Tomorrow's Low Carbon Cars

Driving innovation and long term investment in low carbon cars

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Motoring Towards Sustainability project

This report is part of ippr's Motoring Towards Sustainability programme which is examining the role of the car in progressive and environmentally sustainable transport policy. This research is made possible through the generous support of BMW, Direct Line, RSPB and Shell International.

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Executive summary

Road vehicles account for 22 per cent of all UK carbon dioxide (CO_2) emissions, the majority of which comes from passenger cars. Over the next twenty years, road transport's share of total CO_2 emissions is expected to rise compared to other sectors such as energy or services. Low carbon car technologies and fuels present car manufacturers, fuel suppliers and the Government with one of the principal means of reducing the CO_2 emissions from road transport and enhancing fuel diversity.

Last year the Government introduced a new target requiring one in ten new cars sold in the UK to be low carbon with exhaust emissions of 100 g/km of CO_2 or less by 2012. Achieving the low carbon car target will require the introduction of new technologies and lightweight design features that help to make conventional cars more energy efficient. But even the most energy efficient cars will not deliver carbon emission reductions on the scale likely to be needed to reduce the climate change impacts of road transport over the longer term.

The Government has made an ambitious commitment to move towards a 60 per cent cut in carbon emissions by 2050. Achieving such deep cuts in carbon emissions will require the introduction of radically different transport fuels. There is a growing consensus amongst fuel suppliers and car manufacturers that hydrogen holds out the most promise for replacing fossil fuels in road transport over the coming decades.

The future of Liquefied Petroleum Gas

Since coming into power, this Labour Government has proactively used the tax system to encourage environmentally friendly cars. Recent reforms to Vehicle Excise Duty (VED) and Company Car Tax (the personal tax on private use of company cars) mean that motorists with cars that produce lower CO_2 emissions now pay less tax. Progressive reductions on the duty for Liquefied Petroleum Gas (LPG) illustrate how influential fuel duty can be in helping to create a market for a new, alternative fuel. A litre of LPG currently costs less than half the price of petrol at the pump. Starting from scratch, LPG is now available from over 1,200 filling stations in the UK.

But a combination of advances in pollution abatement technologies, the availability of lower sulphur fuels and improvements in the environmental performance of conventional petrol and diesel cars suggests that the case for LPG will grow increasingly weak. European standards have led to significant reductions in the exhaust emissions of air pollutants from new cars. Compared to the latest petrol car, LPG offers no air quality benefit. Compared to diesel, LPG offers no CO_2 advantage as diesel fuelled cars are very efficient at converting the energy contained in the fuel into motive power.

In 2002, the LPG duty break cost the Government about £50 million in lost revenue. This is expected to rise to a further £60 million in 2003. The Government has pledged not to alter the fuel duty differential for road gas fuels, such as LPG, until 2004 at the earliest. The 2003 Budget, however, announced a review of the future of road gas fuels signalling the need for a change in policy.

ippr recommends that:

- *CO_2 should become the principal policy driver for both car and fuel taxation in the light of the improvements in emissions of air pollutants.*
- *From the 2004 Budget, the duty break awarded to LPG should be progressively reduced so that it reflects its CO_2 benefits.*

Shifting to lower carbon fuel taxation

The current structure of fuel duty incentives is not well equipped to deal with tomorrow's low carbon fuels because it does not distinguish fuels by their 'well-to-wheel' CO_2 emissions. Well-to-wheel CO_2 emissions not only account for the exhaust emissions created from driving the car but also the emissions created in the production and distribution of the fuel.

The environmental rationale underlying differential rates of fuel duty for alternative fuels is somewhat unclear. Biofuels (such as biodiesel from rape seed oil and bioethanol from sugar beet or woody biomass sources) produce less well-to-wheel CO_2 emissions than road gas fuels like LPG or natural gas. Yet biofuels currently have a higher rate of duty than road gas fuels.

The Government's fuel duty policy lacks a clear long term strategy linked to environmental benefits. The fairly arbitrary basis by which the Treasury sets fuel duty differentials for alternative fuels has left it open to criticism, as there is little evidence that duty levels are being set on a rational basis.

There is too much secrecy in the way fuel duty incentives are set by the Treasury leaving companies uncertain of the Government's long term intentions regarding low carbon fuels. The experience with LPG underlines the pitfalls of short term price signals. The Government should avoid creating another dead end market that is dependent on public subsidy by developing longer term price signals that reflect climate change objectives.

ippr recommends:

- *Developing differential rates of fuel duty for alternative fuels based on well-to-wheel CO_2 emissions. This would help to:*
  - *Distinguish and reward lower carbon forms of fuels – differentiating fuels not only by their exhaust emissions but also the emissions created in the production and distribution of the fuel.*
  - *Send a longer term price signal of the Government's commitment to lower carbon transport fuels – giving fuel suppliers and car manufacturers greater certainty to make longer term investments in lower carbon fuels and car technologies.*
  - *Provide a benchmark for comparing the environmental performance of current and emerging fuels – enabling greater transparency in how duty incentives for alternative fuels are developed.*

The UK's Fuel Cell Vision

In the Prime Minister's 2003 speech on sustainable development he stated that:

"Hydrogen holds out the potential to replace fossil fuels, especially in transport, and could transform our energy system – offering a vision of a transport system that is completely clean with no exhaust emissions."

The UK has the potential to become a hub for the manufacture and deployment of hydrogen and fuel cell vehicle technologies. But we are at risk of missing out on this opportunity. The Department of Trade and Industry (DTI), the Carbon Trust, the Energy Saving Trust (EST) and the Engineering and Physical Sciences Research Council (EPSRC) all manage Government funded programmes for supporting low carbon vehicle technologies and fuels. But they only have small pots of money earmarked for hydrogen and fuel cell vehicle research and industry development, and there is confusion about how these programmes compliment one another.

We are currently lagging behind the United States, Canada, Japan and Germany, whose governments have made significant investments in hydrogen and fuel cell vehicle research and development (R&D) as well as demonstration projects. The Government is currently developing a UK Fuel Cell Vision to raise the profile of the hydrogen and fuel cell vehicle industry in the UK and attract foreign investment.

ippr recommends that:

- *The UK's Fuel Cells Vision should have three key objectives to:*
  1. *Make the UK an attractive market for hydrogen and fuel cell vehicle investments by promoting regional projects and demonstrations*

2. *Take a co-ordinated approach to hydrogen and fuel cell vehicle research and industry development in the UK by identifying synergies between Government funded programmes and avoiding duplication of effort*
3. *Collaborate with other countries to pool resources and share results. The Prime Minister should take the lead in identifying opportunities for international partnerships for developing hydrogen and fuel cell vehicle projects.*

- *Hydrogen and fuel cell vehicle R&D should receive greater funding support in the Government's next Spending Review 2004-2006.*
- *The Government should introduce venture capital funding specifically targeted at the development and commercialisation of hydrogen and fuel cell vehicle technologies. Venture capital grants could be channelled through the Low Carbon Innovation Programme run by the Government funded Carbon Trust.*
- *The UK's Fuel Cell Vision should be central to the Government's forthcoming Innovation Strategy. The Innovation Strategy should seek to develop a better understanding of the contribution that a hydrogen and fuel cell vehicle industry could make to both economic and resource productivity.*

Motoring towards sustainability

Tomorrow's Low Carbon Cars is part of ippr's Motoring Towards Sustainability programme. Cars have many impacts on the environment including air and noise pollution as well as indirect effects on land use such as habitat loss. This report is focused on the CO_2 impacts of cars and the contribution that low carbon cars could make to the UK's climate change commitments.

ippr recognises that low carbon car technologies and fuels are only part of the solution to sustainable mobility. Whilst they can help to cut pollution they cannot reduce traffic congestion or road casualties. Other aspects of the Motoring Towards Sustainability programme will examine how road user charging could cut congestion and the effect of road traffic on communities.

Cars and the environment

Affordable cars have brought people freedoms and opportunities they could have scarcely imagined fifty years ago. We now commute further to work, often take our children to school by car and rely on our cars to access out of town shopping centres.

Last year car sales reached a record 2.5 million, which was 11 per cent higher than sales in 2000 (SMMT, 2002), and car ownership levels are set to increase in the foreseeable future. But our car dependency comes at a price to the environment and society. Problems of urban air pollution, climate change, noise pollution and our continuing dependence on oil sources will not only affect us but generations to come.

Some motoring facts and figures

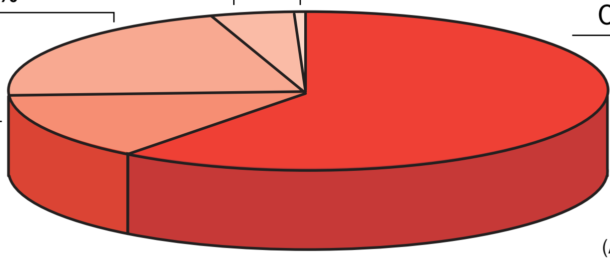
- *71 per cent of households have access to a car. One in six households own two or more cars*
- *Growth in car travel and the fall in bus patronage seen over the last twenty years have been accompanied by stable motoring costs and rising bus fares*
- *The distance travelled by car has increased by 61 per cent since 1980, up from 388 to 624 billion passenger kilometres*
- *The average number of trips made by car has increased by 24 per cent since the mid 1980s, up from 517 to 639 (DfT, 2003)*

The amount of air pollutants emitted by new cars has reduced considerably in recent years. Nonetheless, mitigating the local effects of air pollution from road transport, especially in urban areas, remains a concern for policy makers and will be important to meeting the Government's air quality objectives. There are still many unanswered questions regarding the health implications of air pollutants and their link to respiratory problems. But the greatest challenge for car manufacturers, fuel suppliers and the Government will be to reduce the contribution that cars make greenhouse gas emissions.

Carbon dioxide (CO_2) is the main greenhouse gas responsible for climate change worsened by human activity. To date, the effect of increases in road traffic on CO_2 emissions have been largely offset by improvements in vehicle efficiency. The average car today produces 178 grams per kilometre (g/km) of CO_2, a seven per cent reduction on average emissions in 1997 (SMMT, 2002). The European car industry has made a voluntary agreement to reduce CO_2 emissions from the new car fleet to an average of 140 g/km by 2008.

Despite this road transport remains a significant source of CO_2 emissions accounting for 22 per cent of all UK CO_2 emissions, the majority of which comes from passenger cars (DfT et al, 2002). Over the next twenty years, road transport's share of total CO_2 emissions is expected to rise compared to other sectors such as energy or services (IAG, 2003).

Contribution of different vehicle types to CO_2 emissions from road transport in 2000



(AEA Technology, 2001)

The Government has a legally binding target under the 1997 Kyoto Protocol to cut greenhouse gas emissions by 12.5 per cent below 1990 levels over the period of 2008-2012. In addition, the Government's Climate Change Programme has set a goal to cut CO_2 emissions by 20 per cent below 1990 levels by 2010. A recent report by the Sustainable Development Commission (SDC, 2003) revealed that whilst the UK is expected to meet its Kyoto commitments, we are not on track to deliver our 2010 target for a 20 per cent reduction in CO_2 emissions. Road transport was identified as one of the major culprits. In future the road transport sector will need to bear greater responsibility in helping to deliver our climate change commitments.

This report examines how Government can create a policy framework for driving innovation and long term investment in low carbon car technologies and fuels. It builds on the ippr report H_2: Driving the Future (Foley, 2001) which examined the policy implications of developing hydrogen as a fuel for road vehicles.

New and emerging car technologies and fuels

UK cleaner vehicle statistics

- *Cleaner vehicles make up a small percentage of the total vehicle fleet – around 0.2 per cent. Of this 0.2 per cent, almost all the vehicles use Liquefied Petroleum Gas (LPG) (EST, 2003)*
- *Around 25,000 new LPG vehicles or conversions are produced each year (LPGA, 2003)*
- *In 2001, 660 petrol hybrid-electric cars were sold in the UK (EST, 2002)*
- *In 2002, there were 374 electric cars registered almost 50 per cent down on 2001 (DVLA, 2003)*

There are a wide range of cleaner vehicle fuels and technologies. The technologies and fuels discussed in this report are shown in the following box.

Cleaner car fuels and technologies

Liquefied Petroleum Gas (LPG) is a by-product of oil refining but it also occurs naturally from on and offshore oil and gas production. Most LPG cars are 'bi-fuel' carrying both petrol and LPG enabling them to switch from one fuel to the other. It costs around £1,500 to convert a car to run on LPG. The LPG market in the UK is almost entirely after-market conversions whereby petrol vehicles are converted to run on LPG after they come off the production line (EST, 2002).

The environmental benefits of LPG are expected to grow increasingly weak as the environmental performance of conventional vehicle technologies continues to improve. This is compounded by the fact that LPG conversions vary greatly in terms of their emissions performance. Cow-boy converters, whose poor quality conversions produce poor emissions, have tarnished the credibility of the LPG car market. The Government is beginning to take steps to improve the regulation of LPG conversions and stamp out non-approved converters.

Natural gas is predominantly methane found in underground or undersea fields often associated with oil. Natural gas needs to be either liquefied or compressed for storage on board a vehicle – Liquefied Natural Gas (LNG) or Compressed Natural Gas (CNG). But bulky and heavy storage tanks are required making natural gas less practical for small passenger cars.

Natural gas refuelling systems have however proved more popular with supermarket delivery trucks and bus fleets.

Gas-to-liquid fuels can be made from natural gas and blended with diesel. They can be used in conventional diesel vehicles without any engine modification. Gas-to-liquid fuels have the potential to reduce emissions of local air pollutants and produce significantly lower particulates than Ultra Low Sulphur Diesel (ULSD) and sulphur free diesel (Shell, 2003). Several major trials of gas-to-liquid fuels have already been undertaken in the United States and South East Asia and bus demonstration projects are planned in Europe.

Biofuels can be derived from two main sources – annual food crops and woody crops. Some annual food crops can be used for making liquid fuels. For example, oil seed rape can be esterified as a diesel substitute called Rape Seed Methyl Ester (RME). RME can be used as a direct substitute for diesel, but this presents some technical problems and requires minor engine modifications (Fergusson, 2001). Blending RME into conventional diesel however requires no engine modification. Blending up to five per cent RME achieves better emissions results than higher percentage blends or 100 per cent biodiesel (Greenergy, 2002).

Ethanol can also be derived from cereal and sugar crops, such as sugar beet and blended with petrol for use in vehicles. There is also the potential for deriving ethanol from woody or lignocellulosic sources such as straw or fast growing trees, like willow, from which wood can be harvested. Ethanol could also be cost effectively produced from farm wastes, forestry residues, domestic or commercial waste. Waste materials are unlikely to supply vast amounts of ethanol for road transport, but in some local areas using waste products to produce ethanol could help to minimise waste and improve resource efficiency.

Hydrogen can be used in adapted internal combustion engines or fuel cell vehicles. A hydrogen powered vehicle produces no local air pollutants or greenhouse gases from its exhaust. The only emission is small amounts of water vapour. The emergence of fuel cell technology has increased interest in the use of hydrogen as a fuel for road vehicles. Fuel cells function in a similar way to batteries in that they have no moving parts and convert chemical energy into electricity very efficiently and silently. Unlike batteries, fuel cells never need to be recharged and will produce electricity for as long as the hydrogen fuel is provided. An internal combustion engine vehicle can lose more than 80 per cent of the energy it generates, either as waste, heat or friction. A hydrogen fuel cell may lose only 40 per cent and is therefore very fuel efficient.Whilst hydrogen vehicles are zero emission, this does not account for any emissions that might be created in the process of producing the hydrogen in the first place. Hydrogen is not like traditional fuels, such as coal, oil or gas, which have to be mined or drilled out of the ground. Its strength lies in its flexibility and the fact that it can be produced from a wide range of energy sources. It is therefore more like electricity. As with electricity if the hydrogen is made from fossil fuels then significant amounts of pollution will still be released into the atmosphere. But hydrogen made from renewable energy sources, such as wind and solar power or biomass, would be pollution free. Renewable hydrogen is therefore the ultimate end point (Foley, 2001). One of the technological hurdles is that hydrogen must be either compressed or liquefied to reach the energy densities needed to power a road vehicle. Compressed hydrogen gas currently requires bulky storage tanks that take up a lot of room. Liquefaction requires more energy than compression, using the equivalent of 25 per cent of the energy stored in the fuel (EST, 2002). Hydrogen storage technologies still need further development but they continue to develop at a rapid rate. Most major fuel suppliers have made significant investments in researching the next generation of hydrogen storage technologies.

There is a growing consensus amongst fuel suppliers and vehicle manufacturers that hydrogen will be the fuel of the future. Leading vehicle manufacturers have devoted a significant proportion of their research and development budgets to developing tomorrow's hydrogen and fuel cell cars. The last few years has seen several high profile launches of hydrogen fuel cell car demonstration models. Electric powered cars were the original concept for the zero emission car in that they are extremely quiet and produce not exhaust pollution. In an electric vehicle, batteries and electric motors replace the conventional internal combustion engine. But despite decades of battery development, battery cars have failed to live up to consumer expectations. Limited range and long re-charging times suggest they are unlikely to be a commercial success with motorists and will be confined to niche applications or use in inner city areas (EST, 2002; Fergusson, 2001).

Hybrid-electric cars have overcome the limitations of dedicated electric cars by combining an electric battery with the power and performance of a conventional engine. The car runs on its zero emission battery in stop-start traffic and is therefore ideal in congested, urban driving conditions. The engine is used to drive the car outside urban areas, to travel at high speeds or to recharge the batteries. Unlike dedicated battery cars, hybrid-electric cars do not require electric refuelling facilities and have the advantage of being able to refuel at any petrol forecourt. Petrol-hybrid cars first went on sale in the UK in 2001. Petrol-hybrid cars are very energy efficient achieving a 30 per cent saving in exhaust CO_2 emissions over the equivalent petrol car. They cost around £3,000 more than their petrol counterparts. The Energy Saving Trust (EST), which is Government funded, provides grants of £1000 towards the purchase of petrol-hybrid car, but there is still a significant price premium which is thought to be why sales are yet to pick up in the UK.

Low carbon cars and government policy

July 2002 saw the launch of the Government's Powering Future Vehicles Strategy which seeks to support the transition to low carbon road transport and looks ahead to new and emerging technologies and fuels capable of producing much lower greenhouse gas emissions. The Powering Future Vehicles Strategy introduced a new target for low carbon cars. The target requires one in ten new cars sold in the UK to be low carbon with exhaust emissions of 100 g/km of CO_2 or less by 2012.

The Powering Future Vehicles Strategy has also led to the creation of a new joint government-industry body called the Low Carbon Vehicle Partnership (LowCVP). The LowCVP is an action and advisory group that will promote the shift to low carbon transport, help industry, consumers and environmental and other stakeholders to participate in the shift and maximise competitive advantage to the UK (DTI, 2003a).

In the coming years, valuable carbon savings could be achieved through developments in technologies and designs that make existing conventional cars more energy efficient (EST, 2002). Achieving the low carbon car target will require the introduction of energy efficient car technologies capable of producing exhaust emissions of 100 g/km of CO_2 or less. This could include hybrid-electric cars or conventional diesel cars with lightweight, fuel saving design features. The Government will have an important role to play in helping to create a market for more energy efficient cars through the provision of tax incentives and purchase grants (for reducing the price premium of hybrid-electric cars for example).

Whilst the low carbon car target will help to encourage investments in energy efficient car technologies and designs it will not necessarily stimulate the introduction of new road transport fuels. The concern is that even the most energy efficient cars will not deliver carbon emission reductions on the scale likely to be needed to reduce the climate change impacts of road transport over the longer term (PIU, 2002). In the Energy White Paper, published in February 2003, the Government made an ambitious commitment to move towards a 60 per cent cut in carbon emissions by 2050. Over the coming decades, this will require radically different technologies and fuels.

Imperial College produced a report for the Prime Minister's Strategy Unit in the Cabinet Office on the technology options for addressing climate change. It found that if deep cuts in carbon emissions – of around the 60 per cent mark – are to be achieved in the long term, then the development of the hydrogen option will be critical (ICCEPT, 2002).

Hydrogen powered cars are still some way off and the transition to a hydrogen road transport system will not be straightforward. For example, hydrogen storage technologies still need further development and there is currently no infrastructure for delivering hydrogen to vehicles. Government intervention will be needed to help drive technological innovation in future hydrogen and fuel cell car technologies as well as long term investments in the development of hydrogen refuelling infrastructure.

Key conclusions

- ***Road vehicles account for 22 per cent of all UK CO_2 emissions. Road transport's share of total CO_2 emissions is likely to rise over the next twenty years.***
- ***The Government should continue to encourage developments in technologies and designs that help to make conventional cars more energy efficient.***
- ***The introduction of new low carbon transport fuels will be needed to reduce the climate change impacts of road transport over the longer term.***
- ***The Energy White Paper commits to moving towards a 60 per cent cut in carbon emissions by 2050. Hydrogen currently holds out the most promise for achieving such radical reductions in carbon emissions.***

Low carbon motoring taxes

Since coming into power, this Labour Government has proactively used the tax system to encourage environmentally friendly cars. Recent reforms to Vehicle Excise Duty (VED) and Company Car Tax (the personal tax on private use of company cars) mean that motorists with cars that produce lower CO_2 emissions now pay less tax.

For the last few years, VED for new cars has been graduated according to a car's CO_2 emissions. The 2003 Budget introduced a new lower rate of VED for cars with very low levels of CO_2 emissions not exceeding 100 g/km. The new VED rate and the trial of a new environmental label for cars based on VED emissions bands will strengthen the incentive for motorists to choose cars that are more fuel efficient or run on alternative fuels. A recent opinion poll found that 80 per cent of motorists thought it was fair that drivers of high polluting cars pay more car tax than lower emission cars (Taylor Nelson Sofres, 2003).

Since April 2002, Company Car Tax has been paid on a proportion of the car list price ranging from 15 to 35 per cent for higher CO_2 emission cars. The new tax system has had a fairly immediate effect on the purchasing decisions of large companies. A recent study found that 92 per cent of 180 companies surveyed said that their employees had been influenced by the tax change increasing the popularity of cars with lower CO_2 emissions. Over a third of the companies anticipated a shift to cars capable of running on both conventional and alternative fuels (Monks Partnership, 2003).

There is already evidence that the Government's CO_2 related taxation measures are having an impact on the profile of the UK car fleet. In the coming years, diesel – which is more fuel efficient and hence lower carbon – is expected to compete with petrol for at least an equal share of the car fuels market. Diesel took a record 23.5 per cent market share of new car registrations in 2002 compared with five per cent in 1990 (SMMT, 2002).

The future of Liquefied Petroleum Gas (LPG)

To date, the most accessible alternative road fuel in the UK has been LPG. Progressive reductions in LPG duty illustrate how influential fuel duty can be as a tax instrument for helping to create a market for a new, alternative fuel. A litre of LPG currently costs less than half the price of petrol at the pump. Starting from scratch, LPG is now available from over 1,200 filling stations in the UK (EST, 2003).

When the duty rate for LPG was frozen in 1996 there was an air quality advantage to be obtained from using LPG compared to petrol cars. Since then, European standards for exhaust emissions of regulated air pollutants (often referred to as the 'Euro' standards) have led to significant reductions in the air pollutants from new cars. The Euro IV standard for petrol cars takes effect from 1st January 2005, yet many vehicle manufacturers have already started to introduce cars with an emissions performance equivalent to Euro IV standard. Compared to a Euro IV petrol car, LPG offers no air quality benefit.

Vauxhall Astra (Model Year 2002)	Engine cc.	CO_2 (g/km)	NOX (g/km)	PM (g/km)	Euro standard
LPG	1598	151	0.031	n/a	IV
Petrol	1598	172	0.026	n/a	IV
Diesel	1686	119	0.412	0.023	III

(Vehicle Certification Agency, 2003)

Compared to diesel, LPG offers no CO_2 advantage as diesel fuelled cars are very efficient at converting the energy contained in the fuel into motive power. Diesel has an air quality penalty, although rapid advances in catalysts for oxides of nitrogen (NOx), traps for capturing particulate matter (PM), sulphur free diesel and gas-to-liquid fuels indicate that this will be a short term trade off. A number of car manufacturers plan on fitting NOx catalysts to new cars than run on very low sulphur fuels, with a sulphur content of 10 parts per million (ppm). Several fuel suppliers are starting to trial gas-to-liquid fuels that can be blended with diesel and used in standard diesel engines. Gas-to-liquid fuels can reduce particulate emissions by a third compared to sulphur free diesel (Shell, 2003).

A combination of advances in pollution abatement technologies and cleaner fuels, as well as the probable extension of the Euro standards suggests that the environmental case for LPG will grow increasingly weak. In 2002, the LPG duty break cost the Government about £50 million in lost revenue. This is expected to rise to a further £60 million in 2003 (see appendix for further details).

Government policy, to date, has been to encourage the development of the LPG vehicle market. The Government pledged not to alter the fuel duty differential for gas fuels until 2004 at the earliest to help encourage fuel suppliers to invest in LPG infrastructure and in turn stimulate investment in LPG vehicle technologies. The 2003 Budget, however, announced a review of the future of road gas fuels signalling the need for a change in policy.

It is questionable how long LPG should benefit from a duty of nine pence per kilogram (the equivalent of 6.5p per litre) in light of its marginal environmental benefits. Removing the duty differential in one fell sweep would be unwise as it would probably cause the LPG market to collapse overnight. It would also lead to understandable appeals from companies who have made considerable investments in LPG refuelling and vehicle technologies in response to fiscal incentives. There are many transferable lessons Government and industry can take away from the LPG experience. The lessons include how to market an alternatively fuelled vehicle to fleet managers and reconcile local planning and safety concerns about new refuelling pumps.

The Government has, however, committed to providing a fiscal regime that encourages take up of low carbon vehicles and fuels. Car taxation already reflects CO_2 impacts. In accordance with the Powering Future Vehicles Strategy, ippr recommends that CO_2 should become the principal policy driver for both car and fuel taxation in the light of the improvements in emissions of air pollutants. From the 2004 Budget, the duty break awarded to LPG should be progressively reduced so that it reflects its CO_2 benefits.

The PowerShift programme

The Government funded PowerShift programme, run by the Energy Saving Trust (EST), has around £10 million each year for providing grants towards the additional cost of purchasing cleaner fuelled vehicles. Approximately £8 million is currently spent on providing grants for LPG conversions. On environmental grounds it would be difficult to justify continuing to offer PowerShift grants to LPG conversions which should be phased out. PowerShift funding should be diverted to helping to create a market for new and emerging lower carbon vehicles such as hybrid-electric, biofuel, fuel cell and hydrogen vehicles.

Shifting towards lower carbon fuel taxation

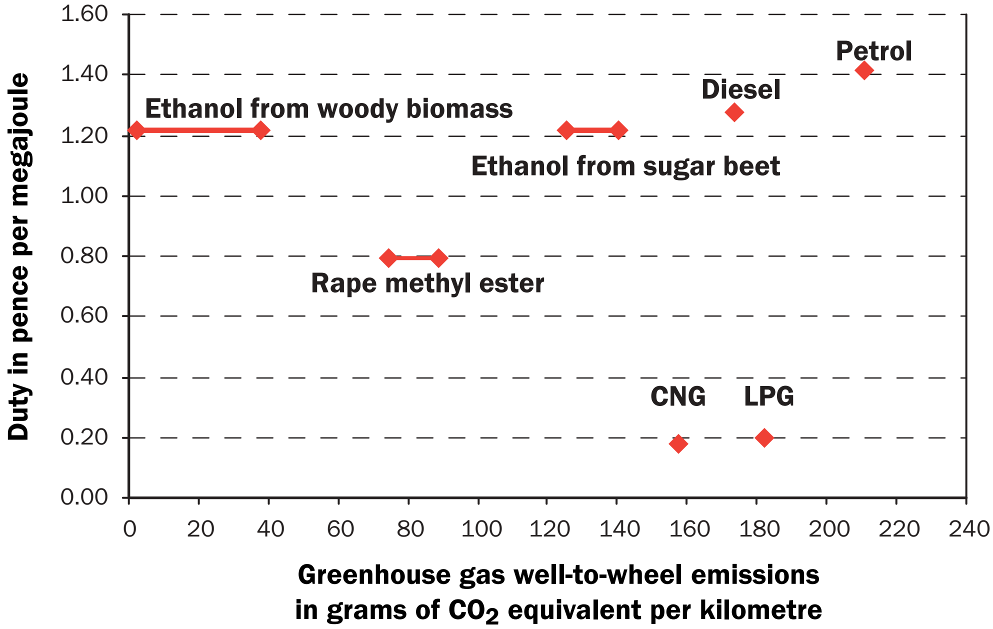
Recent budgets are already supporting a shift in focus towards new and emerging fuels that have the potential to produce lower CO_2 emissions. The 2002 Budget exempted hydrogen from fuel duty and introduced a new duty rate for biodiesel, set at 20 pence per litre below the Ultra Low Sulphur Diesel (ULSD) rate. The 2003 Budget announced that a new duty rate for bioethanol, set at 20 pence per litre below the Ultra Low Sulphur Petrol (ULSP) rate, would come into effect in January 2005.

The current structure of fuel duty incentives is however not well equipped to deal with tomorrow's low carbon fuels. It does not distinguish fuels by their method of production and hence does not account for the CO_2 emissions created in the production and distribution of the fuel.

What are well-to-wheel emissions?

'Well-to-wheel' CO_2 emissions not only account for the exhaust emissions created from driving the car but also the emissions created in the production and distribution of the fuel. The graph and the table show the well-to-wheel emissions for various fuels, measured in grams of CO_2 equivalent per kilometre, compared to their duty breaks. Both the biodiesel and bioethanol options produce less well-to-wheel emissions than LPG or Compressed Natural Gas (CNG). Yet biofuels currently have a higher rate of duty than road gas fuels.

Relationship between fuel duty and well-to-wheel greenhouse gas emissions*



*** Notes:**

1. *The greenhouse gas well-to-tank and well-to-wheel emissions as well as the tank-to-wheel energy consumption figures are extracted from the 2002 General Motors study of advanced fuel/vehicle systems in Europe. The car used in the study was the GM Opel Zaphyra.*
2. *LPG was not considered in the General Motors study. LPG was estimated as a first approximation equal to diesel (straight distillation). The LPG composition was assumed to be 50/50 weight propane/butane.*
3. *The greenhouse gas well-to-tank and well-to-wheel emissions for natural gas (CNG) are based on the EU fuel mix.*
4. *It is assumed that the efficiency of the internal combustion engines is the same for ethanol as for gasoline.*
5. *It is assumed that the efficiency of the internal combustion engines is the same for RME as for diesel.*
6. *The graph and table includes the new duty rate for bioethanol, set at 20 pence per litre below the ULSP duty rate, which comes into effect in January 2005.*

		Petrol	Diesel	Biodiesel	Bioethanol			LPG	CNG
		Ultra Low Sulphur Petrol (ULSP)	Ultra Low Sulphur Diesel (ULSD)	Rape Seed Methyl Ester (RME)	Sugar beet	Ligno-cellulosic crops e.g. straw, woody biomass			
Excise duty	P/l	45.82	45.82	25.82	25.82	25.82	g/kg	9	9
Lower Heating Value	MJ/Kg	43.2	43.2	36.8	26.8	26.8		46	50
Density	Kg/l	0.75	0.84	0.88	0.79	0.79			
Energy density	MJ/l	32.4	36.3	32.5	21.3	21.3			
Excise duty	**P/MJ**	**1.41**	**1.28**	**0.79**	**1.21**	**1.21**		0.20	0.18
Greenhouse gas well-to-tank emissions	**g CO2 equivalent/ MJ**	**Mean 13.1**	**Mean 10.2**	**Mean -34.2**	**Lower -13.9 Upper -19.8**	**Lower -55.7 Upper -70.3**		**Mean 10.2**	**Mean 14.3**
Tank-to-wheel energy consumption	MJ/Km	2.44	2.09	2.09	2.44	2.44		2.44	2.23
Greenhouse gas well-to-wheel emissions	**g CO2 equivalent/ Km**	**Mean 211.1**	**Mean 173.5**	**Mean 88.8**	**Lower 140.1 Upper 125.7**	**Lower 38.1 Upper 2.4**		**Mean 181.9**	**Mean 157.7**

Are tomorrow's biofuels receiving adequate support?

The shortcomings with the current fuel duty system become more striking when assessing the duty breaks offered to biofuels. The CO_2 benefits of different types of biofuels will vary according to the crop source and the energy used in the process of growing and cultivation. There are fairly wide variations in the well-to-wheel CO_2 emissions offered by different types of biofuels, although it is generally the case that ethanol produced from woody or lignocellulosic crops offer the lowest CO_2 emissions.

In the coming years, Rape Seed Methyl Ester (RME) and ethanol from sugar beet could be used as a fuel extender. A few major supermarkets are showing growing interest in supplying a new fuel product which blends up to five per cent of RME into conventional diesel. Using RME as a fuel mixer has the advantage of not requiring any engine modifications. Several car manufacturers have also developed ethanol car models that use 'E85' fuel based on a blend of 85 per cent ethanol and 15 per cent gasoline. But, to date they have largely been available in North America and few exist in the UK.

RME and ethanol from sugar beet are unlikely to satisfy a large proportion of the UK's road transport needs and will probably develop as niche transport fuels. A recent report by the Energy Saving Trust (EST), Institute for European Environmental Policy (IEEP) and National Society for Clean Air (NSCA) (2002) assessed the long term potential for biomass to supply UK transport energy needs by 2050. For the purpose of illustration it assumed that up to 25 per cent of UK agricultural land might become available for biomass sources which is approximately four million hectares. It found that RME and ethanol from sugar beet could supply 12-30 per cent of current demand. But higher yielding crops from woody biomass sources, such as willow, could meet 50 per cent of UK road transport fuel demand. Unlike sugar beet, which requires high quality arable soil, woody biomass can thrive on poorer soils and in the wetter, cooler climates more common to the UK. Growing woody biomass sources is also less likely to threaten biodiversity, compared to rape seed or sugar beet, or require the use of intensive farming practices such as chemical fertilisers.

As a hypothetical illustration, the EST et al report (2002) helps to demonstrate the potential benefits of biofuels and woody biomass sources in particular. In reality it is somewhat unlikely that up to 25 per cent of agricultural land would be set aside for growing energy crops exclusively for transport fuels. The Government would probably need to give farmers subsidies for growing biofuels, which may not fit in wider agricultural policy objectives. Some waste agricultural products could be used for producing ethanol but this would be limited in supply. There is also likely to be increasing demand for woody biomass sources for generating renewable electricity for heat and power. Competing land use pressures and energy demands suggests the UK would probably need to import large amounts of woody biomass derived fuels to meet up to 50 per cent of road transport demand.

Nonetheless, amongst the range of biofuel options, woody biomass sources offer the most versatility in helping to meet future transport energy needs and reducing CO_2 emissions. Woody biomass could also provide a renewable energy feedstock for producing future fuels like hydrogen. The 2003 Budget states that the Government is particularly keen to support the development of bioethanol from woody biomass. But, at present the technology for converting woody biomass and wastes into liquid transport fuels is in its early stages of development. They are currently more expensive than established technologies for converting food crops like oil seed rape and sugar beet into liquid fuels (Fergusson, 2001).

The Government currently offers a duty incentive for biodiesel, set at 20 pence per litre below ULSD, and from 2005 plans to introduce the same level of duty incentive of bioethanol. Whilst this will help to encourage some take up of RME and ethanol from sugar beet, it is unlikely to stimulate fuel suppliers to make significant, longer term investments in the development and commercialisation of technologies needed for converting woody biomass into liquid fuels. By not distinguishing different biofuels according to the CO_2 emissions created in their production, the Government risks providing inadequate support to woody biomass. This is despite the promising CO_2 benefits that woody biomass fuels could offer in the medium to longer term.

Distinguishing and rewarding lower carbon forms of fuels

The environmental rationale underlying differential rates of fuel duty for alternative fuels is somewhat unclear. A recent report by the cross party Environmental Audit Committee (EAC) criticised the Government's fuel duty policy for lacking a clear long term strategy linked to environmental benefits. It argued that:

"The Treasury could do far more to set out a coherent long term strategy for fuel duties, and demonstrate how the current incentives for biofuels, road fuel gases (such as LPG), and hydrogen fit into this" (EAC, 2003).

The fairly arbitrary basis by which the Treasury sets fuel duty differentials for alternative fuels has left it open to criticism. Friends of the Earth, for example, have argued that:

"Different bits of industry have trumpeted their solution and got bits of subsidy but there is little evidence that this is being done on a rational basis" (FT, 2003).

ippr's research has revealed that companies generally feel there is too much secrecy in the way fuel duty incentives are set by the Treasury. Many companies also argued that they were uncertain of the Government's long term intentions regarding fuel duty differentials and, as a consequence, were cautious of making longer term investments in alternative fuels.

The LPG experience underlines the pitfalls of short term price signals. The Government should avoid creating another dead end market that is dependent on public subsidy by developing longer term price signals that reflect climate change objectives.

ippr recommends developing differential rates of fuel duty for alternative fuels based on well-to-wheel CO_2 emissions. This would help the Treasury to develop a clear, long term strategy for fuel duty based on supporting the transition to low carbon vehicles. It would:

- *Distinguish and reward lower carbon forms of fuels – this would help to differentiate fuels not only by their exhaust emissions but also the emissions created in the production and distribution of the fuel.*
- *Send a longer term price signal of the Government's commitment to lower carbon transport fuels – this would help to give fuel suppliers and car manufacturers greater certainty to make longer term investments in lower carbon fuels and car technologies.*
- *Provide a benchmark for comparing the environmental performance of current and emerging fuels – this would help to provide greater transparency in how duty incentives for alternative fuels are developed.*

Key conclusions

- ***From the 2004 Budget, the duty break awarded to LPG should be progressively reduced so that it reflects its CO_2 benefits.***
- ***Amongst the range of biofuel options, woody biomass sources offer the most versatility in meeting future transport energy needs and reducing CO_2 emissions.***
- ***The environmental rationale underlying differential rates of duty for alternative fuels is somewhat unclear and there is too much secrecy in the way duty incentives are set.***
- ***The Government should develop differential rates of duty for alternative fuels based on well-to-wheel CO_2 emissions. This would help to distinguish and reward lower carbon forms of fuels and send a long term price signal of the Government's commitment to lower carbon cars.***

Hydrogen and policies for the longer term

In the Prime Minister's recent speech on sustainable development he stated that:

"Hydrogen holds out the potential to replace fossil fuels, especially in transport, and could transform our energy system – offering a vision of a transport system that is completely clean with no exhaust emissions" (Blair, 2003).

In the last few years there has been a flurry of articles in the press heralding hydrogen as the fuel of the future and the answer to our climate change and energy supply problems. So why does it feel as if we're still stuck in first gear? In his speech, Tony Blair offered a reason why so little progress has been made when he observed that:

"The trouble with long term issues is that they seldom fit political timescales. The impact of some of the measures we announce today will not be felt under this Government, or even this generation. We have to do what is right for the long-term" (Blair, 2003).

There is no doubting that mass produced hydrogen powered cars are still some way off and that there are many challenges ahead. The technologies for storing hydrogen on board cars still need further development. Hydrogen cars will require a completely new refuelling infrastructure and there is currently great uncertainty about how that infrastructure might be developed and how much it will cost.

Constraints on renewable energy supplies also mean that renewable hydrogen is almost certainly decades away from being a mass market option. The Energy White Paper aspires to produce 20 per cent of electricity from renewable energy sources by 2020 (this could be about 80 TWh/yr). Meeting this aspiration will be very challenging and it doesn't even make any allowance for the renewable electricity that could be needed for supplying hydrogen to road vehicles. To illustrate the scale of the challenge – the current electricity demand for producing hydrogen for the road vehicle fleet in Great Britain would be around 230 terawatt hours/year (TWh/yr). Hydrogen, as a consequence, is falling victim to the politics of the shorter term.

Where taxes can't reach

Environmental taxes can be powerful policy instruments in steering the market towards lower carbon options and bringing forward investments in near commercial options. The rapid switch to low sulphur fuels in the late 1990s and the impact of Company Car Tax on the purchasing decisions of business illustrates how effective tax signals can be. It has already be discussed how longer term, low carbon price signals could help to speed up the development and commercialisation of the technologies needed for converting woody biomass into liquid fuels.

The very fact that the Treasury is constantly lobbied by different interest groups for fuel duty subsidies underlines how influential tax incentives must be in affecting business investments and consumer behaviour. But it is fair to question the degree to which tax signals can create 'new' low carbon options and persuade companies to invest and explore radically different technology pathways they probably wouldn't have otherwise.

The limits to the tax system become apparent when thinking about what kinds of Government support will be needed for enabling the transition to hydrogen and fuel cell cars. A commitment to a particular tax policy can only be made within a Parliamentary term. Whilst it provides a good indicator of intent, it is unlikely to have a major impact on the ten to fifty year investment decisions of vehicle manufacturers, fuel suppliers and other technology development companies.

The 2002 Budget exempted hydrogen from fuel duty. This was important in helping to send a strong political signal of the Government's commitment to developing hydrogen as a road fuel. But tax breaks alone are unlikely to give companies the confidence to invest what could be millions of pounds into hydrogen technology research and new hydrogen refuelling infrastructure.

Technological innovation over the longer term

If hydrogen-powered cars are to become a future reality, tax incentives for hydrogen will need to be complemented by policies and programmes that support technological innovation over the longer term. Innovation is a common theme in government strategy papers. But the Government has yet to adequately recognise the links between innovation and environmental policy.

Innovation can be difficult concept for government to grapple with. Policy makers like to know what a particular policy measure is likely to cost and what its environmental outcomes are likely to be. The hitch with innovation is that the process of research, development and 'learning by doing' yields options whose costs and benefits are as yet unknown (Anderson et al, 2001). It might even result in options that prove to be a dead end. Innovation by definition is uncertain and can appear highly risky for government.

But in the decades to come, mitigating climate change could depend on developing policies that foster technological innovation in the development of hydrogen powered vehicles. Political leadership will be essential to supporting technological innovation of this kind and the Government appears to be waking up to this fact. Following the Johannesburg World Summit, Tony Blair wrote a joint letter with Goran Persson, Prime Minister of Sweden, to Romano Prodi, President of the European Commission, calling for greater EU commitment to the innovation of environmental technologies, such as hydrogen fuel cells.

"Faster development and greater use of new technologies has the potential massively to modernise the way our economy works. It can modernise our production and consumption patterns, our infrastructures and our technologies. Clean and more resource efficient technologies can contribute to a rich and healthy environment, and be a driving force for innovation, development of new businesses, job creation and growth." (Blair and Persson, 2003).

Climate change should be the prime motivation for supporting the development of hydrogen technologies and infrastructure over the longer term. But what Blair and Persson also acknowledge is that new low carbon vehicle technologies, such as hydrogen fuel cells, could also be good for economic prosperity and help diversify the manufacturing sector.

Key conclusions

- ***Hydrogen holds out the potential to replace fossil fuels, especially in road transport, but this is some way off and there are many challenges ahead.***
- ***Hydrogen has fallen victim to the politics of the shorter term.***
- ***Tax breaks alone are unlikely to give companies the confidence to invest millions of pounds into hydrogen technology research and new hydrogen refuelling infrastructure.***
- ***Policies for supporting innovation and long term investment in hydrogen and fuel cell cars will be critical to addressing climate change in the decades to come.***

Hydrogen and fuel cells – the next industrial success story

There is already a great deal of interest in hydrogen fuel cells in the UK with over a hundred organisations involved in fuel cell initiatives including universities, manufacturing companies, financial organisations and trade associations. In recent years, there have been a number of high profile hydrogen and fuel cell initiatives such as the London Hydrogen Partnership and the Tees Valley Hydrogen Partnership. Both these projects are concerned with promoting London and the Tees Valley as centres for hydrogen and fuel cell development. Tom Delay, Chief Executive of the Government funded Carbon Trust, has recognised that hydrogen and fuel cells represent a significant growth area for the UK.

"We have the opportunity to develop the UK as a base for manufacture and deployment of fuel cell technologies. We must act now if we are to make the most of this commercial opportunity" (Delay, 2003).

But we are at risk of missing out on this opportunity. In the last ten years around £90 million has been spent on fuel cell projects in the UK, although only £12 million came from government sources (Copper et al, 2003). Compared to other industrialised countries this spending is limited.

Government funded programmes with a remit for supporting hydrogen and fuel cell vehicles

Despite his strong oil industry links, President Bush has introduced a range of federal spending programmes for supporting the development of hydrogen powered cars. 2002 saw the launch of FreedomCAR, a joint public-private partnership to promote the development of hydrogen as a primary fuel for cars and trucks. In his State of the Union message earlier this year, President Bush called for a Freedom Fuel initiative and proposed spending $1.7 billion [£1.1 billion] on fuel cell and hydrogen vehicle research and development (R&D) over the next five years. The proposal includes $720 million [£450 million] in new spending, in addition to $1 billion [£650 million] already budgeted for hydrogen and FreedomCAR programs (US DoE, 2003).

"In this century, the greatest environmental progress will come about not through endless lawsuits or command-and-control regulations, but through technology and innovation… A single chemical reaction between hydrogen and oxygen generates energy, which can be used to power a car – producing only water, not exhaust fumes. With a new national commitment, our scientists and engineers will

Programme	Aim	Funding	Is the funding specific to hydrogen and fuel cell vehicles?
Renewable Energy and Sustainable Generation programmes run by the Engineering and Physical Sciences Research Council (EPSRC)	Provides grants for new and renewable energy technology projects including hydrogen and fuel cell technologies From 2003, the EPSRC will run a new Sustainable Generation and Supply Initiative. It will allocate funding for 'blue skies' hydrogen and fuel cell research both for vehicles and stationary applications such as homes and offices	Around £0.8-1 million per year Between £2-2.5 million over the next four years	No
Advanced Fuel Cells Programme run by the Department for Trade and Industry (DTI)	Supports the research and pre-development of fuel cell technologies both for vehicles and stationary applications	£2 million per year	No
Low Carbon Innovation Programme (LCIP) run by the Carbon Trust	Works closely with business in supporting product development and the commercialisation of new and emerging low carbon technologies for the market place. Fuel cells and hydrogen infrastructure have been identified as key areas for investment	Around £25 million per year Total of £75 million over the next three years	
Ultra Low Carbon Car Challenge run by the Energy Saving Trust (EST)	Supports the design and production of affordable low carbon cars	£10 million over the next three years	No

overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen, and pollution-free. Join me in this important innovation to make our air significantly cleaner, and our country much less dependent on foreign sources of energy" (President Bush, State of the Union Message, 2003).

For the Bush administration the attraction to hydrogen is probably not so much climate change but a means of helping to make the US less dependent on foreign sources of energy. But this only serves to underline why hydrogen is beneficial from both an environmental and energy supply perspective. It is unrealistic to expect the UK to compete with the spending commitments made by the US. But the Freedom Fuel initiative underlines how feeble Government expenditure on hydrogen and fuel cell cars has been.

Why are we lagging behind?

One of the major reasons why the UK is lagging behind is because the Government does not want to appear to be 'picking winners' and choosing hydrogen and fuel cell technologies over other vehicle technologies. Despite the rhetoric about the benefits of hydrogen in the Powering Future Vehicles Strategy, no specific long term policies or initiatives were introduced for supporting the development of hydrogen or fuel cell vehicles.

In April 2003, Alistair Darling, the Secretary of State for Transport, launched the Government's Ultra Low Carbon Car Challenge – a £10 million prize fund for helping to design an affordable ultra low carbon passenger car, capable of mass production within a near to medium time scale, at a competitive price. The idea of the challenge is commendable and should help to spur investments in cutting edge, fuel efficient car designs and raise public awareness of low carbon car technologies. But there is a danger that this money will be spread too thinly and will not target enough support to hydrogen and fuel cell vehicle technologies. It's hardly surprisingly the UK is currently not viewed as an attractive market for hydrogen and fuel cell investments compared to Japan, Canada or Germany.

The Japanese Government has set a target for 50,000 fuel cell cars to be on the road in Japan by 2010. In 1993, the Ministry of Economy, Trade and Industry established one of the world's largest joint industry-government-university programmes for hydrogen and fuel cell R&D. The World Energy Network (WE-NET) programme has involved testing and developing hydrogen production and storage technologies. Other national projects such as the Japan Fuel Cell and Hydrogen Project focus on demonstrating hydrogen fuel cell vehicles and hydrogen refuelling facilities. In 2002, the Japanese Government spent a total of 22 billion YEN [£120 million] on hydrogen and fuel cell R&D and its expected to rise to 31 billion YEN [£165 million] this year (Daito, 2002).

Canada has become one of the global leaders in fuel cell R&D, enabled by strong and co-ordinated government support in the form of direct funding and strategic guidance (DTI, 2003b). The Canadian Government spends around C$34 million [£15 million] per year on hydrogen and fuel cell research and industry development. (This includes research into fuels cells for both vehicles and stationary applications such as homes and offices). Canada has proactively sought to develop and grow a Canadian hydrogen and fuel cell industry. Since 1996, the Canadian Government has allocated C$60 million [£28 million] to 'Industry Canada' (Hart et al, 2002). Industry Canada has sought to attract foreign investment into Canada's fuel cell sector, strengthen university research capacity in the area of hydrogen and fuel cells, and encourage strategic partnerships between research institutes and industry.

Germany has made significant investments in hydrogen and fuel cell vehicles. In 1992 the German Government established the Clean Energy Partnership, part of its national strategy for sustainability. The five-year government-industry partnership is concerned with demonstrating hydrogen's viability as a fuel for everyday life. The German Government is currently working with a number of vehicle manufacturers who plan on producing small numbers of hydrogen and fuel cell powered buses and cars from this year.

When it comes to capitalising on technology innovations, the UK's track record is poor. Despite the potential for wind power particularly in the North East of England and Scotland, procrastination has meant that we are way behind the Danes. Danish wind turbine companies now have a market share of half the world market with a turnover of 3 billion euros [£2 billion] and account for 16,000 jobs in Denmark alone (Danish Wind Power Association, 2003).

Textbooks on hydrogen and fuel cells often point out that the fuel cell has its roots in British history. Sir William Grove set out the basic principles of a fuel cell in the 1830s although it was not until a century later that the British scientist, Francis T Bacon, actually made a fuel cell that could produce power. Yet, of the estimated 4,000 fuel cell systems that have been built and operated around the world only a handful were developed in the UK (Cropper et al, 2003). The British have a reputation for allowing ideas invented here to be exploited elsewhere. It would be a sad irony if we failed to build on home-grown technologies and turn fuel cell vehicle technologies into the next industrial success story for the UK.

Key conclusions

- ***The UK has the potential to become a hub for the manufacture and deployment of hydrogen and fuel cell vehicle technologies.***
- ***The UK is currently lagging behind the US, Canada, Japan and Germany, whose governments have made significant investments in hydrogen and fuel cell vehicle R&D as well as demonstration programmes.***
- ***The Government's policy of 'not picking winners' is obstructing innovation and allowing ideas for hydrogen and fuel cell technology developments to be exploited elsewhere.***

The hydrogen and fuel cell industry at a cross-roads

In recent months the profile of UK hydrogen and fuel cell activity has received a welcome boost. The Government has shown growing interest in fostering the development of a UK hydrogen and fuel cell industry and catching up with the likes of Canada and Japan. May 2003 saw the launch of Fuel Cells UK, an industry network that will work with the Department for Trade and Industry (DTI) and other government funded agencies in supporting fuel cell research, participation in research projects and support for new start-ups in the sector.

The DTI are also developing a web based Fuel Cells Forum for academia, industry, venture capitalists and other stakeholders to exchange and disseminate information on fuel cell related news, business developments and patents. Following consultation with industry, the Government plans on announcing its UK Fuel Cell Vision later in the autumn of 2003. There is a long way to go before the UK is regarded as a world player in hydrogen and fuel cell R&D. But developing a Fuel Cell Vision for the UK is a bold first step and suggests that we are heading in the right direction.

The UK's Fuel Cell Vision is not only about vehicles but also the use of hydrogen and fuel cells in offices and homes. This report is, however, primarily concerned with use of hydrogen and fuel cells in vehicles.

The UK's Fuel Cell Vision

If the UK's Fuel Cell Vision is to go beyond Ministerial gestures it should be backed up by a number of concrete policy objectives. ippr recommends that the UK's Fuel Cell Vision should have three key objectives to:

1. Make the UK an attractive market for hydrogen and fuel cell vehicle investments

The UK's Fuel Cell Vision should raise the profile of the UK hydrogen and fuel cell vehicle industry and attract foreign investment by:

- *Promoting regional hydrogen and fuel cell vehicle projects – The London and Tees Valley Hydrogen Partnerships will provide an opportunity to test hydrogen and fuel cell vehicle and refuelling technologies in real world conditions and raise public awareness of their environmental benefits. A number of major fuel suppliers and vehicle manufacturers have signed up to these partnerships and will be helping to finance demonstrations. The Tees Valley Hydrogen*

Partnership has helped to put the North East on the map as a leading region in the development of low carbon energy technologies. The Government should encourage other regions throughout the UK to develop similar high profile partnerships that attract private investment.

- *Identifying first mover markets for introducing hydrogen refuelling infrastructure – The UK's Fuel Cell Vision should attempt to identify vehicle markets where the introduction of hydrogen refuelling infrastructure could be first developed and tested. Bus or delivery vehicle fleets would be good starting points. Buses are particularly good candidates for hydrogen because they refuel at depots and have fixed routes (Foley, 2001). Many lessons could be gained regarding the most practical way of storing hydrogen and the development of safety standards.*

2. Take a co-ordinated approach to hydrogen and fuel cell vehicle research and industry development in the UK

There are currently a number of Government funded programmes with an interest in supporting the R&D of hydrogen and fuel cell vehicle technologies. These include programmes managed by the DTI, the Engineering and Physical Sciences Research Council (EPSRC), the Carbon Trust and EST. There is currently duplication of effort and confusion about how these programmes should compliment one another. The UK's Fuel Cell Vision should identify the synergies between these Government funded programmes to co-ordinate delivery of support and ensure that resources are not being wastefully used. It not yet clear what role the LowCVP will play and how it will interact with these various programmes. Developing a co-ordinated approach to hydrogen and fuel cell vehicle research and industry development should be a key objective of the UK's Fuel Cell Vision.

In addition to co-ordinating Government programmes and partnerships, it will also be important to find ways of linking the research ideas of universities and research councils to the investment decisions being made by companies regarding product development. The newly created Fuel Cells UK could act as a broker for enabling strategic research collaborations between research organisations and industry.

3. Collaborate with other countries to pool resources and share results

The Government has already signed up to the International Energy Agency (IEA) agreements on hydrogen and fuel cells which state that the UK will work in partnership with other countries in undertaking hydrogen and fuel cell research. At an IEA meeting in April 2003, Spencer Abraham, US Secretary of Energy, proposed that the US and the EU work together in aiming to get competitively priced hydrogen cars on the market by 2020. The IEA has no funding of its own but it does provide a framework for sharing results and pooling the research investments of countries.

The European Commission does have funding for R&D as well as demonstration projects which is channelled through its Research Framework Programmes. The Fifth Research Framework Programme (1998-2002) earmarked 120 million euros [£90 million] to hydrogen and fuel cell research. In the Sixth Research Framework Programme (2003-2006), research on sustainable energy and transport has a budget of 2.1 billion euros [£1.5 billion]. The budget for research on hydrogen and fuel cells has yet to be determined. But it is envisaged that it will be increased substantially not least because the EC recently formed a High Level Group on Hydrogen and Fuel Cells involving business leaders from major fuel suppliers and vehicle manufacturers.

The UK is currently participating in a European wide hydrogen fuel cell bus research project. Through the Clean Urban Transport for Europe (CUTE) project the EC has awarded 18.5 million euros [£13 million] to nine European cities for trialling hydrogen fuel cell buses. Three hydrogen fuel cell buses will begin operation in London in 2004. A priority for further collaborative research projects should be to find ways of producing and storing hydrogen, developing hydrogen refuelling infrastructure and setting safety standards.

The Prime Minister has already called for greater EU support for technological innovation and further developments in hydrogen and fuel cell technologies for cutting carbon emissions. The Prime Minister should also take the lead in identifying opportunities for international partnerships for pooling resources and co-operating with other countries in developing hydrogen and fuel cell vehicle projects. The Group of Eight (G-8) major industrialised nations should be a target for collaborations. The Prime Minister's involvement would demonstrate international leadership and underline the Government's political commitment to taking forward the UK's Fuel Cell Vision.

Money talks

It has already been highlighted that the Government does not spend anywhere near as much on hydrogen and fuel cell vehicle R&D as some other industrialised countries. Whilst the Engineering and Physical Sciences Research Council (EPSRC), Carbon Trust and EST all run programmes for supporting low carbon technologies, they do not have specific funding earmarked for hydrogen and fuel cell vehicles. The EPSRC, Carbon Trust and EST receive many bids for funding support and as a consequence they can only currently allocate small pots of money to hydrogen and fuel cell vehicle research, demonstration projects and industry development. The DTI's Advanced Fuel Cell Programme has been under-funded for many years. Its tiny research budget, of £2 million per year, is expected to support fuel cell research not only for vehicles but also homes and offices. ippr would like to see hydrogen and fuel cell vehicle R&D receive greater funding support in the Government's next Spending Review 2004-2006.

The area where Government support for technological innovation has been weakest is in relation to product development and commercialisation. Turning a prototype idea into a commercially viable product requires considerable capital investment. Developing innovative ideas for hydrogen and fuel cell vehicle technologies must appear particularly costly and risky to business. ippr recommends that the Government help shoulder this risk through the provision of venture capital grants. The Low Carbon Innovation Programme (LCIP), run by the Carbon Trust, already provides venture capital funds for helping to get new and emerging low carbon technologies to the market place. The Government should provide additional funding for venture capital grants specifically targeted at the development and commercialisation of hydrogen and fuel cell vehicle technologies. This additional funding could also be channelled through the LCIP.

The Government has many policy interests and it is unrealistic to expect that hydrogen and fuel cell vehicles will be a spending priority over improvements in schools or hospitals. It is therefore important that the UK's Fuel Cell Vision seeks to pool resources with other countries to maximise the impact of additional funding for hydrogen and fuel cell vehicle R&D and venture capital grants.

The Government's Innovation Strategy

The Government is currently developing an Innovation Strategy for the UK to be published in the autumn of 2003. As part of this Strategy the Government is looking to identify how innovation can promote greater resource efficiency that benefits both the environment and business. The growth of a hydrogen and fuel cell vehicle industry in the UK offers a means of both reducing the environmental impact of road vehicles and potentially creating new industries and jobs in manufacturing and engineering. Taking forward the UK's Fuel Cell Vision should be central to the Government's forthcoming Innovation Strategy. The Government should seek to develop a better understanding of the contribution that a hydrogen and fuel cell vehicle industry could make to both economic and resource productivity.

Key conclusions

- ***The Government's decision to develop a UK Fuel Cell Vision is a bold first step, but it needs to be backed up by a number of concrete objectives.***

- ***The UK's Fuel Cells Vision should have three key objectives. It should:***

  1. ***Make the UK an attractive market for hydrogen and fuel cell vehicle investments.***

  2. ***Take a co-ordinated approach to hydrogen and fuel cell vehicle research and industry development in the UK.***

  3. ***Collaborate with other countries to pool resources and share results. The Prime Minister should take the lead in identifying opportunities for international partnerships for developing hydrogen and fuel cell vehicle projects.***

- ***Hydrogen and fuel cell vehicle R&D should receive greater funding support in the Government's next Spending Review 2004-2006.***

- ***The Government should introduce venture capital funding specifically targeted at the development and commercialisation of hydrogen and fuel cell vehicle technologies. Venture capital grants could be channelled through the Carbon Trust's Low Carbon Innovation Programme.***

- ***It is unrealistic to expect that hydrogen and fuel cell vehicles will be a spending priority over improvements in schools or hospitals. It is therefore particularly important that the UK's Fuel Cell Vision seeks to pool resources with other countries to maximise the impact of additional funding for hydrogen and fuel cell vehicle R&D and venture capital grants.***

- ***The UK's Fuel Cell Vision should be central to the Government's forthcoming Innovation Strategy. The Innovation Strategy should seek to develop a better understanding of the contribution that a hydrogen and fuel cell vehicle industry could make to both economic and resource productivity.***

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Appendix

Annual losses of revenue from the fuel duty break for Liquefied Petroleum Gas (LPG)

	2000	2001	2002	2003 (expected)
Annual LPG sales (tonnes)	19,600 tonnes	50,581 tonnes	82,767 tonnes	Approx. 100,000 tonnes
Annual LPG sales (litres)	19,600 tonnes x 1,975 = 38,710,000 litres	50,581 tonnes x 1,975 = 99,897,475 litres	82,767 tonnes x 1,975 = 163,464,825 litres	100,000 tonnes x 1,975 = 197,500,000 litres
LPG revenue collected	38,710,000 litres x 0.065 = £2,516,150	99,897,475 litres x 0.065 = £6,493,336	163,464,825 litres x 0.065 = £10,625,214	197,500,000 litres x 0.065 = £12,837,500
Equivalent amount of petrol	387,100,00 litres/ 1.25 = 30,968,000 litres	99,897,475 litres/ 1.25 = 79,917,980 litres	163,464,825 litres /1.25 = 130,771,860 litres	197,500,000 litres /1.25 = 158,000,000 litres
Equivalent petrol revenue	30,968,000 litres x 0.458 = £14,183,344	79,917,980 litres x 0.458 = £36,602,435	130,771,860 litres x 0.458 = £59,893,512	158,000,000 litres x 0.458 = £72,364,000
Annual loss of revenue	£14,183,344 - £2,516,150 = £11,667,194	£36,602,435 - £6,493,336 = £30,109,099	£59,893,512 - £10,625,214 = £49,268,298	£72,364,000 - £12,837,500 =£59,526,500
Annual loss of revenue (to the nearest million)	**£12 million**	**£30 million**	**£49 million**	**£60 million (expected)**

Table produced by ippr
Automotive LPG sales in tonnes from Customs and Excise/LPGA (2002). 2003 figures estimated by ippr.
Duty on LPG is the equivalent of 6.5 pence per litre. Duty on petrol is 45.8 pence per litre.
A litre of LPG allows a vehicle to travel around 80 per cent of the distance it could travel on a litre of petrol.