Energy Saving Trust

Road fuel gases and their contribution to clean low-carbon transport

Submission by the Energy Saving Trust

November 2003

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ENERGY SAVING TRUST

This is the response of the Energy Saving Trust to the consultation paper on road fuel gases and their contribution to clean low-carbon transport, jointly issued by DfT/HMT/HMCE in June 2003. This response should not be taken as representing the views of individual Trust members.

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

Acknowledgements

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Contents

EST Fuel Gas Consultation Response

Executive summary

EST proposes a 10-year fiscal framework for LPG that would offer *conditional* support for LPG, provided air quality and carbon benefits can be assured over time through the introduction of dedicated mono-fuel LPG vehicles. To achieve this, industry and government must work together: industry must improve fuel availability and vehicle technology; government must provide fiscal stability. If *both* sides do not make these commitments, the environmental benefits of LPG will not be realised. EST considers that the same framework should apply to CNG.

1. Summary of key issues

Environmental benefits of LPG

Carbon benefits

Taking into account fuel carbon content and upstream energy use, well-to-wheel carbon emissions from LPG vehicles are approx 18% lower than from petrol vehicles and similar to those from diesel. With dedicated engines, well-to-wheel emissions could be 25–30% better than petrol and 10% better than diesel. To achieve these carbon benefits, dedicated LPG engines must be produced. Mono-fuel vehicles offer significant carbon emissions reduction benefits compared to both conventional petrol and diesel engines.

Air quality benefits

Long-term benefits of new OEMs will be limited because tougher regulated emissions standards are driving improvements to petrol and diesel vehicles. However, high quality LPG conversions will continue to offer air quality benefits because they are replacing existing polluting vehicles. This will particularly benefit polluted urban areas. To achieve air quality benefits, conversions of LPG vehicles must be subject to more stringent quality controls (see summary of recommendations).

Cost implications of raising LPG excise duty: 'break-even' analysis

LPG is currently about 38 pence per litre on the forecourt, which is about half the price of petrol or diesel. However this price advantage is offset by additional costs, which include:

- Fuel economy: a litre of LPG takes you a shorter distance than a litre of petrol or diesel;
- Price premium: it costs extra to buy an LPG bi-fuel OEM vehicle, or to convert an existing vehicle.

EST has developed a methodology to calculate the point at which LPG 'breaks-even' with diesel and petrol i.e. the point at which it loses its price advantage in terms of running costs. This analysis indicates that, when premium purchase costs are taken into account, LPG's cost advantage over diesel is significantly reduced, and any short-term price increase will have a marked impact on the market for LPG vehicles.

The future of LPG: dedicated mono-fuel vehicles

Mono-fuel vehicles are essential if LPG is to retain its environmental advantage over conventional fuels. If these vehicles do not come to market, LPG will increasingly lose its environmental benefits, as the overall fleet becomes cleaner. There is no technological reason why mono-fuel vehicles cannot reach the market within the next three years. However, fuel infrastructure is a key issue – fuel availability barriers can be overcome, provided there is a stable fiscal framework and adequate investment to overcome consumer fears over fuel availability. Further, due to improved fuel economy, mono-fuel LPG vehicles will be able to withstand a higher duty rate than current OEM LPG vehicles before they lose their price advantage over diesel and petrol.

Alternative fuels in the UK and overseas

EST believes that the future of the automotive sector lies in the gradual development of a mixture of technologies and fuels. EST sees, for example, no conflict between greater numbers of petrol-hybrid and mono-fuel LPG cars. If the market for LPG collapses, it could hamper industry investment in cleaner alternative fuels and vehicle technologies, and could also hamper the development of future cleaner fuels such as hydrogen. Evidence from other countries that have attempted to develop alternative road fuels shows that in most cases, raising the cost of LPG fuel duty has had significant negative impacts on the LPG market. In contrast, Germany has recently set a stable fiscal framework for CNG up to 2020.

2. Summary of recommendations

Improving Conversions

There is a strong case for high-quality LPG conversions to address air quality concerns in urban areas, provided the quality of conversions is improved:

1. Certified at the time of completion by a registered inspector. The existing LPGA Approved Installer Scheme offers a sound and established basis for such a programme;
2. For Euro IV, installing only LPG systems that are on a register as having been certified by the manufacturer that they meet specified levels of emission performance for that specific vehicle. Random checking to be undertaken in an extension of the existing Conformity of Production testing arrangements;
3. For Euro III and Euro II, installing only LPG systems that are on the PowerShift or autogas+ scheme which have demonstrated good emissions performance.

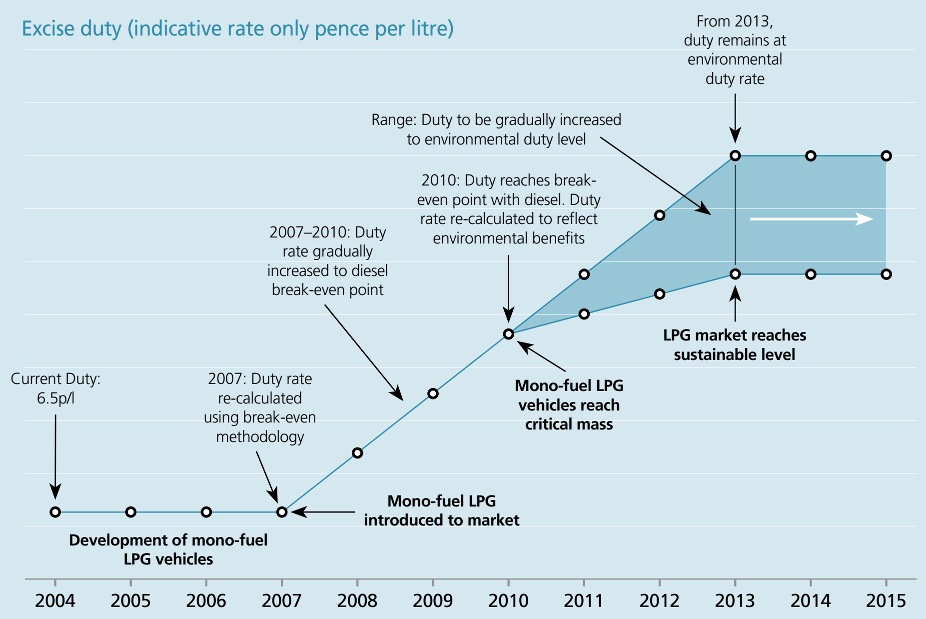
EST cleaner low carbon fuel framework

EST proposes a 10-year fiscal framework for LPG that would offer *conditional* support for LPG, provided air quality and carbon benefits can be assured over time through the introduction of dedicated mono-fuel LPG vehicles. EST supports the application of this framework to all alternative fuels, such as CNG, biofuels, and, in the longer term, hydrogen.

Under the EST framework, fuel duty would be maintained at its current level for the next 3 years (from 2004) in order to create the market conditions for mono-fuel vehicles to be introduced to market. In 2007, the break-even rate for LPG would be calculated against diesel based on the fuel economy of mono-fuel LPG vehicles. The duty rate would be gradually raised to this level by 2010.

In 2010, the fuel duty rate would be re-calculated based on the environmental benefits of the fuel. The duty rate should gradually rise to this level over a further 3 years (creating a 10-year framework). After this time the duty would remain constant at this level. *The EST proposal is summarised in Chart 1 below.*

CHART 1 : EST 10-Year Fiscal Framework for LPG



Support for CNG

CNG has the potential to make a major positive contribution to reducing air pollution in urban areas. However, the market for CNG is at a very early stage in its development. To accomplish this, a stable fiscal framework is necessary, both to incentivise the development of CNG vehicles and infrastructure and to allow a secondary market to develop. EST considers that the cleaner low carbon fuel framework should be applied to CNG as well as to LPG. This implies that the tax revenue should remain at its current level for the next 3 years, and should be re-evaluated at that point.

This consultation and the future of EST programmes

Government decisions on fuel taxation have important implications for EST's TransportEnergy programmes, and for the market for AFVs in general. **In light of this, a new system of vehicle grants is to be proposed for TransportEnergy**. A number of options will be considered for grants to be awarded to vehicles with the lowest emissions. These options will be discussed with key stakeholders.

1. Introduction

The Energy Saving Trust (EST) is a non-profit company, funded largely by the UK Government to deliver sustainable energy solutions to households, small firms and the road transport sector. EST is one of the UK's leading organisations fighting to combat climate change. This response should not be taken as representing the views of individual Trust members.

EST, through the TransportEnergy initiative, delivers innovative solutions, programmes and information in a campaign to reduce the damaging effects of transport on the environment and seeks to promote sustainable mobility. TransportEnergy is the 'umbrella brand' for the Trust's environmental transport programmes, which include PowerShift and CleanUp.

TransportEnergy PowerShift

Launched in 1996, the TransportEnergy PowerShift programme has been set up with the aim of 'kick-starting' the market for cleaner Alternative Fuel Vehicles (AFVs) in the UK. AFVs can reduce the output of carbon dioxide, the main global warming gas, as well as limiting the negative impact of vehicles on local air quality by cutting emissions of local pollutants.

PowerShift promotes AFVs and can offer grant support to help with the purchase of vehicles that have proven emissions benefits and that are technically viable. These include vehicles running on natural gas (CNG and LNG), liquefied petroleum gas (LPG) and electricity (including hybrids). PowerShift aims to transform the markets for clean fuel vehicles in the UK by breaking down the barriers to their development and large-scale market adoption. PowerShift has a budget of £30m from 2001–4.

TransportEnergy CleanUp

The TransportEnergy CleanUp Programme aims to improve air quality in pollution 'hotspots' by encouraging the fitting of emissions reduction equipment to the most polluting vehicles. TransportEnergy CleanUp Campaign will target the nine worst pollution areas in the country[1]. The TransportEnergy CleanUp Campaign has a budget of £30 million allocated to the initiative (2001– 2004).

This consultation and the future of EST programmes

Government decisions on fuel taxation have important implications for EST's TransportEnergy programmes, and for the market for AFVs in general. **In light of this, a new system of vehicle grants is to be proposed for TransportEnergy**. Grants are currently provided on a percentage of the additional cost of conversion or at a specified level depending on the cost and type of technology. However, EST considers that, with the introduction of lower emissions vehicles that use hybrid and electric technologies, it has become difficult to calculate the additional cost of these technologies and hence difficult to set a grant based on percentage of additional cost.

1. London, West Midlands, Greater Manchester, West Yorkshire, Tyneside, Liverpool, Sheffield, Nottingham, Bristol.

EST will discuss these issues with key stakeholders in the public and private sector will be invited to comment. Please see Appendix A for a summary of key issues.

As an indication of EST thinking, the programme could be structured around a simple sliding scale based on percentage emissions improvement for each vehicle, perhaps compared to vehicles in its market segment (see Table 1 below).

TABLE 1

20% lower emissions	30% lower emissions	40% lower emissions	50% lower emissions
£1,000	£1,500	£2,000	£2,500

2. Policy framework: reducing CO_2 and air pollution from the transport sector

2.1. Reducing CO_2 emissions from road transport

Following the Kyoto climate change conference in December 1997, the UK has a legally binding target to reduce greenhouse gas emissions to 12.5% below 1990 levels by the period 2008 to 2012. This means a reduction equivalent to 27 million tonnes of carbon (MtC). The UK also has a domestic aim of reducing CO_2 emissions to 20% below 1990 levels by 2010, and is committed to putting itself on the path to cut CO_2 emissions by 60% by about 2050[2].

Since 1990, the average carbon efficiency of new cars entering the fleet has improved by 10%[3], largely because voluntary agreements between the EC and the European, Japanese and Korean automotive industry associations[4]; stipulate that the average of new passenger cars sold in the European Union will be 140 gCO_2/km by 2008 for ACEA and 2009 for JAMA and KAMA (a reduction of about 25% from the base year of 1995)[5]. The UK Government expects this voluntary agreement to reduce the UK's carbon emissions by 4 Million Tonnes by 2010[6].

Despite these improvements in new vehicle CO_2 emissions, increases in car ownership and miles travelled mean that total carbon emissions from car transport have been roughly flat for the last decade[7]. In 2001, road transport contributed 21% of total UK CO_2 emissions[8].

In addition to the EC voluntary agreements, the Government has put in place a number of strategies designed to deal cut CO_2 from road transport, including:

- The 10 Year Plan for Transport promised a reduction of 1.6MtC in carbon dioxide emissions[9]. The impending review of the 10 Year Plan will show how successfully, or otherwise, Government is moving toward the targets;
- The Powering Future Vehicles strategy, published in 2002, set targets that within the next decade one-in-ten new cars sold in the UK will be low-carbon vehicles with emissions of 100 grammes per kilometre (g/km) CO_2 or less, and that one-in-five new buses will also be low-carbon[10]. These targets were reaffirmed in the Energy White Paper, published in 2003;
- The Low Carbon Vehicle Partnership (LowCVP) – an action and advisory group – that will promote the UK's shift to low-carbon transport, help industry, consumers, environmental and other stakeholders to participate in the shift, and maximise the competitive advantage for UK businesses[11]. EST is a key contributor to the work of the LowCVP.

2. 'Our energy future- creating a low carbon economy', DTI 2003.
3. DTI, Energy White Paper, 2003.
4. ACEA, JAMA and KAMA respectively.
5. 'Implementing the Community Strategy to Reduce CO_2 Emissions from Cars: Third annual report on the effectiveness of the strategy (Reporting year 2001)', EC Communication to European Parliament and Council, 2002.
6. DEFRA, 'Climate Change UK Programme – Summary', http://www.defra.gov.uk/environment/climatechange/cm4913/summary/03.htm.
7. DTI, Energy White Paper, 2003.
8. Digest of Environmental Statistics http://www.defra.gov.uk/environment/statistics/des/globatmos/gafg07.htm.
9. DEFRA, 'Climate Change UK Programme – Summary', http://www.defra.gov.uk/environment/climatechange/cm4913/summary/03.htm.
10. Powering Future Vehicles: the Government Strategy. DfT, DTI DEFRA and HMT, July 2002.
11. DTI, Energy White Paper, 2003.

EST supports the Government's CO_2 reduction targets and initiatives, and is working with government and industry to cut emissions from the transport and energy sectors. AFVs have the potential to make a positive contribution to the achievement of these targets.

2.2. Air quality – a key policy driver

Road transport is the main source of air pollution in the UK. Air quality concerns have historically been the principal driving force behind moves to encourage cleaner fuels and vehicle technologies. The main air pollutants from road vehicles include carbon monoxide (CO), oxides of nitrogen (NO_x), benzene and particulate matter, which can have negative effects on health, particularly in urban areas. These impacts are well documented:

- A 1998 report from the Committee on the Medical Effects of Air Pollutants concluded that in 1996 the deaths of between 12,000 and 24,000 vulnerable people may have been brought forward by short-term exposure to air pollution, and that a further 14,000–24,000 hospital admissions may have been associated with short-term exposure to air pollution[12];
- In London alone it is estimated that 380 deaths a year, and 1,200 hospitalisations can be linked to air pollution from transport, while minor breathing problems due to exhaust fumes could affect as many as half a million people[13].

Air quality problems are to be addressed through the Government National Air Quality Strategy for England, Scotland, Wales and Northern Ireland, set out in 2000. This sets health based air quality standards and objectives for eight key air pollutants to be achieved between 2003 and 2008. These objectives were supplemented and tightened for some pollutants by the first addendum to the air quality strategy published in 2003.

The targets set in the addendum are to be achieved between 2003 and 2010 in the UK, and aspirational targets are set for London to 2015. Meeting these objectives will also ensure that the UK will meet the objectives set out in the Daughter Directives of the EU Air Quality Framework Directive. Reducing air pollution from road transport will play a significant role in helping to meet these objectives.

European Union air pollution regulations for new vehicles ('Euro' standards)[14] have significantly reduced air pollutants from the new vehicle fleet. Euro I standards were effective 1993, while Euro II standards were introduced from 1996. Euro II vehicles now form the majority on the road and future emissions reductions will depend largely on their replacement by vehicles subject to Euro III (2001) and Euro IV (2006) standards. Vehicles are increasingly manufactured to Euro IV standards even in advance of a legal requirement.

However, while Euro standards on air quality are driving emissions downwards, they are insufficient to guarantee that the UK will meet its Air Quality targets. Recognising this, many Local Authorities have designated Air Quality Management Areas (AQMAs). So far 122 authorities have been set up with a further 9 anticipated. There are two key problems:

12. 'Quantification of the effects of air pollution on health in the UK', Committee on the Medical Effects of Air Pollutants, January 1998. COMEAP.
13. NHS Executive, 'On the Move', October 2000.
14. See Appendix A, Table 19 for details of Euro standard emission limits.

a) Vehicle fleet turnover is fairly slow (average vehicle life roughly 10–12 years)[15]; and

b) Older cars create far more than pollution than newer cars.

These points are illustrated in Table 2 below:

TABLE 2 : **Fleet composition projection for 2005[16]**

Euro standard and year	Cars	LGV	Rigid HGV	Artics	Bus
Pre-Euro I (pre-1993)	10%	6%	2%	1%	1%
Euro I (1993)	15%	11%	9%	4%	4%
Euro II (1996)	30%	33%	39%	36%	36%
Euro III (2000)	18%	51%	50%	59%	59%
Euro IV (2005–7)	27%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Source: Low Emission Zones – National vehicle emission standards Consultation Results Paper, TTR 2003.

It can be seen that the majority of cars on the road in 2005 will likely not meet the Euro III emission limit, and importantly, 10% will be pre-Euro vehicles. The total vehicle numbers in the car fleet is high, and therefore very significant, because old vehicles have a disproportionate impact on air pollution.

For example, in London by 2007, cars built before 1993 (pre-Euro standard) will comprise only 0.7% of the fleet, but will be responsible for 4.5% of all NO_x emissions from cars, and 1.7% of all road transport NO_x emissions[17]. These problems are exacerbated by the growth of diesel, since the Euro IV standard for NO_x is three times higher for diesel than for petrol. From 1992 to 2002, the number of diesel-engine vehicles licensed increased more than four-fold, compared to an 8 per cent growth rate for petrol engine vehicles[18].

Conclusion

EST considers that it is essential that air quality issues remain a key consideration in the debate over the future of road fuels, at least until the UK has met these objectives i.e. until the end of 2010 for the UK, and until 2015 for London.

15. Total vehicle parc.

16. Exact date of Euro standard can vary slightly between vehicle class.

17. 'The London Low Emission Zone Feasibility Study: A Summary of the Phase 2 Report to the London Low Emission Zone Steering Group', AEA Technology 2003.

18. DTI Energy Statistics 2003: See Appendix A, Table 18 for details.

3. Environmental performance of LPG

This consultation focuses on the tax rate for gaseous fuels, including LPG and CNG, which currently benefit from favourable tax rates. These rates have encouraged this development and have helped stimulate market transformation. There are currently 1,380 fuel sites, which is a good step toward the provision of an accessible supply for most motorists in Great Britain.

In addition, vehicle manufacturers have developed off-the-assembly-line bi-fuel LPG vehicles (see below), and some are developing mono-fuel LPG vehicles which could result in a consistent 20% improvement in tailpipe emissions.

Sections 3, 4 and 5 provide the following:

- EST view on the environmental performance of LPG;
- The implications of changes to the excise duty on the existing and future LPG market;
- The potential for mono-fuel vehicles to come to market;
- EST proposal for setting duty rates for LPG.

This section presents the EST view of the environmental benefits of using LPG as a road transport fuel.

3.1. Air quality

Combustion system design and tailpipe clean-up have significantly reduced emissions from both petrol and diesel engines in recent years and this trend will continue, driven by EU regulation. The air quality benefits of LPG compared to new petrol and diesel engines are therefore in decline. However, Euro standards alone are insufficient to guarantee that the UK will meet its Air Quality targets. Therefore there is a strong air quality case for good quality LPG conversions.

Air quality benefits are very dependent on vehicle age and engine type. Diesel vehicles typically have higher emissions of NO_x, due to the higher combustion temperatures of more efficient engines, and higher particulate emissions, because of combustion characteristics (droplet formation). LPG generally has cleaner combustion than even petrol.

3.1.1. LPG in the new vehicle fleet

Data on page 13 compares Euros II, III and IV values for diesel, petrol and LPG cars for the main regulated emissions.

3.1.1.1. NO_x

NO_x is the largest remaining pollution problem related to petrol engines (though diesel emissions remain worse). Emissions standards for cars are as in Table 3 below:

TABLE 3

Standard	NO_x emissions (g/km)	
	Petrol	Diesel
Euro II	0.5 (inc HC)	0.6 (inc HC)
Euro III	0.15	0.50
Euro IV	0.08	0.25

Good quality LPG conversions emit approx 0.04g/km, and therefore are better than even the Euro IV requirement for petrol vehicles. However, the benefits are clearly largest when applied to older vehicles.

Diesel NO_x emissions are higher, but will fall as older vehicles are replaced. The total car stock, even at Euro IV diesel standards, will emit approx 125kt NO_x (less than 10% of current UK NO_x emissions from all sources). In the long term, the potential for LPG cars to contribute effectively to NO_x emissions reduction is very limited: the largest potential will be in substituting for diesel vehicles. But, as diesel conversions are not generally economic, this requires purchase of a new LPG vehicle in preference to a diesel.

3.1.1.2. Hydrocarbons

Hydrocarbon emissions standards for cars are as in Table 4 below:

TABLE 4

Standard	HC emissions (g/km)	
	Petrol	Diesel
Euro II	0.5 (inc NO_x)	0.6 (inc NO_x)
Euro III	0.2	N/a
Euro IV	0.1	N/a

Hydrocarbon emissions from diesel engines are low and therefore not regulated.

At Euro IV petrol levels, the entire car fleet would emit approx 50kt of hydrocarbons, less than 5% of the UK total. Some new petrol vehicle emissions are already half those of the Euro IV standard. LPG engine emissions are 30% lower again (for the Vauxhall Astra). In addition the hydrocarbons emitted (smaller alkanes) generally have a lower photo-chemical oxidation creation potential (POCP) than liquid fuel emissions. Even so, in the long term, LPG can have little impact over and above the regulations already legislated.

Similar issues apply to carbon monoxide.

3.1.1.3. Particulate matter

Particulate emissions standards for cars are as in Table 5 below:

TABLE 5

Standard	PM emissions (g/km)	
	Petrol	Diesel
Euro II	N/a	0.08
Euro III	N/a	0.05
Euro IV	N/a	0.025

Particulate emissions from petrol engines are inherently low and therefore not regulated. LPG emissions are lower still.

At Euro IV diesel levels, the entire car fleet would emit approx 12kt of particulates, less than 5% of the UK total PM_{10}. The bulk of transport related PM emissions are from heavier diesel vehicles. So, for PM pollution, LPG vehicles offer minimal advantages over petrol vehicles and declining advantages over diesel.

3.1.2. Air quality benefits: the case for conversions

As noted above, Euro standards alone are insufficient to guarantee that the UK will meet its Air Quality targets. Therefore EST believes that there is a strong air quality case for good quality LPG conversions. Indeed, LPG vehicles (if OEM or other good quality conversions) offer benefits over both petrol and diesel vehicles. For the most problematic urban emissions (NO_X and PM_{10}), the advantages are most significant over diesel.

3.1.2.1. EST programmes: emissions reductions

EST TransportEnergy programmes have proved that high quality LPG conversions and OEMs can deliver significant savings in air pollution. Between 1997 and 2001, PowerShift has cut emissions of NO_X by around 106,000kg and PM by 9,457kg[19].

However EST recognises that poor quality conversions have undermined the programme. We are therefore addressing this issue in this response (see section 3.1.2.4.).

3.1.2.2. Conformity of production (COP) testing

EST performs COP tests on vehicles that have been grant funded under the PowerShift programme, to ensure that these vehicles are achieving the required emissions reductions to which the vehicles were approved onto the PowerShift Register. Additionally, COP aims to drive through improvements and raise standards by ensuring that vehicles, equipment and converters that fail to meet the required standards are subject to further testing after a period of investigation and rectification. EST only funds vehicles which are proven (by type approval tests) to offer significant emissions advantages both in local and global terms.

19. For full table of PowerShift emissions reductions from LPG see Appendix A, Table 15.

EST tests the vehicles against the required NO_x, HC and CO_2 reductions, depending on the Euro classification of the vehicle and on the amount of funding the equipment supplier is applying for, and judges the performance of the vehicle accordingly. EST is concerned that the methodology used may not adequately account for natural degradation of emissions performance over time; with the growth of PowerShift and the LPG industry it is deemed appropriate to review the test methodology. EST is currently exploring options to update COP testing, for example it may be decided to draw on European Type Approval Emissions Testing methodology and In-Service Conformity checking. **EST will discuss these changes with key stakeholders.**

3.1.2.3. Improving the quality of conversions

The LPG market in the UK has undergone significant change over the last 2–3 years. LPG converters broadly fall into two broad camps:

1) **OEM[20]/OEM approved** – vehicle manufacturers/converters approved by vehicle manufacturers;
2) **Independent** – converters not approved by vehicle manufacturers.

OEM/OEM approved converters have demonstrated greater reliability and environmental performance than independent converters. Of the latter group, LPGA-approved converters generally produce better results than non-approved converters.

The OEM share of the total conversion market is increasing rapidly. **EST estimates that the OEM market share is likely to reach 50% by the end of this year** (see Table 6 below):

TABLE 6

LPG Market Share	2001	2002	2003 Estimate
OEM Share (%)	11	18	36
Converter Share (%)	89	82	64

Source: TRANSTECH Market Survey For EST, 2003

If OEM sales and sales through LPGA approved installers are viewed as 'Quality Assured', then EST estimates that the overall total number of 'Non Quality Assured' sales was in the range 8,500 to 15,000 in 2002, which represents 34% to 60% of the total market. This should decrease in future – at least in line with growing OEM share.

3.1.2.4. Improving conversions: policy options

Despite the growing number of LPGA-approved, and OEM conversions, EST considers that unregulated conversions continue to be a major problem. So-called 'cowboy converters' are giving LPG a bad name. This bad publicity could, in turn, taint the entire AFV market, damaging the prospects of hydrogen, for example. Therefore it is imperative that the situation regarding converters is addressed.

EST recommends all conversions should be:

- **Certified at the time of completion by a registered inspector. The existing LPGA Approved Installer Scheme offers a sound and established basis for such a programme;**

20. OEM refers to Original Equipment Manufacturers.

- **For Euro IV, installing only LPG systems that are on a register as having been certified by the manufacturer that they meet specified levels of emission performance for that specific vehicle. Random checking to be undertaken in an extension of the existing Conformity of Production testing arrangements;**
- **For Euro III and Euro II, installing only LPG systems that are on the PowerShift or autogas+ scheme which have demonstrated good emissions performance.**

The EC–ACEA Voluntary Agreement will require government to collect and report to the European Commission data on the fuel economy of vehicles, including those powered by LPG. To meet this requirement, government may have to implement systematic emissions testing of LPG conversions.

3.2. Carbon

The carbon emission benefits (compared to liquid hydrocarbons) of LPG arise from three separate factors:

- The lower carbon content per unit of energy output;
- The lower upstream 'well-to-tank' emissions; and
- The ability to use the fuel more efficiently.

Fuel carbon content

The carbon content of LPG is 16.4kgC/GJ, which is 10% lower than petrol and 13% lower than diesel.

Well-to-tank benefits[21]

Energy use in fuel transportation is similar for all fuels. Other upstream carbon emissions are approximately 10% for petrol, 6% for diesel and 2% for LPG (1% each in refining and compression). Use of LPG therefore produces 'well-to-tank' benefits of approximately 8% (4%) of total energy throughput compared to petrol (diesel).

Engine efficiency benefits

LPG is generally used in bi-fuelled vehicles in converted spark ignition (petrol) engines, i.e. in engines not optimised for LPG. In these cases the fuel efficiency (km per unit of fuel energy) of LPG vehicles is similar to that of petrol.

Spark ignition engine efficiency is approximately 15–20% worse than the efficiency of a comparable compression ignition (diesel) engine, i.e. a diesel engine with comparable maximum power output and measured over the standard test cycle.

Some sources quote even higher savings for diesel. There are a number of potential sources of confusion. Diesel efficiencies are better:

- By 11% if quoted per litre of fuel rather than per energy unit;

21. Figures from 'Fuelling Road Transport: Implications for Energy Policy', EST, IEEP, NSCA 2002.

- If compared at maximum engine efficiency rather than over a full drive cycle; and
- If compared at similar engine capacities (e.g. 1.6l) rather than similar power output.

EST believes the 15–20% quoted is reasonable for comparable engines under realistic operating conditions.

However, LPG fuel characteristics are intrinsically better than petrol for use in SI engines (the octane rating is approx 110), and therefore engines optimised for LPG use could have fuel efficiencies 10% better than petrol, i.e. only 5–10% worse than diesel.

Using LPG in dedicated engines is the most carbon efficient use of this fuel. It allows a higher efficiency to be achieved than for heavier hydrocarbons, whereas other potential uses (typically in boilers) are at the same efficiency as other hydrocarbons. From the point of view of total carbon emissions this is a critical point. Other transport fuels such as biofuels have lower life cycle carbon emissions, but that may not be the critical determinant for 'total carbon' policy. Given a limited (fixed) quantity of both biofuels and LPG, the carbon benefits are determined by where each fuel can most efficiently substitute for a conventional alternative. For LPG this is certainly in automotive uses, provided that dedicated engines can be developed.

If the total propane export[22] were to be used as automotive LPG as a substitute for petrol, the UK carbon emissions reduction achieved would be approx 0.3MtC/year, rising to 0.5MtC/year if the LPG were used in dedicated engines. This would involve approximately 2 million light vehicles running on LPG and would be a significant (although not huge) contribution to the UK Climate Change Programme. To put it in perspective, it is broadly similar to the EST target for household lighting by 2010.

3.3. Conclusion: environmental benefits of LPG

Carbon benefits

- Taking into account fuel carbon content and upstream energy use, well-to-wheel carbon emissions from LPG vehicles are approx 18% lower than from petrol vehicles and similar to those from diesel. With dedicated engines, well-to-wheel emissions could be 25–30% better than petrol and 10% better than diesel;
- To achieve these carbon benefits, dedicated LPG engines must be produced. Mono-fuel vehicles offer significant carbon emissions reduction benefits compared to both conventional petrol and diesel engines.

Air quality benefits

- Long-term benefits of new OEMs will be limited because tougher regulated emissions standards are driving improvements to petrol and diesel vehicles;

22. Only small quantities of LPG are imported (0.2Mt of each of propane and butane). But significant quantities are exported – 3.0Mt, of which 2.0Mt is propane and 1.0Mt butane. See Appendix A for analysis of fuel availability.

- However, high quality LPG conversions will continue to offer air quality benefits because they are replacing existing polluting vehicles. This will particularly benefit polluted urban areas;
- To achieve air quality benefits, conversions of LPG vehicles must be subject to more stringent quality controls.

3.3.1. Implications for excise duty rate

- EST considers that the environmental benefits of LPG justify Government support to achieve further market penetration for this fuel;
- However, this support should be conditional upon LPG continuing to provide environmental benefits over time;
- *A detailed proposal for the LPG excise duty rate can be found in section 6;*
- Cost implications (to consumers) of changes in the fuel duty are examined in section 4.

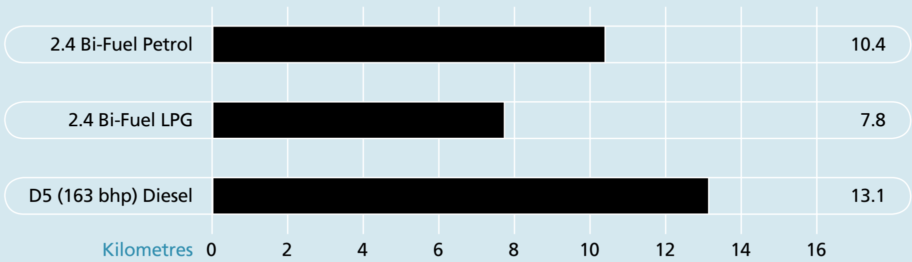
4. Determining the level of LPG fuel duty – a 'break-even' analysis

4.1. Introduction

LPG is currently about 38 pence per litre on the forecourt, which is about half the price of petrol or diesel[23]. However this price advantage is offset by additional costs, which include:

- Fuel economy: a litre of LPG takes you a shorter distance than a gallon of petrol or diesel (see Chart 2);
- Price premium: it costs extra to buy an LPG bi-fuel OEM, or to convert an existing vehicle.

CHART 2 : Distance travelled for 1 litre fuel: Volvo S60 (Km)



4.2. Introduction: a 'break-even' analysis

EST has developed a 'break-even' methodology to help decision-makers estimate the impact increases in LPG excise duty have on the consumer. The methodology is based on the economics of running an LPG car as opposed to a diesel or petrol car. The question the methodology seeks to answer is; at what rate of excise duty does LPG lose its fuel price advantage over diesel, and over petrol? In other words what is the 'break-even' point?

See Table 7 below for full methodology.

TABLE 7 : EST break-even methology

1. **ESTABLISH THE COST PER KILOMETRE FOR EACH VECHICLE.** *This is a simple multiplication of the amount fo fuel used to travel one kilometre, and the amount it currently costs to buy a litre of fuel at the pump.*
   - **Cost per km = (litres per kilometre) x (pump price of fuel per litre)**
2. **CALCULATE THE 'BREAK-EVEN' PUMP PRICE.** *This calculates the cost of running an LPG vehicle, with its lower energy value, compared to comparable petrol and diesel modes at current pump prices.*
   - **Break-even pump price of LPG (p/l) = Cost per km of Petrol or Diesel vehicle/litres used per km by LPG vehicle**
3. **CALCULATE THE 'BREAK-EVEN' EXCISE DUTY.** *This is level of excise duty at which LPG loses its price advantage over petrol and diesel.*
   - **Break-even excise duty (p/l) = (break-even pump price) – (actual pump price – current excise duty)**

23. Some back-to-base fleets have their own bunkered LPG that can reduce the cost by a further 8-10 pence per litre.

4.3. Limitations of the analysis

There are various limitations and uncertainties involved in this approach, including:

- Number of vehicles included: ideally this analysis would calculate the 'break-even' excise duty for every LPG vehicle. However, to keep the analysis manageable, EST has only used publicly available data for OEM LPG vehicles[24]. While this restricts the number of vehicles used, it does have the advantage of helping to find comparable models to test against each other[25];
- Variance of results: each vehicle has a different fuel economy performance and therefore a different break-even point. Therefore in order to come to general conclusions over excise duty it is necessary to include as many comparable vehicles as possible;
- Passenger cars only: this analysis only includes passenger cars, because the data is more easily available. It could be repeated for other light-duty vehicles.

4.4. Example: Volvo S60 Model Year 2004

4.4.1. Table 8 presents the results of the break-even analysis for this vehicle, using the methodology presented above:

TABLE 8 : **Break-even analysis: Volvo S60 Model Year 2004**

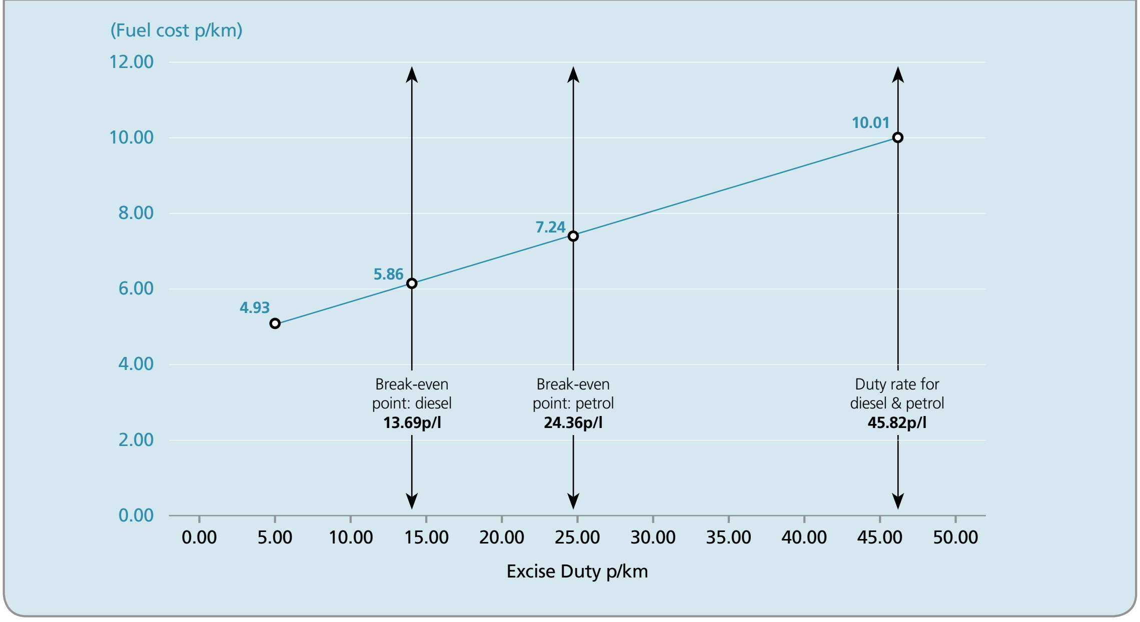
Model Variant	**Fuel**	**l/100km**	**l/km**	**Average pump price p/l***	**cost per km**	**Current excise duty p/l**	**Break-even pump price: Diesel (p/l)**	**Break-even excise duty: Diesel (p/l)**	**Break-even to P pump price (p/l)**	**Break-even excise duty: Petrol (p/l)**
D5 (163 bhp)	Diesel	7.6	0.076	77.11	5.86	45.82	–	–	–	–
2.4 Bi-Fuel	LPG	12.9	0.129	38.24	4.93	6.50	45.43	13.69	56.10	24.36
2.4 Bi-Fuel	Petrol	9.6	0.096	75.38	7.24	45.82	–	–	–	–

4.4.2. These results are presented in Chart 3, showing that even small increases in the LPG duty rate quickly raise the cost per km for LPG to a break-even point with petrol and diesel[26].

4.4.3. Finally, it is helpful in making this point to look at how the cost per kilometre affects fuel costs over longer distances – see Table 21, Appendix B. *Another example, for the Vauxhall Astra Model Year 2003, is also included in the Appendix B (Table 22 and 23; Chart 7)*

24. Vehicle Certification Agency. Website: http://www.vcacarfueldata.org.uk/.
25. A full list of vehicles used in the comparative analysis is included in Appendix A, Tables16–17.
26. If the duty rate for LPG were to be raised to the same rate as petrol and diesel, its costs per kilometre would be nearly double that of diesel.

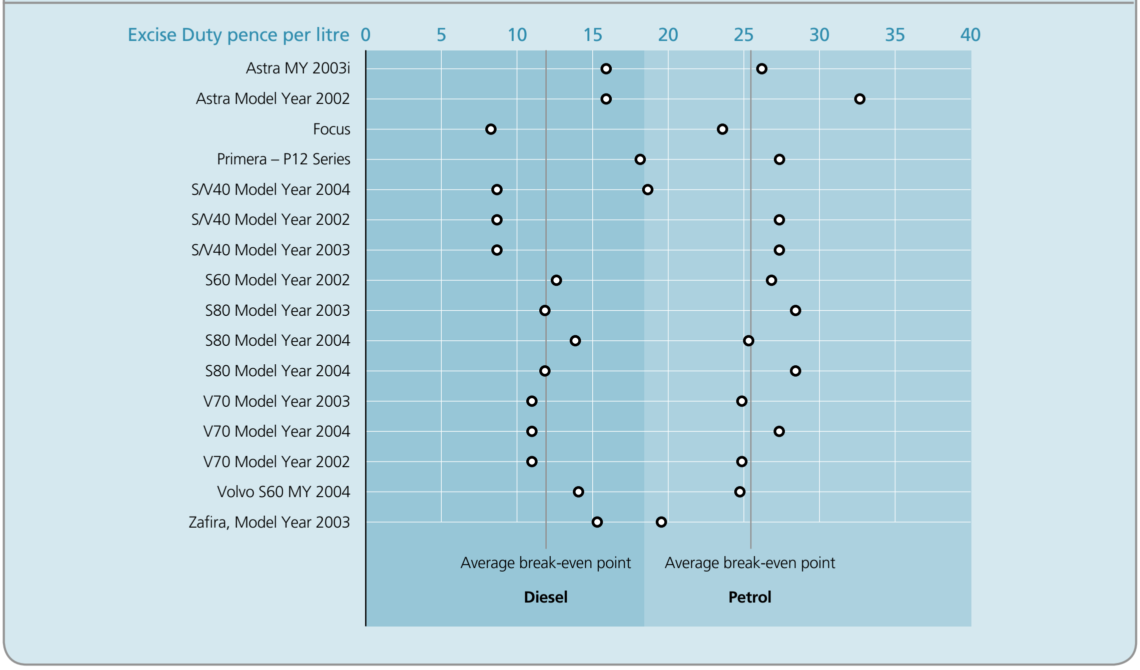
CHART 3 : Volvo S60 Break-even point (MY 2004)



4.5 Next step: including more vehicles

EST has repeated the break-even analysis for a selection of OEM LPG cars currently available in the UK, for which comparative information on similar models was readily available[27]. The results show that there is considerable variation between the break-even points for each individual model (see Chart 4 below; Table 24 in Appendix B).

CHART 4 : Break-even rate: Selected models



27. Data for LPG, Petrol and Diesel model variants taken from VCA website 01/08/03. See Appendix A, Tables 16–17 for full list.

4.6. Conclusions on fuel price

The 'break-even' approach offers policy-makers a method to attempt to quantify the impact that changing the level of excise duty on LPG will have on the consumer. Key conclusions:

- There is clearly a significant variation between each vehicle. This implies that fuel excise duty is a rather blunt policy instrument, since it impacts upon each vehicle differently;
- Nevertheless, this analysis indicates the range of values that should be taken into account when calculating fuel duty levels;
- The analysis should be frequently updated to take into account changes in fuel economy;
- It is not enough to look only at the cost of LPG as a fuel; it is also important to consider the upfront, or 'premium' cost incurred to the purchaser. It is also necessary to look at the various ways in which Government policies ameliorate these additional costs. This stage of the analysis is presented below.

4.7. Additional costs of LPG

New cars and vans powered by LPG are roughly £1,500–£2,000 more expensive than conventionally fuelled vehicles. PowerShift grants are available for between 50% and 75% of this extra cost. Converting an existing petrol car or light van to run on LPG costs between £1,200 to £1,800 and PowerShift grants are available for between 30% and 50% of this cost. Converting a diesel vehicle to run on LPG is much more costly, but may be suitable for vehicles which have a long service life. At present, the only grants available under the CleanUp programme are for converting black cabs to run on LPG.

LPG cars and light vans registered on, or after March 2001 with low CO_2 emissions have a lower Vehicle Excise Duty, which equates to an annual reduction of £5–£10 compared to petrol and £10–£20 compared to diesel. Personal Benefit in Kind (BIK) tax liability can also be lower for LPG cars. The company car BIK tax uses vehicle list price as a starting point, with maximum and minimum taxable percentages ranging from 15% to 35%. A discounting structure is then applied in accordance with the car's CO_2 emissions. Drivers can benefit from lower BIK rates provided the CO_2 emission values are entered on the V5 (logbook) in accordance with the results of the manufacturer's Type Approval.

Type approved LPG fuelled vehicles also receive a further reduction in BIK of 1% of the list price of the car (for vehicles converted to run on LPG, this does not include the extra cost of conversion). Most insurance companies will charge the same premiums for LPG vehicles as they would a conventionally fuelled vehicle, providing it is produced by an Original Equipment Manufacturer or converted by a LPG Association (LPGA) approved converter. Premiums for after-market conversions by other converters are generally higher.

London's Congestion Charge has quickly become a major incentive to buy LPG vehicles[28], because all passenger and light commercial vehicles that are listed under Band 4[29] of the TransportEnergy

28. For instance Vauxhall have stated that sales of their Dual Fuel cars and vans 'have been boosted by the London congestion charge' (Vauxhall statement on website, 16/04/03).

29. 40% less NO_x and HC than Euro IV.

PowerShift Register, receive a 100% discount from the charge. EST provides the technical support for the discount scheme in London, and supports the implementation of similar schemes in other urban areas, particularly those with air quality problems.

4.8. Results of the analysis: impact of premium price and grants

4.8.1. Assumptions and limitations

- London Congestion Charge: the analysis does not currently factor in the effects of the charge because it does not incentivise drivers who do not drive in central London to choose an LPG vehicle;
- Other fiscal incentives: the analysis does not currently take VED, BIK and CCT into account, although these could be included if required[30];
- Length of ownership: EST has produced two separate sets of results, based on two assumptions over the premium cost;
  a) 12-year ownership: assumes that the premium cost is evenly spread over the entire 12-year lifetime of the vehicle: The cost is "passed down" through the second and third-hand market
  b) 3-year ownership: this assumes that the initial purchaser keeps the car for 3 years, but is unable to add the premium cost into the second-hand price.
- Vehicle kilometres travelled: EST has used a figure of 12,000 km per annum;
- Additional costs are either £1,500 or £2,500. Both costs are examined in the model;
- Grants are available to cover either 50% or 75% of these costs.

4.8.2. Presentation of results

The price premium has a large impact on the cost-per-kilometre of each model. As might be expected, the premium has a much lower impact if the costs are spread over the entire 12-year lifetime of the vehicle than if costs are concentrated in the first three years of ownership.

Table 9 and Chart 5 help illustrate this point using the Volvo S60 used in the above example.

TABLE 9 : **Volvo S60 MY 02 Break-Even Excise Duty (p/l)**

		3-year ownership		**12-year ownership**	
		Diesel	**Petrol**	**Diesel**	**Petrol**
	Fuel cost only	15.52	32.29	12.23	26.45
£1,500 Premium	No grant	–3.99	5.86	6.71	19.15
	50% grant	3.23	15.64	9.29	22.56
	75% grant	8.46	22.72	10.70	24.43
£2,000 Premium	No grant	–7.34	1.31	5.17	17.11
	50% grant	0.44	11.86	8.39	21.37
	75% grant	6.55	20.14	10.22	23.79

30. VED offers limited benefit in making cost comparisons, because LPG and diesel models typically fall into the same VED bracket.

CHART 5 : Volvo S60 Break-even point (MY 2004) (Fuel cost per Km)

The break-even analysis presented above has been repeated for all vehicles, including price premium and grants: see Table 26 and Chart 8 in Appendix B.

4.9. Conclusions from price premium and grant analysis

- **When fuel price is taken on its own, it appears that LPG could withstand an increased excise duty in the range of 7.9p/l to 15.5p/l total excise duty (i.e. an increase of 1.4p/l to 9p/l over the current rate) to break-even with diesel;**
- **However, when premium purchase costs are also taken into account, LPG's cost advantage over diesel is significantly reduced, and any price increase has a marked impact upon the break-even point;**
- **This is magnified if one assumes a high premium cost (say £2,000) which is paid for by an initial purchaser over a short period of time (say 3 years), and is not in receipt of a grant.**

5. The future of LPG and dedicated mono-fuel vehicles

EST considers that the only way LPG vehicles will maintain their environmental benefits over new vehicles is for auto manufacturers to deliver dedicated LPG vehicles to the marketplace.

This section will:

a) Discuss whether these vehicles will reach the market; and

b) Incorporate mono-fuel vehicles into the break-even analysis.

5.1. Issues surrounding mono-fuel vehicles

5.1.1. Potential benefits of mono-fuel vehicles

In addition to environmental benefits, dedicated vehicles could:

- **Offer enhanced fuel economy, which in addition to lowering CO_2 emissions would reduce the need for lower fuel prices and enable the Government to raise the tax rate (see section 5.2);**
- Reduce the premium cost: removing the need for conversion would reduce the upfront cost; however, economies of scale resulting from high market penetration would be required to significantly reduce costs;
- Improve convenience: manufacturers should be able to design cars around the gas tanks, placing them under the floor or luggage compartment to limit the imposition on valuable passenger space[31].

5.1.2. Market barriers and uncertainties

EST considers that theoretically, domestically produced LPG could power 8–10% of the UK fleet[32]. However, there are significant barriers remaining. EST has identified two key categories:

5.1.2.1. Fuel infrastructure and availability

- **Fuel must be available in sufficient quantities and at sufficient distribution to support a mono-fuel fleet.** This is vital if a sustainable market for LPG vehicles, including a secondary market, is to develop;
- LPG coverage is improving: currently there are of 1,351 LPG refuelling stations in the UK[33] compared to 11,400 petrol stations[34];
- However, the total number of petrol stations has been decreasing – EST is advised that this number may stabilise at around 5,000. EST is also advised that if around half of this reduced total supplied alternative fuels, this would be enough to secure coverage.

31. Hardy, Jeffrey 'Natural Selection: Evolving Choices for Alternative Fuels and Vehicle Technologies', Draft Version 2, UNEP-DTIE, 2003.
32. EST calculation: 2,750,000 vehicles at 20,000 km/year, using 0.05 litres of LPG/km would use around 2 million tonnes of LPG. Currently the UK exports 3m tonnes LPG p.a. and uses 80k tonnes p.a. for road transport. See Appendix A for more detail on fuel availability.
33. EST clean fuels website, accessed 12/09/03.
34. PIA website, accessed 12/09/03.

- Consumers must be very confident that fuel will be available before they will purchase mono-fuel vehicles;
- **EST considers that fuel availability issues can be overcome provided there is a stable fiscal framework and adequate investment, to overcome consumer fears over fuel availability.**

5.1.2.2. Automotive sector investment:

- Major international auto manufacturers take investment decisions on a European, and/or global basis. It is unclear whether the UK is a big enough market to justify this investment;
- However, numerous countries in Europe and around the world have introduced favourable fiscal policies for RFGs (this is explored in more detail in section 8). **Consequently, EST believes that there is the opportunity for auto companies to transfer LPG mono-fuel technology to other countries and markets**.

5.1.3. Technology barriers

EST considers that the technology for mono-fuel LPG vehicles should, given sufficient investment, be commercially available within the next 3 years. This position is based on two factors.

5.1.3.1. EST technology programmes: EST has received numerous proposals for LPG technology demonstration projects. These include:

- LPG hybrid van;
- LPG dual fuel system for trucks;
- Diesel common rail dual fuel LPG and CNG system for small van;
- Dedicated LPG system for a car;
- Sequential liquid phase injection LPG fuelling system designed specifically for London taxis.

5.1.3.2. Market information: auto manufacturers have communicated to EST that such technology should be able to ready for production in less than 3 years.

5.1.4. Conclusion: mono-fuel vehicles and fuel availability

- EST believes that provided sufficient research and development funds are committed, **there is no technological reason why mono-fuel vehicles cannot reach the market within the next three years;**
- However, for such vehicles to appear on the market, fuel infrastructure barriers must be overcome.

5.2. Including mono-fuel vehicles in the break-even analysis

EST has repeated the 'break-even' analysis established above to include a fictional dedicated LPG vehicle. The following assumptions have been made:

- The mono-fuel LPG vehicle is assumed to have 20% better fuel economy (l/100km) than the current LPG OEM model used in the earlier examples;
- The same comparable vehicles are used as for the previous examples:
  a) The mono-fuel model is assumed to be available in 2006
  b) The comparable models have failed to achieve any further fuel economy improvement between now and then.

Headline results

These results indicate that mono-fuel vehicles will have significantly higher break-even points than their bi-fuel predecessors. This point can be illustrated by looking at the range of break-even points for the actual bi-fuel and estimated mono-fuel vehicles (see Table 10 below).

The full results of this analysis are presented in Table 26 and Chart 9 in Appendix B.

TABLE 10 : **Break-even points: Low-and-high range for current bi-fuel and estimated mono-fuel vehicles (p/l)**

	Diesel		**Petrol**	
	Low	**High**	**Low**	**High**
Mono-fuel	17.8	30.2	30.8	42.9
Current vehicles	7.9	15.5	18.3	32.2

Conclusion

EST analysis indicates that mono-fuel LPG vehicles will be able to withstand a higher duty rate than current OEM LPG vehicles: possibly in the range of 17.8p–30.2p for diesel and 30.8p–42.9p for diesel (these figures will depend on actual vehicle performance).

- **EST considers that the Government should set fuel prices at their current level for a limited time, to incentivise and challenge the auto industry to bring dedicated LPG vehicles to market.** Three years seems a reasonable time for this to be achieved;
- However, market barriers discussed above must be overcome. EST suggests that a longer-term fiscal framework should be set, which will set the conditions for industry to make the necessary investment. However, industry must also make a commitment to producing the required technology and infrastructure. This approach is discussed in the following section.

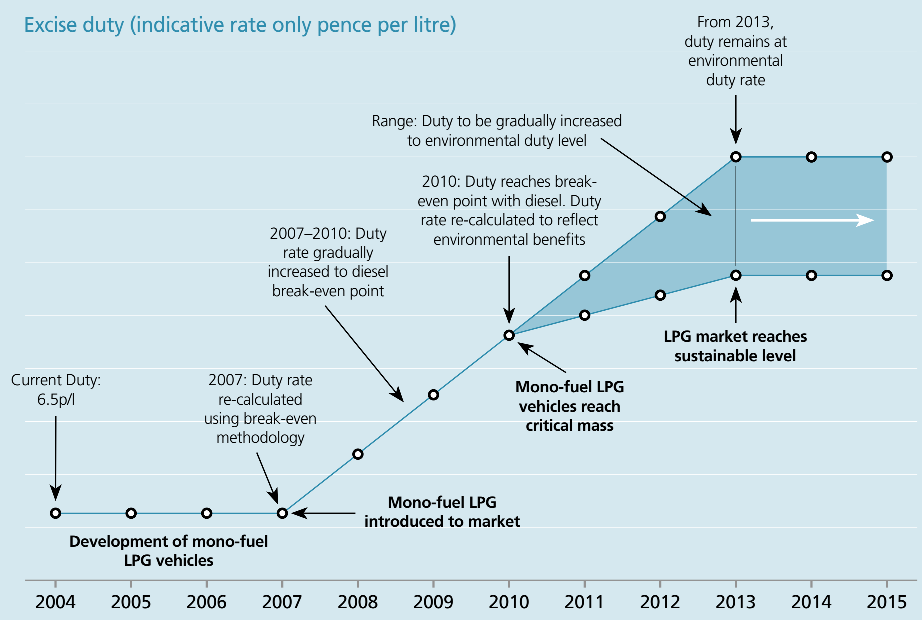
6. The EST cleaner low carbon fuel framework

EST proposes a 10-year fiscal framework for LPG that would offer *conditional* support for LPG, provided air quality and carbon benefits can be assured over time through the introduction of dedicated mono-fuel LPG vehicles.

Under the EST framework, fuel duty would be maintained at its current level for the next 3 years (from 2004) in order to create the market conditions for mono-fuel vehicles to be introduced to market. In 2007, the break-even rate for LPG would be calculated against diesel based on the fuel economy of mono-fuel LPG vehicles. The duty rate would be gradually raised to this level by 2010.

In 2010, the fuel duty rate should be re-calculated based on its environmental benefits, then the duty gradually raised to this level a further 3 years (creating a 10-year framework). After this time the duty would remain at the environmental duty level. *The EST proposal is summarised in Chart 6 below:*

CHART 6 : EST 10-Year Fiscal Framework for LPG



Impacts and implications

Other fuels

EST supports the application of this framework to all alternative fuels, such as CNG, biofuels, and, in the fullness of time, hydrogen.

Grants

Government grants should be made available to help reduce the premium costs of purchasing cleaner, lower carbon vehicles. For these vehicles to receive grants they would have to demonstrate proven emissions reductions over comparable vehicles, and would compete with other fuels and technologies for such funding. **See Appendix A for a summary of options for a grant-funding programme.**

The market for conversions

LPG fuel price increases will serve to de-incentivise the conversion market, as they will not achieve the same fuel economy performance as mono-fuel vehicles. Until this time it is imperative that stricter controls be put in place on conversions. A risk of this approach is that owners of converted vehicles will lose their fuel price benefit when it does begin to rise.

Revenue loss

A favourable excise duty for LPG, even for a 3-year period, will result in a certain amount of lost revenue. **EST considers that a continued lower rate of excise duty can be justified for a limited time provided long-term environmental and market transformation benefits result.** Forecasting future revenue loss from LPG market penetration is currently extremely difficult at the present time, due to the uncertain state of the market.

For instance, it is unclear how many LPG vehicles will be on the road over the next 5–10 years, and what the environmental performance of these vehicles will be. The former depends on the excise duty, the availability of grant funding and fuel prices, to name just three uncertainties. The latter depends on the availability of mono-fuel LPG vehicles from 2006, the market penetration of these vehicles and the proportion of converted vehicles remaining in the fleet.

Finally, it is unclear whether LPG will substitute for petrol or diesel, or a combination of the two. Currently most conversions are from petrol cars, due to the cost savings LPG currently offers. However many consumers now choose LPG OEMs in preference to diesel; a trend that should continue with the advent of mono-fuel LPG vehicles.

Therefore **EST considers that it is not currently possible to generate an accurate forecast of future revenue loss from LPG vehicles in the marketplace.**

Confidence in the UK AFV market

Maintaining the confidence of the automotive and energy industries in the AFV market is a vital consideration. EST believes that if the LPG market were to disappear it would be far harder for future Governments to inculcate confidence in other alternative fuels (hydrogen for instance). **EST considers that for the good of the future AFV market, it is important that a previously supportive Government does not leave LPG high and dry.**

7. Compressed natural gas

This section will examine the environmental benefits of CNG, provide a brief overview of the current state of the market, and make recommendations on fiscal support based on the EST alternative fuels framework.

7.1. Environmental benefits

A vehicle fuelled by natural gas can significantly reduce the impact of vehicle emissions on local air quality, particularly when compared to diesel. Engines can be either lean burn or stoichiometric, but emissions are generally cleaner with a stoichiometric engine since it also allows for a three-way catalyst to be fitted. Compared to a Euro III diesel engine, a mono-fuel stoichiometric natural gas engine will have around 70–80% lower NO_x emissions, and about 95% lower emissions of particulate matter. Tailpipe CO_2 emissions are usually equivalent to that of diesel, although this can be improved by up to 10% if the combustion system is fully developed. The emissions improvements of air quality pollutants from a natural gas engine compared to a petrol engine is less marked, with around a 10–15% reduction in NO_x emissions, and a small reduction in carbon monoxide (CO) emissions. CO_2 on the other hand can be reduced by up to 30%.

Dual-fuel and mono-fuel lean burn natural gas engines do not provide the same air quality benefits as a mono-fuel stoichiometric natural gas engine, but can still reduce emissions of NO_x by 30–40% compared to a Euro III diesel. Emissions of CO_2 are lower for these engines, with emissions reduced by up to 20% compared to diesel. There is also a significant reduction in noise and vibration from a dedicated natural gas vehicle compared to a diesel vehicle due to the switch from a compression engine to a spark ignition engine. Typically this would be about 10dBA quieter than a diesel vehicle, which is a perceived halving in noise levels. This makes natural gas particularly suitable for operating in noise-sensitive locations, such as night-time or high street delivery vehicles or refuse vehicles. A dual-fuel engine should also provide some noise reduction benefits, particularly when the vehicle is operating under full load and burning a greater proportion of gas. Reduced noise has significant knock-on benefits for decreasing road transport emissions as it may allow some operators to overcome night-time delivery curfews, thus decreasing congestion levels at peak times and thereby reducing emissions.

Emissions data from PowerShift natural gas conversions is available in Appendix A, Table 20.

7.2. Costs

The additional cost of buying a new dedicated natural gas vehicle depends on the type of vehicle. A large commercial vehicle such as a truck currently costs between £20,000 and £40,000 more than a conventional vehicle. For vans the premium is about £4–6,000. TransportEnergy grants are available for up to 75% of this additional cost. Converting an existing vehicle to dual-fuel is likely to cost between £10,000 and £25,000 and TransportEnergy PowerShift grants are available for approved conversions listed on the PowerShift Register. These costs would reduce over time, were CNG to acquire a greater market share.

Converting existing petrol vehicles to natural gas is slightly more expensive than converting to LPG. There are a number of approved natural gas conversions on the PowerShift Register that are eligible for a grant of up to 75% of the conversion cost. Large commercial vehicles with diesel engines can be converted to run on natural gas. This is a specialist task which is currently only undertaken by a limited number of companies, but is cheaper than purchasing a new natural gas vehicle, so may be an option for fleet operators wishing to switch their vehicles to gas more quickly or for vehicles with a long service life. Approved diesel to natural gas conversions are listed on the CleanUp Register, with grants of up to 75% of the conversion cost available.

Fuel costs for a small vehicle fuelled by natural gas are under 6 pence per mile (compared to 10 pence per mile for petrol). Up to 30% savings on fuel costs can be obtained for large commercial vehicles compared to diesel. Tests on dual-fuel vehicles have demonstrated fuel savings of between 6–15%. Vehicles over 3.5 tonnes may also qualify for a Reduced Pollution Certificate (RPC) and a subsequent reduction of up to £500 in annual road tax. In addition, natural gas cars and light vans registered on, or after March 2001 with low CO_2 emissions also have lower Vehicle Excise Duty, which equates to an annual reduction of £5–£10 compared to petrol and £10–£20 compared to diesel.

Personal Benefit in Kind (BIK) tax liability can also be lower for natural gas cars. The company car BIK tax uses vehicle list price as a starting point, with maximum and minimum taxable percentages ranging from 15% to 35%. A discounting structure is then applied in accordance with the car's CO_2 emissions. Drivers can benefit from lower BIK rates provided the CO_2 emission values are entered on the V5 (logbook) in accordance with the results of the manufacturer's Type Approval. Type approved natural gas fuelled vehicles also receive a further reduction in BIK of 1% of the list price of the car (for vehicles converted to run on natural gas, this does not include the extra cost of conversion).

Discounts from the London Congestion Charge are also available for the very cleanest natural gas vehicles on the PowerShift and CleanUp Registers. Cars and light duty vehicles in band 4 of the PowerShift Register, or heavy commercial vehicles over 3.5 tonnes in bands 2, 3 or 4 of the PowerShift Register (or equivalent standard on the CleanUp Register) are eligible for a 100% discount from the charge, subject to payment of a £10 annual registration fee.

7.3. Availability

At present there are around 30 public refuelling stations for CNG. Whilst some early users of natural gas vehicles installed slowfill stations, which involved refuelling overnight, most operators are now opting for fast-filling refuelling stations, which can be installed at a company's depots, provided the space is available.

A CNG compressor refuelling station can cost between £250,000 to £500,000 depending on capacity, but grants are available from TransportEnergy for up to £100,000 provided the site gives third party access. Enhanced Capital Allowances (which allows the costs to be written off in the first year) are also allocated for CNG refueling sites. Whilst CNG refueling sites need a compressor to dispense the fuel, LNG is simply stored on site in a tank and refilled by tanker when required so costs of installation are much lower. Public LNG refueling stations have recently opened at several motorway services and depot-based LNG stations are also eligible for TransportEnergy grants.

As an alternative to purchasing a CNG or LNG refueling station, this can be outsourced to the natural gas suppliers, who can install, supply and operate your site on a rental basis. The installer should ensure that the installations fulfill the requirements of the Health and Safety Executive, the environmental requirements of the Local Authority and regulations of the regional fire officer.

The Natural Gas Vehicle Association (NGVA) has an accreditation scheme that requires the suppliers of refuelling stations to be trained and operate to a high standard. Being accredited is not a legal requirement, but it is strongly recommended that operators use an accredited company to ensure a safe and reliable conversion or service (the NGVA accreditation scheme also covers converters, and NGVA accreditation is a requirement for PowerShift approval for natural gas converters.)

7.4. Conclusions – CNG

- CNG has the potential to make a major positive contribution to reducing air pollution in urban areas. However the market for CNG is at a very early stage in its development. To accomplish this a stable fiscal framework is necessary, both to incentivise the development of CNG vehicles and infrastructure and to allow a secondary market to develop;
- **The EST cleaner low carbon fuel framework should be applied to CNG. This implies that the tax revenue should remain at its current level for the next 3 years, and should be re-evaluated at that point.**

8. The market for alternative fuel vehicles in the UK and overseas

8.1. The UK AFV market

While the subject of this consultation is LPG and CNG, it is important to briefly review other technologies and fuels, and to introduce ways in which EST looking at supporting them. In recent years, the market for cleaner vehicle fuels and technologies has become more diverse. However the overwhelming majority of the UK vehicle market is petrol based. Cleaner fuelled vehicles make up a tiny proportion of the total vehicle fleet – around 0.2% – of which most are Liquid Petroleum Gas vehicles (see Table 11 below).

TABLE 11 : **Private cars currently licensed in 2001: by method of propulsion (,000)**

Petrol	**Diesel**	**Petrol/Gas**	**Gas/Gas BiFuel /Gas-Diesel**	**Electric & Hybrid-Electric**	**Others[35]**	**Total**
20,555.80	3,318.60	21.1	2.8	0.5	0	23,898.80

Source: DfT Transport Statistics, 2003

8.1.1. Current fuel availability

It is also instructive to look at the number of AFV refueling stations in comparison to conventional fuels (see Table 12).

TABLE 12

Total Petrol Stations*	11,400
Total LPG stations	1,351
Total Natural Gas stations	12
Electricity recharching points	8

Source: EST clean fuel map, accurate as of 10/09/03

* PIA website, accessed 12/09/03.

8.1.2. Scotland's autogas+ initiative

The TransportEnergy autogas+ programme, (which operates in Scotland only) is run by EST on behalf of the Scottish Energy Efficiency Office, and aims to help establish a sustainable market for LPG and alternative, cleaner fuel vehicles. The programme provides grants to convert modern cars and light vans to run on liquid petroleum gas (LPG), and is open to individuals and businesses. Unlike PowerShift, which only provides grants for vehicles on the PowerShift register autogas+ provides grants for vehicles not on the register. However, PowerShift also covers Scotland; therefore customers are asked to use the PowerShift programme if their vehicle is on the PowerShift register, in order to maximise the reduction in exhaust emissions achieved; otherwise they may use autogas+. Because the grants under PowerShift are variable, the autogas+ programme tops-up the grant that would be received under PowerShift to the standard autogas+ of £800. This ensures that customers receive the same level of assistance whichever programme they use.

35. Steam and Fuel cells.

8.1.3. Biofuels

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.

8.1.4. Hydrogen

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. **EST believes that if the market for LPG collapses, it could hamper confidence in fuel and automotive industry; this could damage future attempts to put in place hydrogen infrastructure.**

8.1.5. Methanol

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[36]) – which is likely to limit its usage as a road fuel.

8.1.6. 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, however, currently electricity is predominantly generated by fossil fuels, leading to significant 'well-to-wheel' CO_2 emissions from electric vehicles. 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

36. Future fuels report (SMM2, 2002).

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 currently cost significantly more than conventional petrol or diesel vehicles, however TransportEnergy grants are available. In addition the batteries are expensive and tend to be leased rather than purchased outright.

8.1.7. 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 £3,000 more than their equivalent petrol cars, however both the Toyota Prius and Honda Civic IMA currently attract PowerShift grants worth £1,000 per vehicle. Obviously the running costs of hybrids are significantly lower due to their excellent fuel consumption performance. 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.

8.1.8. 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.

8.1.9. EST support for new fuels and technologies

EST runs two programmes devoted to research, development and deployment of cutting-edge cleaner, low-carbon technologies. These are the New Vehicle Technology Fund, and the Ultra Low Carbon Car Challenge. Further, EST envisages its TransportEnergy programmes to take account of new fuels and technologies. For instance, EST sees a future where hybrid vehicles play a more important role in PowerShift programmes, alongside alternative fuelled vehicles.

8.1.10. Conclusion: UK AFV market

- EST believes that the future of the automotive sector lies in the gradual development of a mixture of technologies and fuels. The proportion of hybrids, LPG, CNG and other fuels and technologies will, hopefully, increase over time, offering a wider array of cleaner, lower-carbon options for consumers. EST sees, for example, no conflict between greater numbers of petrol-hybrid and mono-fuel LPG cars: the marketplace is big enough for both of them;

- Aside from petrol hybrids, none of the technologies mentioned above can compete with LPG and CNG in terms of CO_2 and air quality reductions in the short term;
- If the market for LPG collapses, it could hamper confidence in fuel and automotive industry; this could damage future attempts to put in place hydrogen infrastructure.

8.2. Other country experience

Many countries around the world have adopted strategies to increase the use AFVs, which often include a favourable fiscal regime. Some of these initiatives are briefly described in Table 13:

TABLE 13 : **Subsidies for AFVs in the EU**

France	7,600 Euro for heavy-duty (or €760 for cars) running on CNG, LPG and electric vehicle; an additional 1,500 Euro subsidy for EVs is available from EdF (the French electricity utility).
Italy	4,500 Euro for an electric vehicle, and 2,300 Euro for a CNG-vehicle
Netherlands	Up to 15% of the cost of an EV or HEV as part of the DEMO programme; subsidies for conversion of buses to LPG or CNG

8.2.1. Sweden

In the 1970s, Sweden reduced taxes on LPG, successfully triggering a demand for new vehicles and substantial investments in LPG infrastructure. Subsequently, the government increased the taxes on LPG to cover the loss of fiscal income due to the transition from gasoline to LP Gas, and the use of LP Gas dropped[37].

8.2.2. Netherlands

LPG has long benefited from a tax break in the Netherlands. However in recent years, LPG systems have become technically much more complicated than before due to more stringent emissions legislation, driving up the price for LPG systems. This price increase has not been compensated by the tax break on fuel, which has stayed at the same level, therefore the annual mileage for which it was financially attractive to use LPG steadily increased. Accordingly, the share of LPG cars in the Dutch fleet decreased significantly from around 10% in 1990 to around 6% in 1998[38].

8.2.3. New Zealand

In the late 1980's New Zealand fuel tax exemptions on CNG and LPG stimulated a national fleet of 100,000 CNG and 50,000 LPG vehicles. Then, in the early 1990's an excise tax was introduced which led to severe reductions in the consumption of CNG and LP Gas such that the fleet of CNG vehicles is today below 1,000 and LP Gas powered vehicles number around 18,000 to 19,000 vehicles[39].

37. Hardy, Jeffrey 'Natural Selection: Evolving Choices for Alternative Fuels and Vehicle Technologies', Draft Version 2, UNEP-DTIE, 2003.
38. 'DEPLOYMENT STRATEGIES FOR HYBRID, ELECTRIC AND ALTERNATIVE FUEL VEHICLES', International Energy Agency 2003, ANNEX VIII/XXI.
39. Hardy, Jeffrey 'Natural Selection: Evolving Choices for Alternative Fuels and Vehicle Technologies', Draft Version 2, UNEP-DTIE, 2003.

8.2.4. CNG in Germany

There are currently around 15,000 CNG vehicles on the road in Germany and more than 350 filling stations. Filling stations are currently opening at an average rate of 15 per month; the Government is expecting 1,000 additional filling stations within 4 years, sufficient to supply around 500,000 CNG vehicles by 2010. The Government has set a guaranteed preferential treatment for CNG as a fuel until 2020: for comparable energy content the consumer pays €0.44, while a litre of Super gasoline is charged at €1.05[40].

8.2.5. Conclusions

- EST considers that the examples of Sweden, Netherlands and New Zealand point to the risks of increasing fuel duty on LPG: in each of these cases raising the cost of LPG had significant negative impacts on the LPG market;
- The example of Germany shows that other major European countries are once again thinking seriously about how to foster the greater market penetration of AFVs, and are making long-term commitments to market transformation.

40. Frankfurter Allgemeine Zeitung, 10 September 2003.

Appendix A

EST Low-carbon programme: options and next steps

A new system of vehicle grants is to be proposed for TransportEnergy. Grants are currently provided on a percentage of the additional cost of conversion or at a specified level depending on the cost and type of technology. However, EST considers that, with the introduction of lower emissions vehicles that use hybrid and electric technologies, it has become difficult to calculate the additional cost of these technologies and hence difficult to set a grant based on percentage of additional cost. **EST will discuss these issues with key stakeholders. There are numerous options, some of which are outlined below.**

EST VIEW: KEY PRINCIPLES

EST would support a grant programme based on the principles outlined below:

1. Sliding scale

The grants could be provided on a sliding scale that would calculate the amount of grant by looking at the vehicle's emissions improvement (as per Table 14).

TABLE 14

20% lower emissions	30% lower emissions	40% lower emissions	50% lower emissions
£1,000	£1,500	£2,000	£2,500

2. Carbon and *air pollution*

EST believes that there is a strong case for a combined approach: a programme that ranks vehicles based on their air pollution performance as well as well as their carbon savings.

3. Technology and fuel neutral

EST considers that the new programme should not incentivise one particular fuel or technology. Instead, vehicles should be ranked according to their emissions performance within their market segment (see below).

4. Market segment approach

EST would support a grant scheme that awarded incentives based on clear market segments: a vehicle would have to significantly out-perform vehicles in its class in order to receive a grant. This would help promote innovation across the market, and help avoid a situation in which only small cars receive a grant. There could be also be a cut-off point for high-polluting vehicle classes.

5. The 'EST recommendation'

In addition to the new grant-funding scheme, EST would support a system in which all vehicles achieving a certain percentage emissions reduction would receive the 'TransportEnergy recommendation'.

ADDITIONAL OPTIONS

There are, of course, many additional options for the grant system. Some of these are briefly included below. This is not an exhaustive list and not ranked in any particular order. These and many other options will be discussed with stakeholders.

1. CO_2 only

There is a case to be made that the grant programme should only reward low-carbon cars. The CO_2-only approach could be based on well-to-wheel or tank-to-wheel emissions.

2. Separate petrol and diesel programmes

It can be argued that it would be preferable to separate out Petrol and Diesel. This would incentivise the production of the lowest-polluting vehicles possible for both fuels, and avoid a situation where the fuels' intrinsic properties were rewarded i.e. petrol cars are generally better on air quality than diesel but worse on CO_2.

3. Technology based

The programme could seek to incentivise the implementation of technologies that would reduce carbon and/or air pollution. EST could facilitate such a programme through its vehicle technology registers.

4. Emissions-to-weight ratio

Similar to the market segment approach, a programme that ranked vehicles on an emissions-to-weight ratio would provide incentives for all vehicles to become cleaner, rather than simply providing incentives for small vehicles.

TABLE 15 : **PowerShift Emissions Savings from LPG 1997–2001 (kg + %)**								
Vehicle	**Car**	**CDV**	**Vans**	**Light Trucks**	**Minibuses**	**Buses**	**Total**	**% total reduction**
				1997–8				
CO_2	40,275	–42,608	–50,370	–	–	7,650	–45,053	–2%
NO_X	410	737	1,083	–	–	6,732	8,962	67%
PM	–	64	200	–	–	107	372	96%
				1998–9				
CO_2	156,804	–76,038	–231,045	–5,475	– 13,140	10,200	–158,694	–3%
NO_X	1,594	1,315	4,969	118	283	8,976	17,255	73%
PM	–	115	918	22	52	143	1,249	98%
				1999–00				
CO_2	428,526	–340,860	–379,965	–	–	–	–292,299	–3.0%
NO_X	4,357	5,897	8,172	–	–	–	18,426	89%
PM	–	515	1,509	–	–	–	2,024	100.0%
				2000–1				
CO_2	1,020,300	–881,648	–1,063,245	–	–10,950	14,450	–921,093	–3%
NO_X	10,374	15,252	22,867	–	236	12,716	61,445	82%
PM	–	1,332	4,224	–	44	202	5,801	99.5%
				Total				
CO_2	1,645,905	–1,341,153	–1,724,625	–5,475	–24,090	32,300	–1,417,138	–3.24%
NO_X	16,735	23,202	37,091	118	518	28,424	106,088	80%
PM	–	2,026	6,851	22	96	452	9,446	99%

Baselines: Cars, vans, minibuses, light trucks, buses: Cleaner Vehicle Task Force report on alternative fuel vehicles 1998.
CDV diesel baseline based on Vauxhall Astra 1.6 16V 5 door estate from VCA website.

LPG fuel availability

LPG consists of the heavier alkane gases that are relatively easy (compared to natural gas) to liquefy by pressure alone. These are propane (C_3H_8) and butane (C_4H_{10}).

Sources of LPG

UK production of LPG is 6.5Mt. Of this 4.0Mt is propane, of which 2.7Mt is from natural gas liquids (NGLs) and 1.3Mt is from refineries; and 2.5Mt is butane, of which 2.0Mt is from NGLs of 0.5Mt is from refineries.

Imports and exports

Only small quantities of LPG are imported (0.2Mt of each of propane and butane). But significant quantities are exported – 3.0Mt, of which 2.0Mt is propane and 1.0Mt butane. Current UK use (all demands) is approximately 2.1Mt[41].

UK production trends

LPG production from UK sources (both refineries and offshore hydrocarbon production) has been reasonably constant in recent years. This trend may be expected to continue for the next decade. In the very long term, declining UK Continental Shelf gas production will inevitably reduce LPG production, but the initial decline in gas production is largely from the 'dry gas' fields in the Southern North Sea, which yield little LPG.

There is no absolute limit to the fraction of LPG that can be derived from each barrel of hydrocarbon resource. In principle, refinery operations could be altered to increase the quantity of LPG produced and further expand the LPG market. However, the costs of doing this might well be large. For the foreseeable future LPG should therefore be viewed as a significant niche fuel.

UK uses by sector

44% of UK consumption is in petrochemicals (non-energy use) with most of the remainder in industrial, commercial and agricultural energy use. Household sector LPG accounts for only 0.3Mt (15%). Automotive demand is an even smaller fraction – 66kt (3% of LPG, or 4% of propane) in 2001. However, this is rising rapidly, reaching 87kt/year in the 3rd quarter of 2002. In the UK, it is propane that is used for automotive LPG.

International comparisons and trends

LPG is primarily used as an industrial and domestic heating fuel in regions of countries without access to natural gas. As the penetration of the natural gas network in Europe expands, these demands for LPG are likely to fall.

Automotive LPG use is also expanding rapidly elsewhere in Europe and worldwide.

41. There are significant 'statistical differences' and 'stock changes' in UK energy data that account for the discrepancy between 'supply' and 'production + imports – exports'.

Conclusion on future availability for UK automotive use

UK exports of propane alone of 2Mt annually are more than 20 times larger than current automotive LPG use in the UK. With falling demand in some overseas markets, the scope for increasing LPG use in UK transport is significant. UK petrol demand is approximately 21Mt. The implication is that if all UK propane exports were diverted for use in the transport sector this would substitute for approximately 10% of UK petrol demand.

TABLE 16 : **Comparable Models Used for Break-Even Analysis**

	Manufacturer and Model	Engine CC	Trans.	Fuel Type	CO_2 (g/km)	Euro Standard	Metric combined fuel consumption (l/100km)	Combined HC & NO_x emissions (g/km)	Emissions Particles (g/km)	NO_x emissions (g/km)	Vehicle Excise Duty (VED) as from 1st March 2001 (£)
Primera – P12 Series	1.8 Dual Fuel 4/5 door	1769	5MT	LPG	155	III	9.5	N/A	N/A	0.025	115
	2.2TD 102kW 4/5 dr & Estate	2184	M6	Diesel	164	III	6.1	0.506	0.044	0.455	135
	1.8 4/5 door	1769	5MT	Petrol	177	III	7.4	N/A	N/A	0.01	145
S80 Model Year 04	2.4 Bi-Fuel	2435	A5	LPG	215	IV	13.3	N/A	N/A	0.023	155
	D5 (163 bhp)	2401	A5	Diesel	207	III	7.8	0.44	0.033	0.41	165
	2.4 Bi-Fuel	2435	A5	Petrol	240	IV	10	N/A	N/A	0.066	160
S80 Model Year 04	2.4 Bi-Fuel	2435	M5	LPG	187	IV	11.6	N/A	N/A	0.023	155
	D5 (163 bhp)	2401	M5	Diesel	172	III	6.5	0.47	0.03	0.427	155
	2.4 Bi-Fuel	2435	M5	Petrol	220	IV	9.2	N/A	N/A	0.017	160
S/V40 Model Year 04	Bi-Fuel 1.8	1783	M5	LPG	168	III	10.4	N/A	N/A	0.04	135
	1.9 D (115 bhp)	1870	M5	Diesel	142	III	5.4	0.379	0.032	0.349	115
	1.8i (122 bhp)	1834	M5	Petrol	164	III	6.9	N/A	N/A	0.071	125
V70 Model Year 03	2.4 Bi-Fuel	2435	M5	LPG	197	IV	12.2	N/A	N/A	0.011	155
	D5 (163 bhp)	2401	M5	Diesel	177	III	6.7	0.46	0.033	0.43	155
	2.4 Bi-Fuel	2435	M5	Petrol	219	IV	9.1	N/A	N/A	0.043	160
S80 Model Year 03	2.4 Bi-Fuel	2435	M5	LPG	187	IV	11.6	N/A	N/A	0.023	155
	D5 (163 bhp)	2401	M5	Diesel	172	III	6.5	0.47	0.03	0.427	155
	2.4 Bi-Fuel	2435	M5	Petrol	220	IV	9.2	N/A	N/A	0.035	160
Zafira, Model Year 03	1.8 16v 5 Door Estate	1796	M5	LPG	184	IV	11.4	N/A	N/A	0.023	135
	2.0 DTI 5 Door Estate	1995	M5	Diesel	175	III	6.5	0.442	0.024	0.414	155
	1.6 16v 5 Door Estate	1598	M5	Petrol	180	IV	7.5	0.063	N/A	0.026	145
Focus	1.8 Zetec LPG (EYDL) 3 & 5 Door Saloon (17 inch tyre)	1796	M5	LPG	172	IV	10.7	N/A	N/A	0.006	135
	1.8 TDCi 3/5 Door Saloon/ Estate (17 inch tyre)	1753	M5	Diesel	145	III	5.5	0.431	0.034	0.414	115
	1.8i 16V 3/5 Door Saloon (17 inch tyre)	1796	M5	Petrol	185	III	7.8	N/A	N/A	0.043	145
Astra, Model Year 02	1.6 16v 5 Door Hatch	1598	M5	LPG	151	IV	9.3	0.073	N/A	0.043	115
	2.0DTi 16v	1995	M5	Diesel	154	III	5.7	0.457	0.042	0.435	135
	1.8i 16v (3, 4 & 5 door)	1796	M5	Petrol	190	IV	7.9	N/A	N/A	0.008	160

TABLE 17 : **Comparable Models Used for Break-Even Analysis continued**

	Manufacturer and Model	Engine CC	Trans.	Fuel Type	CO_2 (g/km)	Euro Standard	Metric combined fuel consumption (l/100km)	Combined HC & NO_x emissions (g/km)	Emissions Particles (g/km)	NO_x emissions (g/km)	Vehicle Excise Duty (VED) as from 1st March 2001 (£)
S/V40 Model Year 02	1.8 Bi-Fuel	1783	M5	LPG	168	III	10.4	N/A	N/A	0.04	135
	1.9 D (115 bhp)	1870	M5	Diesel	142	III	5.4	0.379	0.033	0.349	115
	1.8 Bi-Fuel	1783	M5	Petrol	193	III	8.1	0.27	N/A	0.079	160
S/V40 Model Year 03	Bi-fuel 1.8	1783	M5	LPG	168	III	10.4	N/A	N/A	0.04	135
	1.9 D (102 bhp)	1870	M5	Diesel	142	III	5.4	0.432	0.035	0.421	115
	Bi-fuel 1.8	1783	M5	Petrol	193	III	8.1	N/A	N/A	0.079	160
S60 Model Year 02	2.4 Bi-Fuel	2435	M5	LPG	185	IV	11.4	N/A	N/A	0.04	135
	D5 (163 bhp)	2401	M5	Diesel	171	III	6.5	0.483	0.032	0.443	155
	2.4 Bi-Fuel	2435	M5	Petrol	211	IV	8.8	N/A	N/A	0.046	160
V70 Model Year 02	2.4 Bi-Fuel	2435	M5	LPG	197	IV	12.2	N/A	N/A	0.043	155
	D5 (163bhp)	2401	M5	Diesel	177	III	6.7	0.46	0.033	0.43	155
	2.4 Bi-Fuel	2435	M5	Petrol	219	IV	9.1	N/A	N/A	0.018	160
V70 Model Year 04	2.4 Bi-Fuel	2435	M5	LPG	197	IV	12.2	N/A	N/A	0.011	155
	D5 (163 bhp)	2401	M5	Diesel	177	III	6.7	0.46	0.033	0.43	155
	2.4 Bi-Fuel	2435	M5	Petrol	227	IV	9.5	N/A	N/A	0.02	160

TABLE 18 : **Growth of Diesel Relative to Petrol: Private car registration by type of engine 1992 to 2001**		
Year	**Petrol Engines**	**Diesel engines**
1992	19203	909
1993	18913	1185
1994	18794	1507
1995	18675	1828
1996	19073	2095
1997	19336	2389
1998	19525	2693
1999	19961	2810
2000	20259	3065
2001	20556	3319

Source: DTI Energy Statistics 2003.

Euro Standards

TABLE 19: **Emission Limits for Cars not exceeding 2.5 tonnes laden (a)**								
Euro Standard	**No. Seats**	**Fuel Type**	**CO**	**HC**	**NO_x**	**HC + NO_x**	**PM**	**As from (b)**
EURO III	up to 9	Petrol	2.30	0.20	0.15	N/A	N/A	01/01/00
	up to 9	Diesel	0.64	N/A	0.50	0.56	0.05	01/01/00
	Note (c)	Diesel	0.80	N/A	0.65	0.72	0.07	01/01/01
	Note (d)	Diesel	0.95	N/A	0.78	0.86	0.10	01/01/01
EURO IV	up to 9	Petrol	1.00	0.10	0.08	N/A	N/A	01/01/05
	up to 9	Diesel	0.50	N/A	0.25	0.30	0.025	01/01/05

a) 'Euro 3 and 4' (Directive 98/69/EC).

b) The above dates refer to new vehicle types; dates for new vehicles are 1 year later.

c) Temporary concession for diesel cars over 2.0 tonnes laden weight which are off road or >6 seats (unladen weight from 1206 to 1660 kg). Concession ceases on 31/12/02.

d) Temporary concession for diesel cars over 2.0 tonnes laden weight which are off road or >6 seats (unladen weight over 1660 kg). Concession ceases on 31/12/02.

TABLE 20 : **PowerShift CNG Emissions Savings 1997–2001 (kg/a, %)**

Vehicle	Car	Vans	Light Trucks	Minibuses	Buses	RCV	LGV	Total	% total reduction
1997–8									
CO_2	891	5,115	495	–	14,960	58,685	–	80,146	3%
NO_X	5	730	71	–	2,910	1,443	–	5,158	21%
PM	–	135	13	–	71	360	–	579	80%
1998–9									
CO_2	–	6,600	165	1,320	3,740	16,005	264,600	292,430	4%
NO_X	–	942	24	188	728	393	6,199	8,474	12%
PM	–	174	4	35	18	98	775	1,104	81%
1999–00									
CO_2	1,782	–	660	–	–	–	215,600	218,042	4%
NO_X	9	–	94	–	–	–	5,051	5,154	10%
PM	–	–	17	–	–	–	631	649	78%
2000–1									
CO_2	–	165	1,650	–	–	–	558,600	560,415	4%
NO_X	–	24	236	–	–	–	13,087	13,346	10%
PM	–	4	44	–	–	–	1,636	1,684	78%
Total									
CO_2	2,673	11,880	2,970	1,320	18,700	74,690	1,038,800	1,151,033	4%
NO_X	14	1,696	424	188	3,638	1,836	24,338	32,133	12%
PM	–	313	78	35	89	458	3,042	4,016	79%

Baseline Vehicles: Cleaner Vehicle Task Force report on alternative fuel vehicles 1998

Appendix B: Break-even analysis

TABLE 21 : **Volvo S60: Effect of increased excise duty on fuel cost**

	Excise Duty (p)	Cost per km (p)	Cost per 5,000km	Cost per 10,000km	Cost per 20,000 km
LPG	6.5	4.93	£246.65	£493.30	£986.59
For comparison: Diesel cost	45.82	5.86	£293.02	£586.04	£1,172.07
For comparison: Petrol cost	45.82	7.24	£361.82	£723.65	£1,447.30
	10	5.38	£269.22	£538.45	£1,076.89
LPG-Diesel Break-even rate	13.69	5.86	£293.02	£586.05	£1,172.09
	15	6.03	£301.47	£602.95	£1,205.89
	20	6.67	£333.72	£667.45	£1,334.89
LPG-Petrol Break-even rate	24.36	7.24	£361.85	£723.69	£1,447.38
	30	7.96	£398.22	£796.45	£1,592.89
	35	8.61	£430.47	£860.95	£1,721.89
	40	9.25	£462.72	£925.45	£1,850.89
Petrol & Diesel Excise Duty	45.82	10.01	£500.26	£1,000.52	£2,001.05

Example 2: Vauxhall Astra Model Year 2003

TABLE 22 : **Break-Even Analysis: Vauxhall Astra Model Year 2003**

Model Variant	Fuel	l/100km	l/km	Average pump price p/l*	Cost per km (p) duty p/l	Current excise	Break-even to D pump price p/l	Break-even excise duty: Diesel	Break-even to P pump price	Break-even excise duty: Petrol
2.0 DTI 16v 5 Door Hatchback	Diesel	5.7	0.06	77.11	4.40	45.82	77.11	–	93.89	–
1.6 16v 5 Door Hatchback	LPG	9.3	0.09	38.24	3.56	6.50	47.26	15.52	57.55	25.81
1.6 16v 5 Door Hatchback	Petrol	7.1	0.07	75.38	5.35	45.82	61.91	–	75.38	–

CHART 7 : Astra Break-Even point (MY 2003) (Fuel cost per km)

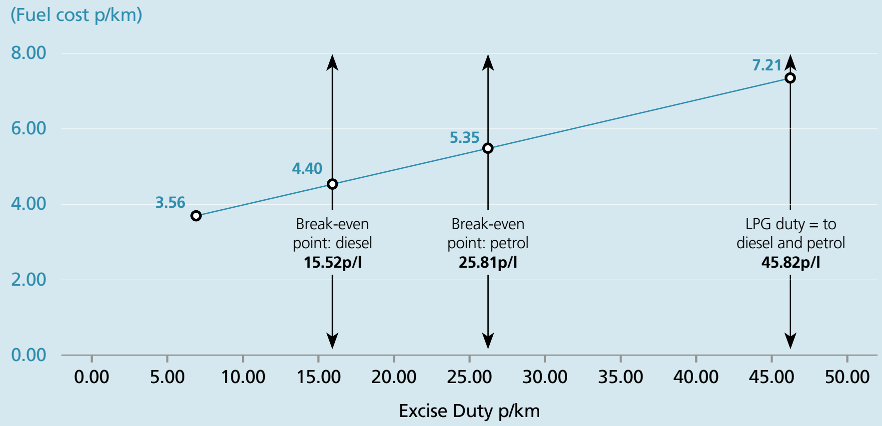


TABLE 23 : **Vauxhall Astra- Effect of increased excise duty on fuel cost**

LPG excise duty	**Excise Duty**	**Cost per km (p)**	**Cost per 5,000km**	**Cost per 10,000km**	**Cost per 20,000 km**
For comparison: Diesel cost	45.82	4.40	£219.76	£439.53	£879.05
For comparison: Petrol cost	45.82	5.35	£267.60	£535.20	£1,070.40
LPG	6.5	3.56	£177.82	£355.63	£711.26
LPG	10	3.88	£194.09	£388.18	£776.36
LPG-Diesel Break-even rate	15.52	4.40	£219.76	£439.52	£879.04
LPG	20	4.81	£240.59	£481.18	£962.36
LPG-Petrol Break-even rate	25.81	5.35	£267.61	£535.22	£1,070.43
LPG	30	5.74	£287.09	£574.18	£1,148.36
LPG	35	6.21	£310.34	£620.68	£1,241.36
LPG	40	6.67	£333.59	£667.18	£1,334.36
Petrol & Diesel Excise Duty	45.82	7.21	£360.65	£721.31	£1,442.62

TABLE 24 : **Break-even points: selected comparable bi-fuel models: fuel only**			
	Detail	**Diesel**	**Petrol**
Astra MY 2003	2.0 DTI 16v 5 Door Hatchback	15.52	25.81
Astra, Model Year 2002	1.6 16v 5 Door Hatch	15.52	32.29
Focus	1.8 Zetec LPG (EYDL) 3 & 5 Door Saloon (17" tyre)	7.90	23.21
Primera – P12 Series	1.8 Dual Fuel 4/5 door	17.77	26.98
S/V40 Model Year 04	Bi-Fuel 1.8	8.30	18.27
S/V40 Model Year 2002	Bi-Fuel 1.8	8.30	26.97
S/V40 Model Year 2003	Bi-Fuel 1.8	8.30	26.97
S60 Model Year 2002	2.4 Bi-Fuel Manual	12.23	26.45
S80 Model Year 03	2.4 Bi-Fuel Manual	11.47	28.04
S80 Model Year 04	2.4 B-Fuel Automatic[42]	13.48	24.94
S80 Model Year 04	2.4 Bi-Fuel Manual	11.47	28.04
V70 Model Year 03	2.4 Bi-Fuel	10.61	24.49
V70 Model Year 04	2.4 Bi-Fuel	10.61	26.96[43]
V70 Model Year 2002	2.4 Bi-Fuel	10.61	24.49
Volvo S60 MY 04	2.4 Bi-Fuel	13.69	24.36
Zafira, Model Year 2003	1.8 16v 5 Door Estate	14.93	19.17
Average		**11.92**	**25.46**

42. Automatic transmission gives better fuel economy than manual for this model variant; hence it has a higher break-even point.

43. The different break-even point is because the fuel economy of the comparable petrol model improved for MY 04, giving a higher break-even.

Fuel + premium cost and grants: results for all vehicles used in analysis

The break-even analysis presented above has been repeated for all vehicles, including price premium and grants. The most straightforward way to display the results for all the comparable vehicles is to take the average break-even point for LPG against petrol and diesel under each cost premium and grant funding scenario. While the average break-even point has a limited value as a tool to set the excise duty (due to the large variation between each vehicle), it is helpful to illustrate the point that premium costs and grants have a significant impact on the break-even rate.

These results are presented as a table and a chart, below.

TABLE 25 : **Average break-even excise duty rate under different premium costs, grant funding, and length of ownership scenarios (p/l)**

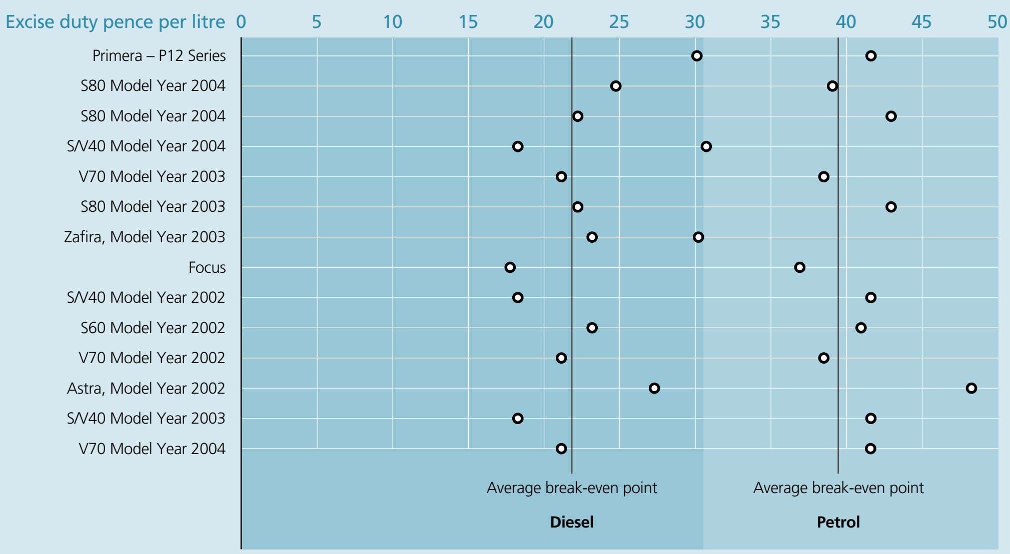
		12-Year Ownership		**3-Year Ownership**	
		Diesel	**Petrol**	**Diesel**	**Petrol**
	Fuel costs only	11.34	25.42	11.34	25.42
£1500 Premium	£0 grant	5.80	18.07	–4.62	4.24
	50% grant	8.38	21.49	1.53	12.41
	75% grant	9.81	23.39	5.80	18.07
£2000 Premium	£0 grant	4.26	16.03	–7.60	0.29
	50% grant	7.48	20.30	–0.81	9.30
	75% grant	9.32	22.74	4.26	16.03

CHART 8 : LPG Excise Duty: Average break-even points for selected comparable vehcles at 20,000 per year

TABLE 26 : **Adjusted break-even points assuming LPG vehicles are mono-fuel**

Model	Variant	Diesel	Petrol
Primera – P12 Series	1.8 Dual Fuel 4/5 door	30.15	41.66
S80 Model Year 04	2.4 Bi-Fuel	24.79	39.11
S80 Model Year 04	2.4 Bi-Fuel	22.27	42.99
S/V40 Model Year 04	Bi-Fuel 1.8	18.31	30.77
V70 Model Year 03	2.4 Bi-Fuel	21.19	38.54
S80 Model Year 03	2.4 Bi-Fuel	22.27	42.99
Zafira, Model Year 2003	1.8 16v 5 Door Estate	23.22	30.25
Focus	1.8 Zetec LPG (EYDL) 3 & 5 Door Saloon (17 inch tyre)	17.80	36.95
S/V40 Model Year 2002	1.8 Bi-Fuel	18.31	41.65
S60 Model Year 2002	2.4 Bi-Fuel	23.22	41.00
V70 Model Year 2002	2.4 Bi-Fuel	21.19	38.54
Astra, Model Year 2002	1.6 16v 5 Door Hatch	27.34	48.30
S/V40 Model Year 2003	Bi-fuel 1.8	18.31	41.65
V70 Model Year 04	2.4 Bi-Fuel	21.19	41.63
Average		**22.11**	**39.72**

CHART 9 : Estimated break-even points: mono-fuel LPG vehicles



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