ALTERNATIVE VEHICLE FUELS

INTRODUCTION

Alternative vehicle fuels are those that present an opportunity to reduce the dependence on traditional oil derived fuels whilst offering increased environmental benefits. The move away from petrol and diesel dependency for surface transportation to cleaner, more sustainable fuel types is regarded by many as a viable means to improve the current environment. However, without serious investment in terms of technology and infrastructure, and rigid commitment from governments, the potential for alternative fuel use may not be realised in the short term. As supplies of oil reduce and are eventually depleted, alternative fuels are likely to emerge as a necessity.

The main fuel types that can be realistically considered as viable alternative options, offering greater environmental benefit than traditional oil derivatives and the potential for widespread usage to replace or substitute petrol and diesel, are shown in Table 1 below. Electricity, though not a fuel type, offers another alternative form of power for vehicles.

Fuel/Energy Type	Source	Supply	Stage of Development	
			Vehicle Technology	Vehicle Availability
Natural Gas	Naturally occurring fossil fuel	Abundant global reserves	Well developed	Commercially available OEM vehicles
Liquefied Petroleum Gas	Bi-product of the oil refining process and natural gas extraction	Limited as 1% from oil refining and 3% from natural gas extraction	Well developed	Commercially available OEM vehicles
Hydrogen	Derived from renewable and/or non-renewable sources	Abundant depending on method of production	Technology for internal combustion exists. Ongoing research and experimental technology for fuel cell development	Limited commercial availability of OEM internal combustion vehicles. Research and prototype fuel cell vehicles only
Bio Fuels	Biomass or natural gas			
Bio Diesel	Esterification of rape seed	Relative to available land suitable for feedstock cultivation	Fully developed. Conventional technology requires little modification for use	Widespread commercial availability (conventional vehicles)
Ethanol	Fermentation of seed oils or conversion of natural gas	Dependent on production method	Well developed	Commercially available OEM vehicles
Methanol			Well developed	Commercially available OEM vehicles
Dimethyl Ether			Limited development as relatively new automotive fuel	Not commercially available, research and prototype vehicles only
Electricity	Derived from renewable and/or non-renewable sources	Abundant depending on method of production	Battery technology requires further development for widespread use. Hybrid vehicle technology exists. Fuel cell remains in development	Limited commercial availability of battery and hybrid vehicles. Research and prototype fuel cell vehicles only

Table 1: Alternative Vehicle Fuels

Each type of alternative vehicle fuel has benefits and disadvantages that affect it's potential for widespread usage. Certain fuels can offer substantial environmental benefits in terms of emissions reductions yet incur a high cost of production and limited availability. Conversely, other fuels may have a reduced environmental benefit but are inexpensive to produce. On a global scale, the availability of alternative fuels in terms of feedstock supply may vary according to geographical and climatic conditions and thus a fuel with widespread availability in certain regions may not be applicable in others. These factors must be considered when assessing the future potential of alternative automotive fuels.

NATURAL GAS

Natural gas is the second most abundant fossil fuel after coal. Naturally occurring, the gas requires only minimal processing from extraction for use as an automotive fuel. Many countries possess an existing infrastructure to supply natural gas for domestic purposes, which presents a significant opportunity for wider usage as an alternative vehicle fuel. In addition, natural gas is often used as a feedstock energy source for the production of other alternative fuels such as ethanol, methanol, dimethyl ether and hydrogen, and can be used in fuel cells.

The gas is predominately composed of methane (approximately 94%), which is a stable, non-toxic molecule. With a high octane number affording increased thermal efficiency and more complete combustion due to its ability to mix easily with air, natural gas can reduce fuel consumption compared to petrol and offer lower engine emissions. Life cycle energy and emissions are also lower than for conventional fuels. However, methane is an important greenhouse gas contributing to global warming.

In ambient conditions natural gas has low energy content, yet this is raised when compressed and optimised when liquefied. This property has significant implications for the use of the gas as a vehicle fuel, where storage and weight are of great importance. To allow similar vehicle ranges to conventional fuels, larger volumes of natural gas are required. This important issue requires further development, however research into adsorbed natural gas storage may yield future improvements.

Tests undertaken to compare the HGV performance of natural gas engines against diesel engines for Commercial Motor magazine (Commercial Motor, 2001) indicate the environmental and cost benefits of natural gas (see Tables 2 to 5). Essentially, the benefits of NGVs are:

- Reduced noise;
- Reduced emissions; and,
- Reduced costs.

	Internal	External [a]
CNG	55.8	71.9
LNG	59.8	74.1
Diesel	61.4	79.1

Table 2: A comparison of noise emissions (dB(A)) measured at tickover between engine types.
Note: [a] measured approximately 1.0m from the right rear of the cab.

	Emissions (g/kWh)				
	HC	CO	NOx	CO2	PM
Diesel [a]	0.864	1.442	7.014	756.3	0.373
LNG	0.180	0.017	1.532	698.0	0.013
CNG	0.212	0.018	0.962	674.0	0.007
Euro 5 [b]	0.55	4.0	0.962	674.0	0.07

Table 3: A comparison of exhaust emissions between fuel types.
Notes: [a] Diesel engine built to Euro-1 standard.
[b] Proposed emissions standards for 2005-8.

	Fuel (litre/kg)	Total km (miles)	Mpg (litre/100km)
CNG	89.5/67.8 [a]	209.8 (130.4)	6.62 (42.7)
LNG	89.7/65.5 [b]	209.8 (130.4)	6.62 (42.7)
Diesel	69.1	209.8 (130.4)	8.56 (32.9)

Table 4: A comparison of fuel consumption between engine types.
Notes: [a] 1kg of CNG contains the same energy as 1.32 litres of diesel.
[b] 1kg of LNG contains the same energy as 1.37 litres of diesel.

	Cost (p/mile)	Fuel (£)
CNG	18.1	27,150
LNG	18.1	27,150
Diesel	25.4	38,100

Table 5: A comparison between fuel costs for engine types (covering 150,000 miles per year).

Natural gas is currently the cheapest of all the fossil-based fuels (including LPG) when fuel costs are considered alone. It costs under £0.06 per mile to run a smaller vehicle on natural gas (compared with £0.10 or more on petrol). The cheaper costs of natural gas are due to reduced fuel duty.

Grants are available from TransportEnergy's Powershift programme for the conversion of vehicles to natural gas. CNG and LNG are best suited to heavier vehicles as opposed to liquefied petroleum gas (LPG), which is mostly used in light vans and cars.

One of the obstacles to growth in NGVs has been the lack of refuelling stations. There are a limited number of public refuelling stations in the UK, although many companies have opted for the installation of depot-based facilities and open them for public use.

An additional benefit of using NGVs is that they are exempt from the London Congestion Charge.

LIQUEFIED PETROLEUM GAS (LPG)

LPG arises from the processes of natural gas and crude oil extraction and as a by-product of oil refining. It is composed of a mixture of petroleum gases, with propane and butane the most significant of these. Though inextricably linked to the continued exploitation of crude oil and natural gas reserves, LPG is currently a realistic alternative fuel that can offer life cycle energy and emissions benefits over petrol and reduced emissions at point of use. To date, LPG is the most predominant alternative fuel with approximately 4 million vehicles in use worldwide.

LPG is well suited for use in most types of vehicle and can be used in either bi-fuel or dedicated engines. The high octane and therefore high compression ratio allows LPG to offer greater energy efficiency than petrol. However, LPG engine technology requires further development to improve performance.

LPG is a cheap alternative to petrol or diesel (about half the price on the forecourt), with over 1000 public refuelling facilities now available[1]. It is environmentally favourable compared to conventional fuels because of the lower tailpipe emissions (CVTF, 2000).

LPG has proved particularly popular as a fuel for cars and vans, most of which are bi-fuel; they carry both petrol and LPG and can change from one to the other at the flick of a switch. Powershift grants are available for the conversion of vehicles to run on LPG.

HYDROGEN

Hydrogen can be produced from practically any energy source both renewable and non-renewable. Commonly, production is from the electrolysis of water and steam reformation or gasification of a feedstock, with natural gas as the most significant source.

[1] http://www.transportenergy.org.uk/action_cleaner_lpg.cfm, accessed on 25 November 2003.

For vehicles, hydrogen offers unrivalled environmental impact at point of use due to the absence of carbon in the fuel. The emissions from combustion comprise solely water with some nitrogen oxides emissions when burnt in air. These benefits however, can be significantly reduced when life cycle production emissions and energy utilisation are considered. In particular, hydrogen produced from electrolysis where electricity has been generated from fossil fuel combustion has some of the highest emission levels of all fuels.

Hydrogen can be used separately or combined with natural gas in conventional spark ignition engines. On board storage is usually by means of liquefied gas or metallic hydrides, however due to the low energy content by volume, storage presents a barrier to wider uptake. Furthermore, the highly flammable nature of hydrogen has additional practical implications that need to be addressed.

The development of fuel cell technology may lead to greater use of hydrogen for vehicular purposes. Hydrogen can be used as a feed fuel for the generation of electricity by reverse electrolysis in fuel cells. The potential exists for hydrogen to play an important role in the development of the zero emission vehicle.

BIO FUELS

The four main types of bio fuel are ethanol, methanol, dimethyl ether (DME) and bio diesel, all of which can be produced from energy crops. The fermentation of biomass is used to produce ethanol, methanol and DME, although these fuels can also be derived from natural gas. Bio diesel is produced from the esterification of vegetable oils extracted from oil containing crops such as rapeseed and palm. Though they can be derived from renewable sources, the processes of crop cultivation, harvesting and production require energy that affects the life cycle environmental impact of these fuels. In practice and with the exception of bio diesel, most bio fuel is produced from the conversion and processing of natural gas.

Both ethanol and methanol are commonly used with conventional petrol in engines that are able to run on fuel mixtures. DME is a recently developed alternative fuel that has yet to be widely tested, however due to its inherent properties it is well suited to compression engines. Bio diesel has a clear advantage over other alternative fuels as it can be used in existing engines either as a mixture or substitute for conventional diesel.

ELECTRICITY

Electricity presents a potential alternative means of propulsion for automobiles. Using electricity as a power source, it is feasible to develop vehicles that have no adverse environmental emissions at the point of use. However, during the production of electricity high levels of energy use and emissions may arise with negative effects for the total environmental benefits of its use as a vehicle fuel. The impact of electricity generation is most damaging from the combustion of fossil fuels, and in particular coal. Yet, when generated from renewable sources it can have negligible environmental impacts.

Currently, development of battery technology severely impedes the prospects for electric vehicles, with the issues of size, weight and energy density restricting vehicle capabilities. However the concept of electric vehicles is not new and they have experienced some niche market success. In the UK, electric vehicles comprise the largest share of the alternative vehicle population with over 15,000 in use, mostly for milk delivery. Though not able to match the range of conventionally fuelled vehicles, electricity may have bright prospects in other niche markets and for smaller applications such as scooters and compact urban cars where range is less of an issue. A major advantage held by electricity is the ability to recharge at home at the users' convenience.

The greatest potential for electricity is likely to be its generation within fuel cells, however this remains an area of advanced technological development that is not expected to become available for some years. More realistic prospects for electricity use in vehicles arise from the continued development of hybrid engines.

REFERENCES

Cleaner Vehicles Task Force (CVTF) (2000). *An Assessment of the Emissions Performance of Alternative and Conventional Fuels:* The Report of the Alternative Fuels Group of the Cleaner Vehicles Task Force. HMSO, Norwich.

Commercial Motor (2001). Dash to Gas, in *Commercial Motor*, 11-17 October 2001.