Energy Saving Trust

Pathways to Future Vehicles

A 2020 Strategy

April 2002

The Energy Saving Trust

The Energy Saving Trust (EST) is a non-profit company funded largely by the Government to deliver sustainable energy solutions to households, small firms and the road transport sector. EST is one of the UK's leading organisations tackling the causes of climate change.

transport**action**

TransportAction

TransportAction is run by the EST and mainly funded by the Government Department of Transport, Local Government and the Regions (DTLR) and by the Scottish Executive. TransportAction is the umbrella brand for the EST's environmental transport programmes which include PowerShift and CleanUp. TransportAction delivers innovative solutions, programmes and information, and campaigns to reduce the damaging effects of transport on the environment, seeking to promote sustainable mobility.

PowerShift and CleanUp are complementary programmes. PowerShift aims to create a sustainable market in the UK for new, mainly small, vehicles (cars and vans) which run on clean fuels. CleanUp focuses on reducing the emissions of commercial and public service diesel vehicles (such as lorries, buses, emergency vehicles and refuse trucks) and black cabs, either by converting their engines to run on natural gas or by fitting emissions reduction equipment to the exhausts of diesel vehicles.

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1.0. EXECUTIVE SUMMARY

In the next few decades the greatest challenge for vehicle manufacturers, fuel suppliers and Governments will be to reduce the carbon dioxide (CO_2) emissions from road transport. Road transport contributes 22% of the UK's greenhouse gas emissions, and this share is likely to rise. As part of its overall action to tackle climate change the Government will need to reduce emissions from road transport initially through better fuel efficiency, and ultimately zero carbon fuels.

The PowerShift programme is currently helping to create a market for cleaner fuels such as Liquefied Petroleum Gas (LPG) and natural gas. Over the next few years it is envisaged that the LPG market will reach sustainability in the marketplace. Natural gas is likely to remain a viable alternative for depot based vehicles, and will develop in this niche market.

However, to achieve progressive improvement in CO_2 emissions from vehicles, while also improving local air quality, more effort will be needed to encourage increased fuel efficiency and low carbon fuels. There are a range of options that show significant promise for achieving major carbon savings: hybrids, biofuels and electric vehicles. Of these, electric batteries will need to improve very significantly to meet consumer needs outside niche markets, and until this is achieved it would not be prudent to invest in major infrastructure for mass-market recharging. Biofuels could fulfil some niche demand but further development of liquid fuels from high yield crops would be needed if biofuels are to play a significant role. In the period to 2010, hybrid vehicles, that currently combine an electric battery with the power and performance of an engine, offer the most cost effective mass market option. New and emerging hybrid vehicles have the potential to double fuel economy and halve CO_2 emissions.

To stimulate this shift, EST recommends that Government works in partnership with vehicle manufacturers and fuel suppliers in striving for:

at least 10% of all new car sales in the UK to be low carbon by 2010.

A 'low carbon car' should be defined as: **less than or equal to 100 g/km CO_2** measured on a **well-to-wheels** basis. The European car industry has made a voluntary agreement to reduce tailpipe CO_2 emissions from the new car fleet to an average of 140 g/km by 2008 which is about 160 g/km in well-to-wheel CO_2 emissions. The low carbon car target is intended to drive forward innovation in low carbon car technologies beyond what is likely to be achieved by the existing European voluntary agreement. It should not be viewed as a 'stick' but should be backed up by Government incentives and subsidies to ensure its achievement.

Defining a low carbon car target in terms of a CO_2 emission standard rather than a specific fuel or technology will ensure that no low carbon options are ruled out. Setting a well-to-wheel standard will give confidence to both vehicle manufacturers and fuel suppliers to invest in the development of new and emerging low carbon vehicle technologies and fuels.

In the period to 2010, new bus fleets could achieve rapid improvements in fuel use and CO_2 emissions, and current diesel hybrid technologies are showing encouraging results. EST recommends that Government works in partnership with bus companies and fuel suppliers in striving for:

at least 25% of all new bus registrations in the UK to be low carbon by 2010.

Unlike cars, data on the CO_2 emissions of buses is not readily available. It will therefore be important that an agreed test cycle be used for all future low carbon buses. This should be readily applicable to all technologies, including hybrids, and reflect typical bus operating conditions.

EST *provisionally* recommends that every bus classified as low carbon should achieve a well-to-wheel CO_2 saving of at least 30% compared to its current equivalent diesel bus. However, the definition for a low carbon bus should be reviewed when more data on the CO_2 performance of new and emerging low carbon bus technologies becomes available. Diesel hybrid buses, for example, could potentially deliver as much as a 50% saving.

Setting progressively tighter targets for low carbon vehicles will encourage the development of more energy efficient vehicles. But, they will not alone be sufficient to stimulate innovation in low carbon fuels that are likely to be needed to prevent dangerous climate change in the very long term. From today’s viewpoint the most promising technology for achieving zero carbon road transport is hydrogen. Both non-fossil electricity and sequestration of CO_2 from fossil fuels could potentially deliver ‘zero carbon hydrogen.’ Mass-market zero carbon hydrogen fuel may not be achieved until after 2020, but hydrogen needs to be actively encouraged to help keep this option open.

Buses are the most likely starting point for the introduction of hydrogen vehicles because they refuel at depots and current gaseous hydrogen storage technology provides adequate range. Encouraging the development of hydrogen refuelling infrastructure in a limited number of sites provides an opportunity to demonstrate and develop hydrogen fuel cells and hydrogen production technologies.
EST recommends that Government works in partnership with bus companies, fuel cell companies and fuel suppliers to achieve:

5–10% of new bus registrations in the UK to be run on hydrogen fuel cells by 2010.

In practice, this would require the introduction of a small number of hydrogen fuel cell buses. In the year 2010, it would only mean the introduction of between 150 and 300 hydrogen fuel cell buses[1].

Beyond 2010 it is difficult to forecast what vehicle technologies will be dominant in the market place. Hydrogen may well be the best longer term option for delivering a zero carbon road transport system, but there will be many challenges ahead. The pathways to developing a hydrogen refuelling infrastructure remain unclear, as do the costs. In addition, if zero carbon hydrogen is to become a viable option then the Government’s policy to encourage renewable electricity will need to go much further.

1. According to SMMT data, the average number of new bus registrations is about 3000 per year.

Before the end of this decade Government should review the progress of new and emerging low carbon vehicle technology developments and consider setting an **'ultra low carbon' target and standard for 2020**. In addition the **2010 target for hydrogen fuel cell buses could be extended**. Government will also need to assess whether setting a **hydrogen car target for 2020** would help to drive forward developments in hydrogen cars as well as hydrogen storage and production technologies.

EST recommends that Government backs up its targets by developing a **Low Carbon Vehicle Partnership** as a means of formalising and strengthening the links and synergies between the Department of Trade and Industry (DTI) Foresight Vehicle programme, EST's PowerShift programme and the Carbon Trust's Low Carbon Innovation Programme (LCIP). The Low Carbon Vehicle Partnership could:

- Help to co-ordinate the delivery of information, support and advice for low carbon vehicle technologies and fuels.
- Act as an advisory group to Government on the development of policies for supporting the transition to a zero carbon road transport system.

A favourable fiscal framework will also be needed to aid the transition to low carbon vehicles through fuel duty differentials, Company Car Tax and Vehicle Excise Duty. If low carbon vehicles are to be successfully introduced, public support will be critical.

All these policies will therefore need to be supported by initiatives for raising public awareness about new and emerging low carbon vehicle fuels and technologies.

2.0. INTRODUCTION

Climate change has become one of the principal drivers for environment and energy policy at both a national and international level. Increasingly the UK will be shifting from its dependence on fossil fuels and will be reducing carbon dioxide (CO_2) emissions by using fossil fuels more efficiently. The Government's Powering Future Vehicles draft strategy (2001) recognises the importance of facilitating the transition to a low carbon transport system and looking ahead to more radically different technologies and fuels capable of producing much lower greenhouse gas emissions.

There is growing consensus amongst leading vehicle manufacturers and fuel suppliers that hydrogen could well be the fuel of the future. Hydrogen vehicles present Government with an opportunity for cutting greenhouse gas emissions whilst also reducing our dependency on oil. However, in the period to 2010, there will be other low carbon opportunities also worthy of Government support. New and emerging vehicle technologies, such as fuel efficient hybrid electric vehicles, hold great promise as low carbon options. Within this decade, significant carbon savings could potentially be achieved through innovations in technologies and designs that help to make existing conventional vehicles more energy efficient.

Nonetheless the Performance and Innovation Unit's (PIU) Energy Policy Review (2002) has highlighted that even the most energy efficient vehicles will not deliver carbon emission reductions on the scale likely to be needed in the very long term. The development of both more energy efficient vehicle technologies as well as low carbon fuels will therefore be necessary.

Hydrogen looks like the best long term option at the present time. But if there were a breakthrough in battery technologies then electric vehicles might present a challenge to hydrogen vehicles. Biofuels might also present a low carbon opportunity, possibly as a fuel extender. But they are only likely to make a significant contribution to overall UK road transport fuel demand if technology to manufacture liquid fuels from woody resources is developed and commercialised.

The Society for Motor Manufacturers and Trader's (SMMT) Future Fuels report (2002) highlights the importance of zero carbon sources of energy within a hydrogen road transport system. Environmental campaigning groups are keen to see the growth of the hydrogen vehicle market provide a case for investing in more renewable energy capacity. Both business and environmentalists therefore share the same destination point: to deliver a zero carbon road transport system. But the pathways to getting there remain unclear. Both non-fossil electricity and sequestration of CO_2 from fossil fuels could potentially provide 'zero carbon hydrogen.'

Whilst hydrogen offers a means of delivering a zero carbon road transport system, it is a longer term option and there will be many challenges ahead. There is no agreement on how a hydrogen refuelling infrastructure should be developed. Also, the shift to 'renewable hydrogen' will require reductions in the costs of renewable energy technologies and considerable development of renewable electricity capacity.

If Government is to keep its options open, it will need to help industry develop low carbon transport fuels even where these are not the cheapest carbon reduction options at the present time. Within this decade, the Government should have the foresight to keep the hydrogen option open on the basis that it is showing the most potential for delivering the longer transition to a zero carbon road transport system.

2.1. Scope of EST's Pathways to Future Vehicles 2020 Strategy

This strategy will examine three key pathways to achieving low carbon vehicle fuels and technologies:

1. The pathways to 2005
2. The pathways to 2010
3. The pathways to 2020

The division between each of the pathways is to a degree artificial because, in reality, there will be overlap between them. But the purpose is to identify:

- What are likely to be the key low carbon technologies and fuels that offer a stepping stone to a zero carbon road transport system.
- What kind of Government support will be needed to help drive forward the development of these low carbon fuels and technologies, and at what point will this support be most needed.

This strategy principally focuses on the opportunities within the future **car, other light duty vehicle** and **bus** markets. It does not consider other larger vehicles, such as lorries. Information on the future development of low carbon fuels and technologies for lorries is both limited and largely unverified. EST is therefore confident only to draw policy conclusions regarding the prospects for current alternative fuels and technologies in the lorry sector.

3.0. THE CLEANER VEHICLES MARKET

3.1. The four key drivers for cleaner vehicles

1. Climate change

The UK Government has a legally binding target under the 1997 Kyoto Protocol to reduce greenhouse gas emissions by 12.5% below 1990 levels over the period 2008–2012. In addition, the Government's Climate Change Programme has set a goal to cut UK CO_2 emissions by 20% below 1990 levels by 2010. Road transport is the third largest source of greenhouse gas emissions responsible for 22% of all UK emissions (DETR, 2000). Transport is also predicted to be the fastest growing source of greenhouse gas emissions. CO_2 is the main greenhouse gas responsible for climate change worsened by human activity. Tackling the CO_2 emissions from road transport will therefore be critical to meeting climate change commitments, and is the focus of the Government's Powering Future Vehicles draft strategy.

2. Air Quality

Air quality has continued to improve over the years. Nonetheless, road transport is the main source of air pollution in the UK. The main air pollutants from road vehicles include carbon monoxide (CO), oxides of nitrogen (NOx), benzene and particulate matter. A recent report by the Committee on the Medical Effects of Air Pollutants (2001) found a growing link between traffic emissions and health problems such as asthma and other respiratory diseases. The Government published its National Air Quality Strategy for England, Wales and Northern Ireland (2000) which sets objectives for air quality improvements. These objectives were further tightened at the end of 2001. Reducing air pollution from road transport will play an important role in helping to meet these objectives.

3. Energy security

Transport accounts for about 74% of all UK oil consumption of which the majority is attributable to road vehicles (DTI, 2002). Increasing fluctuations in oil prices and the civil unrest created by the September 2000 fuel protests underline our over-dependency on oil. The recent PIU Energy Policy Review (2002) highlights the importance of reducing oil dependence within the transport sector in the longer term.

4. Noise pollution

Vehicles can be a significant source of noise pollution. In congested urban centres the noise pollution from road traffic can be a major public nuisance. Local Authorities are required to address noise pollution concerns under the Environment Act 1995. Most Local Authorities impose curfews on noisy delivery vehicles to prevent them from entering residential areas during the night.

Air quality has historically been the principal driving force behind moves to encourage cleaner fuels and vehicle technologies in the UK. Although air quality objectives will remain important, it is expected that tightening emission standards for new vehicles will increasingly allow those objectives to be delivered. Climate change objectives, on the other hand, are very far from having been achieved. EST therefore agrees with the analysis in the Powering Future Vehicles draft strategy that reducing carbon emissions will increasingly become the most important environmental driver of vehicle fuel and technology.

3.2. Cleaner vehicle fuels and technologies

The overwhelming majority of the UK vehicle market is petrol based. About 20% of road vehicles are powered with diesel. Cleaner fuelled vehicles make up a tiny proportion of the total vehicle fleet – around 0.2% – of which most are Liquid Petroleum Gas vehicles. In recent years, the cleaner vehicle fuels and technologies market has become more diverse.

3.2.1. Current technologies

Liquefied Petroleum Gas (LPG) vehicles

In the UK, automotive LPG is commercial propane, a by-product of oil refining but it also occurs naturally from on and offshore oil and gas production. A litre of LPG currently costs less than half the price of petrol or diesel at the forecourt. Most types of vehicle can be built, or converted, to run on LPG. It is significantly easier and less costly to convert a vehicle with a petrol engine than one running on diesel. As a result, LPG has proved particularly popular as a fuel for cars and vans that would normally run on petrol. Most LPG cars and vans are 'bi-fuel' which means they carry both petrol and LPG and can change from one to the other at the flick of a switch, or automatically after starting up on petrol. The typical cost of converting a passenger car or light duty vehicle to run on LPG is currently around £1500.

Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) vehicles

Natural gas is predominantly methane, mainly found in underground or undersea fields and often associated with oil. Natural gas engines are far quieter than diesel engines making them suitable for overnight deliveries and in noise sensitive areas. Natural gas must be liquefied (LNG) or compressed (CNG) for on board storage, but bulky and heavy storage tanks are required. These vehicles therefore cannot compete with the range offered by petrol or diesel. Refuelling options for natural gas range from cheap, slow fill compressors, which refuel a vehicle overnight, to high-tech stations which can refuel a vehicle in a similar time to petrol or diesel.

3.2.2. Possible next phase technologies

Electric vehicles

Electric vehicles are extremely quiet with no tailpipe pollution. If the electricity were generated from renewable energy sources then electric cars would create zero well-to-wheel carbon emissions. In an electric vehicle, batteries and electric motors replace the conventional internal combustion engine. It costs as little as 1p a mile to run a car on electricity compared with around 10p on petrol. Electricity is most suited for use in city-based cars and vans with set journey patterns requiring a limited range of up to 50 miles. Electric vehicles cost about the same as conventional petrol or diesel vehicles but the batteries are expensive and tend to be leased rather than purchased outright.

Hybrid vehicles

Hybrid vehicles currently use a combination of a small conventional engine and an electric motor. Battery power is used at lower speeds and for stop-start driving in urban areas. The engine is used to drive the vehicle outside urban areas, to travel at high speeds or to recharge the batteries. Unlike dedicated electric vehicles, hybrid vehicles do not require electric recharging facilities. They are essentially more energy efficient, liquid fuel vehicles due to the higher efficiencies achievable with electric traction especially at slow speeds. Petrol hybrid cars have only recently entered the UK market and cost around £3000 more than their equivalent petrol cars. Hybrids can be configured in many different ways. For example, the hybrid system can be combined with a fuel cell instead of an internal combustion engine.

Biofuel vehicles

Biofuels are alcohols, ethers, esters and other organic compounds made from biomass such as herbaceous and woody plants, agricultural and forestry residues or municipal waste. In theory biofuels can be carbon neutral but in practice the carbon savings from biodiesel made from primary crops is limited because growing and processing the crops requires high levels of energy use and other inputs such as fertilisers. In the UK biodiesels, largely derived from rape seed oil, can be used as a direct substitute for diesel fuel, but this presents some technical problems and requires engine modifications. Given the likely limitations in supply, blending up to 5% into conventional diesel is preferable with no significant technical problems. In the April 2002 Budget, duty on biodiesel was cut by 20p compared to the standard diesel rate.

Fuel cell vehicles

Fuel cells are devices that convert the energy stored in a fuel directly into electricity. Fuel cells function in a similar way to batteries in that they have no moving parts and convert chemical energy into electricity very efficiently. Like a battery cell, multiple fuel cells are stacked together to increase the voltage. Unlike batteries, fuel cells never need to be recharged and will produce electricity for as long as the fuel – usually hydrogen – is provided. Fuels cells can be used in both vehicles and buildings for providing energy. The most commonly used fuel cell technology for vehicles is the Proton Exchange Membrane (PEM) fuel cell. There are currently no hydrogen fuel cell vehicles that are commercially available but there are many hydrogen fuel cell buses and cars that are already in demonstration.

Hydrogen vehicles

Hydrogen is a versatile fuel – it can be used in adapted internal combustion engines or fuel cell vehicles. Hydrogen is not like traditional fuels which can be mined or drilled out of the ground. It is not a primary energy source. Rather, like electricity, hydrogen is an energy carrier that has to be manufactured, by splitting it out of the compounds in which it occurs naturally such as water and natural gas. Hydrogen's advantage is that it can be produced from a range of sources to suit what is most accessible or available locally. As with electricity, if the hydrogen is made from fossil fuels then significant amounts of pollution will still be released into the atmosphere. Only hydrogen from renewable energy sources offers a truly sustainable and carbon free option.

Hydrogen must be either liquefied or compressed to reach the energy densities needed by road vehicles. Liquefaction uses the equivalent of 25% of the energy stored. More efficient ways of storing hydrogen, such as metal hydrides, are being developed but they still store less energy per unit volume than petrol or diesel.

Methanol vehicles

Methanol is an alcohol fuel mainly derived from natural gas in production plants. Methanol can be used as a primary fuel (usually blended with up to 15% petrol) in vehicles designed or modified for its usage. Vehicle manufacturers withdrew vehicles that could accommodate both petrol and methanol from the market about 5 years ago following corrosion problems. There is some commercial interest in developing a fuel cell directly run on methanol. There are, however, serious safety issues associated with methanol – it is toxic to humans if ingested or absorbed through the skin (SMMT, 2002) – which is likely to limit its usage as a road fuel.

4.0. PATHWAYS TO 2005

The Government's Powering Future Vehicles draft strategy suggests that in the coming years the principal driver for cleaner vehicle policy will be to reduce the CO_2 emissions from road transport. As more Euro IV petrol and fuel efficient diesel cars enter the UK market, both the air quality and CO_2 advantage of LPG will be eroded. In the period to 2005, vehicle manufacturers and fuel suppliers are expected to increasingly focus their resources on developing new and emerging low carbon fuels and technologies.

4.1. LPG vehicles

When the PowerShift programme was established in 1996, there was a clear air quality and greenhouse gas advantage to be obtained from using LPG compared with petrol cars. Since then the emissions performance of both petrol and diesel cars have significantly improved. European standards for tailpipe emissions of regulated air pollutants (often referred to as the Euro standards) have led to progressive reductions in vehicle air pollution. The Euro IV standard for petrol cars comes into force on the 1st January 2006, although some car manufacturers have already started to sell Euro IV petrol cars. Even the latest technology LPG cars will only offer a limited margin in terms of NOx emissions compared with the ultra clean Euro IV petrol cars (EST/DTLR, 2001). LPG is likely to retain some air quality benefit in terms of NOx and particulates relative to diesel cars. But, the substantial air quality benefits offered by LPG cars 10 years ago appear increasingly marginal.

The carbon benefits of LPG cars depend upon the lower carbon content of the fuel and the higher octane rating. Both of these are relatively minor and so the carbon benefits are limited. The well-to-wheel CO_2 benefit of a LPG car is typically around 11% compared to a petrol car. But there are no CO_2 savings compared to diesel cars that are more efficient at converting the energy contained in the fuel to motive power. There is also no current technical way of introducing fuel efficient technologies, such as direct injection systems, for LPG cars.

COMPARISON OF THE WELL-TO-WHEEL CO_2 EMISSIONS FOR A LPG, PETROL AND DIESEL CAR

Source: Cleaner Vehicles Task Force, 2000

Currently, the LPG market is almost entirely for after-market conversions whereby petrol vehicles are converted to run on LPG after they have come off the production line. These conversions differ widely in terms of their emissions performance with typical good quality conversions costing between

£1000–£2000. The PowerShift programme will provide a grant towards the conversion cost. The PowerShift Register ensures that only approved conversions benefit from a PowerShift grant. But failing to regulate conversions that do not benefit from a PowerShift grant is producing large numbers of poor quality LPG vehicles. This has been a particular problem in rural north and mid Wales where there are no PowerShift approved converters.

4.1.1. The market transformation effects for LPG

The market for LPG cars and other light duty vehicles has been growing strongly. There are currently around 55,000 LPG vehicles on the roads (of which 10,000 were supported with PowerShift grants).

In the last year, the LPG market has started to take off largely because of investments by fuel suppliers in LPG refuelling points. At the end of 2001, the number of LPG refuelling points had risen to over 1000. In the UK, there are around 13,000 petrol and diesel refuelling sites and so this constitutes nearly 8% coverage. However, virtually all LPG vehicles are bi-fuelled which means they are not fully dependent on this network and can also refuel at petrol forecourts when access to LPG fuel is limited.

LPG refuelling coverage still needs to be improved especially within inner city areas and remote, rural areas if people are to take advantage of the lower duty on LPG fuel which the Government has pledged to maintain until 2004. The Minister for Energy, Brian Wilson, recently announced an additional £1 million for the PowerShift programme (from the DTI Boost Fund) for helping people in rural Scotland, Wales and East Anglia gain access to cheaper LPG fuel. But, the market is already well on its way to becoming self sustaining with an increasing number of LPG vehicles being purchased without any form of subsidy.

Whilst LPG has the attraction of being one of the less well utilised parts of the average oil barrel, its development as a vehicle fuel will be limited by supply constraints. Although LPG could be imported its global penetration will be restricted to around 5% relative to the petrol and diesel powered share of the vehicle fleet.

4.2. Natural gas vehicles

There are only a few hundred CNG and LNG vehicles in use within the UK. The majority of these are heavy duty vehicles. This is largely because:

- The fuel tanks required to give dedicated natural gas vehicles sufficient range carry a significant weight and volume penalty.
- Natural gas refuelling facilities are expensive – between £0.25 million for slow fill and £1 million for fast fill CNG sites.

In Germany, the Federal Government has invested in the development of natural gas bus trials in air pollution hot spots. The CleanUp programme has identified that there are more cost effective ways of reducing the particulate and hydrocarbon emissions from buses through the application of pollution abatement technologies, such as end of pipe particulate traps. As a rule of thumb, a particulate trap can improve particulate emissions by two Euro standards. However, particulate traps cannot tackle NOx emissions and so natural gas vehicles still have a NOx advantage.

The use of cleaner diesel fuels, such as water emulsion diesel, also offers a relatively cost effective means of improving air quality. Current trials with buses have shown that mixing up to 12% water content with diesel can achieve a 12% reduction in both tailpipe NOx and particulate emissions.

Natural gas vehicles can achieve a 10–12% improvement in tailpipe CO_2 emissions over diesel vehicles. The high costs of widespread investment in natural gas refuelling facilities suggest that, in the coming years, natural gas will be most suited to heavy duty lorries and large delivery vehicles. Large delivery vehicles powered by natural gas have the attraction of being very quiet and therefore ideal for overnight deliveries.

4.3. The prospects for biofuels

The only biofuel likely to make a short term contribution to UK transport fuels is biodiesel. This is largely derived from rape seed oil, but may be made from a number of sources, including wastes. However, none offers the UK resource base to provide more than a very small fraction of transport energy demand. At best, biodiesel will become a niche fuel.

The extent of carbon reduction achieved using biodiesel depends on the fossil fuel input to fuel production and transport. This is generally estimated to be in the range of 25–50% of the energy output. Biodiesel is therefore effectively a low, but not zero, carbon fuel.

The role of biomass in reducing carbon emissions requires other potential uses of biomass energy (heat and power) to be considered. In general, better carbon reduction benefits (per unit area of land under biomass) are achieved by growing higher yielding crops than rape seed. At present high yield crops are not used to manufacture liquid fuels. In the longer term, this might be possible provided the technology can be developed to convert woody biomass and wastes into liquid transport fuels.

4.4. Will there always be a trade off between air quality and greenhouse gas emissions?

In the last year, there has been a shift towards CO_2 based vehicle taxation with both Vehicle Excise Duty (VED) and Company Car Tax now graduated according to CO_2 emissions. The aim of the Government's Powering Future Vehicles draft strategy is to develop policies that support 'low carbon' vehicles. But this all implies that the air pollution created by road vehicles will be addressed by other means. As it currently stands, many urban areas are not expected to meet the 2004/5 air quality objectives set out in the Government's National Air Quality Strategy particularly the objectives for particulate matter and NO_2.

In the coming years, diesel will compete with petrol for an equal, if not higher, share of the vehicle fuel market. Whilst current diesel engines continue to become more fuel efficient and hence lower carbon, they still possess an air quality penalty. Advances in NOx catalysts and particulate traps for both cars and buses offer a means of reducing this penalty. For maximum performance, however, they require fuels with a very low sulphur content such as 10 parts per million (ppm). Since 1997, HM Treasury has provided a fuel duty incentive for Ultra Low Sulphur Diesel (ULSD) which has a sulphur content of 50 ppm. It now accounts for virtually all the diesel consumed by road vehicles. With appropriate fiscal incentives fuel suppliers could be encouraged to also introduce 10 ppm low sulphur fuel in the UK.

The air pollution from road vehicles will continue to be a concern for policy makers. There are still many unanswered questions about the health implications of air pollutants. But, in the coming years the extension of existing mandatory Euro Standards, beyond Euro IV, will deliver significant reductions in air pollution created by vehicles. In the next few decades, the greatest challenge for vehicle manufacturers, fuel suppliers and Governments will be to reduce the CO_2 emissions from road transport. The leading options for lower carbon vehicles, hybrids and fuel cells, also offer the prospect of significant air quality benefits. Hence the growing policy interest in the transition to 'low carbon' vehicles is both timely and critical. It is expected that there will be synergies rather than conflicts between climate change and air quality objectives.

4.5. Recommendations for 2005

- The market in LPG vehicle conversions that do not benefit from a PowerShift grant remains unregulated. An accreditation scheme for all LPG vehicle conversions should be developed based on the existing PowerShift Register for approved conversions.
- The Euro IV standard for petrol cars officially comes into force on the 1st January 2006, although car manufacturers have already started to introduce cars with an emissions performance equivalent to Euro IV standard. Once Euro IV petrol cars become established within the UK market, the Government should review its position on LPG. The sustained provision of PowerShift grants is unlikely to be necessary as the LPG market is already becoming increasingly self sustaining. But, this does not mean support for LPG should be withdrawn altogether. Government could continue to maintain a fuel duty differential for LPG. Public authorities could also provide an incentive for LPG vehicles by allowing them access to future Low Emissions Zones that prohibit certain vehicles from entering areas where air quality is poor.
- The CleanUp programme should continue to provide grants for converting engines to run on natural gas or for fitting emissions abatement equipment. It should be left to fleet managers and bus operators to decide on the most cost effective way of reducing air pollution and greenhouse gas emissions.
- 10 ppm low sulphur fuel should receive a higher fuel duty differential than ULSD (50 ppm sulphur fuel) as it will aid the introduction of advanced particulate traps and NOx catalyst technologies. Trials of water emulsion diesel should be extended and, if they prove successful, the Government should consider using fuel duty incentives to encourage its more widespread use.
- A great deal of research into different biofuel options has already been conducted. But there is a case for further work to help develop woody crops as a vehicle fuel, which could potentially offer high carbon benefits in the longer term.

- The 2002 Spending Review (which will determine Government expenditure for the period 2003–2006) should allocate funds for the development of low carbon vehicle fuels and technologies in line with meeting the objectives of the Government's Powering Future Vehicles Strategy. (The opportunities for new and emerging low carbon vehicle fuels and technologies are discussed in the following Pathways to 2010 and 2020 sections).

5.0. PATHWAYS TO 2010

In the coming years, a new generation of low carbon vehicle fuels and technologies could start to make their mark. The period to 2010 is likely to see the progressive 'electrification' of the vehicle. Improvements in the energy efficiency of vehicles, through the use of hybrid-electric technologies and lightweight aluminium body designs, are likely to deliver significant carbon savings.

Despite the excitement about hydrogen cars today, it is not expected that they will have a significant impact on the UK car market until there is an adequate public hydrogen refuelling infrastructure. Rather there is an opportunity for Government to support the use of hydrogen in the bus market first. In the period to 2010, the introduction of a small number of hydrogen fuel cell buses provides an opportunity to learn from the application of hydrogen fuel cells and hydrogen production technologies.

5.1. The electrification of the car

5.1.1. Battery-electric cars

The electric car was the original concept for a zero emission car. TransportAction is currently supporting the demonstration of 15 TH!NK electric cars in London powered by renewable electricity and is now supporting a similar demonstration in Edinburgh with funds from the Scottish Executive. But, despite decades of battery development, the limited range and long re-charging times of electric cars mean they remain a long way from meeting consumer expectations. For example, the Peugeot 106 electric car has a maximum speed of 56 mph, a range of 45 miles and a re-charging time of 6 hours. Further advances in lead acid and lithium-ion batteries have the potential to reduce re-charging times, but it is widely expected that electric cars will remain confined to niche markets such as special purpose vehicles and delivery fleets in inner city areas.

Outside niche markets, the future of the electric car does not appear optimistic, but it cannot be discounted altogether. If a breakthrough in the performance of battery technologies occurred at some future point, then there is no reason why the prospects for electric cars could not be just as good as hydrogen cars. As with hydrogen, if the electricity is produced from renewable energy sources then the carbon savings would be high.

5.2. Hybrid cars

Struggles with the development of dedicated battery cars, have led car manufacturers to divert their efforts towards developing hybrid technologies. Hybrid cars combine an electric battery with the power and performance of a conventional engine. The two main types of hybrid engine-electric motor configuration are the:

1. Fully fledged hybrid

In town and city environments, fully fledged hybrids will automatically switch to their zero emission battery in stop-start driving conditions. Fully fledged hybrids have the potential to significantly improve fuel efficiency and hence reduce CO_2 emissions. For long distance or motorway driving, the CO_2 benefit is reduced as the hybrid car will predominantly rely on its conventional engine. But this is balanced by the significant amount of stop-start driving vehicles do in urban and city areas.

2. Mild hybrid

Mild hybrids are much simpler in design. The electric motor is only used to power the vehicle during start up. During normal driving conditions the vehicle is propelled by its engine. Mild hybrids cannot offer as high fuel efficiencies and hence CO_2 savings as fully fledged hybrids, but they can improve tailpipe CO_2 emissions by up to 15%.

5.2.1. Petrol hybrid cars

The hybrid cars currently on sale run on petrol. In the UK there are only two hybrid petrol models commercially available – the Toyota Prius and the Honda Insight. Both are based on the fully fledged hybrid configuration. The Prius is a family sized, 5 door car which offers a 30% saving in tailpipe CO_2 emissions compared to its equivalent conventional petrol car. The Insight is a two seat, micro car with lightweight aluminium structures that significantly reduce fuel consumption. The Insight offers a 30% saving in tailpipe CO_2 emissions compared to an equivalent car such as the micro Smart petrol car. In the coming years, further car manufacturers are expected to enter the petrol hybrid car market.

The current market leader is the Prius. At the end of 2001, sales of the Prius reached 55,000 worldwide. Despite only being launched in Japan in 1997 it has already sold double the number of electric cars worldwide over the last decade.

Whilst the growth of the LPG car market has been closely linked to the growth in the number of LPG refuelling sites, petrol hybrid cars have the advantage of being able to refuel at any petrol forecourt thus enabling them to be introduced at no extra infrastructure cost. The principal barrier to the take up of petrol hybrid cars will therefore be their price premium. Hybrid cars are more expensive to manufacture because they are technically complex, accommodating both electric motor and conventional engine technologies. The Prius currently has a price premium of about £3000. 660 Prius cars were sold in the UK in 2001 which is the lion’s share of European sales. The sales of these cars were supported by a £1000 Government grant, administered as part of the PowerShift programme.

When this £1000 subsidy is added to the fuel savings achieved by the Prius, the £3000 cost differential is reduced but it remains a significant price barrier.

Car type	Distance per year	Annual fuel saving
Private car	16,000 km	£305
Company car	32,000 km in first 3 years	£610

5.2.2. How could PowerShift grants transform the market for petrol hybrid cars in the period to 2010?

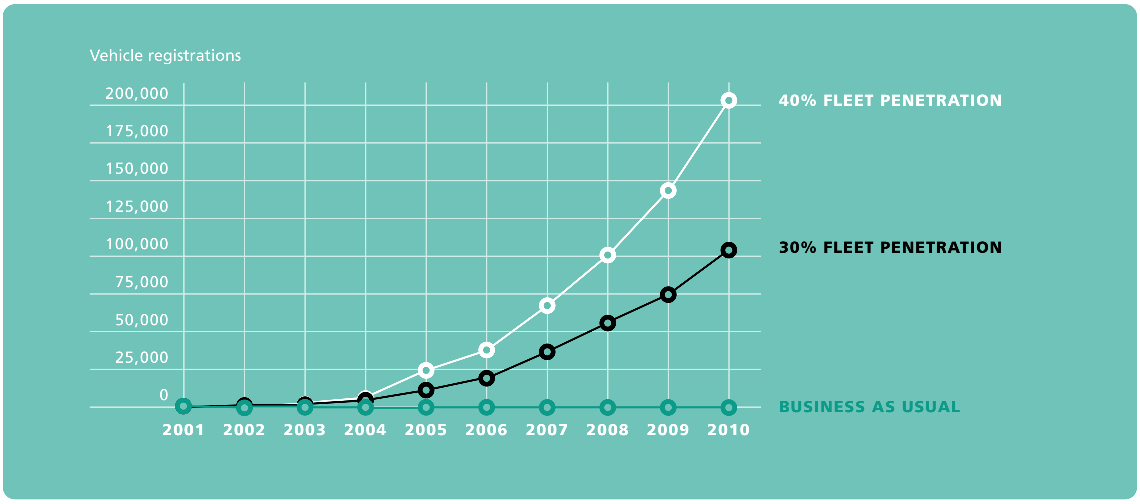
EST commissioned a modelling study[2] to examine the impact that the PowerShift programme could have on the petrol hybrid market in the UK. The model is based on the Prius car as it reflects the typical type of car purchased by a consumer or company car fleet operator. It therefore assumes a 30% saving in tailpipe CO_2 emissions.

The model also assumes that a PowerShift grant of £1000 per vehicle will continue to be provided until 2005, when it will be lowered to £800 per vehicle. From 2006 to 2010 the grant per vehicle is again lowered to £500. Because the growth of the petrol hybrid car market is not limited by fuel availability, it will be highly sensitive to changes in vehicle availability. The fleet penetration of petrol hybrid cars is difficult to forecast because Prius sales in the UK only date back to 1999. The model therefore examines two possible fleet penetration scenarios: a conservative scenario and a more optimistic scenario:

PowerShift Scenario 1: a conservative scenario. With these above assumptions, by 2010:

- A total of about 200,000 petrol hybrid cars could have entered the UK market. In the year 2010, about 5% of all new car registrations could be for a petrol hybrid car.
- The cumulative emissions avoided could be around 0.9 million tonnes of carbon.
- The total PowerShift spend could be around £164 million in the period to 2010.

THE IMPACT OF POWERSHIFT GRANTS ON THE PETROL HYBRID CAR



The Business As Usual scenario assumes a 10% increase in the fleet penetration of petrol hybrid cars.

PowerShift Scenario 2: a more optimistic scenario. With the above assumptions, by 2010:

- A total of about 370,000 petrol hybrid cars could have entered the UK market. In the year 2010, about 10% of all new car registrations could be for a petrol hybrid car.
- The cumulative emissions avoided could be around 1.8 million tonnes of carbon.
- The total PowerShift spend could be around £307 million in the period to 2010.

2. See appendix 9.1 for the detailed modelling results and the assumptions behind the model.

The costs of any Government subsidy programme will be very sensitive to the grant level, especially in later years when market penetration is highest. There is a need to ensure that PowerShift grants are sufficient to provide an incentive when the market is underdeveloped without placing unnecessary strain on public finances when the market is more bouyant.

Whilst the modelling is based on the attributes of the Prius model it indicates what impact PowerShift grants could have in helping to transform the market for hybrid car technologies more generally.

5.2.3. Expected developments in hybrid car technologies

In the coming years, there is likely to be considerable diversification in the types of hybrid configurations being developed. The above modelling, based on the petrol hybrid Prius car, is therefore only a snapshot of the carbon savings that hybrid cars could achieve in 2010. Hybrid technologies are also being developed for diesel cars. Adding diesel's advantage in fuel efficiency to the hybrid configuration is expected to deliver even lower carbon emissions than petrol hybrid cars. But, diesel hybrid cars will require additional advanced after-treatment systems for reducing NOx and particulate emissions. They will therefore carry a larger price premium than petrol hybrids when first introduced.

It is difficult to predict the fuel economy, and hence CO_2 savings, that future hybrid cars could achieve. This is because existing models and prototypes incorporate other vehicle features (such as lightweight structures) which are not integral to the hybrid technology and could be applied to comparable vehicles of any other fuel or engine type to equally good effect (Fergusson, 2001). But, it is widely thought that hybrid technologies are capable of doubling the fuel economy and halving the CO_2 emissions of an average sized petrol engine.

It is therefore important to account for the potential and expected advancements in hybrid technologies both for petrol and diesel car engines when developing public policy.

5.3. Hybrid taxis and small delivery vehicles

The amount of private investment going into the development of hybrids suggests they have the versatility to become the next generation technology not only for cars but also the wider light duty vehicle market. For example, the single most important influence on the buying behaviour of taxi owner-drivers is fuel costs. Hybrids should offer particularly attractive fuel efficiency benefits in stop–start driving conditions which tend to characterise inner city operations. The fuel efficiencies offered by hybrid technologies therefore suggest that taxis would provide a captive market for their application.

5.4. Diesel hybrid buses

The development of hybrid technologies for larger diesel vehicles, such as buses, is less advanced than that of lighter duty vehicles. Diesel hybrid buses would be ideal for city and urban driving conditions because they could run on their zero emission electric battery in congested traffic. Diesel hybrid buses are still largely in demonstration. As a consequence, data on their carbon performance is patchy, variable and therefore difficult to validate. Diesel hybrid bus demonstrations are showing at least a 30% improvement in tailpipe CO_2 emissions. But, they could be expected to achieve as much as a 50% improvement in tailpipe CO_2 emissions.

The cost of a diesel hybrid bus is currently double that of a conventional bus. As with hybrid cars, the availability of PowerShift type grants could help to bring the price premium down quickly. Diesel hybrid buses are also likely to be attractive to bus operators as their higher fuel efficiencies will reduce their running costs. In the UK, the Wright Bus Group plan on developing a production line diesel hybrid bus by the end of the year.

5.5. Hybrid technologies: a stepping stone or merely a cul-de-sac?

Even the most robust advocates of internal combustion engine hybrid car technologies expect that in time they will be surpassed by something better – most probably hydrogen fuel cells. This has led some market analysts to suggest that the development of hybrid technologies could lead to a cul-de-sac and divert attention and resources away from the advancement of hydrogen vehicles. It is far more likely that the development of hybrid technologies will aid the learning necessary to ease the development and commercialisation of hydrogen fuel cell vehicles. Improvements to electronic control systems and electric drive trains, for example, are all vital elements of the progressive electrification of the motor vehicle from which hydrogen fuel cell technologies will benefit (Fergusson, 2001). In the Summer of 2003, Toyota will be launching a fuel cell hybrid vehicle in Tokyo which incorporates a fuel cell and a battery to ensure a constant supply of electrical power. It is therefore more logical to conclude that hybrid vehicles will provide a necessary stepping stone between the fossil fuel cars of today and the hydrogen vehicles of tomorrow.

In any event, the option of zero carbon hydrogen vehicles is decades away, as zero carbon hydrogen will require major changes to energy infrastructure – such as substantially expanding electricity resourced from renewable energy sources. In contrast fossil fuel hybrids are a demonstrated technology and can deliver substantial carbon savings through improved energy efficiency in the period to 2010 (IEA, 2000 and MIT, 2000). There is therefore no case for neglecting the realisable benefits of hybrids because of possible longer term options.

5.6. Kick starting the hydrogen option with buses

In the longer term, energy efficient vehicles alone will not be sufficient in delivering carbon reductions on the scale likely to be needed to prevent dangerous climate change (IEA, 2000 and PIU, 2000). However, new low carbon fuel infrastructure will take many years to develop. Even though the future of hydrogen is uncertain, early steps are needed if it is to be opened up as an option for the future.

Government interventions should seek to minimise costs by supporting the most appropriate niche markets. Buses are widely expected to be the starting point for the development of hydrogen refuelling infrastructure for road vehicles. Buses are good candidates for hydrogen because they refuel at depots and have fixed routes. In contrast to private vehicles they therefore do not require a seamless refuelling network. Also, refuelling can be supervised by specialist staff and can take place overnight if necessary.

Current compressed gaseous hydrogen storage technology provides adequate range for buses, and they can achieve high fuel efficiencies comparable to that of diesel hybrid buses.

5.6.1. The prospects for hydrogen fuel cell buses

Thirty buses, based on the DaimlerChrysler 'Citaro' model design, will be piloted throughout Europe as part of the Clean Urban Transport for Europe (CUTE) project. Three of these buses will be operated in London between 2003 and 2005. They are being part subsidised by the Government's New Vehicle Technology Fund worth £9 million. The Californian authorities have introduced a Zero Emission Bus (ZEBUS) mandate requiring that 15% of all new bus purchases in California are for zero emission buses by 2008. Hydrogen fuel cell buses will play a key role in complying with this mandate.

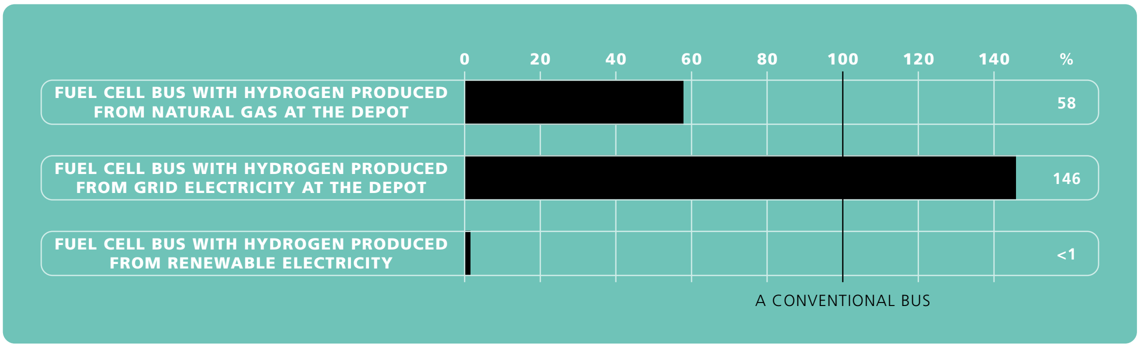
The prototype hydrogen fuel cell buses currently available cost £995,000 which is nearly ten times the price of a conventional diesel bus. International policy measures, such as the California ZEBUS mandate, will help to drive down their costs. In the period to 2010, the Government should also have a role in helping to create a market for their development, otherwise there is a risk that hydrogen fuel cell buses will remain permanently relegated to demonstration projects.

5.6.2. Developing hydrogen production and refuelling facilities at bus depots

The very first hydrogen production and refuelling facilities are likely to be expensive as large amounts of skilled labour and time will be required. The infrastructure costs for the three hydrogen buses being operated in London, as part of the CUTE project, is around £0.5 million. However, as with the introduction of any new technology the costs could be expected to fall quickly will increased application.

The most cost effective way of producing hydrogen today is from natural gas using 'reformer' technologies. Natural gas produces less CO_2 per unit of hydrogen compared to coal or oil. Natural gas is currently responsible for 48% of global hydrogen production (IEA, 2000). In the early stages of a hydrogen bus market, natural gas is likely to be the preferred source of hydrogen.

COMPARISON OF THE WELL-TO-WHEEL CO_2 PERFORMANCE OF HYDROGEN FUEL CELL BUS OPTIONS MEASURED AGAINST A CONVENTIONAL DIESEL BUS



Source: Hart, 2002

All hydrogen fuel cell buses create no tailpipe pollution. But this does not account for pollution created in the transportation and production of the fuel. The above graph therefore shows the well-to-wheel CO_2 performance of various hydrogen fuel cell bus options compared to a diesel bus.

Hydrogen can also be produced by electrolysis whereby water molecules are split by electricity to derive their hydrogen atoms. Using 'electrolyser' technologies with grid electricity is currently a relatively high CO_2 option, because the UK electricity mix remains largely dependent on fossil fuel based sources of power. But the long term benefits of introducing what is likely to be a small number of hydrogen fuel cell buses that use grid electricity suggest the short term trade offs would be worthwhile. This is because developing electrolyser technologies, for producing hydrogen from electricity, will provide a stepping stone for introducing other forms of greener electricity derived from renewable energy sources (as described in section 6.4).

5.7. National targets for 2010

California is renowned for having introduced cleaner vehicle mandates to help reduce traffic pollution. The mandates have played an important role in the rapid development of low carbon fuels and technologies within the state. The current Government prefers to work in partnership with industry in achieving shared environmental targets. The LPG car market is a good illustration of how Government regulation is not always necessary. The combination of PowerShift grants, fuel duty incentives and partnership working with vehicle manufacturers and fuel suppliers has been effective in transforming the market for LPG cars in the UK.

The PIU Energy Policy Review (2002) states that the role of a target should be to "provide an obvious means of focusing both policy makers' and market participants' attention on areas where new policy measures may be required or existing ones adjusted. In doing so, it should also provide a focus for innovation at a time when clearer market support is premature, and help to stimulate a modest amount of investment, especially in R&D."

Low carbon vehicle targets should not be viewed as 'sticks' and should be backed up by Government incentives and subsidies to ensure their achievement.

The purpose of a low carbon vehicle target should be to:

Drive forward innovation in the development of low carbon vehicle fuels and technologies

5.7.1. Characteristics of low carbon vehicle targets

EST recommends that the Government develop a low carbon vehicle target in terms of:

A CO_2 emission standard rather than a specific fuel or technology to ensure that no low carbon option is ruled out.

A well-to-wheel CO_2 emission standard[3] that not only accounts for the tailpipe emissions but also the emissions created in the transportation and upstream production of the fuel.

A well-to-wheel CO_2 emission standard would ensure that:

- Both the vehicle manufacturing and fuel supply industries play a role in the transition to low carbon vehicles, and in turn both benefit from Government incentives and subsidies.

3. There is no standard way of measuring well-to-wheel CO_2 vehicle emissions. As part of joint industry initiative, involving major vehicle manufacturers and fuel suppliers, a study of the well-to-wheel CO_2 performance of various European vehicle options will be published in April 2002 by the US Argonne Laboratory. It will provide a useful source of information for policy makers.

- Fuel suppliers are given confidence to invest in the technologies and infrastructure needed to support the introduction of new low carbon fuels, such as hydrogen, in the longer term.

5.7.2. Setting a national target for low carbon cars

The Powering Future Vehicles draft strategy (2002) proposes that 8–12% of new car sales could be low carbon within the decade. But, it does not define a 'low carbon' car and this needs to be done to make clear what kinds of emission reductions the car and fuel industry should be working towards.

The European car industry has made a voluntary agreement to reduce tailpipe CO_2 emissions from the new car fleet to an average of 140 g/km by 2008 (equivalent to a 25% reduction). In well-to-wheel emissions this is around 160 g/km of CO_2 for petrol and diesel cars. About 15% of well-to-wheel emissions come from the transportation and upstream production of the fuel – what is often referred to as the 'well-to-tank' emissions (MIT, 2000)[4]. The European voluntary agreement is therefore expected to have a significant impact on improving the CO_2 performance of the new car fleet.

SMMT data suggests the European car industry is currently on track to meet the voluntary agreement by 2008. Over the past few years, CO_2 levels across the distribution of the new car fleet have steadily fallen[5]. Cars achieving under 140 g/km in tailpipe CO_2 emissions rose to 10.2% in 2001, from 8.2% in 2000 and less than 4% in 1997.

It is expected that the voluntary agreement will require the continued displacement of petrol cars by more fuel efficient diesel cars. But it will also require the introduction of more:

	Example	Tailpipe CO_2 emissions	Well-to-wheel CO_2 emissions[6]
Smaller sized diesel cars	Audi A2 (diesel)	116 g/km	134 g/km
	Ford Fiesta (diesel)	120 g/km	138 g/km
Smaller sized petrol cars	Daihatsu Cuore (petrol)	124 g/km	143 g/km
Micro cars with energy efficient, light weight body designs	Smart (petrol)	118 g/km	136 g/km
	Smart (diesel)	90 g/km	104 g/km
Energy efficient, family sized cars	Prius (petrol hybrid)	120 g/km	138 g/km

There would be no added value in Government setting a target for low carbon cars based on a standard that merely reflects the CO_2 savings that new cars could be expected to achieve as part of meeting the European voluntary agreement. It is hoped additional policy measures, such as labelling, fuel and vehicle taxation, will extend the effect of the voluntary commitment to 120 g/km tailpipe CO_2 emissions (which is 138 g/km in well-to-wheel CO_2 emissions).

4. A recent study by the Massachusetts Institute of Technology (MIT) revealed that, on average, well-to-tank emissions account for about 15% of the total well-to-wheel emissions from conventional petrol and diesel engines.

5. See appendix 9.2 for how the CO_2 distribution of new car registrations in the UK has altered between 1997 and 2001 (based on SMMT data).

6. Well-to-wheel CO_2 emissions have been calculated from VCA (2001) tailpipe data. The well-to-tank emissions are assumed to account for 15% of the total well-to-wheel emissions.

EST therefore proposes that the Government work in partnership with car manufacturers and fuel suppliers in striving for:

At least 10% of all new car sales in the UK to be low carbon by 2010.

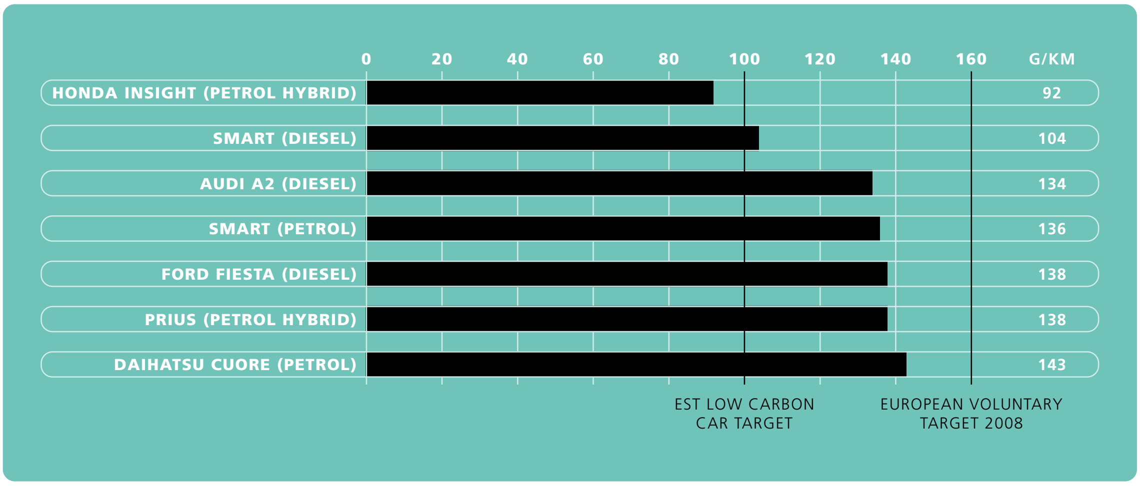
A 10% market share corresponds to approximately 200,000 car sales in the year 2010. If a 10% target is to be stretching but realistic then it is recommended that:

A low carbon car should be defined as: less than or equal to 100 g/km of CO_2 measured on a well-to-wheels basis.

By definition this would mean that vehicles using existing alternative fuels like LPG and CNG would be unlikely to be classified as low carbon. Rather, the purpose of a low carbon car target would be to drive forward innovation in low carbon car technologies beyond what is likely to be achieved by the European voluntary agreement.

The precise level of an innovation driving target is a matter of judgement. EST's assessment is that a standard much above 100 g/km would be insufficiently challenging and not consistent with the mass market trend implied by the European voluntary agreement. A standard much lower than 100 g/km, on the other hand, would risk being viewed as too difficult to engage industrial effort.

THE WELL-TO-WHEEL CO_2 PERFORMANCE OF CURRENT CAR TECHNOLOGIES



The Honda Insight achieves 92 g/km well-to-wheel CO_2 emissions, which demonstrates that there are already hybrid technologies on the market that would be classified as 'low carbon'. Other options that EST expects could potentially contribute towards a 2010 low carbon car target include future:

- Petrol hybrid engine-electric motor cars
- Diesel hybrid engine-electric motor cars
- Hybrid fuel cell-electric motor cars
- Hydrogen fuel cell cars
- Dedicated electric battery cars

- Biofuel powered cars
- Conventional, micro diesel cars with lightweight, fuel saving design features

Achieving a target for 10% of all new car sales in the UK to be low carbon by 2010 will require public investment of the type modelled in Section 5.2.2.

The cost to Government, in terms of PowerShift type spend, is likely to be a maximum of £100 million in the year 2010. The total spend over the period to 2010 is likely to be around £300 million.

The lifetime carbon savings should be around 1.4 million tonnes of carbon by 2010.

In the period to 2010, the market in low carbon cars, that achieve 100 g/km well-to-wheel CO_2 emissions, is likely to be a niche one. However, setting an ambitious low carbon car target would help to give industry confidence to invest in their longer term development so that significant carbon savings can be achieved within the next decade.

By 2020, carbon savings of approximately 7.5 million tonnes per year could be anticipated.

5.7.3. Developing low carbon taxi and small delivery vehicle schemes

In parallel with the target for low carbon cars, EST proposes that the Government work in partnership with taxi owner drivers, delivery fleet operators and fuel suppliers in developing:

Low carbon taxi and small delivery vehicle schemes in major UK cities by 2010.

The definition for a low carbon taxi or small delivery vehicle should broadly reflect that of a low carbon car but should allow for variations in delivery vehicle size.

5.7.4. Setting a national target for low carbon buses

Whilst there have been progressive improvements in the fuel efficiency and hence CO_2 emissions from new cars, there has been little improvement in the environmental performance of new buses. However, the relative size of the new bus fleet compared to the new car fleet suggests that low carbon fuels and technologies could have a much faster impact on the bus market. On average there are around 3000 new bus registrations[7] in the UK each year compared to around 2 million new car registrations (SMMT, 2001). There is therefore opportunity for also setting a target for low carbon buses for driving forward the development of low carbon technologies within the bus market.

EST proposes that the Government work in partnership with bus companies and fuel suppliers in striving for:

At least 25% of all new bus registrations in the UK to be low carbon by 2010.

It is difficult to set a standard for a low carbon bus because of the wide variation in bus types and sizes. Unlike cars, data on the CO_2 emissions of buses is not readily available. It will therefore be important that an agreed test cycle be used for all future low carbon buses. This should be readily applicable to all technologies, including hybrids, and reflect typical bus operating conditions.

7. This figure refers to purpose built buses and not coaches. It is difficult to forecast future bus registrations because of variations in, for example, scrapping rates. 3000 is the average number of new bus registrations between 1998 and 2001 based on SMMT data.

For the present, though, EST has based its **provisional** recommendation on data from London Buses[8] which may not necessarily be representative of the CO_2 emissions performance of buses throughout the UK. We also do not consider the whole range of bus sizes but just make a recommendation for a single and double decker bus. On the basis of the information available, it is recommended that:

A low carbon single decker bus should be defined as: less than or equal to 575 g/km of CO_2 measured on a well-to-wheels basis.

A low carbon double decker bus should be defined as: less than or equal to 1030 g/km of CO_2 measured on a well-to-wheels basis.

A well-to-wheel CO_2 emission standard of 575 g/km for a single decker bus and 1030 g/km for a double decker bus would ensure that every bus classified as low carbon achieves a CO_2 saving of at least 30% compared to its current equivalent diesel bus. However **the definition for a low carbon bus should be reviewed when more data on the CO_2 performance of new and emerging low carbon bus technologies becomes available**. Diesel hybrid buses, for example, could potentially deliver as much as a 50% saving.

5.7.5. Keeping the hydrogen option open

As with the definition for a low carbon car, specifying a CO_2 emission standard for a low carbon bus enables Government to be technology neutral. Whilst a 25% target for low carbon buses would achieve significant carbon savings, it may do little to bring forward the use of new low carbon vehicle fuels such as hydrogen.

In the period to 2010, hydrogen fuel cell buses will not be the cheapest option for achieving carbon reductions. Diesel hybrid buses are likely to be much easier to introduce, as they will be significantly less expensive and require no new refuelling infrastructure. Without Government intervention, it is highly likely that the market will choose to fully deliver this target using diesel hybrid buses.

There is growing evidence to suggest that buses will be the starting point for the introduction of hydrogen vehicles. The development of a hydrogen refuelling infrastructure will take a very long time, but it is therefore prudent to get the hydrogen option in play as soon as possible. Within this decade, buses provide the least costly route for UK PLC to spend money on making some initial progress with the hydrogen option and therefore keeping it in play.

EST therefore recommends that, in tandem with the 25% target for low carbon buses, the Government should work in partnership with bus companies, hydrogen fuel cell companies and fuel suppliers in striving for between:

5–10% of all new bus registrations in the UK to be run on hydrogen fuel cells by 2010.

In practice, this would require the introduction of a small number of hydrogen fuel cell buses. In the year 2010, it would only mean the introduction of between 150 and 300 hydrogen fuel cell buses. But, it would provide an opportunity to demonstrate and develop hydrogen fuel cells and hydrogen production

8. Based on London Bus data, a conventional diesel double decker bus produces 1470 g/km CO_2 well-to-wheel emissions, whilst a single decker diesel bus produces 819 g/km CO_2 well-to-wheel emissions. The well-to-tank emissions are assumed to account for 15% of the total well-to-wheel emissions.

technologies. By setting a 2010 target for hydrogen fuel cell buses, Government would not be 'picking winners' but helping industry to keep open the option of developing hydrogen as a zero carbon transport fuel.

The long term costs of developing a low carbon economy are expected to be very large. Nevertheless, it is important that early steps are cost effective. The current price premium for a hydrogen fuel cell bus is approximately £800,000, but this is expected to fall as the market moves from early prototypes to niche production. The extent of cost reduction will depend on the scale of production within Europe and internationally. It seems very likely that the price premium will be less than £300,000 by 2010 although some estimates are as low as £50,000 (Hart, 2002). The size of any hydrogen bus subsidy programme should depend on the success of the industry in reducing costs, with the programme restricted to 5% of new bus registrations if costs do not fall towards the lower end of the projected range. On this basis:

The cost to Government, in terms of PowerShift type spend, is likely to range from £15 million to £45 million in the year 2010.

6.0. PATHWAYS TO 2020

By the end of 2020, an increasing number of new cars and buses are likely to be run on low carbon fuels and technologies. The challenge for policy makers will be to facilitate the transition to a zero carbon road transport system. The prospects for battery electric vehicles or even vehicles powered by fuel derived from woody biomass cannot be ruled out. But hydrogen currently appears to be the most promising option for eventually achieving the transition to a zero carbon road transport system.

Before hydrogen can be used as a mainstream vehicle fuel there will be many challenges to overcome. There are still technical barriers regarding the development of fuel cells and hydrogen storage technologies for vehicles. There is also no agreement on how a hydrogen refuelling infrastructure will develop and how much it will cost. Introducing hydrogen vehicles will therefore be dependent on co-ordination between industry and Government.

With Government support, the market in hydrogen buses and other larger, depot based hydrogen vehicles could begin to take off in the period to 2020. But, hydrogen cars are unlikely to have a major impact on the private car market until after 2020. In the period to 2020, hydrogen will remain dependent on fossil fuel based sources of power. On the basis of current and expected increases in renewable energy capacity it is not thought that production of renewable hydrogen could be a major option until after 2020.

In the period to 2020, cleaner vehicle policy will be driven not only by the need to reduce greenhouse gas emissions but also by increasing pressures on oil reserves. The attraction of hydrogen will be that it offers a potential solution to long term environmental and energy supply problems that will come into even sharper focus over the next couple of decades.

6.1. Hydrogen cars

The hydrogen car is often touted as being the car of the future. Hydrogen itself can be used in much the same way as a conventional fuel. But the key to hydrogen is that when used in either an adapted internal combustion engine or fuel cell car, absolutely no greenhouse gas emissions are created. A hydrogen internal combustion engine will create NOx emissions but it is widely expected that this could be reduced with NOx catalysts.

However, from the perspective of energy consumption the benefits of a hydrogen internal combustion engine are questionable as energy is lost both in manufacturing the hydrogen and storing it in the vehicle and then again by burning it in an inherently inefficient internal combustion engine.

Hydrogen fuel cells have the advantage of being much more energy efficient than conventional internal combustion engines. The prototype hydrogen fuel cell cars currently being developed achieve a fuel efficiency of about 40%. But, further fuel efficiencies may be possible as fuel cell technologies continue to develop.

BMW is currently the only car manufacturer leading the case for hydrogen internal combustion engine cars. The rest – including GM, Ford, DaimlerChrysler, Toyota and Honda – all have significant investments in hydrogen fuel cell cars.

A lot of development still needs to go into hydrogen fuel cell cars particularly in relation to on board hydrogen storage technologies. Currently, the tank required for on board storage of compressed hydrogen gas is too bulky to acceptably fit into the average car whilst liquefying the hydrogen takes a substantial amount of energy. However, concerns about hydrogen storage are probably not insurmountable. Ford, for example, is currently developing a hydrogen fuel cell car which it claims will store enough hydrogen on board to give it the same range as a conventional car.

Virtually every leading car manufacturer has made public statements claiming that they will have their own model of hydrogen car market ready in the next 3–5 years. It is unknown when hydrogen fuel cell cars will actually be available to buy in the showrooms across the UK. As with hybrid cars, fiscal incentives and PowerShift type grants could help to reduce their price premium when they are first introduced. But, car manufacturers are unlikely to take the risk of putting their hydrogen car models on even limited production lines until there is an adequate number of public places for hydrogen refuelling. The problem is that without sufficient demand for hydrogen fuel from road users, fuel suppliers are unlikely to take the risk of developing a hydrogen refuelling infrastructure. This is often referred to as the chicken and egg situation.

6.2. Developing a hydrogen vehicle infrastructure

The fact that hydrogen is not widely available poses perhaps the most significant obstacle to the widespread use of hydrogen as a vehicle fuel. A hydrogen refuelling infrastructure is often perceived to mean the development of a national hydrogen pipeline system that would have massive costs. But there is actually no consensus about how a hydrogen infrastructure should develop. There are several pathways which could avoid the costs and complications inherent in developing a centralised hydrogen refuelling system. The recent Institute for Public Policy Research (IPPR) report ‘H2: Driving the Future’ has already examined these various pathways in some depth. This section builds on that work.

6.2.1. The option of on board hydrogen production

A possible way around the infrastructure problem is to use reformers for producing hydrogen on board the car from an interim fuel such as methanol or petrol which are easier to handle and store. On board reformers bypass the need to deliver hydrogen to the vehicle in the first place. A number of car manufacturers, including DaimlerChrysler and General Motors, are testing the application of on board methanol and petrol reformers in conjunction with their fuel cell cars. There are a range of arguments for and against these two options for hydrogen reformers:

On board reformation of methanol

For

- In the short term, methanol production would not pose a problem because large plants for producing methanol already exist today.
- On board hydrogen production from methanol is a relatively simple process and can be achieved at relatively low temperatures.

Against

- Methanol refuelling would require quite significant changes to the current transportation fuel distribution and dispensing system. Methanol is far more corrosive than petrol and so a refuelling infrastructure would have to be developed in terms of new storage tanks, pipes and dispensing pumps.
- As just an interim step it would be difficult to justify, as the existing refuelling infrastructure would have to be changed twice – once to support methanol refuelling and again to support hydrogen refuelling.
- A number of vehicle and fuel companies have expressed safety concerns about the toxicity of methanol.
- Technologies for on board reformation of methanol may add to the weight and cost of the vehicle.

On board reformation of petrol

For

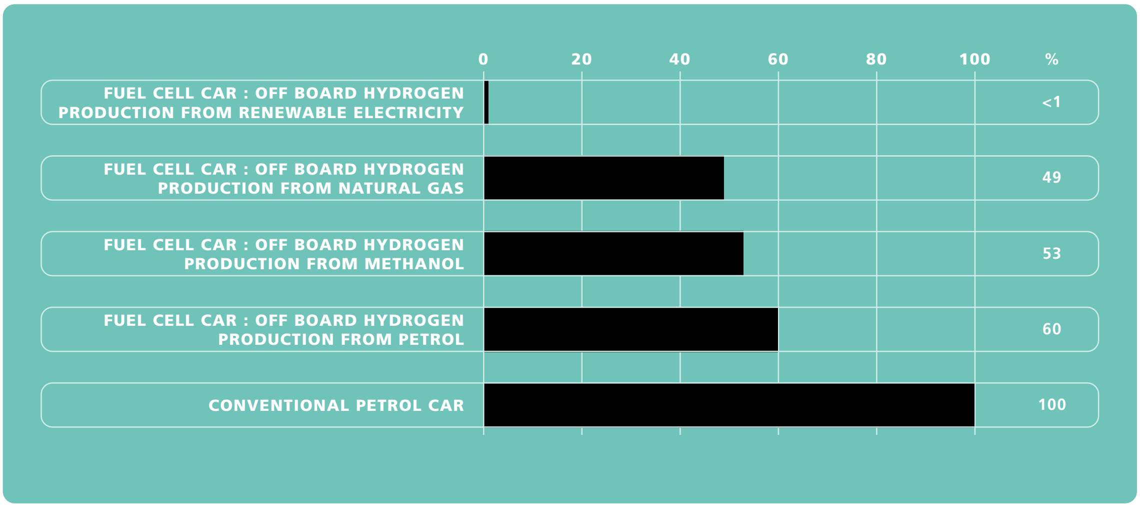
- Petrol is already widely available at forecourts across the UK.
- Using petrol to produce hydrogen would eliminate the problem of having to develop a new refuelling infrastructure.

Against

- Petrol that is virtually sulphur free would have to be used as fuel cells are easily damaged by impurities (although zero sulphur petrol, or very close to it, could be in wider use before the next decade).
- On board hydrogen production from petrol is a technically difficult process and can only be achieved at very high temperatures.
- The carbon savings are significantly lower than those from other fuel cell car options.
- Technologies for on board reformation of petrol may add to the weight and cost of the vehicle.

6.2.2. On board reformers – a costly distraction?

COMPARISON OF THE WELL-TO-WHEEL CO_2 PERFORMANCE OF VARIOUS FUEL CELL CAR OPTIONS MEASURED AGAINST A CONVENTIONAL PETROL CAR



Source: Shell, 2001

Hydrogen fuel holds out the promise of developing greater fuel diversity within road transport and increasing the proportion of energy supplied from low carbon energy sources and eventually zero carbon energy sources such as renewable energy. But the danger of going down the pathway of on board reformers is that:

- Vehicle manufacturers and fuel suppliers could get locked into technologies that are reliant on high carbon sources of hydrogen such as petrol.
- It could distract resources away from cleaner sources of hydrogen and delay the development of a zero carbon road transport system.

Assuming fuel cell cars are able to store hydrogen on board, then there appears to be little justification for on board reformers.

6.2.3. Developing a distributed hydrogen refuelling network

Perhaps the least costly route to direct hydrogen refuelling will be to produce the hydrogen locally from natural gas or electrolysis. Local hydrogen production has the advantage of:

- Producing hydrogen off board the vehicle which is much cleaner and more efficient than producing it on board the vehicle.
- Avoiding the costs associated with producing the hydrogen elsewhere and then having to transport it to hydrogen refuelling points throughout the UK via pipelines or large fleets of hydrogen tankers.
- Being able to tap into existing natural gas or electricity distribution networks for producing hydrogen locally such as at a refuelling depot. Investment would be needed in reformer and electrolyser technologies for producing and storing hydrogen locally. But as long as there is access to a natural gas or electricity supply, then hydrogen production and refuelling facilities could in theory be sited anywhere within a local area. Sites with compression facilities for producing CNG for road vehicles

might also be adapted to produce hydrogen on site. However, natural gas is already used for heating and electricity generation. Becoming too dependent on natural gas as a source of hydrogen could exacerbate energy security concerns associated with increasing imports of gas.

The development of a distributed hydrogen refuelling infrastructure fits in with how:

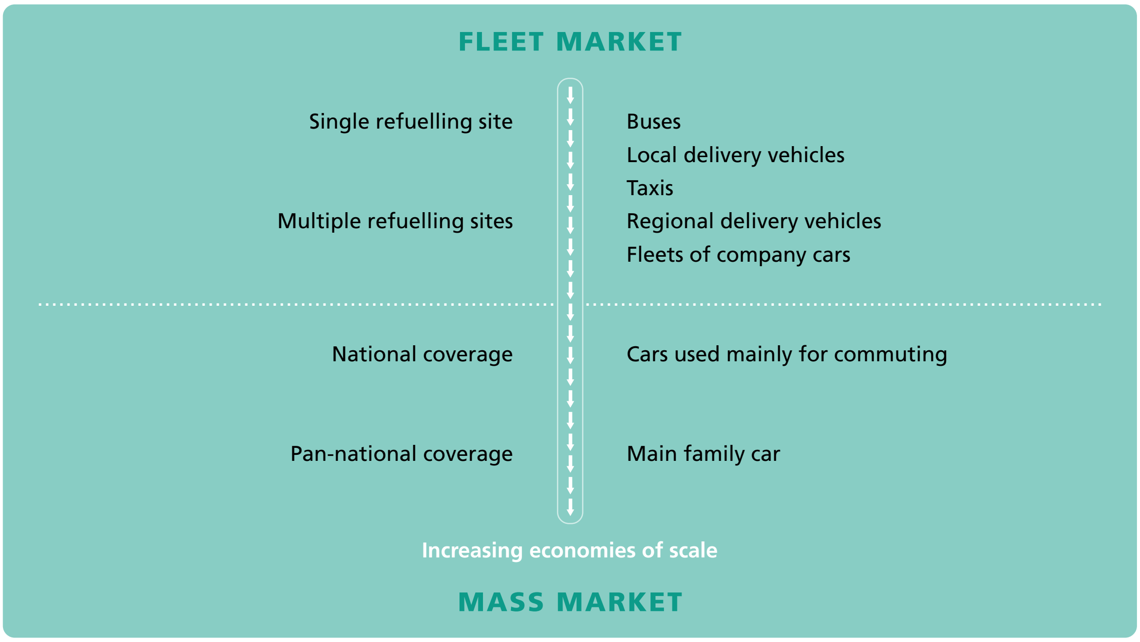
- The hydrogen vehicle market is expected to develop.
  As already discussed, in the pathways to 2010 section, the hydrogen vehicle market is expected to begin with buses followed by other fleet vehicles. Producing hydrogen locally would allow a hydrogen refuelling infrastructure to develop incrementally to reflect the pace at which the market grows. Facilities for hydrogen production and refuelling could be developed as and when bus operators or fleet managers choose to purchase hydrogen vehicles.
- The energy sector as a whole appears to be evolving.
  Within the energy sector the development of stationary fuel cells and micro Combined Heat and Power (CHP) units has raised interest in the provision of more efficient, reliable decentralised energy services. A number of energy supply companies already have commercial investments in the development of reformer technologies that could produce hydrogen to meet the needs of both buildings and vehicles within local areas. In the period to 2020 there is likely to be increasing synergy between the energy and transport markets.

6.3. A pathway from fleet markets to mass market

Experience from the introduction of other cleaner fuels has shown that it is easier to introduce a new fuel within the fleet market first. Once there is significant coverage of hydrogen refuelling facilities within a locality or region, depot based fleet operators are likely to be prepared to take the risk of purchasing large numbers of hydrogen vehicles. For a fleet operator, the fuel savings offered by hydrogen vehicles will make them attractive. As local hydrogen refuelling starts to develop, depot based fleet markets present the most promising market opportunity.

The private car market will be much harder to crack. When purchasing a new car a consumer is likely to be more swayed by aesthetic features rather than fuel savings, and is unlikely to accept the mobility restrictions imposed by limited hydrogen refuelling facilities. According to Shell (2001) hydrogen would need to be supplied to at least 25% of retail sites, before hydrogen cars could start to take off in a major way. It is for this reason that hydrogen is not expected to have a significant impact on the private car fleet until after 2020. But, in the period to 2020, company car fleets are likely to provide a route to developing the private car market.

THE POSSIBLE EVOLUTION FROM FLEET MARKETS TO MASS MARKET



6.4. The ultimate end point – a zero carbon road transport system

It has been reiterated several times above, that the ultimate end point is to develop a zero carbon road transport system. Producing hydrogen from zero carbon sources offers a means of achieving that end point. The two possible longer term options are:

1. To produce hydrogen from fossil fuels and sequester the CO_2

Hydrogen could be produced from a fossil fuel, such as natural gas, without CO_2 emissions through a process called 'CO_2 sequestration' where CO_2 emissions are stored in, for example, deep aquifers under the ground. But there are still questions regarding monitoring of such storage acquifers and concerns about leakage. Sequestering CO_2 emissions also requires large scale investments in new pipelines both for CO_2 disposal and transporting the hydrogen to local refuelling sites. Yet, as already identified, a hydrogen refuelling network is expected to first develop locally with depot based vehicles. The costs of CO_2 sequestration mean that its application is likely to be most viable for transport fuels when hydrogen starts to take off in the private car market.

2. To produce hydrogen from water using renewable electricity

Producing hydrogen from water using grid electricity is currently a relatively high CO_2 option. But it provides a stepping stone to developing the technologies and capabilities needed for eventually producing hydrogen from renewable electricity. If renewable hydrogen production is to become an economically viable option, the UK's renewable energy capacity will need to be substantially increased. It has been estimated that to produce hydrogen from wind electrolysis would currently cost nearly 3–4 times more than it would to produce hydrogen from fossil fuels such as natural gas. Producing hydrogen from solar electrolysis would be even more expensive (NREL, 1999). Although the costs could be expected to quickly fall as renewable technologies mature.

The Government has set a 10% target for renewable electricity by 2010. Even if this target is achieved, very little of this renewable electricity will be available for hydrogen production. The potential development of hydrogen vehicles therefore has implications for energy policy. To illustrate the implications of moving to the widespread production of hydrogen from renewable electricity:

> The current electricity demand for producing hydrogen for the entire UK road vehicle fleet would be around 300 TWh. This is almost as much as current electricity consumption. The PIU Energy Policy Review (2002) recommends a 20% target for electricity supplied by renewable energy sources in 2020. Even if all this renewable electricity were used for road vehicles, it would only make enough hydrogen to supply a quarter of the vehicle fleet.

If zero carbon hydrogen is to become a viable option then the Government's renewable electricity programme will need to go much further.

6.5. National targets for 2020

Beyond the end of this decade it is difficult to predict what vehicle technologies will be dominant in the market place. There is still so much uncertainty as to how a hydrogen refuelling infrastructure will develop that determining how quickly a hydrogen vehicle market could take off is even more difficult. EST therefore recommends that the Government set indicative targets for 2020.

Before the end of this decade, the Government should:

- **Review the progress of new and emerging low carbon vehicle technology developments and consider setting an 'ultra low carbon' target and standard for 2020.** The standard for an ultra low carbon car should deliver at least a 20% improvement on the standard for a low carbon car.
- **Consider extending the 2010 target for hydrogen fuel cell buses.**
- **Assess whether setting a hydrogen car target for 2020 would help to drive forward developments in hydrogen cars as well as hydrogen storage and production technologies.**

7.0. THE IMPLICATIONS FOR POLICY MAKERS

7.1. Supporting the transition to low carbon vehicles

There are three main phases where Government intervention is needed in the process of helping to get low carbon vehicles, which includes hydrogen vehicles, onto the roads:

1. Research and development: designing, developing and testing pre-competitive low carbon vehicle fuels and technologies.
2. Product development and commercialisation: getting new and emerging low carbon vehicle fuels and technologies to the market place.
3. Demonstration, market creation and accreditation: kick starting the market in low carbon vehicle fuels and technologies.

1. Research and development

To date, Government research funds for future vehicles have been limited. The Department of Trade and Industry's (DTI) Foresight Vehicle programme currently has a budget of £80 million for active and completed projects, of which around half comes from industry funding. The DTI's New and Renewable Energy programme supports some projects on fuel cell development, but there is currently no dedicated research programme for hydrogen. The Powering Future Vehicles draft strategy suggests a new R&D programme for hydrogen and other low carbon fuels and technologies. This would help to put the UK on par with other developed countries, like Germany, Japan, Canada and the US, which have been running Government funded research programmes on future vehicle fuels and technologies for some years.

The next Spending Review should make clear that this R&D programme will be funded by new money, rather than re-labelling of existing funding streams. It should also prioritise hydrogen over other low carbon fuels in recognition that this is where most of the pre-competitive research work is needed. If hydrogen is to become a mainstream road fuel then more research and development of, for example, fuel cell components and on board hydrogen storage technologies for smaller vehicles is needed. Any hydrogen vehicle research should:

- Set aside money for blue skies work by academia for designing and testing new hydrogen vehicle technologies.
- Also learn from the parallel development of fuel cells for stationary applications such as homes and offices.

The Government should seek to develop its R&D programme as a means of asserting the UK's position as a world leader in the research of hydrogen and other low carbon fuels and technologies. Where possible the Government should encourage joint research projects with other countries to share learning and avoid duplication of effort. The International Energy Agency (IEA) administers the Hydrogen Implementing Agreement which promotes technical exchanges between member countries and encourages joint research projects. This is just one example of how Government could take forward its research and development at an international level.

The Chief Scientific Advisor's Energy Research Review Group (2002) has recommended that the Government spend up to £400 million more each year on R&D of low carbon technologies for both stationary and transport applications.

2. Product development and commercialisation

Whilst more research and development needs to go into some hydrogen vehicle technologies, there are already low carbon vehicle products that are market ready or close to it. But there is a danger that without Government support, these vehicle and fuel developments will lose momentum on the way to market. For instance, even if an engineering company has a prototype hybrid taxi or delivery van a lot of capital investment will still need to go into the market development of its vehicles. The provision of enhanced capital allowances and venture capital funds or loans would help to reduce the risk to companies wishing to commercialise their products for the market place. Helping to bring new and emerging low carbon vehicle products to the market is likely to have wider benefits to UK PLC. It would help to:

- Avoid companies investing in the development of their low carbon vehicle products elsewhere to the detriment of the UK economy.
- Establish the UK as a base for the engineering and manufacturing of low carbon vehicle technologies which could support the creation of new job opportunities.

3. Demonstration, market creation and accreditation

When low carbon vehicles are first introduced, their viability will need to be tested through demonstrations. Low carbon vehicles will initially be significantly more costly than their conventional diesel or petrol counterparts. In the early stages of the market's development Government will have a role in incentivising private car buyers and fleet operators to purchase low carbon vehicles through the provision of PowerShift type grants. Where necessary, accreditation measures for low carbon vehicle technologies will also need to be employed.

In the period to 2020, hybrid technologies are likely to be the front runner in meeting low carbon vehicle targets. Because hybrid vehicles run on conventional fuels and can be refuelled at any petrol or diesel forecourt, PowerShift type grants are likely to be the most influential way in which Government can bring forward their widespread adoption.

The introduction of a completely new road fuel like hydrogen will require more innovative policy ideas. In the period to 2020, the majority of Government support is expected to be for depot based vehicles such as hydrogen fuel cell buses. To help kick start the development of the hydrogen bus market the Government could encourage:

Hydrogen Bus Partnerships

Within the bus market, bus companies are responsible for managing their own refuelling depots. It is therefore sensible to devise a system whereby grants for the purchase of new hydrogen fuel cell buses and the provision of new hydrogen refuelling facilities could be administered at the same time. Government could encourage fuel suppliers to enter into Hydrogen Bus Partnerships with major bus operators in the UK. These Hydrogen Bus Partnerships could then be eligible to apply for the necessary Government grants.

But, helping to create a market in low carbon vehicles will require further funds from Government, particularly for hydrogen vehicles. This should therefore be an important consideration when spending decisions are made.

7.1.1. Joining up the work of Government programmes and Government funded agencies

The DTI's Foresight Vehicle programme and EST's PowerShift programme, sponsored by the Department of Transport, Local Government and the Regions (DTLR) and the Scottish Executive, are currently the two main programmes responsible for delivering Government support for cleaner vehicles. Both these programmes will have a role in helping to meet national targets for low carbon and hydrogen vehicles:

> The DTI Foresight Vehicle programme currently manages the Government's future vehicle research. It could adapt its existing research and development work to give priority to low carbon fuels and technologies particularly those that support the development of hydrogen vehicles. It could inherit the proposed new R&D programme for hydrogen and other low carbon fuels and technologies, to help fund its work.
>
> EST's PowerShift programme currently administers Government grants for supporting the purchase of cleaner vehicles and the provision of new refuelling infrastructure. It also currently manages the demonstration of new vehicle technologies. The PowerShift programme has been given about £11 million funding per year until 2004. To date most of its activities have been driven by air quality priorities. Through its existing networks with vehicle manufacturers, fleet operators and fuel suppliers, the PowerShift programme could expand its programme to help create a market for low carbon vehicles. Using funds from the Government's £9 million New Vehicles Technology Fund the PowerShift programme could extend its existing low carbon and hydrogen vehicle demonstration projects. With the provision of extra funding, the PowerShift programme could administer grants specifically designed to support the purchase of low carbon vehicles. It could also establish accreditation measures for new low carbon vehicle technologies (for heavy and light duty vehicles).

The Carbon Trust has responsibility for supporting the development and commercialisation of new and emerging low carbon technologies through:

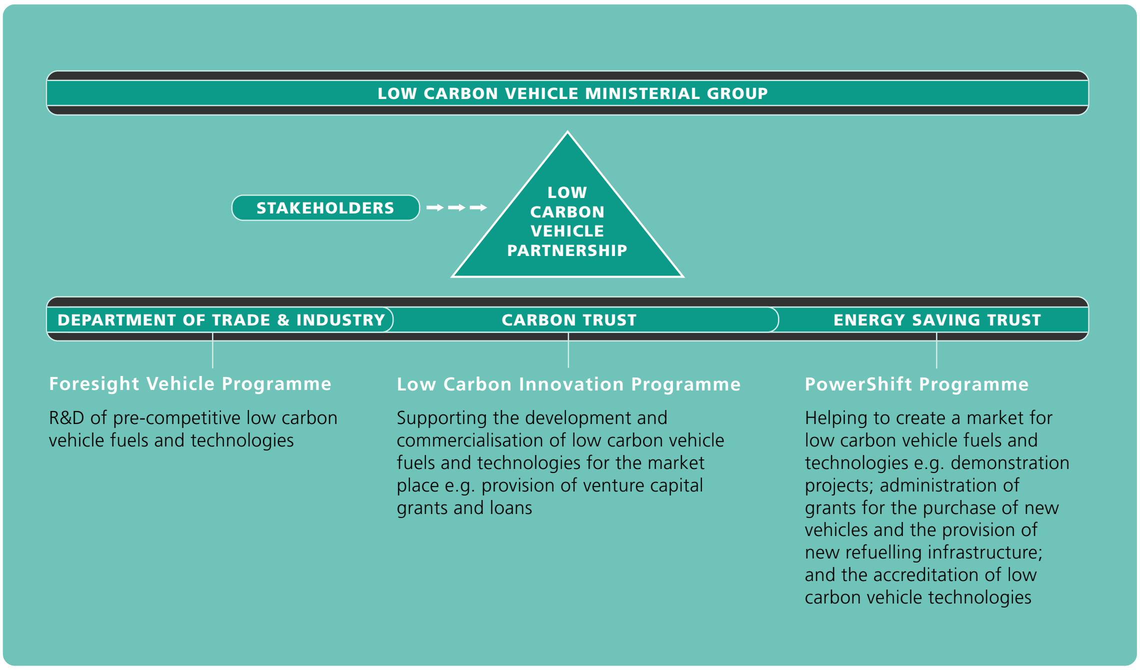
> The Low Carbon Innovation Programme (LCIP) which provides venture capital grants or loans to companies. It is worth £20 million–£25 million a year.

Some funds from the LCIP could be directed towards companies interested in developing their low carbon vehicle products for the market place. The Carbon Trust also has a remit for supporting the development of low carbon energy technologies, such as stationary fuel cells. There is therefore an opportunity for providing venture capital funds for supporting the commercialisation of innovative, low carbon technologies within both the energy and transport markets. There may be a case that the LCIP should receive a boost in funding to support this work.

In addition, HM Treasury's Green Technology Challenge could incentivise companies to develop their low carbon products for the marketplace through the provision of tax breaks such as enhanced capital allowances.

The Powering Future Vehicles draft strategy proposes the formation of a Low Carbon Vehicle Partnership that would report to a Low Carbon Ministerial Group. EST recommends that the Government develop the **Low Carbon Vehicle Partnership** as a means for:

> **Formalising and strengthening the links and synergies between the DTI's Foresight Vehicle programme, EST's PowerShift programme and the Carbon Trust's Low Carbon Innovation Programme (LCIP).**



The DTI's Foresight Vehicle programme, EST's PowerShift programme and the Carbon Trust's LCIP would have specific roles and responsibilities, but their work should be seen as mutually supportive. The three programmes should interact closely in sharing information and co-ordinating industry-Government initiatives. Each of the programmes would bring their existing stakeholder relationships with – for example, fleet managers, engineering companies, vehicle manufacturers, and Local Authorities – to the partnership. The Low Carbon Vehicle Partnership could:

- Help to co-ordinate the delivery of information, support and advice for low carbon vehicle technologies and fuels.
- Act as an advisory group to Government on the development of policies for supporting the transition to a zero carbon road transport system.

7.2. Supporting the transition to hydrogen vehicles

In the coming decades, the real challenge for policy makers will be to help introduce hydrogen as a new road transport fuel. In comparison, other low carbon vehicle technologies are likely to be relatively easier to introduce. Hybrid vehicles use a conventional petrol or diesel refuelling infrastructure and whilst electric vehicles require dedicated electric refuelling points, supplies of electricity are readily available. In contrast, there are currently many possible pathways to developing a hydrogen refuelling infrastructure and uncertainty about costs. EST therefore proposes that:

The Low Carbon Vehicle Partnership should establish a Hydrogen Vehicle Sub Group.

The Hydrogen Vehicle Sub Group should involve stakeholders, such as fuel suppliers and vehicle manufacturers, already linked to the wider Low Carbon Vehicle Partnership. But it should also involve other key stakeholders who will be pivotal to the transition to hydrogen vehicles such as environmental organisations, motoring organisations, consumer groups and independent academic advisors. The Hydrogen Vehicle Sub Group could be charged with developing longer term proposals for supporting the transition to zero carbon hydrogen.

7.3. Sustaining a market in low carbon vehicles – providing tax incentives

The three key ways in which Government can develop a favourable fiscal framework is through:

1. **Reform of fuel duty**
   Following the removal of the fuel duty escalator, a fundamental review of road fuel duty policy is needed. The Government has pledged to maintain a fuel duty differential for gas fuels, such as LPG and CNG, until at least 2004. But in the period to 2010, the road fuels market is likely to become increasingly crowded. A more sophisticated fuel duty system will need to be developed to differentiate the price of low carbon fuels at the pump and make them more attractive to drivers.

   As the fuel that offers the most promise for zero carbon road transport, there is a case for arguing that hydrogen should be exempt from fuel duty for a period sufficient to allow the market to establish itself. In the period to 2020, the hydrogen vehicle market is expected to be relatively small and so the cost to HM Treasury is also likely to be small.

   But once the market starts to take off, the duty on hydrogen could be banded to reflect the carbon content of the hydrogen source so that the lowest carbon sources of hydrogen, such as renewable hydrogen, receive the highest benefits. This would send a clear signal to fuel suppliers of the Government's longer term commitment to a zero carbon road transport system.

2. **Reform of the bus fuel duty rebate**
   If bus operators are to have a fiscal incentive to purchase buses which run on low carbon fuels, such as hydrogen, then the fuel duty rebate for buses will need to be reformed. Bus operators currently receive an 80% rebate on diesel duty. A number of organisations, including IPPR and the Commission for Integrated Transport (CfIT), have advocated replacing the fuel duty rebate with a mileage subsidy. This would enable Government to subsidise bus services but in a way that benefits not only diesel buses but also buses run on low carbon fuels.

3. **Further reforms to vehicle taxation**
   Recent reforms to Vehicle Excise Duty (VED) and Company Car Tax mean that vehicles with lower carbon emission levels now pay less tax. Petrol hybrid and electric cars already receive higher discounts under the Company Car Tax system. But in the coming years the graduation for VED and Company Car

Tax based on carbon emissions will need to be further widened if changes in the buying behaviour of private car owners and fleet managers are to be achieved.

In the coming years, as more energy efficient vehicles start to enter the UK market, the fuel costs of running petrol or diesel powered vehicles could be expected to fall significantly. This could, however, encourage more car use which could have negative implications for other Government targets such as reducing congestion and road traffic accidents. At some future point there may be justification in raising petrol and diesel fuel prices to reflect the reduced cost of motoring.

7.4. Promoting the take up of low carbon vehicles

Once favourable fiscal incentives have been put in place the Government could work with public authorities and commercial companies in encouraging the take up of low carbon vehicles by:

- **Greening public authority fleets**
  The Government has already made a commitment to purchase cleaner vehicles within its own fleets. It could go a step further and encourage Government departments, Government funded agencies and Local Authorities to adopt targets for low carbon vehicles. The Scottish Executive, Northern Ireland Executive and Welsh Assembly Government should introduce their own targets for low carbon vehicles.
- **Encouraging voluntary corporate commitments to low carbon vehicles**
  Commercial companies, such as DHL, Consignia and BT, own some of the largest vehicle fleets in the UK. Motorvate is the Government backed scheme for reducing total fleet CO_2 emissions by 12% over the next 3 years. As an extension to the existing Motorvate scheme, companies could be encouraged to make a voluntary commitment to replace a proportion of their fleet with more fuel efficient low carbon vehicles. Such commitments would enable companies to improve the carbon performance of fleets whilst also significantly reducing their travel costs.

7.5. Integrating low carbon vehicles into the UK's emissions trading scheme

Transport fleet operators and other transport users may wish to enter the UK's emissions trading scheme on a project basis. Low carbon vehicle projects should be able to gain tradable credits as a means of reducing carbon emissions cost effectively. It will be important to ensure that credits derive from real carbon emission reductions – i.e. they deliver savings additional to the European voluntary agreement – but also that monitoring and evaluation costs are not prohibitive. The existing arrangements for evaluating emission reductions for grant support could provide the necessary evaluation framework.

7.6. Preparation for the low carbon vehicle transition

Public awareness and acceptance will be critical to the transition to low carbon vehicles. In conjunction with other public education initiatives, the Government should be proactive in educating people about new and emerging low carbon vehicle fuels and technologies including hydrogen. Further low carbon and hydrogen vehicle demonstrations will help to raise awareness but the Government could also:

- Support low carbon and hydrogen vehicle exhibitions at museums and major environment or transport conferences.
- Encourage teachers to include lessons about low carbon fuels and hydrogen energy as part of the national curriculum.
- Encourage science and engineering university courses to include lectures on electric drive trains and fuel cell systems.

If hydrogen is to be introduced into the road transport system, work should start now on the development of hydrogen safety standards and handling procedures. Where possible the Government should seek to harmonise hydrogen safety standards with those currently being developed within Europe and the International Standards Organisation.

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9.0. APPENDICES

9.1. The impact of PowerShift grants on the petrol hybrid market in the period to 2010

BUSINESS AS USUAL SCENARIO

TOTAL REG[9]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol–Diesel	1,999,065	1,999,790	1,999,788	1,999,828	1,999,840	1,999,857	1,999,878	1,999,930	1,999,947	1,999,961	19,997,884
HEV[10]–Company	928	210	212	172	160	143	122	70	53	39	2,109
HEV–Private	7	0	0	0	0	0	0	0	0	0	7
HEV–Total	935	210	212	172	160	143	122	70	53	39	2,116
Total	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	20,000,000
Actual Sales	935	760	985								
	total 01–03	1,357									
TOTAL POP[11]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Petrol–Diesel	24,765,155	24,855,583	24,938,725	25,014,556	25,083,840	25,147,063	25,204,763	25,257,428	25,305,530	25,349,436	
HEV–Company	0	928	1,138	422	384	332	303	265	192	123	
HEV–Private	0	7	6	933	1,061	1,180	1,249	1,299	1,328	1,334	
HEV–Total	0	935	1,144	1,355	1,445	1,512	1,552	1,564	1,520	1,457	
Total	24,765,155	24,856,518	24,939,869	25,015,911	25,085,285	25,148,575	25,206,315	25,258,992	25,307,050	25,350,893	
CO_2 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	86,151,821	83,600,821	81,092,832	78,661,843	76,302,561	74,014,296	71,794,830	69,643,036	67,554,171	65,528,228	754,344,437
HEV	31,295	6,828	6,686	5,262	4,748	4,116	3,406	1,896	1,392	994	66,625
Total	86,183,116	83,607,650	81,099,518	78,667,105	76,307,309	74,018,412	71,798,236	69,644,931	67,555,563	65,529,222	754,411,062

NOx (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	64,766	64,792	64,792	64,794	64,794	34,557	34,558	34,559	34,559	34,559	496,731
HEV	12	3	3	2	2	1	1	1	1	0	25
Total	64,778	64,795	64,795	64,796	64,796	34,559	34,559	34,559	34,559	34,560	496,756
PM10 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	48
HEV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	48

9. TOTAL REG = Total annual new vehicle registrations
10. HEV = Hybrid electric vehicle
11. TOTAL POP = Total population of vehicles

POWERSHIFT SCENARIO 1 – A CONSERVATIVE SCENARIO

TOTAL REG	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	1,999,065	1,998,682	1,998,084	1,995,192	1,988,450	1,980,628	1,963,162	1,944,041	1,925,285	1,895,704	19,688,293
HEV–Company	928	1,312	1,911	4,792	11,509	19,314	36,637	55,352	74,018	102,105	307,878
HEV–Private	7	6	5	16	41	58	201	607	697	2,191	3,829
HEV–Total	935	1,318	1,916	4,808	11,550	19,372	36,838	55,959	74,715	104,296	311,707
Total	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	20,000,000
Actual Sales	935	760	985								
TOTAL POP	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Petrol-Diesel	24,765,155	24,855,583	24,937,617	25,011,744	25,076,393	25,128,325	25,167,039	25,183,619	25,177,421	25,149,850	
HEV–Company	0	928	2,240	3,223	6,703	16,301	30,823	55,951	91,989	129,370	
HEV–Private	0	7	12	944	2,189	3,949	8,453	19,422	37,640	71,673	
HEV–Total	0	935	2,252	4,167	8,892	20,250	39,276	75,373	129,629	201,043	
Total	24,765,155	24,856,518	24,939,869	25,015,911	25,085,285	25,148,575	25,206,315	25,258,992	25,307,050	25,350,893	
CO_2 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	86,151,821	83,549,410	81,016,100	78,459,365	75,820,040	73,224,031	70,331,879	67,485,271	64,757,248	61,748,667	742,543,833
HEV	31,295	42,816	60,399	146,996	342,513	557,301	1,027,472	1,512,331	1,959,238	2,646,686	8,327,048
Total	86,183,116	83,592,226	81,076,499	78,606,362	76,162,553	73,781,333	71,359,351	68,997,602	66,716,486	64,395,354	750,870,881
NOx (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	64,766	64,753	64,731	64,627	64,384	34,188	33,853	33,488	33,128	32,566	490,485
HEV	12	17	24	61	145	186	353	536	716	997	3,047
Total	64,778	64,769	64,755	64,688	64,530	34,374	34,207	34,024	33,844	33,563	493,532

PM10 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol–Diesel	4.75	4.75	4.75	4.74	4.72	4.70	4.65	4.60	4.56	4.48	47
HEV	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.07	0.10	0.14	0
Total	4.75	4.75	4.75	4.74	4.73	4.73	4.70	4.68	4.65	4.61	47

PowerShift grant per car

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	£1000	£1000	£1000	£1000	£800	£500	£500	£500	£500	£500

TOTAL POWERSHIFT GRANTS

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
	£935,000	£1,318,000	£1,916,000	£4,808,000	£9,240,000	£9,686,000	£18,419,000	£27,979,500	£37,357,500	£52,148,000	£163,807,000

Summary of PowerShift scenario 1: a conservative scenario

New petrol hybrid car registrations in 2010 – 104,296
Total petrol hybrid car population by 2010 – 201,043
CO_2 emissions avoided in 2010 – 1,133,868 tonnes
Cumulative CO_2 emissions avoided by 2010 – 3,540,181 tonnes
Total PowerShift spend over the period to 2010 – £163,807,000

POWERSHIFT SCENARIO 2 – A MORE OPTIMISTIC SCENARIO

TOTAL REG	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	1,999,065	1,998,580	1,997,777	1,993,995	1,975,352	1,961,866	1,932,538	1,899,126	1,856,393	1,796,796	19,411,488
HEV-Company	928	1,413	2,217	5,985	24,428	37,869	66,388	98,400	140,330	198,935	576,893
HEV-Private	7	7	6	20	220	265	1,074	2,474	3,277	4,269	11,619
HEV-Total	935	1,420	2,223	6,005	24,648	38,134	67,462	100,874	143,607	203,204	588,512
Total	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	20,000,000
Actual Sales	935	760	985								
TOTAL POP	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Petrol-Diesel	24,765,155	24,855,583	24,937,515	25,011,335	25,074,787	25,113,630	25,133,633	25,119,759	25,070,010	24,976,582	
HEV-Company	0	928	2,341	3,630	8,202	30,413	62,297	104,257	164,788	238,730	
HEV-Private	0	7	13	946	2,296	4,532	10,385	34,976	72,252	135,581	
HEV-Total	0	935	2,354	4,576	10,498	34,945	72,682	139,233	237,040	374,311	
Total	24,765,155	24,856,518	24,939,869	25,015,911	25,085,285	25,148,575	25,206,315	25,258,992	25,307,050	25,350,893	
CO_2 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	86,151,821	83,544,682	81,002,277	78,407,085	75,266,280	72,454,197	69,117,291	65,761,864	62,191,015	58,163,016	732,059,527
HEV	31,295	46,126	70,075	183,592	730,145	1,096,185	1,877,683	2,718,716	3,755,602	5,156,642	15,666,062
Total	86,183,116	83,590,808	81,072,352	78,590,678	75,996,425	73,550,382	70,994,975	68,480,580	65,946,616	63,319,658	747,725,589
NOx (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	64,766	64,749	64,720	64,584	63,914	33,829	33,269	32,633	31,815	30,675	484,954
HEV	12	18	28	76	310	366	646	964	1,372	1,943	5,733
Total	64,778	64,767	64,748	64,660	64,224	34,194	33,914	33,596	33,188	32,617	490,687

PM10 (tonnes)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Petrol-Diesel	4.75	4.75	4.75	4.74	4.69	4.65	4.57	4.49	4.37	4.22	46
HEV	0.00	0.00	0.00	0.01	0.02	0.05	0.09	0.13	0.19	0.27	1
Total	4.75	4.75	4.75	4.74	4.71	4.70	4.66	4.62	4.56	4.48	47

PowerShift grant per car

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	£1000	£1000	£1000	£1000	£800	£500	£500	£500	£500	£500

TOTAL POWERSHIFT GRANTS

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
	£935,000	£1,420,000	£2,223,000	£6,005,000	£19,718,400	£19,067,000	£33,731,000	£50,437,000	£71,803,500	£101,602,000	£306,941,900

Summary of PowerShift Scenario 2: a more optimistic scenario

New petrol hybrid car registrations in 2010 – 203,204

Total petrol hybrid car population by 2010 – 374, 311

CO_2 emissions avoided in 2010 – 2,209,564 tonnes

Cumulative CO_2 emission avoided by 2010 – 6,685,473 tonnes

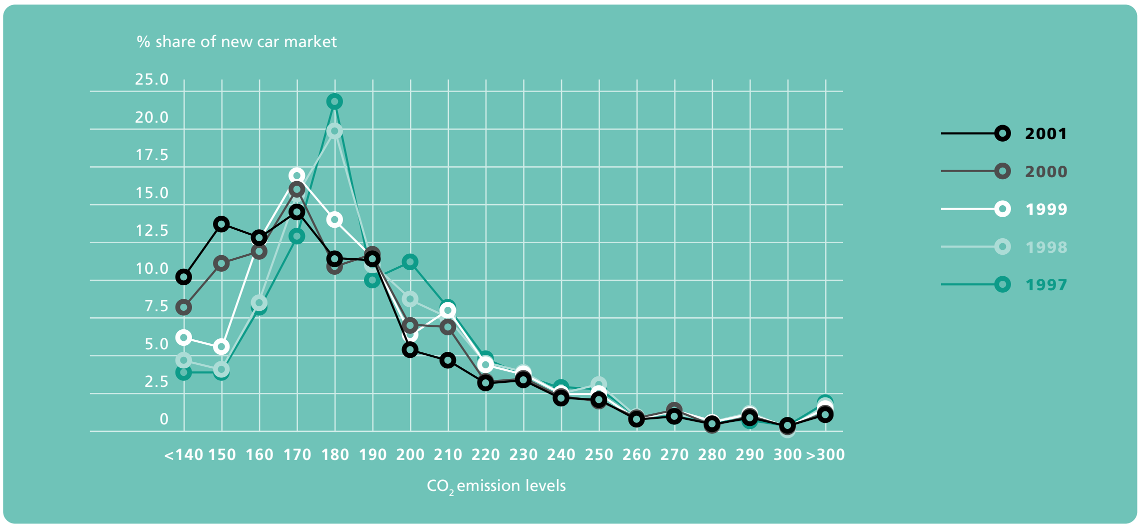
Total PowerShift spend over the period to 2010 – £306,941,900

Model assumptions

- The model assumes that capital and fuel costs are the key factors in purchasing decisions.
- In 2001, UK sales were around 1000 – this represents 0.05% of sales. To start the model, the fleet penetration factor is set at 1% (20 times actual sales).
- Global increase in annual sales of the Prius petrol hybrid has been 12% and 55% in the last two years. The annual percentage increase in the fleet penetration factor has been set at 30% for the PowerShift Scenario 1, 40% for the PowerShift Scenario 2 and 10% for the Business As Usual scenario.
- For company (or high use) cars the km/year is 32000 for the first 3 years and then 16000 for 9 years. For private (low use) cars the km/year is 16000 for 12 years

9.2. CO_2 distribution of new car registrations in the UK (1997–2001)

The average CO_2 emission levels are falling, as new cars become cleaner across the range. The graph below reveals the distribution of the market by CO_2 bands and reveals that the big peak around 180g/km in 1997 has been eradicated. The distribution has become more evenly spread and the level of cars now achieving under 140g/km (the European voluntary tailpipe target) has risen to 10.2% in 2001, from 8.2% in 2000 and less than 4% in 1997.



In 2001 over 15,000 models were already registered that had CO_2 values below 120g/km. The majority of the reduction in average CO_2 levels appears to have come from vehicles under 250g shifting in lower bands. The share of the market over 300g has come down from 1.9 per cent of the 1997 market to 1.2 per cent of the 2001 market, however, this share is unchanged from the 2000 share.

Information supplied by the SMMT.

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