The Environmental Benefits of Alternative Road Transport Fuels

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Abstract

This desktop study assesses the environmental impacts of alternative road transport fuels. The three alternative fuels examined were liquefied petroleum gas (LPG) compared to unleaded petrol, whilst compressed natural gas (CNG) and liquefied natural gas (LNG) were compared to diesel. Vehicle emissions of pollutants and greenhouse gases were taken on a life cycle basis. It was found that in general the three alternative fuels outperform petrol and diesel with respect to a given set of air pollutants. Economic analysis for alternative fuel usage showed a significant cost benefit to using LPG over petrol, especially with current increasing fuel prices.

1.0 Introduction & Background

The government of Western Australia has developed the Perth Air Quality Management Plan (AQMP) to maintain and improve Perth's air quality. The Air Quality Coordinating Committee (AQCC) is responsible for overseeing the implementation of the AQMP. Several distinct working groups have been created to ensure wide consultation occurred during the development and implementation of the AQMP (Department of Environmental Protection 2000). The Vehicle Emissions Reduction (VER) working group was formed to target the single largest adverse source on Perth's air quality, on-road motor vehicles (Department of Environmental Protection 2000).

One of the key AQMP actions identified by the VER working group was to 'Investigate and promote the benefits and feasibility of using compressed natural gas (CNG) and liquefied petroleum gas (LPG) as fuel sources for the road passenger transport and freight sectors where appropriate' (Department of Environmental Protection 2000). This research assesses the environmental benefits of using CNG and LPG in the WA motor vehicle fleet. This study has been extended beyond the scope of this AQMP action, to also consider liquefied natural gas (LNG).

This project assessed each individual fuel's impact on the environment, specifically air quality in Perth's air shed. The emissions for each fuel were considered over its life cycle, namely the pollutants released into the atmosphere from the point when it is extracted, through to the products of engine combustion. The effects of using LPG will be compared to unleaded petrol for use in light duty vehicles, whilst CNG and LNG will be assessed against diesel in heavy duty vehicles. Additionally economic and social considerations will be taken into account with respect to Perth. Cost-effectiveness analysis will be prepared by using existing government and private-sector scenarios. Social considerations include the identification of public attitudes with respect to alternative fuel usage.

This fuel life cycle analysis study differs from others in the sense that it is specific to Western Australia. The conclusions from this report will be utilised by the AQCC to provide direct recommendations to the Minister for the Environment for future policy decisions.

1.1 Fuel information

1.1.1 Liquefied Petroleum Gas (LPG)

LPG (also known as autogas) is the most widely used alternative fuel for transport applications in Australia, accounting for up to 8% of total fuel usage (Figure 1; ALPGA Taskforce 2003). It consists primarily of propane (C_3H_8) and butane (C_4H_{10}), with blends ranging from 50-100% propane by volume. Approximately 75% of Australia's LPG production is derived as a product of crude oil and natural gas extraction, while the remainder is produced as a by-product of petroleum refining (Department of Industry Tourism and Resources 2005; AIP 2002). It has a volumetric energy content of approximately 26.5 MJ/L, which is nearly 25% below that of petrol (34.2MJ/L) (Tedesco 2004).

Production at the Wesfarmers LPG plant in Kwinana, Western Australia began in 1998 and now has the capacity to produce approximately 1000 t/day of LPG for domestic and international markets (Kadir 2005). The natural gas is sourced from the Dampier-Bunbury pipeline, with propane and butane extracted and stored on site, whilst the methane goes towards LNG production. Current Australian consumption of autogas is between 2.4 - 2.7 GL, with approximately 9% (224 ML) consumed in WA (Australian Bureau of Agricultural and Resource Economics 2005; ALPGA 2002).

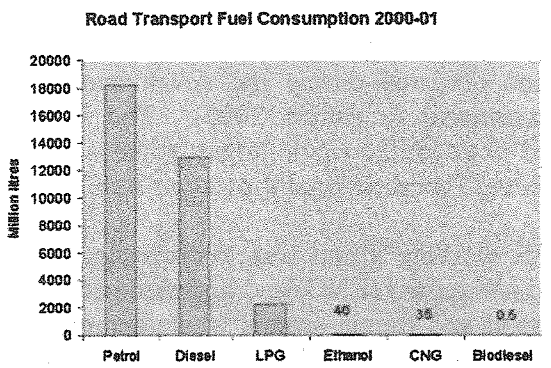

Figure 1: Road Transport Fuel Consumption 2000-01

1.1.2 Liquefied Natural Gas (LNG)

LNG is natural gas that has been chilled to –160°C and is stored and transported as a liquid. As a liquid, natural gas reduces to 1/600 of its original volume. Like domestic natural gas it consists primarily of methane (87-97% by volume) with trace amounts of other hydrocarbons including ethane, propane and butane (Bureau of Transport and Communications Economics 1994). The energy content by volume of 25 mega joules per litre (MJ/L), which is nearly 35% lower than diesel (38.6 MJ/L) (Tedesco 2004).

The Wesfarmers LPG plant in Kwinana currently produces approximately 1000 t/annum of LNG using natural gas sourced from the Damiper to Bunbury pipeline (Kadir 2005). The use of LNG as a vehicle fuel has only emerged over the last few years.. Due to the lower energy density of LNG compared to diesel, it has been limited to use in large freight and refuse trucks. Typical routes include Perth to Kalgoorlie, Albany and Geraldton (pers comm. Rod Jones 2005).

1.1.3 Compressed Natural Gas (CNG)

CNG is natural gas that has been pressurised and stored at up to 25 Megapascals (MPa) (NGV.org 2005). Engine manufacturers recommend that CNG primarily consists of methane (85-90% content by volume) with smaller amounts of ethane, propane and nitrogen (Li 2002). The energy content of natural gas in Western Australia is 41.5MJ/m^3. When compressed however, one cubic metre of natural gas requires a container volume of approximately 4 litres, resulting in only 25% of the operating range of diesel.

CNG has been used as a transport fuel in Australia since 1998 (Envestra Natural Gas Networks Pty Ltd 2005) mainly in urban bus fleets. Currently 15% of Perth's public bus fleet uses CNG, with more than half of the fleet expected to be using it by 2011 (Andrew Webb pers comm.). ABARE statistics show that natural gas usage in theWA road transport sector has steadily increased since 1991 at the rate of nearly 20% per annum (Australian Bureau of Agricultural and Resource Economics 2005).

2.0 Methods and Procedures

As this was a research project, the aim was to collect and collate the relavant information into a concise report. The primary aim was to investigate the environmental implications of alternative fuels, with additional information regarding the social and economic aspects. These topics provided the bulk of the research, and the they were broken down as follows.

The air contaminants considered by this study include, but are not limited to those documented in the Ambient Air Quality National Environmental Protection Measure. These included carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), particulate matter and hydrocarbons (which cause the formation of ozone), as well as greenhouse gases carbon dioxide (CO_2) and methane, and where applicable volatile organic compounds (VOC). Attempts to relate information to a Perth context proved difficult, with many estimates and assumptions necessary. The assessment was broken down into the upstream (emissions associated with extraction, processing, distribution etc) and downstream (engine combustion) sections. The Carnarvon Basin in the North-West Shelf was taken as the primary source of upstream emissions, whilst the emissions from combustion were taken in the Perth airshed. LPG was being compared to unleaded petrol (ULP) in light duty vehicles (gross vehicle mass < 3.5t), and CNG and LNG compared to diesel in heavy vehicles (GVM > 3.5t).

The cost-effectiveness component of this study may be used by the government to estimate budgetary requirements. Where possible, actual cost data has be used, with estimates made for unavailable information. From the consumer's perspective this will assess the benefits (if any) of using alternative fuels by looking at net present value (NPV) and payback. Various assumptions have been used to obtain the results, including the forecasting of petrol and LPG prices into the future. It is clear petrol prices are subject to volatility, and predicting prices is at best difficult due to the myriad of factors that comprise petrol pricing.

The examination of the social aspects of alternative fuel usage encompasses the identification of public perception of the environmental-friendliness of the fuels as well as the barriers to implementation. Conducting a survey was beyond the requirements of this project, so existing literature was examined for consumer behaviour studies with regards to this topic. Surveys conducted by the Australian Liquefied Petroleum Gas Association (ALPGA) examined public attitudes towards the use of LPG Autogas and were heavily utilised.

3.0 Results

3.1 Life Cycle Analysis

The fuel life cycle analysis was produced using results from previous studies undertaken in Australia. In order to relate it to a Western Australian context, some of the data had to be adjusted. The upstream emissions were attributed to WA by multiplying total pre-combustion emissions by 54% (proportion of oil and gas production attributable to WA – Australian Petroleum Production & Exploration Association 2004). The downstream emissions have been attributed to WA on the basis of total vehicle kilometres travelled by light and heavy duty vehicles in WA as a proportion of Australian figures.

The results show that on a 'per kilometre' basis, the life cycle emissions from both CNG and LNG are lower than that of diesel. Figure 2 shows that greenhouse gas emissions dominate the life cycle emissions for a heavy duty vehicle. This is due to the high methane content of natural gas that can be released into the atmosphere as fugitive emissions and the high level of CO_2 tailpipe emissions from diesel. Methane having a greenhouse gas warming potential of 21 (against CO_2) means then even a small amount of emissions has a major greenhouse effect. The greenhouse gas emissions is represented by the sum of CO2-equivalent gases.

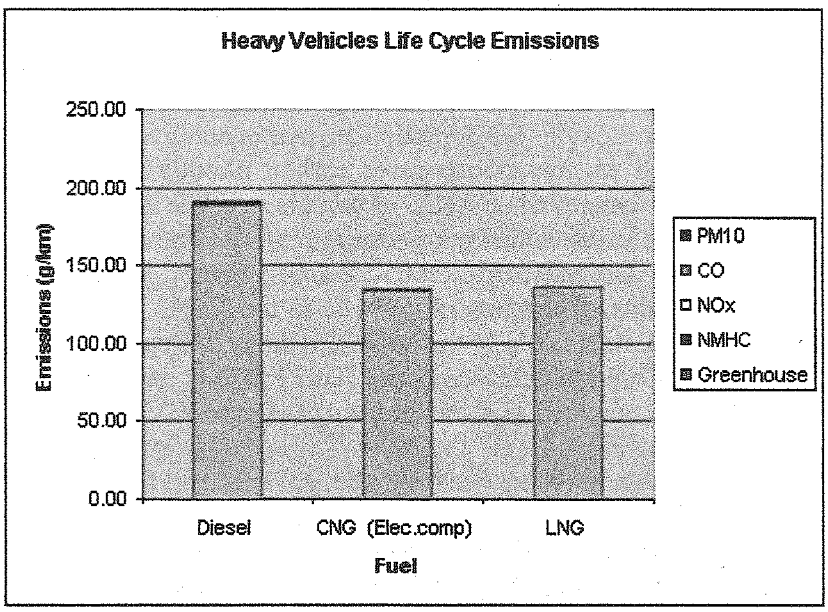

Figure 2: Emissions from Heavy Duty Vehicles in WA (Beer et. al. 2001)
[Note: NMHC = Non-Methane Hydrocarbons]

Calais (2000) suggested that if all 'unaccounted for' gas (from transmission and distribution networks) were classified as fugitive losses, then the net increase in CO2 equivalent greenhouse gas emissions may be as high as 63% above the combustion emissions (Calais 2000).

The results specify a fugitive emissions estimate of 0.1% due to production, transmission and distribution losses. This is a highly contentious issue, and the level of pre-combustion fugitive emissions cannot be fully determined. For CNG particularly, a change in the amount of fugitive emissions can actually result in an increase in total emissions, which can offset its benefits compared to diesel. Improved data is required for fugitive emissions in order to gain a complete understanding of the environmental impacts of fuels.

For light duty vehicles the results indicate lower NOx and NMVOC emissions for autogas (60:40 propane to butane blend) but higher CO emissions. When using a 100% propane blend, which is common in WA, there is a significant reduction in the major emissions (Figure 3).

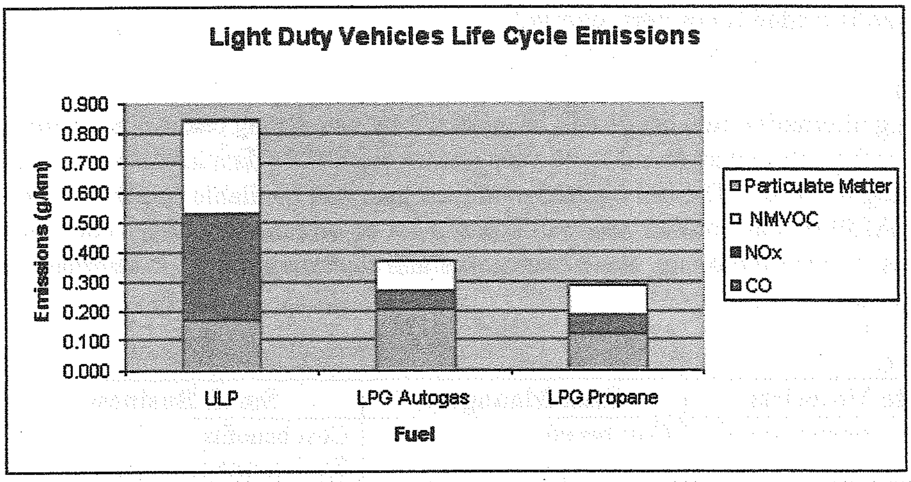

Figure 3: Emissions from Light Duty Vehicles in WA (Beer et. al 2004)
[Note: NMVOC = Non-Methane VOC]

3.2 Economics

Net present value and payback methods were used to determine the financial benefits of using LPG Autogas as an alternative fuel in passenger vehicles. The analysis compares the cost of running a car on petrol versus LPG (both dedicated LPG and aftermarket conversions). The results (Table 1) show that there are significant benefits to using a dedicated LPG vehicle by way of savings on fuel costs using a 5-year time horizon.

Table 1: Payback and NPV for LPG vehicles – 5 year time horizon (Sample vehicle Mitsubishi Magna ES)

	Private Motorist	**Government Vehicle**	**Commercial Vehicles**
Payback (months)	5.5	3.1	4.0
NPV	$2,881.16	$5,671.98	$4,353.17
Discount rate used	11.25%*	9%	9%

*This rate assumes that the additional cost of a dedicated LPG or a conversion is borrowed. This rate is the personal lending rate from National Australia Bank.

The petrol and LPG prices have been estimated for future periods based on end-of-financial year average prices, thus are not as high as current retail prices as of September 2005. The data does not take into account costs such as maintenance or insurance which can be largely assumed to be similar for both vehicles.

A payback period of less than three years is expected for the average consumer running a converted dual-fuel petrol/LPG engine, whilst a dedicated LPG vehicle has a payback of less than six months. A significant positive NPV exists for all cases, meaning that there is a direct benefit to the consumer in dollar terms. Of course these numbers are highly dependent on the variability of petrol and LPG prices, but in the forseeable future the benefit of using LPG over petrol is obvious.

Economic analysis for CNG and LPG usage was not assessed to the same extent as that of LPG due to the lack of information. Anecdotal evidence however suggests that there are financial benefits to using CNG in the Perth public bus fleet due to the current rising diesel prices (Ian Vinnicombe pers. comm.). LNG was identified as having economic benefits for the few companies that use it in Perth (Mfanwy – Sita; Diane – Sands Fridge Lines pers. comm.)

3.3 Social Considerations

The social aspects regarding alternative fuel usage can be assessed by examining consumer attitudes towards these fuels. Such information was found to be very scarce, with little data available by way of surveys especially relating to Perth. The only actual evidence that was available was from three surveys conducted by the ALPGA that looked into public attitudes of automotive LPG. The study was split into three sections; private motorists, small businesses and fleet managers. A summary of the findings is presented in Table 2.

Table 2: Attitudes towards LPG

	Private Motorists	Fleet Managers	Small Business
Percieved advantages	Lower fuel & running costs	Cost benefits	Cost benefits Environmental benefits
	Environmental benefits	Environmental benefits	
	Dual fuel option		
Percieved barriers	Safety issues	Performance negatives	Availability of LPG outside metro areas
	Maintenance	Availability in areas covered	Tank takes up too much space
	Lack of availability outside metro area	Costs	Poor engine performance
	Loss of boot space	Space	Too expensive to convert
		Safety	
Industry Feedback	Promote a new image around the advantages	Educate us about the advantages	Educate us about the advantages
	Make safer	Make LPG vehicles the same or cheaper	Advertise the Cost Savings
	Educate about the environmental benefits	Advertise the cost savings	Keep the price low/lower/cut excise
	Make conversions cheaper	Keep the price low/lower/cut excise	Make LPG vehicles the same or cheaper
	Improve the space issue	Provide data on safety issues	Increase the number of LPG outlets

There are significant percieved barriers to the increased usage of LPG as an automotive fuel, which can be verified by the autogas industry. Kleenheat identifies seven social barriers that include lack of space, safety concerns, price volatility and male versus female attitudes towards LPG autogas usage as actual barriers from an industry perspective (Bill Hazell pers. Comm). Issues regarding lack of availability and reduced vehicle performance are seen as percieved barriers, which tend to match the results of the surveys. These will need to be addressed before alternative fuels such as LPG can gain greater market penetration.

The social implications of using LNG and CNG fuels was difficult to identify due to the comparative lesser usage in Perth. Environmental and economic advantages have been cited as the reasons for using alternative fuels over diesel. Taxes, reduced range or payload (for CNG) and higher maintenance costs (CNG) have been cited as some of the barriers (Ian Vinnicombe pers. comm.)

4.0 Conclusions

Based on the preliminary results, there appears to be a positive environmental benefit to using alternative transport fuels in Western Australia. Reductions in gaseous emissions combined with economic and social benefits suggest the use of these fuels will continue to increase in the future. However there are significant barriers that must be overcome before alternative fuels become mainstream. Issues regarding government subsidies, taxes and the development of renewable energy sources are all likely to have an impact.

Recommendations for future work include an updated life-cycle model specific to Perth with a wider range of vehicle fuels. Lack of consistent data was commonly encountered, especially regarding LNG usage, and the amount of fugitive emissions from fuel sources. Complete collaboration from industry is required to gain the most comprehensive understanding of the true environmental impacts of alternative fuels.

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