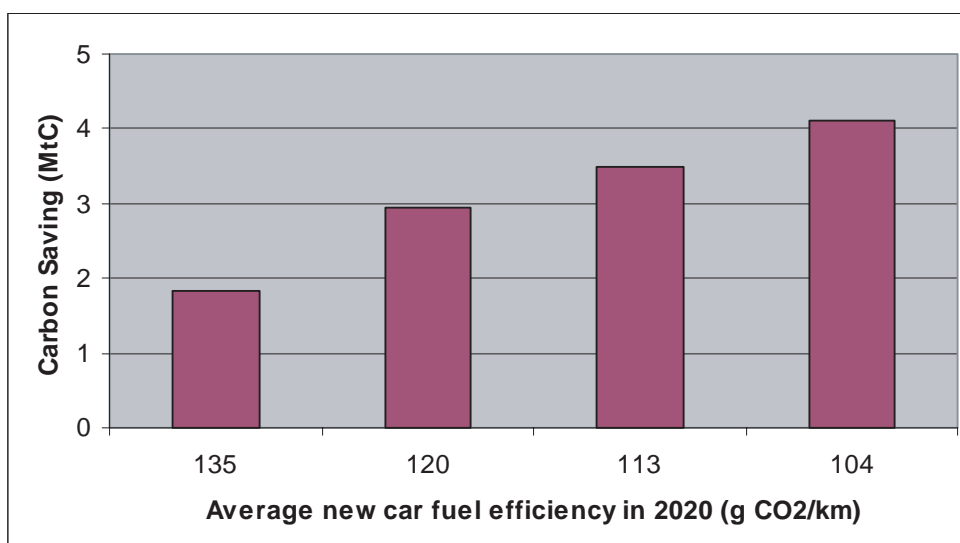
⁵ <http://smmplib/findlay.co.uk/articles/sharedfolder/Publications/ACF22CC.pdf>
⁶ Source: Ricardo – reproduced in the E4tech report section 4.



4.23 Finally, near-term exploitation of biofuels has the potential to deliver further carbon savings. For example, the Government estimate that achieving the Renewable Transport Fuel Obligation (RTFO) target of 5% biofuels sales by volume by 2010 would save around 1MtC.

4.24 Improvements in vehicle technologies can lead to substantial carbon savings. At present carbon emissions from passenger cars in the UK are around 19MtC. The Government estimates that average fuel efficiency for the current passenger car fleet (ie all passenger vehicles presently on the road, new and old) is around 180g/km CO₂, with the new car average for 2006 being 167.7g/km.

4.25 The following chart illustrates the level of carbon savings from passenger cars we might achieve in 2020 if, between now and then, we were able to reduce average new car CO₂ emissions to the levels indicated.



4.26 The above carbon savings are estimates and average new fuel efficiency levels are illustrative only and do not represent Government targets⁷. The figures also take

account of a potential “re-bounce effect” in which higher fuel efficiency lowers the cost of driving compared to alternatives and thus leads to greater car usage and increased total distances travelled by car. If this re-bounce effect proved to be less than assumed – either as a result of other government policies or other factors – then total carbon savings would be higher than shown. Moreover, it should be noted that the graphs above are illustrations for passenger cars only - many of the technology options discussed above are also applicable, to a greater or lesser extent, to other road vehicles such as light duty vehicles, Heavy Goods Vehicles (HGV’s) and Buses, which in combination were responsible in 2005 for another 13.4 MtC of emissions. Thus the graph under-states the total carbon savings possible in the road sector from greater market penetration of existing and nearer market technologies

4.27 There is little doubt that carbon savings of this scale are technologically achievable taking account of the combined potential of existing and near market technologies. The scale and achievability of the possible savings is however by no means the only argument for placing a high priority on progress in this area. Other important considerations are as follows:

- carbon savings in this area are likely to be among the lowest cost options which can be delivered from technology in the transport sector over the next 10-20 years. This is because the savings can be secured from technologies which are already available or close to commercialisation. Nor are the carbon savings dependent on the provision of new transport infrastructure, a lower carbon electricity mix, or major technological breakthroughs which are uncertain.
- As other sections of this strategy make clear, the scope for new technology to deliver very large scale carbon savings in the aviation, rail or shipping sectors is probably quite limited in the near term, not least because the rate of capital stock turnover and replacement in these sectors is much slower. Moreover, progress in the road sector in the development and commercialisation of lower carbon engines, lighter materials, hybrids and biofuels all has some potential for read across to other transport modes over the medium and longer term.
- As E4tech’s work makes clear, technology development is a complex evolutionary process and many nearer market lower carbon technologies are on the pathway to further development of currently longer term options. For example, continued development of hybrid technology may enhance the prospects of for plug-in hybrids and fuel cell vehicles, just as progress with early biofuels will provide some technical and commercial learning relevant to the development of future second generation biofuel options. Similarly, improved internal combustion engine and lightweighting technologies may benefit many future vehicle options. Continuing to develop existing and nearer-market technology options will help, and is to some degree a pre-requisite for, the successful development of longer term options (as well as specific work on the longer term options themselves).
- E4tech’s report highlights that the R,D&D programmes of major international automobile companies tend to be predominantly focused on nearer market options. The automotive industry is therefore well placed to make a major contribution to the commercialisation of technologies in this area.

- The UK has a range of internationally competitive companies with significant capabilities in nearer market options. While there will always be some commercial winners and losers from a changing regulatory environment, these companies would be well placed to benefit from a stronger focus on reducing carbon emissions from the road sector and from the large global markets for lower carbon technologies likely to develop over coming decades.
- Continued fuel efficiency improvements in the car fleet would be likely to deliver some additional benefits aside from carbon savings. Reduced fuel usage would make the economy as a whole more insulated against potential negative impacts from rising fuel costs and would improve energy security. Air quality benefits could also be achieved over time⁸.

4.28 Greater utilisation of existing and close to market technologies for reducing carbon emissions would however have some impacts on the cost of new vehicles. A study by Ricardo Automotive Consultants for the DfT has provided estimates of the relationship between the cost of fuel saving technology and efficiency improvements. For passenger cars these are estimated as typically in the range of £300-£2,500 per vehicle – depending on the scale of carbon reduction achieved⁹. However other studies, such as a review for the European Commission by TNO, IEEP and LAT¹⁰ estimate significantly lower costs of fuel saving technologies. In addition, for many consumers the additional purchase costs of lower carbon vehicles would be offset to a significant degree, if not entirely, by reduced fuel costs over time.

4.29 Despite these considerations, it is by no means certain that all the existing and nearer-market technologies which can deliver carbon reductions will be rolled out at commercial scale across UK vehicle fleets. Recent research suggests carbon emissions have not been high on the list of consumer concerns when buying a car¹¹. Limited market pull from consumers impacts on the range and kinds of vehicles which automotive companies bring to market. Moreover, commencing product development is high risk for manufacturers. As the technology and product development process moves close to commercialisation costs rise substantially. And while the scale of investment is considerable the prospects of return on that investment remain uncertain. These high risks of new model development tend to encourage manufacturers to favour incremental adjustments to existing models over radical re-designs for improved fuel efficiency – there is a natural degree of risk aversion in bringing new models or technologies to market. The fact that a new lower carbon technology has been successfully demonstrated in a prototype model does not necessarily mean that it will be rolled out at commercial scale.

4.30 Moving successfully from the demonstration to the commercial phase of technology development is thus one of the most challenging elements of the innovation process. Reducing risks at this stage can therefore help increase the rate at which new technology options can be brought to market. E4tech suggest that Governments can

8 While, in the short term, increased dieselisation of the car fleet could have negative impacts on local air quality, new Euro emission standards for diesel vehicles coming into force over the next decade will deliver further significant reductions in particulate and NOx emissions from vehicles.

9 The Ricardo work can be found at <http://www.dft.gov.uk/pgr/roads/environment/research/studyintocostsoffuelsavings3845?version=1>.
 10 http://ec.europa.eu/enterprise/automotive/projects/report_co2_reduction.pdf

11 LowCVP “Car Buyer Research Report”, March 2005. http://www.lowcvp.org.uk/uploaded/documents/Consumer_research_-_final_5.05.pdf

play an important role in this area through interventions focussed on public procurement and creation of niche markets for lower carbon vehicles. These interventions can be effective as, by increasing the visibility and certainty of an early market for a new lower carbon model – subject to the attainment of cost and performance criteria – they have the potential to reduce the initial risks faced by companies when considering whether to introduce a new technology to the marketplace.

- 4.31** Given the above considerations, the Government is committed to working at both European and domestic level to develop new measures and policies aimed at strengthening current and future demand for, and provision of, lower carbon vehicles.

European level actions

- 4.32** At the European level, the major existing policy has been a series of voluntary agreements with automotive manufacturer associations. On 7 February of this year the European Commission published its communication on CO₂ emissions from cars and light commercial vehicles. This communication, amongst other things, sets out the Commission's ideas for what should replace the current CO₂ voluntary agreements that expire in 2008/9. These agreements set targets for 2008/9 of 140g/km (average new car tailpipe CO₂ emissions).
- 4.33** The communication calls for the voluntary agreements to be replaced by a legislative framework - a proposal will be delivered late 2007 or mid-2008. It states that this framework should have as its core target 120g/km by 2012. Of this, 130g/km should come from vehicle fuel efficiency, with another 10g/km coming from other measures (for example, biofuels, fuel efficiency improvements in vans, better tyre pressure monitoring, more efficient air conditioning systems etc).
- 4.34** The Government welcomes the Commission's intention to bring forward a legislative framework and supports a move to demanding mandatory fuel efficiency targets. Subject to understanding how the targets will be implemented and subsequent impact assessment, the Government is supportive of the Commission's proposals. However it is our view that the proposals should also set out a longer term strategy for improving vehicle fuel efficiency. The Government announced in Budget 2007 that its longer term objective is that average new car emissions be reduced to 100 grammes of carbon dioxide per kilometre.
- 4.35** In addition, the Government will also work with the Commission and other stakeholders on the range of more detailed regulatory issues relevant to the fuel economy and carbon dioxide emissions of future vehicles. In particular the Government broadly welcomes the Commission's proposals to mandate a range of detailed requirements or minimum standards for future passenger car and light commercial vehicles – including compulsory fitting of tyre pressure monitoring systems, compulsory use of gear shift indicators, maximum tyre rolling resistance limits and minimum fuel efficiency requirements for vehicle air conditioning systems. However before any final decisions are made further discussions will be necessary on the appropriate way of doing this, with a full impact assessment. We will also work with the Commission and EU member states on issues relating to the future evolution of the standard test cycle for establishing a new vehicle's CO₂ emissions – in order to

ensure that the test cycle continues to accurately reflect the comparative emissions performance of different vehicles and that it takes appropriate account of the evolution over time of technologies supporting lower CO₂ emissions from vehicles.

- 4.36** The Government will also seek to ensure that the development of new safety measures and standards for new vehicles at EU and international level recognises the potential impact on fuel economy and that, where significant conflicts occur, these are considered alongside potential safety benefits. While, historically, new safety measures have tended to increase the weight of new vehicles, in general the Government expects that the anticipated trend towards “intelligent safety systems” in vehicles is unlikely to create significant conflicts with fuel economy objectives – indeed there may be some synergies – eg systems which alert drivers to speed limits could also assist in encouraging more fuel efficient driving.
- 4.37** Finally, with regard to European level measures the Government will, along with other EU member states, continue to consider the feasibility and case for including surface transport emissions within future phases of the EU ETS. The EU ETS is currently being reviewed by the European Commission and the Government has been working to encourage the Commission and other member states to consider the inclusion of surface transport.

Domestic level actions

- 4.38** The Government is also continuing to act to strengthen relevant policies at the domestic level:
- We are continuing to strengthen incentives to purchase lower carbon vehicles through the graduated vehicle excise duty regime. In Budget 2007 we announced reduced rates for low-carbon band B cars and increased rates for the most polluting (band G) cars¹².
 - The Government will provide new funding of an initial £20m to support a new programme aimed at accelerating the market penetration of lower carbon vehicles and reducing the barriers faced by companies in moving from prototype demonstrations of lower carbon technologies to full commercialisation. This programme will provide financial support for public procurement of fleet scale demonstrations of lower carbon vehicles (and where appropriate supporting infrastructure). The programme will seek to build on the model of contractual forward commitments in which commitments to purchase vehicles are linked to the achievement of pre-determined cost and performance criteria. The Government will consult on the detailed operation of this new programme later in 2007 – with a view to supporting the first fleet procurements/demonstrations in 2008/9.
 - To ensure that Government leads by example we have set a fleet average car procurement target of 130g/km CO₂ by 2010/11 for new cars purchased by Government and used for administrative operations. We will keep the target under review and look to extend the scope of this target following further analysis.

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The lowest carbon (band A) vehicles are already exempt from VED. For further details on the most recent changes see paras 7.77-7.78 of Budget 2007 - http://www.hm-treasury.gov.uk/media/73B/74/bud07_chapter7_273.pdf

- The Government has launched a new communications campaign – “Act on CO₂” – covering smarter driving and purchasing. This highlights to consumers that they can contribute to tackling climate change without compromising on the type of car they drive – both by purchasing a lower carbon vehicle within a given class and by driving in a more fuel efficient way¹³.

4.39 In relation to biofuels and the development of the Renewable Transport Fuel Obligation (RTFO), the Government also launched a consultation in February of this year. This consultation covers both the detailed implementation of the RTFO over the period 2008/9 to 2010/11 and issues relating to the future evolution of the RTFO after its initial phase¹⁴.

4.40 The Government has made clear that it is committed to increasing the level of RTFO beyond 5% after 2010/11, but only provided certain essential conditions are met – in particular:

- Confidence that the biofuels will be produced in a sustainable way, so that they deliver the maximum practicable carbon savings with the minimum practicable adverse environmental impact.
- Certainty that the use of blends of biofuel higher than 5% will not lead to mechanical problems, particularly for owners of older cars which were not designed to run on such mixtures.
- Confidence that costs to consumers will be acceptable, both in terms of fuel prices at the pump, and in terms of wider economic impacts, including for example the impacts on food prices and other industries which make use of similar feedstocks.

The need to satisfy these conditions has been recognised in the agreement reached at the March 2007 European Council that endorsed the introduction of a 10% by energy content biofuels target by 2020. The UK will continue to work closely with Europe in developing these initiatives further. In particular we shall need to respond to the Commission’s proposals for revising the Biofuels Directive and for implementing the EU biofuel targets. The Government will also want to be satisfied that expanded use of biofuels beyond the 5% level represents an effective use of our biomass resources. Alternative uses of biomass (which can often deliver greater carbon savings at lower cost than producing high quality transport fuel), include using biomass as a substitute for fossil fuels in the generation of electricity and heat. These issues are considered further in the Government’s Biomass Strategy which is also being published alongside the Energy White Paper.

4.41 The Government believes that a combination of strengthened action at the EU and domestic level has the potential to significantly accelerate improvements in average new car fuel efficiency and carbon dioxide emissions from the vehicle fleet over the next 10-15 years. We will continue to work with EU member states, the Commission, and key international and domestic stakeholders to try and ensure that new

¹³ For further details on this communications campaign see <http://www.dft.gov.uk/ActOnCO2/>

¹⁴ Details of the consultation can be found at www.dft.gov.uk/consultations/open/drafttrfo/ The Government is also putting in place more detailed fiscal incentives supporting the use of biofuels, including a duty differential for biogas and from 2008 reduced company car tax for vehicles using E85 bioethanol. An enhanced capital allowance scheme to support the development of the most carbon efficient biofuels plants. For further details see paras 7.47-7.54 of Budget 2007.

regulations and measures in this area are introduced in the most cost effective and efficient manner as possible.

Light duty vehicles, HGV's and Buses

- 4.42** While much of the discussion in this section has focussed on passenger cars, which are the largest source of emissions from the road sector, most of the technologies capable of reducing carbon emissions from cars are also, to a greater or lesser extent, applicable to other road vehicles such as light duty vehicles, Heavy Goods Vehicles (HGV's) and Buses. Hybrid and fuel cell powered buses have already been demonstrated in a range of urban environments as have lorries fuelled by biodiesel. Certain niche vehicle applications may also be particularly suitable for lower carbon options – for example fully electric delivery vans and trucks may be a viable option for delivery patterns which allow for regular re-charging.
- 4.43** In addition to promoting carbon reduction through the application of new technologies, the Department for Transport also plays a key role within the freight and logistics sector in promoting more sustainable ways of distributing goods around the country. The two basic methods used by the Department are the Mode Shift Program (where we directly support the use of rail or water to transport goods where practical) and the logistics Efficiency Programs. The aim of the Efficiency Programs is to reduce the impact of road based logistics. It does this through demonstration projects (such as the successful Safe and Fuel Efficient Driving scheme (known as SAFED), research into logistics and through the promotion of “Freight Best Practice” to industry.
- 4.44** In relation to the bus sector, one of the most important sources of subsidy for buses from central Government is Bus Service Operators Grant (BSOG) currently worth around £400 million in England in 2006/07. Bus subsidy plays a crucial role in supporting the provision of bus services, reducing fares and increasing bus patronage, which in turn play an important economic, social and environmental role. But it is also important to ensure that the government's substantial investment in buses remains as effective and well targeted as possible. BSOG payments are currently linked to fuel consumed and therefore clearly poorly targeted on objectives for patronage, punctuality and quality. Furthermore, by subsidising fuel consumption BSOG does not fit well with our environmental objectives.
- 4.45** The Government's white paper on bus policy *Putting Passengers First* published in December 2006, noted there is potentially a case for refocusing bus subsidy, for example to provide a more direct linkage between subsidy levels and our policy goals. However, it would be important to understand fully the potential impact of any reform to the subsidy regime before deciding whether to bring forward proposals. The Department of Transport is considering these issues further with stakeholders, including whether there is a good case for reforming bus subsidy to focus it more closely on the Government's priorities, such as congestion, the environment and accessibility¹⁵.

Intelligent transport systems

4.46 The Government is also committed to the utilisation of new information and communications technologies to improve traffic management and information for travellers. Many Intelligent Transport Systems (ITS) technologies are likely to deliver their main benefits in reducing congestion and improving traffic flows – which can potentially deliver additional benefits in terms of reduced emissions and improved fuel consumption. The DfT has published an ITS strategy for the roads sector¹⁶. Nor are ITS systems only applicable to road applications - advanced train safety systems, better air traffic systems and electronic navigation for shipping can all contribute to more efficient useage of transport networks. ITS systems can also be used to provide information that helps people make better travel choices - and therefore makes better use of transport and capacity. The DfT's Transport Direct internet system - a world first - enables travellers to plan door-to-door journeys anywhere within Britain, using any mode of transport. Transport Direct already provides information on the carbon emissions associated with car journeys and this will be extended to other modes of public transport later this year.

Further from market and longer term technologies

4.47 While accelerated development of near-market technologies in the road sector has the potential to deliver significant carbon savings, these options cannot by themselves deliver the large scale de-carbonisation of the road and other transport sectors which may be required if longer term domestic and international carbon reduction objectives are to be met.

4.48 To deliver these larger carbon savings, a significant contribution from currently further from market technologies such as second generation biofuels, hydrogen and fuel cells, plug-in hybrids and electric vehicles would be required. In general these technologies require significant cost reductions and/or technological progress to be achieved before widespread commercialisation can be achieved.

4.49 Sections, 6, 7, and 8 of E4tech's report, which consider in detail hybrid electric vehicle technology, biofuels and hydrogen and fuel cells respectively, set out in detail the current technology challenges faced by these options, the relevant UK actors and policies and the current state of innovation. A brief discussion of the key challenges for each technology area are set out here.

4.50 For future evolution of hybrids,"plug-in" hybrids and electric vehicles the key technological challenge is to develop, at acceptable cost to the consumer, battery technology which will allow a much greater contribution and performance from the battery in terms of engine power and vehicle range. Nickel-metal hydride is the battery technology of choice in current commercial hybrids but is generally expected to be replaced by lithium-ion batteries in future models from the end of this decade onwards. Other new battery technology options may also be developed over time.

4.51 All-electric vehicles may be a viable option for consumers who require a car for short urban journeys only but these vehicles do not yet possess the range, size or top

speeds likely to make them attractive for the majority of consumers. Significant battery advances would be required to allow electric vehicles to achieve mass market commercialisation and many view the development of plug-in hybrids, which can potentially combine the lower emissions of electric vehicles with improved range and performance, as an alternative route to widespread use of electricity in vehicles. However costs would need to be reduced significantly before the fuel saving benefits of plug-in hybrids would become attractive for most consumers. Plug-in hybrid development is now a feature of some of the major automotive companies research and development activity.¹⁷

- 4.52** For second generation biofuels the key challenge is to improve the efficiency and reduce the costs of a wide range of potential conversion routes for creating biofuels from lignocellulosic and other organic matter – in order that they become more competitive with existing biofuels chains and in time fossil fuel based alternatives as well. A very wide range of routes for future biofuel production are potentially available and a combination of basic and applied research, demonstration and commercial support is required in order to bring forward these technologies. An issue of particular importance for the future development of biofuels is to ensure that those biofuels that provide additional carbon benefits are rewarded in future market mechanisms and regulatory measures. The Government's current consultation on the future evolution of the Renewable Transport Fuel Obligation discusses in more detail a range of options for rewarding biofuels on the basis of their life cycle carbon emissions and sustainability performance.
- 4.53** Hydrogen and fuel cell technologies face a number of technical and cost challenges before they can become commercially viable options for road or other transport modes. Fundamental fuel cell stack performance is not yet able to deliver the required mix of power density, lifetime, cold start and other properties at acceptable cost. Even if the impact of scale economics is considered, fuel cells currently cost significantly more than the long term cost targets necessary for volume manufacture for mass markets. A mixture of basic, applied research and demonstration trials are needed to explore technological options for performance improvement and cost reduction. In addition, for both fuel cell vehicles and hydrogen powered internal combustion engines, on board hydrogen storage does not yet provide an acceptable range for most vehicles in conventional applications. Hydrogen storage requires basic and applied research and development, depending upon the option under investigation. Novel production methods for hydrogen are also worthy of further research. More detailed consideration of the issues relating to the development of hydrogen as a transport fuel are discussed in Section 8 and Appendix B of E4tech's report.

Carbon impacts of longer term options

- 4.54** The carbon impacts of advanced or second generation biofuels will depend on the specific biofuel in question and any emissions associated with the cultivation of crops and production of the fuels. However a key advantage of many second

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For example at the North American International Auto Show in Detroit earlier this year, General Motors discussed plans to develop a plug-in hybrid car, the Chevrolet Volt.

generation biofuels is the potential they offer for lower carbon emissions over the life cycle. The Government is working with the European Commission, EU member states and other international bodies to develop verifiable and robust environmental standards for biofuels.

- 4.55** For hydrogen or electricity based transport systems the level of carbon savings would be dependent on the energy source used to make the hydrogen or generate the electricity. For electric vehicles or plug-in hybrids, the level of carbon savings would be linked to the electricity mix used to charge vehicle batteries. For hydrogen systems the level of carbon savings will depend principally on the hydrogen production method chosen. Analysis for DTI concluded that there are six distinct hydrogen energy chains that could deliver cost competitive well to wheel CO₂ benefit for transport in the future – production from electrolysis of water using renewable or nuclear electricity, from biomass, from natural gas or coal combined with carbon capture and storage or from a range of novel technologies¹⁸.
- 4.56** Section 9 and Appendix C of E4tech's report considers in more detail the potential carbon emissions impacts of these different routes. This section highlights that further de-carbonisation of the electricity generation mix would increase the scope for a hydrogen or electricity based transport sector to offer very substantial carbon savings. The electricity supply impacts of shifting energy demand for transport towards the electricity sector, whether through use of electricity or hydrogen based road transport, could also be substantial.

Infrastructure issues

- 4.57** It is also important to note in this context that a road transport system in which either hydrogen powered or plug-in hybrid or fully electric vehicles predominated would also be likely to require additional re-fuelling or re-charging infrastructure. New infrastructure requirements for a hydrogen based transport system could be particularly significant – though developments in different technological options for producing, storing and transporting hydrogen could have significant implications for the shape and scale of any future infrastructure in this area. Development of biofuels is less likely to have major new infrastructural implications for the transport system.
- 4.58** The Department for Transport is supporting research work on hydrogen infrastructure issues through the Horizons programme and will continue to assess the case for additional research on infrastructure issues along with other stakeholders. New refuelling or re-charging infrastructure may also be supported within wider demonstration programmes supported via research programmes or procurement activities. That said, continuing uncertainties around the nature and extent of the new infrastructure which may be required to support lower carbon transport limit the degree to which it is possible to plan for new infrastructure at this stage in the technology development cycle.
- 4.59** More generally, the uncertain pace and nature of technology development in longer term lower carbon transport technologies – as well as, in many cases, their

dependence on lower carbon energy sources of electricity generation to deliver very large scale carbon savings, has a number of potential implications for the Government's transport and energy policies. These issues are discussed in more detail in sections 9 and 10 of this strategy.

Policy mix for further from market options

- 4.60** For further from market options E4tech's work suggests that, while regulatory and policy measures impacting on market deployment are extremely important in signalling Government intentions and stimulating additional industrial R&D, they may not be a sufficient driver on their own to deliver rapid and successful innovation. Effective and integrated research, development and demonstration activities – involving both academic and industrial entities, will also be required.
- 4.61** While much can and is being done by the private sector in this area, the costs and risks inherent in further from market technology development are inevitably higher. E4tech's report suggests that the majority of automotive industry R&D is focussed, as would be expected for commercial companies operating in a highly competitive international environment – on nearer market product development activities.¹⁹ The longer term commercial benefits of more distant technologies may be much harder for individual companies or research groups to capture and there may be competition for funding within global companies. For these reasons there is often much more limited internal company investment funding available for the early stages of new technology development and proofing – and such funding has to be fought for against global competition for other development activities within global companies. Government-supported R&D projects can therefore be an important lever in accessing this optional company investment prior to the obligatory investment companies must undertake in specific new model development. Appropriate support can facilitate earlier qualification of technical approaches, and subsequent ramp up of development investment, in those volume manufacturers whose product development and design engineering decision making locus is in the UK, while also encouraging innovation in the supply chain through niche vehicle development and demonstration activity.
- 4.62** As is set out in the Stern Review and the Energy White Paper, Governments have a clear role to play in supporting R,D&D activities across a broad range of lower carbon transport technologies – including road transport options. The Government considers that, while it is unfeasible for the UK to be the global market leader in all lower carbon road transport technologies, there are strong reasons for supporting a broad range of UK academic and industry led R,D&D in these areas. Not least of these is the continuing strength and importance of the automotive sector in the UK.
- 4.63** There are more than 40 companies that manufacture vehicles in the UK. These include seven global volume car makers, van, truck and bus builders and specialist niche vehicle manufacturers. More than 2,600 UK based companies are active in the automotive supply chain and engine and vehicle manufacture volumes are close to

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These would include ensuring that a vehicle meets air quality, safety, and durability standards required by regulation and de-risking the manufacturing and system integration processes to achieve the quality, reliability and cost standards demanded by the market.

an all time high. The turnover of the UK automotive sector in 2005 was estimated at £47 billion, contributing around £10bn of added value to the UK economy. The sector is responsible for around 12% of total UK manufactured exports.

- 4.64** These figures emphasise the continuing significance to the UK economy of maintaining a strong presence in the automotive sector. At a global level, the automotive industry is almost certain to face increasing regulations and policies impacting on fuel economy and carbon emissions, so technological expertise in lower carbon options is likely to be increasingly important for UK automotive sector competitiveness over time. In this respect the UK has a number of strengths on which it can build – the UK is a worldwide centre of excellence for powertrain development and possesses a number of world class low carbon vehicle and powertrain design & development companies. Ford's European centre of excellence for internal combustion engine development at Dunton is the focus of much relevant UK R&D and in the summer of 2006 Ford announced plans to spend £1 billion on environmental engine developments, doubling its previous rate of spending. The UK also has significant strengths in vehicle lightweighting, a pool of relevant engineering skills from world leading motorsport and design engineering companies and a strong academic research capability in relevant technologies such as combustion and materials.
- 4.65** Sections 4-8 of E4tech's report highlight in more detail the areas in which UK companies and research groups are active in low carbon road transport technology development. However the UK's existing capabilities in lower carbon technology development cannot be taken for granted and risk being eroded in the absence of supportive regulatory and R&D environments.
- 4.66** Moreover, many of the UK's major competitors are intensifying their R&D efforts in these areas. Japanese car manufacturers have been recognised as world leaders in a number of fuel efficiency technologies including hybrids – and there is close co-operation between the Japanese car industry and government on the development of progressively more demanding fuel efficiency standards. In France a national programme of activity also reflects their traditional strong links between government and industry. This is exemplified by the recent and current support for hybrid development. Nearer to market major demonstration project activity is financed via the Agence de l'innovation industrielle (All) that has invested 120m€ in projects such as diesel hybrids (led by PSA) and stop-start hybrids (led by Valeo) and plans to spend a further 250m€ over the next three years on similar project activity. Germany's national strategy aimed at promoting alternative fuels and innovative propulsion technologies includes hybrids and synthetic biofuels as medium term development priorities. The German Federal Government has also recently announced a major programme of funding into hydrogen fuel cell vehicles over the next decade.
- 4.67** The Government considers that, in order to maintain a competitive UK position in key technologies, and to help accelerate the introduction of low carbon technologies into the UK manufactured vehicle range, it is desirable that both UK academic and industrial levels of R,D&D in these areas are expanded over time. Such an expansion is also consistent with the conclusions of the Stern Review on the overall need to

expand global levels of R&D in lower carbon technology development – a process in which the UK, as a major industrialised economy and member of the G8 – must play its part.

- 4.68** Section 8 of this strategy discusses in more detail the existing support the Government is providing for R,D&D activities in low carbon transport technology development, and the steps we are taking to expand support levels over time. However a number of key measures can be identified here.
- 4.69** Firstly, in conjunction with the Technology Strategy Board (TSB), DfT and the Engineering and Physical Sciences Research Council will help finance and develop a new Low Carbon Vehicle Innovation Platform providing critical coordination and up to £30million of support from 2008/09 onwards. The Innovation Platform will bring together key stakeholders in the UK automotive sector and provide new funding for UK industry led demonstration and collaborative R&D projects – focussed on nearer and further from market technologies where the UK has or can develop world leading expertise. Assuming the Innovation Platform develops successfully we would expect to extend the programme to run over a number of years.
- 4.70** Secondly, the Government is setting up the Energy Technologies Institute (ETI), a joint venture partnership which brings together public & private sector R&D in the UK, to set strategic direction and fund its delivery. The ETI will have a minimum budget of around £600m over the next decade and will significantly expand the scale of basic and applied R&D into lower carbon technology development taking place in the UK.
- 4.71** The Institute will focus on a small number of specific industrially relevant R&D projects, selected from within a framework of seven themes, which includes low carbon transport technologies. Detailed research priorities for the ETI will be set by the ETI Board on advice from the Research Advisory Group, and informed by work such as the E4tech report. From 2008 onwards, The Department for Transport will contribute £5m per annum of new money to ETI expenditure on lower carbon transport technologies, and will work to ensure ETI's funded research is co-ordinated with national low carbon transport policy directions and other Government and industry activities.
- 4.72** Thirdly, the Government has asked Professor Julia King, Vice-Chancellor of Aston University and former Director of Advanced Engineering at Rolls Royce plc, working with Sir Nicholas Stern, to lead a review to examine the vehicle and fuel technologies which over the next 25 years could help to decarbonise road transport. This review will feed into the work of the Energy Technologies Institute.
- 4.73** In these ways – along with UK participation in European and international research projects, the Government aims to ensure that the UK automotive sector and research base will maintain and develop its strong position in a range of technologies likely to be critical to lower carbon transportation in future decades.

Chapter 5

Low Carbon Technologies and the Aviation Sector

Carbon emissions from the aviation sector

- 5.1** Globally, carbon dioxide emissions from aviation are responsible for around 1.6% of total greenhouse gas emissions¹. In 2004 carbon dioxide emissions from UK domestic aviation were estimated to be 0.7 MtC and from international aviation 10.2MtC. Both of these figures are based on sales of aviation fuel (kerosene) in the UK. The domestic figure represents all domestic flights while the international figure is based on sales of fuel for international flights departing from the UK².
- 5.2** However, aircraft are also responsible for other climate effects, for example, high-altitude emissions of nitrogen oxides (NO_x), which can lead to the production of ozone, and for the formation of contrails – they are also believed to contribute to the formation of cirrus clouds. While scientific knowledge in this area continues to evolve and remains uncertain the total climate change impact of all aviation emissions is presently estimated to be at least two (and possibly four) times greater than the effects of carbon dioxide alone³.
- 5.3** The estimated additional climate impacts of aviation are not the only reason to take a particular interest in emissions from this sector. A second reason is that emissions from the aviation sector are forecast to grow significantly over time - the 2006 Future of Air Transport White Paper Progress Report presented a range of scenarios for growth of aviation demand. After accounting for future UK airport capacity restraints, national air travel demand is forecast to grow under the central case from 228 million passengers per annum in 2005 to 465 million passengers per annum in 2030. Taking account of both forecast growth in aviation demand, and the full climate impacts of aviation, means that this sector could in future represent a significant proportion of total UK greenhouse gas emissions – particularly if efforts to reduce emissions in other sectors are more successful. The Air Transport White Paper (2003) estimated that by 2030, air transport could amount to up to one quarter of the UK's total contribution to global warming. Finally, aviation is, at present, for the average journey, one of the most carbon intensive forms of travel – both for passengers and for freight.

1 Stern Review of the Economics of Climate Change – p.342

2 Only emissions from domestic flights are included in the emissions figures reported for Kyoto Protocol purposes, as there is no international agreement on how to allocate emissions from international aviation.

3 For a summary of the scientific evidence on the full climate impacts of aviation see Aviation and the Global Atmosphere; A Special Report of the Inter-Governmental Panel on Climate Change (1999) – <http://www.grida.no/climate/ipcc/aviation/index.htm>

- 5.4** These considerations all add particular relevance to the question of the potential of new technology to reduce carbon dioxide and other climate related emissions from the aviation sector in the future.

Government position on aviation's climate impacts

- 5.5** In the 2003 Future of Air Transport White Paper and in the 2006 Progress Report on that White Paper – we set out the Government's approach to the future of aviation in the UK and to the continued growth in demand for air travel⁴. Both of these documents make clear that the Government considers that the regulatory frameworks bearing on both domestic and international aviation should strike the right balance between economic, social and environmental goals. The 2006 Progress Report included a commitment to develop a new emissions cost assessment to inform decisions on major increases in airport capacity.
- 5.6** Aviation is by its very nature an international industry and the Government believes for action to be most effective in this area it should be taken at an international level. Consequently, the Government's preferred way of addressing the climate impacts of aviation is through a well-designed emissions trading scheme. The UK is pursuing emissions trading through the International Civil Aviation Organisation (ICAO), but until a truly global solution to this can be found, we are pressing for aviation to be included in the existing EU emissions trading scheme (EU ETS).
- 5.7** The UK has taken a lead in arguing for the early introduction of aviation in the EU ETS. In the last year much work has been done to progress the debate internationally, and on 20 December 2006 the European Commission published its legislative proposal to include aviation in the EU ETS. The proposal sets out a phased approach to including aviation, with intra-EU flights covered from 1 January 2011 and all departing and arriving flights at EU airports being covered from 1 January 2012.
- 5.8** The UK welcomed the publication of the Commission's proposal and will continue to lead the debate in Europe on aviation's incorporation into the EU ETS with the aim of ensuring a robust and environmentally efficient scheme is introduced as soon as possible. Following the publication of the draft legislation we have begun negotiating with other Member States to finalise the details of the legislation. To help inform our negotiating position the Government launched a public consultation on 30 March and we will continue to consult with industry and international partners as the negotiations progress⁵.
- 5.9** That said, the Government has made clear that our focus on the EU ETS does not preclude consideration of additional measures to ensure that aviation plays its part in meeting the challenge of climate change. For example, regarding the anomalous nature of aviation fuel tax exemptions, the UK continues to argue for change to the current international agreements on this exemption and wherever possible we are seeking to re-negotiate bilateral or multilateral aviation agreements to address this. It has not yet been possible to reach a consensus within the ICAO on this matter.

⁴ For the 2003 White Paper and 2006 Progress Report see <http://www.dft.gov.uk/pgr/strategy/whitepapers/air/>
⁵ The consultation can be found at: <http://www.dft.gov.uk/consultations/open/aviationemissionstrading/>

Without international agreement on the issue, market and environmental distortions could result, such as the carrying of extra fuel to avoid tax, which would lead to increased emissions. The ICAO Assembly in 2007 will be the starting point for work to help equip aviation with a structure and legal framework more reflective of today's world.

- 5.10** The Government has also taken action in this area at a domestic level. In December of last year we announced that levels of Air Passenger Duty (APD) would be doubled with effect from 1 February of this year. HM Treasury estimated in the pre-Budget Report that these changes to APD could deliver carbon savings of around 0.3 MtC a year by 2010/11⁶.
- 5.11** The paragraphs above make clear the Government's commitment to addressing the climate impacts of aviation through carbon pricing and related regulatory or fiscal measures. The importance we attach to this approach arises from our view that, through carbon price signals of this kind, the aviation industry will be appropriately incentivised to pursue cost effective approaches to emissions reduction and to the development of new technology to reduce emissions – or, where such measures may not be cost effective – to purchase emissions reduction credits from other sectors operating within the EU ETS. Below we discuss the operational and technological options which are or may become available in time for reducing emissions from the aviation sector.

Air-traffic management options for reducing emissions

- 5.12** There is some potential to reduce emissions from aviation through improved air traffic management. Internationally, the largest gains in this area are likely to arise from more direct routing of aeroplanes – at present there are a range of restrictions and/or charges which apply to certain international aircraft flights and mean that aeroplanes do not always take the most direct route to a destination. The Civil Aviation Authority (CAA) leads for the UK on air traffic management issues, liaising with relevant international organisations, and continues to work for international agreements which will allow the most direct routes for flights.
- 5.13** There has been some progress in this area through international discussions such as the Single European Sky initiative - this is a European Commission initiative that is intended to change the future structure of air traffic control across Europe. The aim is to use more efficient air traffic management that is more closely based on actual flight patterns, rather than using the present arrangements, which are more closely based on national boundaries.
- 5.14** Continuous Descent Approach (CDA) is primarily a noise mitigation measure but one which also offers some carbon reduction benefits. It involves aircraft beginning their descent from high altitude much earlier, leading to a slower and smoother approach before landing. This earlier descent means that aircraft descend at a more efficient speed, therefore reducing fuel burn. Compliance with CDA is already quite high at

Heathrow (around 80%) and other UK airports where the approach is viable. There is, however, further scope for CDA to be rolled out internationally.

- 5.15** In the long-term, potential new airspace management techniques could allow aircraft to be routed to avoid climate-sensitive parts of the sky, where contrails would be produced. However, this remains a complex area with many uncertainties, and would not eliminate CO₂ or NO_x related effects.
- 5.16** Overall, the above measures and other more detailed operational changes to air traffic management procedures have the potential to offer modest improvements to the fuel economy of aviation - potentially reducing average carbon emissions on a per passenger km basis by around 6-12% over the long term.

Improving the fuel economy of the current aviation fleet

- 5.17** New aircraft are more fuel efficient than existing older aeroplanes which are still in operation. Aviation fuel (kerosene) remains a significant cost factor for the airline industry and this has provided pre-existing incentives to improve efficiency - the aviation industry claims that it has delivered around a 70% improvement in fuel efficiency over the past 40 years. Improvement continues to this day with the newest models developed by both Airbus (the A380) and Boeing (the 787) estimated to be up to around 20% more fuel efficient per passenger km than the current typical average. In the case of the 787 roughly one-third of this efficiency improvement will come from the engines; another third from aerodynamic improvements and the increased use of lighter weight composite materials; and the other third from advanced systems. The most notable system advancement contributing to efficiency is a “more electric architecture” which replaces bleed air and hydraulic power with electrically powered compressors and pumps.
- 5.18** The accelerated introduction of more modern aircraft therefore has the potential to quite significantly reduce carbon emissions per passenger kilometre flown. However aircraft are very large, capital intensive investments and the current replacement rate for aircraft is slow. High capital costs in the industry provide a strong business incentive to extend the lifetime of existing fleets. Worldwide, around 60% of aircraft are still in service 30 years later (though major UK and European airlines generally have a higher turnover rate than average and will therefore have a somewhat younger fleet).
- 5.19** The Government believes that the introduction of carbon pricing into the aviation sector – eg through the inclusion of aviation in the EU ETS – would provide an appropriate level of incentive for airlines to gradually accelerate their fleet modernisation programmes – balancing this with the other competitive pressures which they face.

Improving the fuel economy and emissions performance of future aircraft

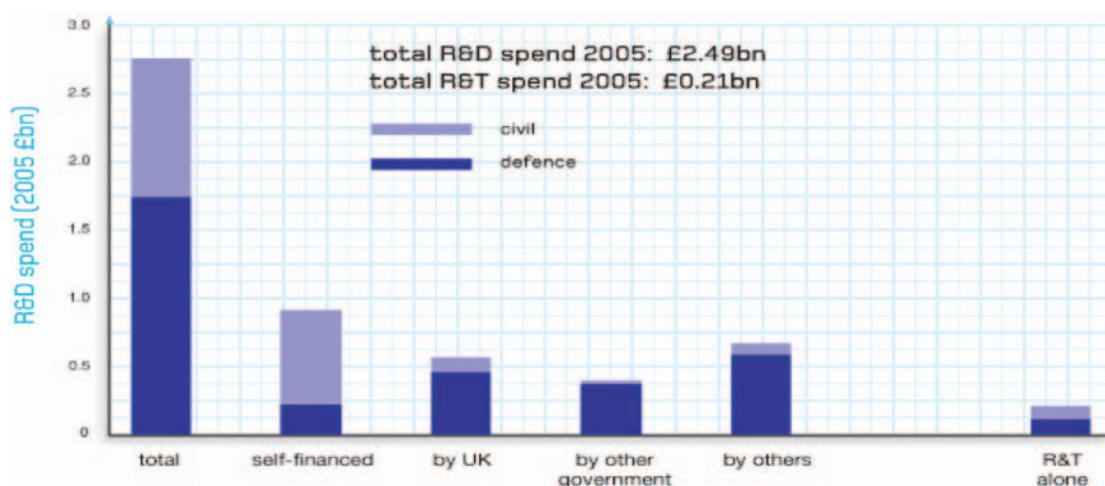
- 5.20** Further improvements in the fuel efficiency of aircraft can be expected beyond that achieved by models presently operational or shortly to come to market. The Advisory

Council for Aeronautics Research in Europe (ACARE) has set a series of ambitious goals for reducing the environmental impact of aviation. These include reducing carbon dioxide emissions from new aircraft by 50% per passenger km (to be achieved from a combination of more efficient aircraft and engines, operations and air traffic management), reducing nitrous oxide (NO_x) emissions by 80% and noise by 50%, all by 2020 (relative to a 2000 base).

- 5.21** The International Civil Aviation Organisation (ICAO) also sets emissions standards for aeroplanes covering: smoke, unburned hydrocarbons, carbon monoxide (CO) and oxides of nitrogen (NO_x). The NO_x standard was recently tightened by 15% effective from 2008 for new engine designs. The UK continues to press for further tightening to be agreed by ICAO in 2010.
- 5.22** Reducing NO_x emissions from aircraft is in many respects almost as important an objective in climate change terms as reducing CO₂, as, over a 50 year timescale, NO_x is as potent as CO₂ in its greenhouse gas effects - due to its role in ozone generation. Thereafter, CO₂ has the dominant climate change effect. However there can be difficult trade offs in this area as some measures to reduce NO_x emissions are likely to reduce the fuel efficiency of aero-engines, thus increasing CO₂ emissions.
- 5.23** Within the UK and internationally, large scale Government and industry funding is being provided to support the development of the next generation of aeroplanes. Research & development into higher fuel economy and lower emission aircraft forms a significant part of those research programmes. Aerospace research involves a large number of public and private agencies, companies, national research organisations and academia. It also requires sophisticated, complex and expensive research infrastructure such as wind tunnels and test facilities.
- 5.24** As the possessor of the world's largest aerospace industry outside the USA, the UK has significant commercial interests in aviation and a strong incentive to maintain competitive advantage in technologies which will deliver improved fuel economy and emissions performance in aeroplanes. The UK aviation industry supports around 276,000 jobs and has a turnover of about £22bn per year (of which more than £15bn are exports). The UK industry is also a very significant funder of R&D. Total aerospace R&D in the UK alone in 2005 was around £2.7bn (including UK Government funding) – though a significant proportion (more than 50%) of this was for defence purposes and, as with the automotive sector, the majority of expenditure is focussed on nearer market activity as opposed to riskier or more speculative research.
- 5.25** The graph below breaks down UK aerospace industry R&D expenditure by source and between civil and defence related activities. Further from market research & technology (R&T) activities are also separately highlighted – and totalled £211.1m (split evenly between civil and defence) in 2005.⁷

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Source SBAC (Society of British Aerospace Companies) 2006. R&T activities are defined as all those R&D activities which are not directly attributable to product development. They can thus be regarded as generic technology development activities which are designed to maintain or expand the technological base.



- 5.26** The UK aviation industry is also engaged in voluntary initiatives such as 'Sustainable Aviation - A strategy towards sustainable development of UK aviation'⁸. This has been developed by all sectors of the UK commercial aviation industry as a long term strategy to balance the needs of the environment with economic growth. It includes adoption by UK industry of the ACARE goals for 2020 as well as establishing a common system for the reporting of total CO₂ emissions and fleet fuel efficiency.
- 5.27** In the UK, the National Aerospace Technology Strategy (NATS) is a partnership between industry, Government and academia to address UK competitiveness in aerospace technology. To pursue the NATS programme the aerospace industry bids NATS projects into the DTI led Technology Programme for support. Through this process the Government is currently providing around £45m per year for civil research and technology demonstration activities via the Department of Trade & Industry (DTI), and the Regions (the Regional Development Agencies (RDAs) in England and the Devolved Administrations in Wales, Scotland & Northern Ireland) - to be matched by a similar amount from industry. This compares to around £20m per year available from DTI through the previous aviation sectoral research and technology support scheme.
- 5.28** Many of the programmes in NATS have a direct bearing on environmental issues – most notable amongst these are the Environmentally Friendly Engine (EFE) Technology Validation Programme and the Integrated Wing Aerospace Technology Validation Programme (IWATVP).
- 5.29** The EFE programme is supporting a range of research and development work into aerodynamic and mechanical designs, novel high temperature materials, low emissions combustion, advanced control systems and actuators – with the overall aim of developing new aero-engines which progress towards the ACARE 2020 goals. EFE will establish and operate two large validation platforms: a gas turbine core and a wind tunnel nacelle/powerplant vehicle. The programme began last year and test vehicles will first run in 2008. Rolls-Royce is leading a consortium of five UK aerospace companies (Goodrich, Bombardier Aerospace, Smiths Aerospace and HS

Marston) and six universities (Queens Belfast, Loughborough, Oxford, Cambridge, Sheffield and Birmingham) with this 5 year, £95m project.

- 5.30** The Integrated Wing programme has the objective of developing key technologies and, via the application of advanced methods, optimising their application at the integrated-wing level. Due to the demanding targets set for sustainable aviation, higher risk/high potential technologies are being considered for application across the product life cycle. These include technologies focussed on wing optimisation, flow control and noise reduction, new materials design and manufacturing and advanced fuel and landing gear systems. Phase1 of this programme is a £34m programme (with £17m from Government) in which there are a total of 17 industrial and academic partners. The lead industrial partner is Airbus, with additional participation from (amongst others) QinetiQ, Bombardier Aerospace, Ultra, Messier-Dowty, BAE systems, GKN, Smiths Aerospace and Eaton.
- 5.31** In the second phase of the programme it is intended that the most promising technologies for advanced integrated wing configuration will be selected for further validation via a large scale physical platform – with the aim of assessing performance, risk and cost/benefits against the ACARE targets⁹.
- 5.32** EU funding for relevant aeronautics research is also substantial. Under Framework Programme Six eight major large Integrated Projects were launched. The major project in the environmental area has been the ‘EEFAE’ (Efficient and environmentally friendly aircraft engine) initiative – targeting reduced aircraft engine CO₂ and NO_x emissions, improved reliability, lower ownership and life cycle costs and shorter time to market. This comprised two major technology demonstration platforms ANTLE (Advanced near-term low emissions) and CLEAN (Component validator for environmentally friendly aero-engine), both launched in 2000.
- 5.33** These projects involved all of Europe’s major aero-engine companies and received more than €100 million in funding, half from the European Commission and the other half from EEFAE’s 20 industrial, university and research partners. A key focus of EEFAE projects has been to coax better combustion from an engine, which means improving how it burns fuel and re-cycles its by-products of heat and emissions. Another goal is to reduce the weight and size of engine-related components and systems, such as gearboxes or the control system that regulates an engine’s rate of combustion.
- 5.34** The ANTLE project has been lead by Rolls-Royce in the UK. Demonstrator testing at maximum engine conditions at a facility, near Madrid, marked the culmination of the project. The test results are now being analysed in detail. Technologies developed and proven as part of this programme will set the foundation for new engine programmes and may be used in the next generation of engines – with the potential to provide a considerable step towards the ACARE environmental goals.
- 5.35** Through the next EU Framework Programme, FP7, which commences this year and will run until 2013, further substantial funding of over €4 billion is available for transport research with about half for collaborative research in aeronautics and air

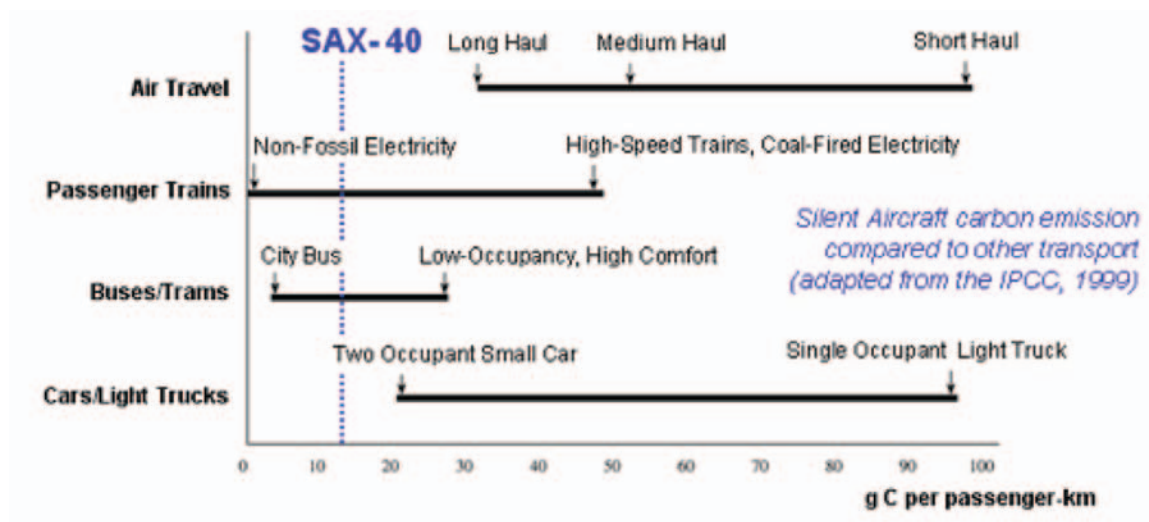
transport. The Commission is also proposing a “Clean Sky” Joint Technology Initiative on more environmentally friendly aeroplane technology as a public private partnership between the Commission and the industry with about €800m of EU funding from the transport programme. “Clean Sky” is a large technology research programme seeking step changes in the reduction of fuel consumption, emissions and noise of future aircraft. Industry will invest an additional €850m representing around 50% of the Clean Sky programme. The CEOs of the major European Aeronautics companies (Airbus, Dassault Aviation, Eurocopter, Liebherr-Aerospace Lindenberg, Rolls Royce Group, Safran and Thales) signed a Memorandum of Understanding in October 2006 agreeing to work together to fund and deliver the Clean Sky programme in addition to existing technology programmes. Clean Sky aims to assess and validate a range of technological approaches with the potential to deliver step changes in component, system and engine technologies, leading to the earlier introduction of new, greener products that will accelerate the reduction of emissions from aviation and increase the competitiveness of European industry.

Longer-term options for re-designing aircraft to optimise fuel efficiency

- 5.36** Despite the very significant levels of funding for R&D into environmentally friendly aero-engine development described above, the current view of many experts in this area is that achieving in full the stated ACARE goals of a 50% carbon reduction per passenger per kilometre (and an 80% reduction in NO_x) remains extremely challenging and may not be delivered solely through incremental evolution of current technology approaches to aeroplane design and operation.
- 5.37** In order to achieve larger scale reductions in emissions, more radical aeroplane designs may need to be considered. One such design is the “SAX-40”. This design was developed as part of the Silent Aircraft Initiative (SAI) – a £2.3m three year collaboration between Cambridge University, the Massachusetts Institute of Technology, Boeing, Rolls-Royce and NASA – and was unveiled last year at the Royal Aeronautical Society. The SAX-40 design, which was originally motivated principally by the goal of substantial aircraft noise reduction – involves a “blended wing” concept in which the fuselage and wings are blended together in a manner comparable to that used in stealth military aircraft. Such designs are more aerodynamic and produce less air drag over the body – it is estimated that the SAX-40 design, which is at this stage only a computer based simulation – could deliver fuel efficiency improvement of around 25% over today’s most efficient aircraft – and with some further potential for reductions beyond that as the existing design was developed as much with noise reduction in mind as reduced fuel consumption. The graph below shows how the SAX team estimate the design would compare against other aircraft and alternative modes of travel.¹⁰

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Figure reproduced from <http://silentaircraft.org/efficiency/>. Note that the figures in the table compare fuel economy and do not take into account non-CO₂ related climate impacts of aviation. Further detail on the SAX-40 design can be found at <http://silentaircraft.org/SAX40/>



5.38 The SAX-40 is at this stage only a conceptual computer based design. Much further work would be required to verify and test many of the proposed innovations within it. However the broad approach may point the way for how future aircraft design needs to evolve if a large step-change in fuel efficiency is to be achieved over the long term.

The scope for powering aircraft from renewable or alternative fuels

5.39 In theory, renewable or other non-fossil fuel based alternative fuels could also provide a potential route to significantly lower carbon emissions from aviation over the long term – though it is widely considered that there are not any commercially viable alternatives to kerosene-based fuels for jet aircraft in the near term.

5.40 In 2003, the Department for Trade & Industry commissioned Imperial College to provide a report on the potential for renewable energy sources in aviation. The study examined both the potential for biofuels and hydrogen based fuel chains for aviation.¹¹ It concluded that methanol, ethanol & biogas were unsuitable for commercial jet aircraft but that hydrogen, biodiesel and FT kerosene (kerosene manufactured from biomass sources through the Fischer-Tropsch process) all had the technical potential to bring savings in the aviation sector's use of fossil fuel energy and emissions of greenhouse gases. However, all of these options would be significantly more expensive to produce compared to the current costs of kerosene though, in the long term, the costs of producing hydrogen and FT kerosene may drop sufficiently for them to become more viable options.

5.41 Other relevant considerations in this area are that hydrogen fuelled aircraft would require new engines and airframes and are unlikely to be seen for many decades. Nor would aeroplanes fuelled by alternative fuels necessarily have a lower climate impact in relation to those using conventional fuels because of the effects of water vapour and NO_x at high altitude. Moreover, due to a range of technical, safety and other economic challenges, it is arguable that both renewably produced hydrogen and biofuels would be used either in road transport or electricity generation in

preference to aviation. That said, the Imperial College study noted that the Fischer Tropsch process for manufacturing biodiesel necessarily produces a minimum of 20-30% kerosene so perhaps the most plausible medium-term route for the introduction of renewable fuel into aviation is FT kerosene produced in conjunction with FT biodiesel and blended with conventional kerosene. Virgin Atlantic, working in conjunction with Boeing and General Electric, has recently announced plans to trial the use of biofuel in a commercial aircraft in the near future.

- 5.42** In other developments in this area Boeing is working on developing fuel cells to power aircraft air-conditioning and electrical systems – and is also working on a prototype fuel cell powered light aircraft. However fuel cells are not presently considered a viable option for large scale passenger aircraft.

Further work on more radical lower carbon options for aviation

- 5.43** The sections above highlight that, while they are at extremely early stages of consideration, there are a number of potential options for achieving significant reductions in the carbon footprint of aviation over the longer term. However these options are at such a large distance from commercial viability that further research, development & test trialing of them is very unlikely to be taken forward by the private sector alone. Nor would inclusion of the aviation sector within carbon pricing mechanisms such as the EU ETS provide sufficient incentives for this in the short—medium term, though it may stimulate the sector to begin considering these options more seriously within their longer term business plans.
- 5.44** Given the above, it will be important to ensure that UK and international public funding is available for research and development work on longer term technological options for lower carbon aviation. The Government believes that the forthcoming EU “Clean Sky” Joint Technology Initiative offers an attractive additional route for supporting international collaborative work on some of the more promising technological options and to deliver extra benefits compared with existing mechanisms. We will work to ensure that the UK aviation industry is an active player in and beneficiary of the Clean Sky programme.
- 5.45** The UK Government will also continue to support relevant domestic academic and industry work in this area. One academic initiative, shortly to be launched, is OMEGA (Opportunities for Meeting the Environmental Challenges of Growth in Aviation). The OMEGA project is being supported by £5m of Government funding and is being led by Manchester Metropolitan University while bringing together a wide range of leading UK academic and industrial expertise in the environmental impacts of aviation and opportunities for mitigation of those impacts. OMEGA will consider a 2050 time horizon and support a range of initial research projects focussed on long term and more radical options for addressing the environmental impacts of aviation. Drawing on the UK’s considerable academic and industrial expertise in a wide range of aviation issues, OMEGA aims to place the UK at the forefront of both policy and technological work in this area.

Conclusion

- 5.46** It is clear that technology innovation can play a significant role in carbon reduction in the aviation sector. At the same time the Government recognises that, on current trends, and in the short-medium term at least, carbon reductions achieved from improved air traffic management and improved aeroplane efficiency are likely to be outweighed by continued growth in the demand for aviation, leading to continued overall growth in total carbon emissions from this sector. It is also likely that, even with significant improvements in fuel economy, the full climate impacts of aviation (when taking account of the additional impacts of emissions at altitude) will remain significant compared to other transport modes. These considerations will continue to be taken into account by the Government in developing its policies towards the aviation sector, alongside consideration of aviation's economic and social benefits.
- 5.47** This section of the LCTIS has also illustrated the significant steps the Government is taking to address the environmental challenges posed by the rapid growth of demand for aviation. We are taking the lead internationally to argue for the inclusion of aviation within emissions trading schemes, while also acting domestically and providing substantial support for relevant technology development. Whilst recognising that the environmental impact of aviation is not simply from carbon, the section has also highlighted the carbon reduction potential offered by a combination of improved air traffic management and continued incremental improvements in the fuel economy of new aircraft – as well as presenting the currently more distant potential for larger scale carbon reduction offered by more radical approaches to the design and fuelling of aircraft over the long term.

Chapter 6

Low Carbon Technologies and the Rail Sector

Introduction

- 6.1** Rail is a relatively energy efficient means of transporting people and freight and, in general terms, tends to have a lower environmental impact than other transport modes. Part of this advantage is inherent given the low rail wheel to rail friction offered by steel wheels running on steel track and the lower aerodynamic drag caused by running train carriages coupled in convoy.
- 6.2** In overall UK terms, rail's carbon emissions are relatively low with rail responsible for less than 1% of total UK carbon emissions. Increasing numbers of passenger and freight services combined with the introduction of newer, heavier and higher performance trains has resulted in modest increases in rail carbon emissions over the past decade. However, rail's carbon efficiency – measured in terms of the amount of carbon emitted per passenger or tonne transported – remains good. In addition, the net impact of increasing rail activity on UK carbon emissions must take account of modal shift ie: where passengers and goods travel by rail instead of road or air. If strong modal shift can be demonstrated, then additional rail activity could lead to a net reduction in UK carbon emissions.
- 6.3** However, it is clear to the Government that rail must improve its carbon efficiency in order to maintain its environmental advantage over other modes and to reduce its operating costs. The rail industry has also recognised the importance of improving its environmental performance to its longer term success. The sections below discuss a range of issues relevant to this.

Electrification

- 6.4** About 40% of the rail network is electrified. Carbon emissions from electric trains therefore depend on the power generation mix. Electric trains are also zero emission at point of use, which is of particular benefit for air quality in pollution “hot-spots” such as city centres. They can also offer improved passenger comfort through reduced levels of passenger noise and vibration.
- 6.5** There are disadvantages with electric trains too. Significantly, they lack the go-anywhere capability of diesels. From a carbon perspective the picture is complex but at present electric trains generally offer a modest benefit over diesels. In future this

will depend on the evolution of the power generation mix and the efficiency performance of diesel engines or their alternatives.

- 6.6** A key future decision for the railway, and for Government, is whether to increase - or indeed decrease - the scope of the electrified network. A wide range of cost, technical and environmental factors will influence this including the relative anticipated carbon performance of different options over time. This issue will be considered further in the Government's long term rail strategy, to be published in the summer.

Industry regulation: ORR's sustainable development consultation

- 6.7** The Office of Rail Regulation recently consulted on how it discharges its duties related to the environment and sustainable development. The ORR has recently published its conclusions. These include commitments to:
- Ensure, by the end of 2007, that a set of key performance indicators are in place to monitor the rail industry's environmental performance.
 - Review key aspects of industry incentives and processes to ensure that sustainable development concerns are adequately taken into account. As part of this revised environmental guidelines will be issued by the end of 2007.
 - Test Network Rail's plans and the emerging conclusions of the periodic review from a sustainability perspective¹.

Rail franchise incentives

- 6.8** The Government will use the rail franchising process to encourage bidders to set out clear plans and objectives for reducing carbon (and wider environmental) impacts of their rail operations. This process has started already with bidders for the West Midlands, East Midlands, Cross Country and Inter City Coast franchises being required to set out plans for reducing environmental impacts.

Design of new rolling stock

- 6.9** Rolling stock has an operational life of around 30 years which is substantially longer than that of typical cars, trucks and buses. Consequently, it takes a considerable time for new environmental technologies to deliver benefits across the national fleet. So, from an environmental perspective, getting the design of trains right at the outset is important given how long they will be in operation. The increased weight of recent train designs – which has a direct knock-on impact on fuel consumption (and on track damage) – has demonstrated that too little emphasis has been placed on environmental issues in the past.
- 6.10** The Department for Transport is currently leading the Inter City Express (IEP) programme which sets out to deliver a best overall value solution for train replacement and demand growth on key long distance routes. For both environ-

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ORR's conclusions can be accessed in full at www.rail-reg.gov.uk/upload/pdf/324.pdf

mental and cost reasons, a key objective will be to ensure that the new high speed train is as fuel efficient as possible. The DfT published the IEP OJEU notice on 8 March 2007 anticipating that the contract will be awarded in early 2009 for the package to design, build, maintain and finance the IEP fleet. It is envisaged that between 500 and 2000 vehicles will be supplied with full in-service deployment taking place from 2014 onwards.

- 6.11** A related issue facing the project is ensuring the new train is sufficiently flexible to adapt to future changes in power-source. For example, if fuel cells or bio-fuels become sustainable, cost-effective options in the lifetime of the new train, then these could replace, or be utilised within, the train's diesel engine.

Regenerative braking

- 6.12** Regenerative braking is a way of slowing an electrically powered train by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors act as generators and return it as electricity into the supply rail or overhead wire. Regenerated power can be re-used by trains within the local substation area, provided that the service density is high, or fed back to the regional supply company for wider redistribution through the grid. A further benefit is reduced maintenance of mechanical braking systems.
- 6.13** The amount of energy saved through this type of system will depend on the type of train operation. A frequent service of trains making stops at short intervals offers opportunities to save 25% in energy consumption. Less dense services stopping less often will save less. Currently, 60% of the electric train fleet is capable of regeneration but only 20% uses this capability. However, significant progress is now being made by Network Rail and train operators in enabling a wider range of rolling stock to regenerate. All modern AC electric passenger trains that are capable of regeneration will be doing so by the middle of 2007, followed shortly after by the equivalent DC units.

Further technical and operational measures to reduce carbon emissions

- 6.14** The rail industry increasingly recognises the importance of maintaining and improving its environmental performance. It has started to monitor its performance more closely and to investigate and introduce measures to reduce its carbon footprint. A strong driver for this has been the increased energy costs faced by the industry. The Government is committed to working with the rail industry to support and facilitate the introduction of more energy efficient technologies and operational practices.
- 6.15** During 2006, the rail industry undertook two important initiatives to improve understanding of how trains use energy and identify opportunities for reducing energy consumption. Firstly, the Association of Train Operating Companies, Bombardier Transportation and National Express Group measured, in as much detail as practicable, the energy consumption and resultant carbon dioxide emission of three representative passenger train classes operating in Great Britain. And

secondly, a research project managed by the Rail Safety and Standards Board considered measures to improve the efficiency of traction energy. A further study is underway to identify opportunities to reduce non-traction energy consumption eg: stations, depots, signalling equipment.

- 6.16** As a result of this work, Government and industry now have a better understanding of measures that could lead to significant reductions in energy consumption in the shorter and longer term. The following table illustrates some of the more significant opportunities:

Short to medium term opportunities	Potential saving (MWh/year)	As percentage of total traction energy consumption
Switching off electric trains over night	350000	3.4
Running shorter trains when extra capacity not required	280000	2.7
Improved driver training and more energy efficient train management	225000	2.2
Reduced idling of diesel trains	200000	1.9
Reduced power consumption for heating and cooling	176000	1.7
More efficient and better managed lighting	79000	0.8
Lighter train batteries	12750	0.1
TOTAL	1322750	12.7
Medium to long term opportunities	Potential saving (MWh/year)	As percentage of traction energy consumption
Hybrid diesel/battery trains	470000	4.5
On-train energy storage	424000	4.1
Shutting down diesel engines not in use	160000	1.5
Weight reduction	85000	0.8
Drag reduction - passenger and freight	94000	0.9
Diesel fuel additives	50000	0.5
Local power generation	48000	0.5
TOTAL	1331000	12.8

- 6.17** As shown above, one of the more significant longer term opportunities lies through the potential benefits of hybrid train technology. Just like a Toyota Prius, a hybrid train would use electric power to move the train at low speeds, with a diesel engine cutting in to provide extra power at higher speeds. And when braking the train's kinetic energy would be converted into electrical energy to recharge the batteries. This technology has already been demonstrated in Japan, and a consortium of Hitachi, Brush Traction and Network Rail has announced a trial later this year on one of the power cars of Network Rail's New Measurement Train. The Government intends to encourage the further development of this technology for

suburban diesel trains, where the benefits will be the greatest. A further enhancement of this approach would be to enable the train to pick up power from overhead or third rails where available.

6.18 There are further opportunities to reduce energy consumption and/or carbon emissions including:

- Switching to a biodiesel blend. The industry is planning a series of test bed and service trials to assess the technical risks involved in using a range of biodiesel blends in existing diesel rolling stock and to evaluate more fully the environmental benefits. Results are expected in summer 2008. The Government announced in the Pre-Budget Report in December 2006 that it would allow duty on biofuels used in railway engines to be charged at a reduced rate of 7.9ppl for the purposes of these pilots. In the 2007 Budget the Government confirmed its intention to permanently reduce the current duty rate for biofuel/rebated gas oil mixtures with the new rate to be determined in the light of the outcome of the pilots and other factors.
- Optimising the rail network for energy efficiency. Reducing the number of unnecessary stops between stations and providing better information to drivers on appropriate speeds could deliver substantial carbon benefits as well as improving performance and increasing the effective capacity of the network. Network Rail is working with its industry partners to develop a scheme for application of this technology, which will be even more effective when applied in combination with precise train positioning using satellites.
- Using onboard electricity meters for all electric trains. Although having no direct benefit, the ability to measure directly the effect of auxiliary power saving, driver training, advisory speed and other traction energy schemes and to compare the energy performance of trains for maintenance purposes has been estimated by Scandinavian countries at around 7% of overall traction energy cost. The Government intends to encourage the system wide deployment of onboard metering. An initial trial is being developed with ATOC and a number of train operators.
- Developing more sustainable stations and depots. New depots and stations offer an opportunity to draw on best practice in sustainable building design, for example by including rainwater harvesting, renewable electricity generation and high standards of energy efficiency. A moderately large station development could also use combined heat and power plants to provide electricity and heating for both the station and any neighbouring retail facility.
- Hydrogen fuel cell technology. In the long term, fuel cells could offer significant environmental benefits for the rail sector if a renewable supply of hydrogen can be developed. However, as discussed in more detail in the road sector chapter, there remain significant uncertainties as to when fuel cells will become a commercially viable option. Nevertheless, progress is being made in overcoming the order of magnitude reductions in cost and increases in cell life that are needed and although switching to fuel cell technology would require a new refuelling infrastructure, this would be less of a problem for rail, which has vastly fewer fuelling points than road. The Government will continue to monitor developments closely and is encouraging

the UK rail sector to participate actively in the forthcoming EC Framework Programme 7 initiative.

- 6.19** The Government will consider carefully its potential role in supporting both shorter and longer term measures. In some cases, for example where there is a clear commercial benefit to implement an energy saving measure, there may be no justification for Government funding or intervention. In others, however, particularly those requiring cross-industry co-operation, where there is considerable perceived risk or no direct commercial benefit, or further significant research, development and demonstration work is required, there may be a case for additional funding or sponsorship.
- 6.20** The Government's long term rail strategy will be published in summer 2007 and will set out a wide-ranging programme for reducing rail's carbon and other environmental impacts.

Chapter 7

Low Carbon Technologies and the Shipping Sector

Emissions from shipping

- 7.1** Globally, shipping has been estimated to account for between 1.8% and 3.5% of global carbon dioxide emissions.¹ The most recent published figure for UK carbon emissions in 2005 from domestic shipping – i.e. journeys from UK port to UK port – is 1.1 MtC, while the figure for UK carbon emissions from international shipping is 1.6 MtC. Both of these figures are based on sales of marine diesel bunker fuel in the UK.²
- 7.2** The Government recognises the UK figure for international shipping is likely to be an understatement of the UK's contribution to global carbon emissions from shipping. This is because the method used to calculate the figure does not take account of the way international shipping companies refuel. The UK, unlike some other countries such as the Netherlands and Singapore, is not a major refuelling hub. Many ships transit goods to and from the UK but refuel elsewhere as it is cheaper or more convenient. Basing the figure for carbon emissions from UK shipping on sales of bunker fuels in the UK will not include emissions from these ships.
- 7.3** Estimates of UK carbon emissions from commercial shipping based on calculating UK GDP as a proportion of global GDP and relating that proportion to global sales of bunker fuels gives a figure for 2004 of 5 MtC.³ Similarly, estimates based on the UK's share of global trade would seem to suggest a figure of 5–6 MtC. However these estimates, while indicative, are very broad and may not be sufficiently accurate as a method for allocating shipping emissions between countries. For these reasons the Government believes further work must be done through international organisations such as the International Maritime Organization (IMO) to secure international agreement on the best approach for allocating carbon emissions from the shipping sector.
- 7.4** Other gases emitted by ships such as oxides of sulphur (SO_x) and nitrous oxides (NO_x) can have climate impacts. Scientific understanding in this area is still evolving and DfT is supporting relevant UK research led by Manchester Metropolitan University.⁴

1 CE Delft (2007), *Greenhouse Gas Emissions for Shipping and Implementation Guidance for the Marine Fuel Sulphur Directive* (http://ec.europa.eu/environment/air/pdf/transport/final_report.pdf, p. 187) - figures vary depending on the method used to calculate emissions.

2 As with aviation, only emissions from domestic shipping are included in the emissions figures reported for Kyoto Protocol purposes.

3 For example, Tyndall Centre (2006), *Living within a carbon budget* (http://www.foe.co.uk/resource/reports/living_carbon_budget.pdf, p. 18).

4 The recent CE Delft report for the European Union suggests that the overall effect of shipping emissions at present is probably to cool the global average temperature, but the cooling is highly localised and may have other climate effects such as altering wind and precipitation patterns. Moreover policies to reduce sulphur emissions from shipping are likely to reduce the cooling effects and the report suggests it is probable that shipping will have a net warming effect on global average temperatures in the near future. CE Delft (2007), p.187.

Shipping's contribution to the UK economy

7.5 Shipping is immensely important for trade, both in the UK and worldwide. Some 95% of the UK's international trade in goods travels by sea. A statistical survey of the UK maritime sector in 2002 put the annual turnover of the sector at £37 billion, providing over ¼ million jobs directly (with a similar figure also in indirect employment). In servicing world trade, the maritime sector makes an important contribution to the UK economy, employing about 14,000 people, largely in London, and generating over £1 billion in overseas earnings. Foreign shipping communities represent a very substantial customer base for UK maritime services and about one fifth of the world fleet is controlled from London. The City of London is the world's leading maritime centre and home to a unique wealth of maritime expertise.

AEA/MAST report

7.6 Shipping is a very fuel efficient method of moving bulk freight, and is generally the most low carbon method currently available for long distance movement of freight on a per tonne basis. Shipping companies spend a large proportion of their operating costs on fuel, providing a significant incentive for shipping companies to invest in improving fuel economy. Though efficient compared to other modes shipping does nonetheless contribute to global carbon emissions, and movement of goods by ships continues to grow. For these reasons, while the shipping sector has not been a major focus of emissions reduction policy or technology development so far, there remains a strong case to consider technology options for reducing the carbon footprint of shipping over time. The Government therefore commissioned AEA Energy & Environment (AEA) and the School of Marine Science and Technology at Newcastle University (MAST) to report on the future technological options for low carbon commercial shipping and their long term economic viability. This report is being published alongside this document (and can be found at www.dft.gov.uk/pgr/scienceresearch/technology/). Below is a summary of its key findings.

Improved journey management and incremental changes to existing shipping technology

7.7 There is some potential to reduce carbon emissions from shipping by reducing fuel consumption through improved fleet management. Examples include better journey planning, effective weather routing, minimising speed variation during journeys, employing larger vessels and using shore-side electricity to power ships at berth in ports.

7.8 Incremental changes to current technologies also have potential to reduce carbon emissions. These changes can be grouped into two sets of techniques. The first would aim to improve the movement of vessels through the water by methods such as refining hull design, using "slick" hull coatings, modifying bow and stern design, improving engine efficiency and aerating the water around the hull. The second set of techniques would aim to improve energy conversion and transmission of power. Examples include using new propeller designs, utilising heat recovered from ship exhausts and switching away from heavy fuel oils.

- 7.9** The majority of these options are already commercially available or likely to be so in the near future - indeed some are already being deployed by the industry, or are likely to be utilised in the short term, as the benefits to be gained in reduced fuel costs outweigh the expenditure necessary to introduce the changes. Other technologies may become viable in the medium term if increases in the price of marine diesel or the introduction of carbon pricing mechanisms to the shipping sector make them more attractive.

Other technological options for improving the fuel economy and emissions performance of future ships

- 7.10** The AEA and MAST report highlighted a range of other technological options for improving the fuel economy and emissions performance of future ships. The options varied in their potential to reduce carbon emissions and the timescales when they were likely to become economically viable, and some of the options are not likely to reach the market in the short to medium term.
- 7.11** One of the more promising technological options is biofuels. The shipping sector would seem to offer several advantages for the use of biofuels for propulsion, including the high sulphur content of marine diesel, the fact that marine engines are more tolerant of different types of fuel than land-based engines. A number of trials investigating the feasibility of running ships on biofuels have recently taken place, and the results have so far been promising. This is encouraging as biofuels could offer potentially large carbon savings, although life cycle impacts of biofuels production need to be taken into account.⁵ The main barrier to biofuels replacing marine diesel fuel is cost. There are also issues associated with the lower energy density of biofuels which would necessitate bigger fuel tanks, their tendency to be more corrosive than conventional fuels, their higher levels of engine deposits and their long term availability.
- 7.12** Various technologies using renewable sources of energy also offer the potential for carbon emissions reductions. For example, different companies around the world are seeking to develop kites or skysails as a means to supplement the propulsion systems of commercial shipping. The reductions in carbon emissions are potentially considerable, but they depend on the average wind speed during the trip, the direction of the wind, the route, seasonal weather variation and transit times. Other options using renewable sources of energy include wave power and photovoltaic cells. Wave power is an unproven technology, however, and both options face issues of cost and durability as well as problems with installation.
- 7.13** Nuclear technology has long been used to power military submarines, and there have been a small number of examples of commercial ships powered by nuclear reactors. Nuclear ships could offer significant reductions in carbon emissions from shipping. There are, however, significant barriers to the development and adoption of this technology by the shipping sector including the high cost, necessary safety precautions and worries over potential security risks. These factors suggest that

⁵ As with biofuels used in road transport, the Government would wish that any biofuels used in shipping were produced in a sustainable way and represented a sensible use of biomass resources. See the Government's Biomass Strategy for further discussion of these issues.

nuclear power is unlikely to be a commercially attractive option for shipping in the near future.

- 7.14** Hydrogen fuel cells face significant barriers before they can become a viable technology for shipping and this technology is likely to become feasible in other forms of transport before shipping. Existing challenges faced by developers of the technology for automobile and other motive applications are likely to be compounded by additional problems in the shipping sector, including issues of power density, space, durability, temperature and cost. Some organisations are conducting research into the potential of hydrogen fuel cells for shipping however, including Rolls Royce who are investigating fuel cells in work sponsored by the European Union.
- 7.15** Electric power is already being exploited by the shipping industry, especially for powering auxiliary systems. Current technology does not offer the option of powering large commercial vessels using electricity stored in batteries, and while other ways of using electricity to power or propel ships are in development it is not clear how effective these will be at reducing carbon emissions. As with other technologies that use electricity, the carbon benefits would depend on the source of the electricity or how the battery was charged.

Encouraging the adoption of low carbon technology in the shipping sector

- 7.16** In order to stimulate interest in the development of more fuel efficient and lower carbon ships, the Government considers that, over time, carbon pricing approaches or related regulations should be extended to the shipping sector as well as other modes of international transport. As with aviation, the shipping industry is an international one and any approach to carbon pricing or other relevant regulations needs to be developed at an international level to be effective. The UK Government has already put a discussion paper to the IMO on emissions trading and the possibilities of extending it to the shipping sector. Another option could be to develop emissions standards for different ship categories, following on from work done by the IMO, and progressively tighten these standards over time. The report by CE Delft for the European Union mentioned above assesses various policy options for reducing the climate impact of shipping⁶.
- 7.17** We will continue to work with the IMO and other relevant international organisations to progress discussions on options for incentivising carbon emissions reductions in the shipping sector – this will include consideration of the potential scope for regional emissions trading schemes and other economic instruments. We will also work within the EU Framework Programme and domestically to examine the case for additional R,D&D into technologies for lower carbon shipping.

6 CE Delft (2007), pp. 207–253.

Chapter 8

Government funding for Research, Development & Demonstration of low carbon transport technologies

- 8.1** There are currently a range of sources of existing and potential funding for research, development and demonstration (R,D&D) into low carbon transport technologies. This section discusses the main sources of existing and future support in this area.

Main existing funding sources

DfT funding for automotive industry led R,D&D

- 8.2** DfT currently spends £5million per year on a grants programme designed to support UK based R,D&D into low carbon road vehicle technologies. Grants are awarded for industry led activities at the research and pre-competitive development stages. This programme is managed for DfT by the Energy Saving Trust (EST) – see <http://www.est.org.uk/fleet/funding/lowcarbonresearch/> for further information.
- 8.3** DfT, through EST, also provides grants for the trialing and demonstration of infrastructure for alternative fuels and vehicles – including infrastructure for biofuels, electric vehicles and hydrogen. Current grant funding for infrastructure projects is around £0.5m per annum.
- 8.4** Moving forward, DfT expenditure on low carbon vehicle R&D will be managed jointly with DTI within a new Innovation Platform supporting low carbon technology development in the UK automotive sector – see paragraph 8.21 below.

Research Councils funding

- 8.5** The Engineering and Physical Sciences Research Council (EPSRC) is currently the main funder of transport research in the UK, with in the region of £50-60million (per annum) funding for all transport-related areas. A list of current grants can be found by browsing the EPSRC 'Funded grants on the web': <http://gow.epsrc.ac.uk/> . The Natural Environment Research Council (NERC), Economic and Social Research Council (ESRC) and the Biotechnology and Biological Sciences (BBSRC) also support some relevant research - as does the UK Energy Research Centre (UK ERC).
- 8.6** EPSRC is also leading the Research Councils' Energy Programme, working with BBSRC, CCLRC, ESRC and NERC. The Research Councils' Energy programme funds energy related research across a range of areas, including the UK Energy Research Centre (UK ERC). Total Research Council expenditure on energy is being increased to £70m per year by 2007-8.

- 8.7** The major programmes with transport related applications are the Supergen Consortia on Bioenergy, Hydrogen and Fuel Cells. NERC, EPSRC and ESRC also fund the Tyndall Centre for Climate Change that has research strands related to the impact of transport on climate change. The Research Councils' Energy Programme is working with its Scientific Advisory Committee and other stakeholders to determine future programme priorities. For further details on the Research Councils' Energy programme activities see <http://www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/default.htm>

Regional Development Agencies (RDAs)

- 8.8** RDA's can potentially support transport R,D&D work where it matches regional priorities. In particular Advantage West Midlands (AWM) is supporting the Premium Auto Research and Development (PARAD) Programme, which is a £70m programme set up to support the luxury automotive vehicle sector- reflecting the significant automotive industry presence in this part of the UK. PARAD consists of a portfolio of research and development projects, aimed at enhancing the manufacturing and design capabilities of West Midlands supplier companies. The programme is supported by AWM, together with numerous partner companies targeted at being over 160 by the end of the programme. Among these companies are the vehicle manufacturers Land Rover and Jaguar, who form part of the Premier Automotive Group in the Ford motor company. PARAD supports a range of project areas relevant to developing lower carbon vehicles, including work on hybrid vehicles and lightweight materials. For further information on the PARAD programme see <http://www.iarc.warwick.ac.uk/>

DTI funding for Hydrogen & Fuel Cells

- 8.9** The hydrogen, fuel cell and carbon abatement technology demonstration fund was launched last year. £15m of this fund has been allocated to technology demonstration of fuel cell and hydrogen technologies. This funding is being allocated through competitive calls and transport related applications will benefit from a share of this funding although stationary (non-transport) power generation applications will also benefit. For further information see <http://www.hfccat-demo.org/>

National Aerospace Technology Strategy (NATS)

- 8.10** The National Aerospace Technology Strategy (NATS) is the result of a partnership between industry, Government and academia to address UK competitiveness in aerospace technology. The aerospace industry bids NATS projects into the DTI led Technology Programme for support. Through this process the Government is providing around £45m per year of civil aviation development funding from the Department of Trade & Industry (DTI), Regional Development Agencies (RDAs) and the Engineering and Physical Sciences Research Council (EPSRC) - to be matched by a similar amount from industry. Many of the programmes in NATS have a direct bearing on environmental issues – most notable amongst these are the Environmentally Friendly Engine (EFE) Technology Validation Programme and the Integrated Wing Aerospace Technology Validation Programme (IWATVP). For further

information on the NATS programme see <http://www.sbac.co.uk/pages/41140383.asp>

EU Framework Programme Funding

- 8.11** The EU spends large sums on transport R,D&D – more than 4 billion Euros is anticipated for Framework Programme 7 which will run from 2007-2013. A significant proportion of this funding is likely to be for low carbon related projects. The Commission will also spend around 2.3 billion Euros on energy research, some of which will have relevance to reducing the carbon impacts of transport.
- 8.12** Framework Programme funded projects must involve collaborations between organisations in different member states. Priority areas for research are agreed with member states. Funds are awarded on the basis of competitive calls or through Joint Technology Initiatives. European Research Area (ERA)-Net communities seek to ensure co-ordination between national programme activities of member states.
- 8.13** EU funding for aeronautics research is particularly substantial. Through Framework Programme 7 significant funding is available for collaborative research in aeronautics and air transport and the Commission is proposing a “Clean Sky” Joint Technology Initiative (JTI) on more environmentally friendly aeroplane technology (see para 5.35 for further details)
- 8.14** The European Commission also intends to bring forward a proposal for a Fuel Cells and Hydrogen JTI. This public-private partnership would focus on the demonstration of fuel cell and hydrogen technologies for various types of transport applications together with stationary power generation and combined heat and power. The JTI would be expected to be operational by early 2008. The UK is encouraging the Commission to bring forward its proposals as soon as possible.
- 8.15** The UK Government actively encourages UK companies and research organisations to participate in the EU R,D&D Framework Programmes. The UK has been successful in securing a significant proportion of the available resources, at around 15%. The Government seeks to maximise benefit in three main ways:
- we actively participates in the process for defining the programme at every level. We are also represented on all the programme committees which approve the workprogrammes, against which applicants bid for funds. The Government seeks to ensure that the Framework Programme focuses as far as possible of UK priorities and strengths.
 - we participate in the various Technology Platforms (TP) set up by the Commission to advise of future research needs in most sector including transport. The outputs of the various TPs have been extensively used to inform the FP7 work programmes.
 - we have set up an extensive network of National Contact Points whose role is inform UK organisations of the opportunities available under the Framework Programmes and to provide help and advice to potential applicants.

Further information on transport research within the EU Framework programme can be found at: http://cordis.europa.eu/fp7/dc/index.cfm?fuseaction=UserSite.CooperationDetailsCallPage&call_id=2.

Information on the National Contact Points can be found at <http://www.fp7uk.dti.gov.uk/>

Future new funding sources

- 8.16** The Government has recognised the case for a significant expansion of the scale of support for R,D&D activities in a range of low carbon technologies, including those relevant to the transport sector. Especially relevant in this context are a number of major new initiatives:

Energy Technologies Institute (ETI)

- 8.17** The ETI is a new initiative - a joint venture partnership which brings together public and private sector R&D in the UK to set strategic direction and fund its delivery.

The objectives of the Energy Technologies Institute are to:

- increase the level of funding devoted to R&D in low-carbon (non-nuclear) energy technologies to meet UK's energy policy goals, both domestically and internationally;
- deliver R&D that facilitates the rapid commercial deployment of cost effective, low carbon technologies;
- provide better strategic focus for commercially applicable energy related R&D in the UK;
- connect and manage networks of the best scientists and engineers both within the UK and overseas to deliver focussed R&D projects to accelerate eventual deployment; and
- build R&D capacity in the UK in the relevant technical disciplines to deliver the UK's energy policy goals.

- 8.18** The Institute starts work during 2007 and reaches full strength next year. Some of the world's biggest energy companies are already involved in this venture and helping to drive the initiative forward. The ETI will have a minimum budget of around £600m over the next decade.

- 8.19** The Institute will focus on specific industrially relevant R&D projects, including R&D in support of demonstration and eventual deployment. The R&D will be carried out in centres of excellence across the UK and overseas. Low carbon transport technologies will be one of the seven key themes of the ETI. Detailed research priorities for the ETI will be set by the ETI Board with advice from the Research Advisory Group.

- 8.20** From 2008 onwards, The Department for Transport will contribute £5m per annum of new money to ETI expenditure on lower carbon transport technologies, and will work to ensure ETI funding fits with national low carbon transport policy directions and is appropriately co-ordinated with other Government and industry research activities. Further information on the ETI can be found at <http://www.dti.gov.uk/science/science-funding/eti/index.html>

Innovation Platform

- 8.21** In conjunction with the Technology Strategy Board (TSB), DfT and EPSRC will help finance and develop a new Low Carbon Vehicle Innovation Platform providing critical coordination and up to £30million of support from 2008/09 onwards. Creation of the IP is a recognition of the growing importance to the UK automotive sector of maintaining and developing world class expertise in a range of technologies relevant to the development of lower carbon vehicles. The Innovation Platform will bring together key stakeholders in the UK automotive sector and provide new funding for UK industry led demonstration and collaborative R&D projects – focussed on nearer and further from market technologies where the UK has or can develop world leading expertise. Assuming the Innovation Platform develops successfully the Government intends to extend extending the programme to run over a number of years.

Public procurement support for small fleet demonstration programmes

- 8.22** The Government will provide new funding of an initial £20m to support a new programme aimed at accelerating the market penetration of lower carbon vehicles and reducing the barriers faced by companies in moving from prototype demonstrations of lower carbon technologies to full commercialisation. This programme will provide financial support for public procurement of fleet demonstrations of lower carbon vehicles (and where appropriate supporting infrastructure). The programme will seek to build on the model of contractual forward commitments in which commitments to purchase vehicles are linked to the achievement of pre-determined cost and performance criteria. It will be developed alongside the work programme for the new Innovation Platform described above. The Government will consult on the detailed operation of this new programme later in 2007 – with a view to supporting the first fleet procurements/demonstrations in 2008.

Environmental Transformation Fund – support for demonstration and deployment activities

- 8.23** In June 2006, the Government announced the creation of a new joint Defra/DTI Fund which will boost investment in demonstration and deployment of lower carbon energy technologies and in energy efficiency. The Fund brings together DTI and Defra's work to support new energy technologies, and to promote the better use of energy. It will complement the Energy Technologies Institute and other forms of support.
- 8.24** The Fund is expected to invest in the demonstration, pre-commercial deployment, and roll-out of low-carbon energy technologies, complementing the work of the Energy Technologies Institute by supporting private sector investment in promising technologies emerging from research and development.
- 8.25** The Environmental Transformation Fund will open in April 2008 and operate initially over the three years to 2010/11. The size of the Fund over this period will be determined through the Government's Comprehensive Spending Review and is expected to be announced later this year, together with more detailed objectives. In order to provide a long-term framework for investment decisions, the Government expects the Fund to continue beyond the current spending round.

OMEGA

8.26 The OMEGA (Opportunities for Meeting the Environmental Challenges of Growth in Aviation) project is being supported by £5m of Government funding and is being led by Manchester Metropolitan University while bringing together a wide range of leading UK academic and industrial expertise in the environmental impacts of aviation and opportunities for mitigation of those impacts. OMEGA will consider a 2050 time horizon and support a range of initial research projects focussed on long term and more radical options for addressing the environmental impacts of aviation. Drawing on the UK's considerable academic and industrial expertise in a wide range of aviation issues, OMEGA aims to place the UK at the forefront of both policy and technological work in this area.

Improving the coherence and co-ordination of R,D&D activities

8.27 The paragraphs above illustrate that existing funding for low carbon transport technologies R,D&D comes from a range of diverse sources – and that new additional sources of potential support for UK industry and academic research groups are also becoming available. While diverse and growing funding streams bring many benefits, in order to maximise the effectiveness and value for money of Government supported activity in this area it will be important to ensure that:

- funding streams appropriately match Government priorities, UK industrial and academic capabilities and that a range of key technology areas for lower carbon transport are addressed
- duplication or un-necessary overlap of funding streams is avoided where possible or appropriate
- un-intended gaps in funding streams or research areas are avoided
- potential beneficiaries of support in the relevant industrial and academic communities have clarity about the different kinds of potential support available and how to access them

8.28 To address these issues the Department for Transport will, working closely with DTI and DEFRA, maintain an ongoing strategic oversight of R,D&D activities in this area across all major transport modes. In particular through our participation in the ETI and the Innovation Platform we will seek to:

- encourage the merging and simplification of funding streams where appropriate – our decision to bring together future DfT and DTI support for UK low carbon vehicle R&D through the Innovation Platform is an example of this approach in practise
- encourage the use of joint calls and wider co-ordination of funding approaches – potentially bringing funding from a range of partners together to allow larger projects or calls to be supported
- ensure that the balance of, and priorities for, funding, continue to match Government's transport and energy policies in this area over time – while maintaining support for a diversity of technology options

- ensure detailed technology research priorities and project proposals are reviewed and assessed by relevant industry and academic experts
- share and publish regularly up-dated information on R,D&D funding programmes, open calls and other relevant developments.
- engage directly with industry and other key stakeholder groups in this area such as the Low Carbon Vehicles Partnership, the National Non-Food Crops Centre and Cenex – the UK centre of excellence for low carbon and fuel cell technologies – in particular to identify areas where research, development and demonstration activities can be most effectively deployed in the UK.

Chapter 9

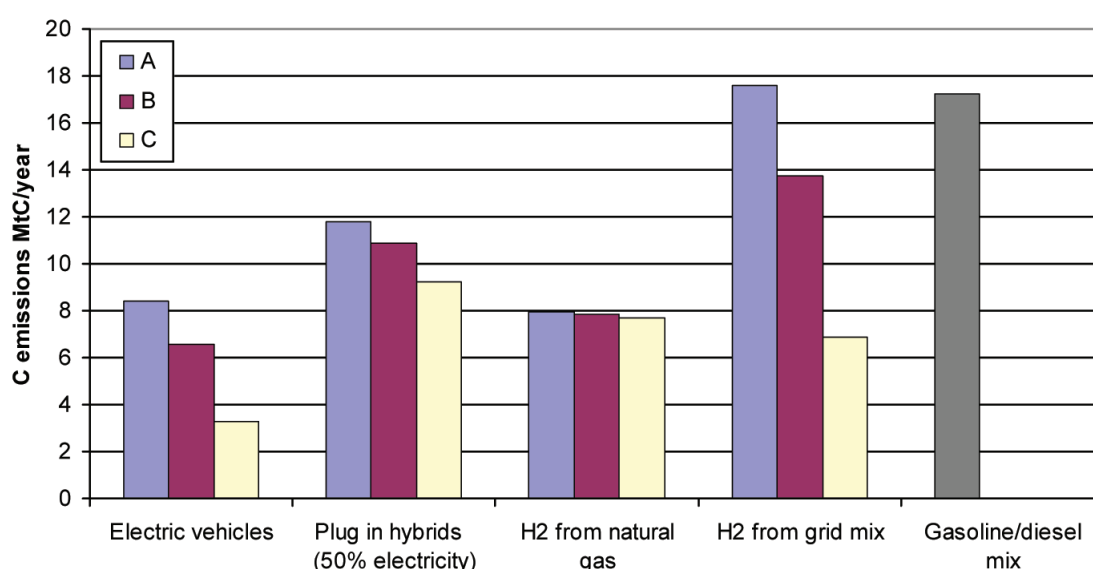
Potential importance of a low carbon electricity mix

- 9.1** At present a fossil fuel, oil, in various derivative forms such as gasoline, diesel and kerosene, provides the vast majority of energy for transportation – both in the UK and globally. An efficient worldwide infrastructure of oil exploration, production, refining and distribution has been built up over many decades to supply a growing worldwide demand for oil for transportation use.
- 9.2** Previous sections of the LCTIS have illustrated that, for different transport modes, there are a wide range of technologies with the potential to reduce carbon emissions from the transport sector over time. However a feature of some of those options with the potential to deliver very significant carbon savings over the long term is their utilisation of electricity to provide new fuels or power for transportation.
- 9.3** Electricity can potentially be used for transport in a variety of ways:
- as currently, to provide power for the electrified parts of the rail network
 - in future, to charge batteries in plug-in hybrids or fully electric vehicles
 - in future, to manufacture hydrogen from the electrolysis of water. The hydrogen may then be used as a transport fuel either in fuel cells or internal combustion engines.
- 9.4** Electricity is an energy carrier rather than an energy source in itself. Significant energy may also be consumed in the manufacture and transportation of hydrogen. The scale of carbon savings offered by a future electricity or electricity/hydrogen based transport system would therefore be dependent on the energy source used to produce the electricity or hydrogen in question. Indeed in certain scenarios there might be no carbon savings at all, although the existence of lower carbon options for electricity and hydrogen generation, such as renewables, nuclear, natural gas (which, while a fossil fuel, is much less carbon intensive than oil) and carbon capture and storage, create the possibility of a future transportation system with very significantly lower carbon emissions than today's.
- 9.5** To illustrate these effects, as part of their report on innovation systems for low carbon road transport technologies, the Government asked E4tech to conduct a very short analysis of the scale of potential carbon savings – and additional electricity demand - which would be implied if the UK's existing passenger car fleet were converted to vehicles using electricity or hydrogen – under a range of different electricity grid mix scenarios. E4tech's analysis is set out in Appendix 3 of their report – a summary of the key points is provided below.

9.6 E4tech considered three electricity grid mix scenarios – one broadly equivalent to today’s grid mix (Scenario A), one modestly de-carbonised compared to today (Scenario B) and one with significant de-carbonisation (Scenario C). Alongside this they considered four technology scenarios – all electric vehicles, plug-in-hybrids (which were assumed to consume 50% of their energy in electric mode), hydrogen produced from reformation of natural gas and hydrogen produced from electrolysis of water.

9.7 The impact on carbon emissions from passenger vehicles under the different grid mix scenarios is shown in the table below – assuming 2004 levels of demand:

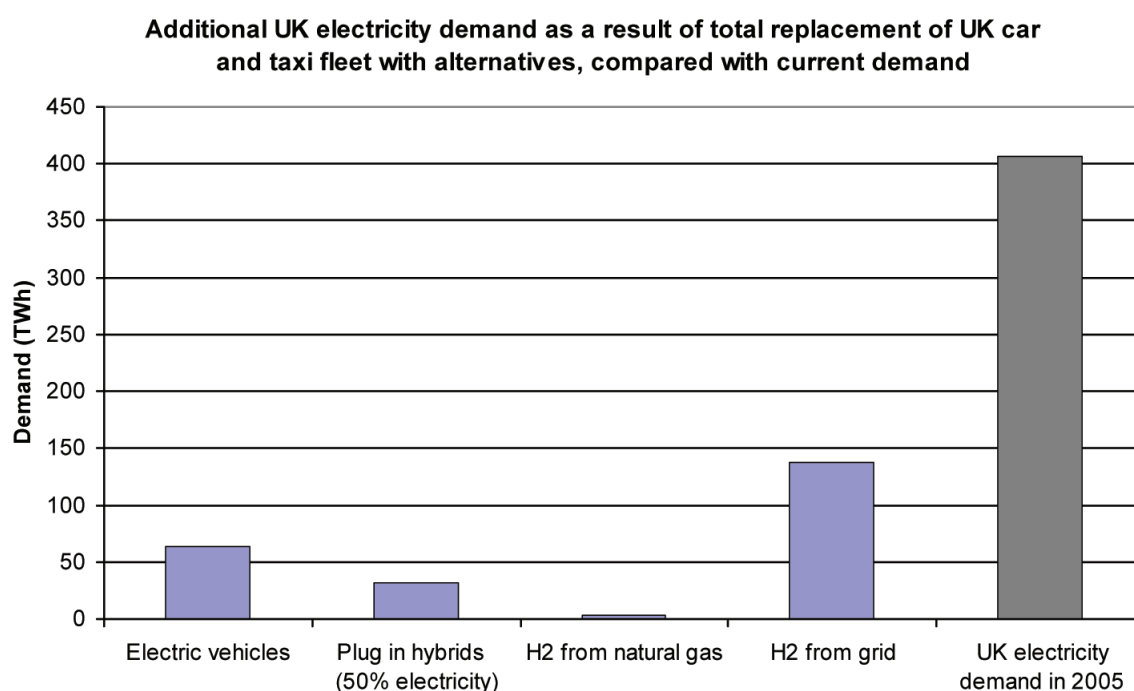
C emissions from replacement of the UK car and taxi fleet with lower carbon options under three grid mix scenarios



The emissions that would result from use of a 50:50 mix of *new* gasoline and diesel vehicles are also shown in the grey column on the right. For comparison, actual carbon emissions from passenger cars in 2004 were 19.4MtC.

9.8 A significant number of caveats should be placed on an analysis of this kind. Firstly, this type of analysis is useful in comparing each technology option by assessing the impacts of using that option alone – however it may be that greater benefits would be achieved through use of a range of technology options. Secondly the options considered are for passenger cars only – not all modes of road or other forms of transport. They assume, for illustrative purposes only, that total distance travelled by passenger car remains static at 2004 levels. Thirdly, the analysis relies on a range of detailed assumptions around vehicle efficiency, technology performance, electricity conversion efficiencies, losses and so on. In particular the vehicle efficiency data assumes an improvement on today’s values for both hydrogen and electric vehicle applications. Significant technology development which would be required for the widespread commercialisation considered here, and even with this development, the all electric vehicles modelled would not have the range necessary for widespread use.

- 9.9** Lastly, the emissions produced from the overall electricity grid mix are, in practice, time-dependent. This is due to different demand levels at different times, and different fuel costs resulting in the use of different power stations providing power. In the future, as energy markets are likely to become more flexible, this time-sensitivity may become greater and so steady-state analysis of the benefits of different options may become less valuable
- 9.10** That said, an analysis of this kind can be considered indicative of the broad emissions levels that would be likely under different scenarios. It suggests that all of the technology options have the potential to give significantly lower carbon emissions than new gasoline and diesel vehicles. This is important, as different options may be needed for different applications, based on the vehicle range and performance required, and may be available in different timeframes.
- 9.11** Based on today's electricity mix, a transition to electric vehicles or plug-in hybrids would have the potential to deliver significant carbon savings, which would increase with further de-carbonisation of the grid mix. Plug-in hybrids offer the potential to extend the electric vehicle range, albeit with lower emissions savings. Using hydrogen produced from natural gas would also offer substantial carbon savings, largely un-related to the grid mix (as the process uses only limited amounts of electricity). However the carbon emissions associated with hydrogen production from electrolysis are very substantially affected by the grid mix – with the current grid mix levels this route would offer no carbon savings compared with new gasoline and diesel vehicles, but with further de-carbonisation of the grid mix the carbon savings would become substantial.
- 9.12** E4tech also considered the scale of additional electricity demand which would be implied by the different technology scenarios outlined above. These are shown, against a comparison of total electricity demand in 2005, in the graph below:



The graph suggests that the additional electricity that would be required to supply 2004 transport demand from passenger cars if electric vehicles were used could be around 16% of current total electricity demand. For plug-in hybrids, this would depend on the time spent in electric mode. Hydrogen produced from grid electricity could lead to much higher additional electricity demand (over 30% of 2005 demand) – as a result of the lower efficiency of the hydrogen supply chain (energy transmission, electrolysis and hydrogen transport) compared with electricity transmission and distribution, and the increased energy use of hydrogen vehicles compared with battery electric ones.

- 9.13** While the impacts on total UK electricity demand from the above technology options are significant, impacts on the requirement for additional generation capacity could be less so. This is because re-charging of electric vehicles or plug-in hybrids, or production of hydrogen by electrolysis, might take place principally at night when electricity demand is lower. This could also potentially be used to help absorb any surplus electricity from intermittent forms of renewable generation.
- 9.14** Again the caveats and uncertainties noted above should be applied to analysis of this kind. That said, the analysis clearly indicates that moving in future to a transport system based on electricity and/or hydrogen could have significant impacts on total UK electricity demand under a range of scenarios. Maintaining efforts to improve the fuel efficiency of vehicles may help to contain the scale of additional electricity demand. But it is clear that, for such a transition to have large scale positive impacts on UK carbon emissions, it would be essential for that additional electricity demand to be met from lower carbon sources of electricity generation. The more “de-carbonised” the electricity mix is, the greater the potential for substantial carbon savings from these future transport technology options. This is an important conclusion which reaffirms the importance of the steps the Government is taking to support current and future forms of lower carbon electricity generation, as well as greater energy efficiency in the utilisation of electricity – these are set out in more detail in the Energy White Paper.

Chapter 10

Uncertainty, technology development and next steps

- 10.1** Various sections of this strategy have assessed the state of development of a wide range of different technologies with the potential to reduce carbon emissions from the transport sector. In doing so we have sought, in broad terms, to distinguish between technologies which can contribute to emissions reduction at the present time or could do so in the relatively near future, and those with longer term potential.
- 10.2** However, it must always be recognised that technology development and deployment is an inherently uncertain process – especially over the longer timescales which are relevant to issues such as carbon abatement and addressing climate change. Technology development is not a linear process which can guarantee the emergence of a particular option by a specific pre-determined date. Historians could point to numerous occasions when new technologies have surprised markets with the speed at which they have advanced and penetrated mass markets – as well as occasions when advances in unexpected areas have upset conventional wisdom about the technologies most likely to emerge. Equally, there are examples of technologies which have failed to justify early optimism or to achieve widespread commercialisation at the scale or speed which was once widely envisaged.
- 10.3** These points are as relevant to lower carbon technology development within the transport sector as they are to any major area of innovation and scientific development. Considering the road sector, for example, even within the space of several decades, views on the most promising future technologies have varied widely. To this day, leading experts and automotive companies hold somewhat differing positions on the potential of biofuels, plug-in hybrids, electric vehicles and hydrogen fuel cells to displace gasoline or diesel and over the timescales at which such technologies might contribute significantly to carbon reduction.
- 10.4** The inherently uncertain nature of technology development has a number of implications for Government policy in this area. Firstly, in respect of policies which impact directly on the commercial deployment of lower carbon technologies – for example carbon pricing mechanisms or other regulatory or tax incentives – it strengthens the case for Governments to develop or maintain a “technology neutral” approach to incentives which does not seek to predict or prescribe which technology options are utilised by private individuals and companies. Technology neutrality will remain a key issue for Government interventions focussed at the market/deployment end of the innovation spectrum.

- 10.5** How technology neutrality may be applied in practise may differ depending on specific circumstances but, broadly speaking, the objective would be to ensure that technologies which deliver similar levels of carbon reduction in the marketplace receive similar levels of incentivisation. In the case of the Renewable Transport Fuels Obligation (RTFO) the issue of technology neutrality is more complex as similar volumes of different biofuels may deliver very different quantities of carbon reduction. For this reason the Government is consulting on options for adjusting the RTFO in future to take stronger account of carbon emissions impacts of different biofuels.
- 10.6** In relation to Government support for R,D&D activities the above considerations also point to an approach which:
- seeks to maintain a broad spectrum of future technology options, through support for a broad variety of R,D&D activities and UK participation in international collaborative activities.
 - avoids placing full reliance on a single or limited number of technology solutions
 - acknowledges the inherently risky nature of R,D&D – and therefore accepts that some projects and technologies supported by Government will disappoint and fail to be commercialised
- 10.7** At the same time, while adopting a technology neutral approach where appropriate, and seeking to keep options open wherever possible, it must also be accepted that Governments cannot afford to be entirely agnostic about the differing potential of technologies to contribute to future carbon reduction. Future decisions on the priorities for and direction of R,D&D funding, as well as on the funding of transport infrastructure and investment, are examples of occasions on which Governments may be forced to reach more definitive judgements about the potential of different technologies to achieve carbon reduction over given timescales. Where this is the case, the Government will seek to make those judgements on the best available science and technology understanding available to it at the time – and to consult widely with relevant industry and academic experts before settling on priorities.
- 10.8** In the case of the transport sector, uncertainty applies not only to the question of *which* of a range of potential technologies may prove to be the most effective in the longer term, but also to the question of the *extent* to which these technology options as a whole will be capable of providing cost effective large scale lower carbon alternatives to existing fossil fuel based modes of transportation, and over what timescales. As various sections of this strategy have highlighted, many of the technologies which could deliver very significantly lower or zero carbon transport are not yet commercially available and require further technological progress and/or cost reduction before they become widely deployed. Moreover, in some sectors such as aviation and shipping, technology options capable of delivering very large scale cost effective reductions in carbon emissions appear to be relatively limited at the present time.
- 10.9** This aspect of technology uncertainty also has implications for policy development. It strengthens the case for a balanced set of incentives which both exploit the

emissions reduction potential of technologies which are already proven or very close to market, as well as encouraging the development of new technology solutions which may or may not prove to be commercially viable. Similarly, technology uncertainty argues for utilising a mix of policies for incentivising emissions reduction in the transport sector – a mix which includes support for technology development alongside a range of non-technology based measures aimed at influencing travel behaviour towards more sustainable options - such as encouraging school, workplace and individualised travel planning, supporting public transport, utilising the potential of teleworking and other options.

- 10.10** The Government's overall strategy for tackling carbon emissions from the transport sector, as set out in section 3 of this strategy and in the transport chapter of the Energy White Paper, aims to deliver this broad and balanced approach. It is clear technology has a major role to play and we are committed to developing a policy and regulatory environment which will enhance innovation and stimulate low carbon transport technology development and deployment in the UK.

Next steps

- 10.11** This strategy has set out in detail a range of policies and new measures the Government is taking to incentivise lower carbon transport technologies. There are clearly many challenges ahead and we will continue to revise and refine our approach in the light of new developments and research
- 10.12** In this context, and bearing in mind the importance of the road sector for transport carbon emissions, the Government has asked Professor Julia King, Vice-Chancellor of Aston University and former Director of Advanced Engineering at Rolls Royce plc, working with Sir Nicholas Stern, to lead a review to examine the vehicle and fuel technologies which over the next 25 years could help to decarbonise road transport. This review will feed into the work of the Energy Technologies Institute and the Government's wider strategy for encouraging innovation in lower carbon transport technologies.
- 10.13** More generally, we will continue to monitor technology developments in this area closely, and will consult with key stakeholders on the implementation of the new expenditure programmes set out in this strategy. While we are confident in our approach, we do not rule out developing new policies or adjusting existing ones in the light of new evidence or research on the best approach for supporting new technology development in this area. This is consistent with our commitment to make the UK an attractive place to develop the new transport technologies which can help us move to a lower carbon future.