



FleetWise Knowledge Pool

Alternative Fuel and Vehicle Technologies



This publication is copyright. No part may be reproduced by any process except in accordance with the provisions of the *Copyright Act 1968*.

© State of Victoria 2011

Authorised by the Victorian Government, 121 Exhibition St, Melbourne Victoria 3000.

If you would like to receive this publication in an accessible format, such as large print or audio please telephone Public Affairs Branch, Department of Transport on (03) 9655 6000.



The FleetWise program was funded by the NSW Environmental Trust and developed by the NSW Government. This document is reproduced with the permission of the NSW Office of Environment and Heritage.

Contents

1. Background	3
2. Conventional fuels	4
Unleaded petrol	4
Diesel	4
3. Alternative fuels	6
Liquefied petroleum gas	6
Biofuels	7
Natural gas, hydrogen and solar-powered vehicles	11
4. Vehicle technologies	11
Direct injection technologies	11
Variable cylinder technologies	11
5. Alternative drivetrain technologies	12
Hybrid electric vehicles	12
Electric vehicles	13
6. Further information	15
References	16

The technologies covered here have been selected because they are currently (or soon to be) commercially available, and are likely to be considered by business fleets.

In addition to conventional vehicle fuels (petrol and diesel), the technologies discussed are:

- liquefied petroleum gas (LPG)
- biofuels (ethanol and biodiesel)
- hybrid electric vehicles
- electric vehicles.

Alternative fuels such as natural gas, hydrogen and solar power are also briefly discussed, as are direct injection and variable cylinder technologies.



Table 1
Average GHG emissions per kilometre of new passenger vehicles
Source: National Transport Council, 2009

Country	Estimated average GHG emission intensity in 2008 (surrogate measure for average fuel consumption)
Australia	215 g CO2 per km
France	140 g CO2 per km
Germany	165 g CO2 per km
United Kingdom	158 g CO2 per km
Italy	145 g CO2 per km

1. Background

Over the past twenty years there have been major technological advances in reducing emissions from conventional motor vehicles. While such advances have led to some improvements in the average fuel consumption of new passenger vehicles in Australia, there is considerable potential for further improvement. Table 1 shows the estimated average greenhouse gas (GHG) emission intensity for some developed countries – this is directly proportional to their average fuel consumption.

In addition to GHG emissions, vehicles also emit a range of other air pollutants which are regulated by national emissions standards.

The recent tightening of these standards has delivered significant environmental benefits. However, despite improvements in fuel efficiency and the tightening of emissions standards, transport sector emissions have continued to increase. There are alternative fuels and vehicle technologies that can be adopted in response to this environmental challenge, many of which offer the potential to reduce both fuel costs and fleet emissions.

2. Conventional fuels

Petrol and diesel currently account for around 97% of the total fuel usage in the Australian passenger vehicle sector, with petrol accounting for around 83% of the total volume of fuel used, and diesel around 14% (ABS 2010). Diesel is mainly used by commercial vehicles (vans, utes, buses and trucks) but is being increasingly used as a fuel for passenger cars.



Unleaded petrol

Unleaded petrol is typically sold with a standard octane level (referred to as RON: research octane number) of 91–93, while premium unleaded fuels typically have a RON of 95 or 98. Energy content can remain the same while the RON changes, however both power output and fuel efficiency can be improved with higher RON fuels because they allow the engine to function closer to its theoretical optimum capacity (if the engine has been designed to operate on high octane fuels and equipped with a knock sensor). Higher octane levels can also boost vehicle fuel efficiency, depending on the vehicle model. As a general rule of thumb, a RON increase of 1 gives a 1% change in fuel consumption. For more information see the NRMA Motoring Blog at www.mynrmacommunity.com/motoring/category/fuels/page/4/.

Environmental performance

Despite significant improvements in fuel quality in recent years, petrol vehicles typically produce more GHG emissions per kilometre than diesel vehicles (all other things being equal). However, in general, conventional petrol vehicles have significantly lower emissions of non-GHG air pollutants (such as particulate matter) per kilometre than their diesel equivalents. Premium unleaded petrol generally delivers lower levels of noxious emissions (i.e. benzene, sulfur and aromatics) than standard unleaded, while the sulfur content of RON 98 is around ten times lower than the national standard for unleaded fuels.

Operational considerations

Using conventional petrol vehicles generally brings with it the following operational advantages:

- Petrol is widely available, providing confidence about access to fuel, particularly in rural or remote areas.
- There is a wide range of vehicle choice, with virtually all petrol-engine cars sold in Australia offered in a range of choices. Considering the ever-growing list of fleet applications, the possibility of picking the exact type of vehicle required to fulfil specific needs can be a significant advantage.

The main disadvantage with conventional petrol engines (compared to diesel engines) is relatively high fuel consumption and associated GHG emissions per kilometre.

In terms of engine performance, the results are mixed. Modern petrol engines generally deliver higher power outputs for the same displacement as their diesel counterparts, but many passenger diesel engines are equipped with a turbo compressor, which increases both torque and power. The result is a similar power output to that of normally aspirated petrol engines, but with much higher torque figures in the lower range of the engine's operating band.

Financial considerations

The cost of purchasing and operating conventional petrol vehicles is typically used as the yardstick for comparisons with other technologies. Conventional petrol vehicles are generally cheaper to purchase than those running on either diesel or LPG, however a number of manufacturers are now offering diesel engines as standard for no extra cost. Some European-sourced cars are often now designed around diesel engine specifications due to its popularity in European countries.

The use of premium unleaded petrol can improve fuel economy in some vehicles, but the higher cost of these fuels tends to negate the potential financial benefit. As a general rule, the use of premium unleaded petrol instead of standard unleaded petrol is likely to deliver a slight reduction in average fuel consumption (in cars with modern engine management systems) with little net cost.

Table 2

Comparing fuel consumption and vehicle performance between diesel and petrol vehicles

Source: Ford Australia (www.ford.com.au)

Make and model	Engine output	Torque	Average fuel consumption per 100 km
Ford MC Mondeo LX diesel-powered engine	120 kilowatts	340 Newton metres	5.9 litres
Ford MC Mondeo LX petrol equivalent	118 kilowatts	208 Newton metres	9.5 litres

Diesel

Historically diesel has been viewed as a commercial vehicle fuel, but the number of diesel-powered passenger vehicles on the Australian market has increased significantly due to a combination of concerns over GHG emissions, a desire to lower average fuel consumption, and an increase in the number of imported diesel models.

Due to its popularity as a commercial vehicle fuel, diesel has a wide distribution network, making it readily accessible to the passenger vehicle market.

Environmental performance

The key strength of diesel engines is that they typically deliver lower average fuel consumption than their petrol (and LPG) counterparts. For example, according to the Australian Government's Green Vehicle Guide (www.greenvehicleguide.gov.au), the Ford Mondeo diesel engine consumes 37% less fuel than its petrol equivalent, while the Volkswagen Golf Trendline (1.7 litre) consumes around 18% less fuel than the petrol model, by volume.

While diesel produces slightly higher GHG emissions per litre consumed than petrol, the lower average fuel consumption of diesel engines generally more than compensates for the higher emissions per litre compared to petrol engines.

However, diesel's GHG benefits should be considered in light of the increased emissions of other air pollutants. Emissions of nitrogen oxides (NO_x), hydrocarbons (HC), and particulate matter (PM) from diesel engines are much higher than from petrol or LPG engines. In the case of the current Euro 4 emissions standards adopted in Australia, the upper limit of NO_x emissions from diesel vehicles are specified at more than three times higher than those for petrol engines (however under Euro 4 standards there is no limit to petrol particulate emissions). Euro 5 standards (are yet to be adopted in Australia) but have the same particulate limit for both diesel and petrol emissions. While these emission differences are reducing with tighter diesel emissions standards, the generally higher air pollution from diesel vehicles can be a particular drawback for using diesel in urban areas.

Improvements to the diesel mix itself, and other vehicle technologies, can further improve the environmental performance of diesel. In 2009 the sulphur content of diesel sold in Australia was reduced from 50 parts per million (ppm) to 10 ppm in ultra low sulphur diesel (ULSD). The low sulfur content of clean diesel can enable emission reduction devices to function more efficiently.

Installing particulate filters can also reduce particulate emissions by over 95% compared to vehicles not featuring a filter. Most new-model diesel passenger vehicles make use of this technology.

Operational considerations

Diesel vehicles have several operational advantages relative to conventional petrol vehicles. These include:

- Diesel vehicles consume less volume of fuel, per kilometre travelled than conventional petrol vehicles. This is particularly true for lower range urban and highway driving conditions.
- The ratios of fuel consumption to vehicle performance for diesel vehicles are better than for conventional petrol vehicles. This is particularly true at lower ranges in urban and highway driving conditions.
- The relatively low fuel consumption of diesel vehicles compared with conventional petrol vehicles tends to give them an advantage in terms of vehicle range (for equivalent volumes of fuel), as shown in Table 2.
- In addition to their lower fuel consumption, diesel-powered engines are a proven technology that has improved significantly over the past twenty years. As a consequence they are as reliable as their petrol counterparts.

However, increasing the use of diesel vehicles can create some operational challenges:

- There are fewer vehicle options available compared to petrol equivalents, however rising fuel prices have enticed an increasing number of automotive manufacturers to bring models with diesel engines into their range. Currently the Ford Territory diesel is the only locally built diesel passenger vehicle on the Australian market.
- Diesel has a higher retail price typically costing 10 cents more per litre than petrol. However, it has a higher energy content than petrol, and this reduces the average fuel consumption of diesel vehicles.

Financial considerations

Modern diesel vehicles make use of advanced combustion technologies and are typically more expensive than their petrol equivalents, meaning that in these cases diesel cars typically need to run more kilometres to provide an equivalent return on investment compared to conventional petrol vehicles. While some of these costs can be offset by the reduced fuel consumption rates of diesel, the higher cost of diesel can negate these savings, making it difficult for fleets to recoup the additional capital cost within the lease life of the vehicle.



3. Alternative fuels

Liquefied petroleum gas

Liquefied petroleum gas (LPG) is the generic name for mixtures of hydrocarbons (mainly propane and butane) compressed to form a liquid. LPG can be used to power a petrol engine after modifications to the fuel and engine systems, which are required for the engine to cope with the lower energy density of LPG compared to petrol. LPG is widely sold at petrol stations throughout Australian cities and in most regional areas. Vehicles that run on LPG can be either purpose-built or converted petrol vehicles. New LPG-fuelled passenger cars are available as either dedicated LPG vehicles, or as dual-fuel vehicles that allow the driver to choose between both LPG and petrol.

Of the major vehicle manufacturers available in Australia, Holden offers its dual-fuel Autogas injection system for the Commodore range, Toyota has a dual-fuel direct injection system available in a 2.7 litre engine in its HiAce van range, and Ford has dedicated LPG vehicles using its E-gas system in its Falcon sedan and ute ranges.

Existing petrol vehicles can also be retro-fitted with a gas conversion kit for LPG use. Two conversion options are available. The first replaces the entire petrol fuel delivery system and tank with an LPG system, while the second adds an LPG delivery system and additional fuel tank to the existing petrol system, producing a dual-fuel system. The complete change to LPG is less common but can provide much better results in terms of fuel efficiency.

It is important to note that gas conversion kits comprise different types of technologies, delivering different economic and environmental outcomes. As a general rule of thumb, the more sophisticated direct injection systems deliver better outcomes than the cheaper gas fumigation systems.

Environmental performance

LPG can offer some GHG and air pollution benefits, but the extent of such benefits is influenced by the LPG engine technology used.

International and academic literature suggests that the use of LPG instead of petrol or diesel can provide some environmental benefits in terms of lower production of non-GHG air pollutants and lower GHG emissions. Studies have found that using LPG in lieu of petrol in passenger vehicles in Australia can decrease GHG emissions by up to 10% given current technology, with the potential to increase to 13% for advanced LPG technologies and LPG sourced from natural gas fields (LGPA 2010). Studies have also highlighted that emissions of NO_x can decrease by around 25%. For more information see the LGPA Industry Strategic Road Map – GHG Paper at <http://lpgaaustralia.com.au/site/library.php?task=detail&type=4&id=0054>, as well as the CSIRO Comparison of Transport Fuels study, 2002, at www.environment.gov.au/settlements/transport/comparison/index.html, and the King Review of low-carbon cars Part II, prepared for UK Treasury in 2008, at www.hm-treasury.gov.uk/king_review_index.htm.

However, the results of international research should be viewed with caution as most LPG vehicles in Australia are dual-fuel vehicles that were converted to LPG operation using an after-market conversion kit. These vehicles generally do not deliver all of the potential environmental benefits of LPG highlighted in academic studies (ALPGA 2002). While technologies are available to improve the performance of LPG vehicles using direct injection technologies, these technologies have not been widely adopted in Australia (ALPGA 2008). As a result, it is difficult to make accurate generalisations about the net environmental benefits of using LPG in Australia.

The use of LPG in lieu of ULP in passenger vehicles in Australia is likely to decrease GHG emissions by up to 10% given current technology and upstream intensity, potentially increasing to a 13% benefit for advanced LPG technologies and LPG sourced from natural gas fields. It should be noted, however, that the degree to which this potential is achieved in real-world operation is a factor of the sophistication of the LPG combustion technology fitted to the vehicles.

Operational considerations

The main operational advantage of LPG is reduced fuel costs. LPG is significantly cheaper on a litre-for-litre basis and does not suffer the same volatility in pricing compared to petrol. However, LPG has around 25% lower energy content than petrol. Even when this lower energy content is taken into account, LPG vehicles generally deliver significantly reduced fuel costs relative to petrol.

Relative to conventional petrol vehicles, LPG has a number of limitations:

- LPG vehicles have higher purchase costs. For example, according to Ford Australia, the factory-fitted Falcon LPG option costs \$1,400 more per vehicle than the petrol option. The after-market conversion of petrol vehicles to LPG may incur an additional cost of up to \$4,500 per car. Financial assistance from the Australian Government is available for converting privately registered vehicles, but not for business users.
- The lower energy density of LPG relative to petrol means that LPG vehicles need to be equipped with larger fuel tanks to travel the same distance as their petrol equivalent. In the case of dedicated LPG vehicles such as the Ford Falcon LPG option, the standard fuel tank increases from 68 litres for the petrol version to 93 litres for the LPG sedan, and 115 litres for the station wagon. This can result in a loss of cargo space or increased vehicle weight, or both.
- LPG is not as widely available as petrol, particularly in regional and rural areas, suggesting that a dual-fuel configuration is required for vehicles that travel large distances in regional areas. While the number of stations that sell LPG is increasing, and most drivers are now within range of a dedicated pump, drivers of LPG-fuelled vehicles should be aware of the location of the nearest retail points. Australian LPG outlets can be found at www.lpgautogas.com.au.
- The range of LPG vehicles sold in Australia is limited. The only factory-fitted LPG vehicles currently available in Australia are large passenger vehicles or light commercial vehicles however the Australian government offers grants for purchasing vehicles with LPG unit filled during manufacture.

- Advances in technology now mean there is no longer a loss in engine power which used to occur when switching from petrol to LPG due to LPG's lower energy density. For example, according to Ford, its dedicated Falcon Eco LPi LPG engine generates 198 kilowatts of power at 5000 rpm which is the equal to the petrol I6 engine when operating on high octane 95 RON unleaded fuel (versus regular 91 RON unleaded) (Ford, 2011).

Financial considerations

LPG vehicles are more expensive to purchase than equivalent petrol vehicles owing to the need to install a gas modification to the vehicle for either dedicated (100%) LPG operation or dual-fuel operation (LPG and petrol). The cost of these conversions can be up to 10%–12% of the purchase price of the conventional petrol vehicle. However, the lower per litre price of LPG can allow fleet managers to recoup these costs over the life of the vehicle.

Changes to fuel excise proposed for July 2011 will see the considerable margin between the cost of LPG and petrol and diesel draw closer with a projected annual price increase of LPG by 2.5cents per year from 1 December 2011, reaching a total of 12.5cents in July, 2015. (Customs Tariff Amendment (Taxation of Alternative Fuels) Bill 2011).

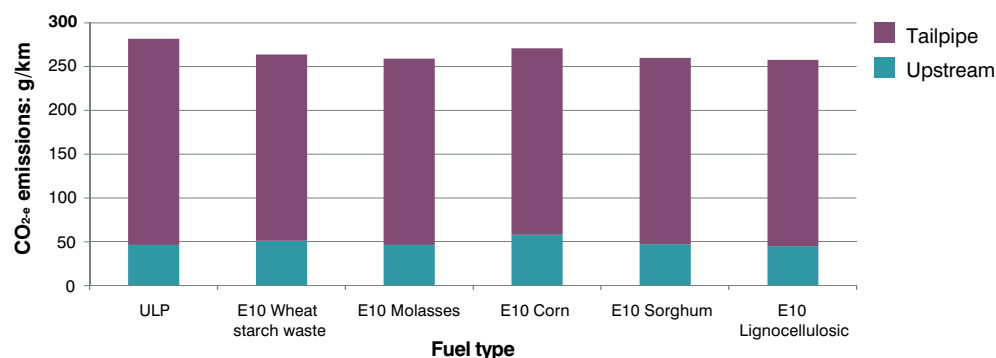


Figure 1

Life cycle GHG emissions from E10 at combustion and production stages, compared to conventional unleaded petrol.

Source: Rare Consulting (2011)

Biofuels

Biofuels are non-fossil fuels produced from biological inputs such as plant crops or animal fats. The two most commonly used biofuels in the world are ethanol and biodiesel. Ethanol is the most widely used biofuel, both in Australia and globally. Biodiesel currently has limited commercial availability in Australia.

Ethanol is an alcohol made by fermenting crops, such as sugar or grain, and then refining this into a transport fuel. It is most commonly used as a fuel extender by blending with petrol. In Australia the current maximum permitted ethanol content in petrol is 10% referred to as E10. E85 blended petrol (an ethanol content of 85%) can also be sold, with the distribution network currently expanding. Most petrol cars sold since 1986 can use these ethanol fuel blends without adverse effect on their engines, but higher blends can be corrosive to engines that have not been modified for ethanol operation.

The *Fuel Quality Standards Act 2000* provides the ethanol labelling standard for service stations supplying ethanol blend petrol: pumps dispensing ethanol blend petrol must clearly display either the exact percentage of ethanol in the blend or that the fuel contains 'up to' a percentage of ethanol. More information is available at www.environment.gov.au/atmosphere/fuelquality/standards/ethanol/labelling.html.

All ethanol is currently produced using 'first generation' technologies of fermentation (sugar) or hydrolysis and fermentation (plant starches) – this means processes that produce ethanol from either grain or sugar crops, which are refined and distilled (UNEP 2009). 'Second generation' ethanol offers the potential to significantly expand the agricultural inputs used to produce ethanol, but these production techniques are not currently commercially ready.

To assist the development of the biofuels industry, the Australian Government set a target of 350 million litres by 2010 (approximately 1% of fuel production). State governments set targets to underpin this national target, with NSW initially mandating 2% ethanol of unleaded petrol sold, increasing to 6% by July 2011.

Biodiesel is a diesel-like fuel derived from the fatty acid esters of plants and/or animals, rather than from a petroleum source. Biodiesel has similar combustion properties to mineral diesel and similarly to ethanol, it can be used as a fuel 'extender' in standard unmodified engines. Common blends of 5% and 20% biodiesel (B5 and B20) are available but most vehicle manufacturers recommend a maximum blend of B5. Higher blends can be accommodated with some vehicle modifications (subject to manufacturer warranty considerations).

In Australia biodiesel is made from a range of feed stocks including canola oil, tallow, used cooking oil and imported oils such as palm oil. There is only a small quantity of biodiesel produced in Australia, but production has increased rapidly over the past few years with the introduction of a 2% biodiesel mandate by the NSW Government in July 2010, which is set to increase to 5% by January 2012.

New biodiesel feed stocks and production techniques are being developed to find cost-effective options at a sufficient scale to produce high volumes of the fuel.

Environmental performance

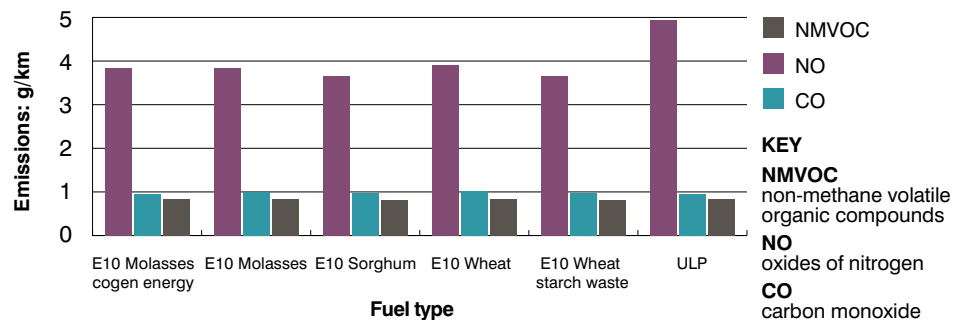
The environmental performance of biofuels is the subject of considerable debate. Reducing GHG emissions is the most commonly cited environmental argument in favour of using biofuels, but such benefits vary depending on the fuel source, production techniques and transport methods. On this basis it is difficult to quantify the precise carbon footprint of biofuels, and care should be taken in making generalisations about their overall environmental performance.

CSIRO has undertaken a number of studies of the emissions profiles of biofuels. According to the findings of one of these studies, the combustion of E10 blended fuel produced under NSW conditions results in around 1.7% lower GHG emissions than 100% petrol (CSIRO 2007a). CSIRO has also found that using biodiesel instead of mineral diesel can deliver GHG savings, particularly when the biodiesel is produced from waste oil (CSIRO 2007b). Figure 1 compares GHG emissions from ethanol and unleaded petrol.

The impacts of ethanol use on air quality are both positive and negative. Compared with tailpipe emissions of carbon monoxide from petrol, tailpipe emissions from ethanol are lower. However, emissions of oxides of nitrogen and evaporative emissions from volatile organic compounds are higher. In terms of air toxics, tailpipe emissions from ethanol contain lower levels of 1,3-butadiene, benzene, toluene and xylene but higher levels of aldehydes (see Figure 2).

Figure 2

Emissions of non-GHG pollutants from E10, various sources, and compared to unleaded petrol. Source: Meyrick and Associates, based on *Appropriateness of a 350 million litre biofuels target*, CSIRO 2003



GHG emissions from biodiesel can be lower than those from mineral diesel, but the outcomes vary according to the source of the biodiesel (see Figure 3) when the whole life cycle of the fuel is analysed. For example, biodiesel produced from used cooking oil can deliver slight greenhouse benefits, but the commercial availability of this source is limited. At the other end of the spectrum, biodiesel produced from palm oil from rainforests produces around 40% higher GHG emissions than mineral diesel, even at biodiesel blends of 5%.

Replacing mineral diesel with a biodiesel blend can also reduce emissions of carbon monoxide, non-methane volatile organic compounds and particulate matter. However, B5 and B20 biofuels have higher emissions of oxides of nitrogen compared to mineral diesel.

Operational considerations

The main advantage of ethanol is that it can substitute a proportion of petrol use with little or no engine modification. Most cars are able to run on E10 fuel without any changes to their engine, but it is prudent to check with the vehicle manufacturer before switching to an ethanol blend.

It is likely that vehicles capable of operating with higher ethanol blends will become available in Australia in the near future. For example, Holden Australia introduced an E85-compatible 3L V6 and 6L V8 Commodore in 2010.

Biodiesel is typically not used for passenger car use in Australia; however under the Diesel Fuel Quality Standard normal diesel with up to 5% biodiesel content can be sold without labelling making somewhat difficult to monitor passenger and commercial vehicle use.

There are some operational limitations associated with using biofuels:

- Biofuel blends have a lower energy intensity per litre than mineral diesel or petrol, which generally means that vehicles operating on biofuel blends have a lower range than when using conventional fuels. The energy content of ethanol is 32% lower than petrol, while the energy content of biodiesel is 14% lower than mineral diesel.
- The food versus fuel debate is also an issue. According to The World Bank, the increasing production of biofuels in the United States and Europe has been one of the main drivers of increases in the prices of internationally traded food commodities in recent years (The World Bank 2008). However, most biofuels produced in Australia from agricultural by-products or non-edible crops and are less likely to have an impact on food prices.

Financial considerations

When considered on a litre-for-litre basis, the use of ethanol blends generally does not deliver a significant fuel cost saving relative to regular petrol. Given the lower energy content of ethanol blends, their use may result in a small increase in fuel consumption and annual fuel costs.

Natural gas, hydrogen and solar-powered vehicles

A number of other fuels are popularly promoted as offering a future alternative to conventional fuels. These include natural gas, hydrogen, methanol, solar energy, and compressed air.

In the near term, the most promising of these alternatives appears to be natural gas. However, the lack of refuelling infrastructure and the non-availability of natural gas passenger vehicles in Australia are significant constraints to the take-up of this fuel.

In the longer term hydrogen holds considerable promise, but the current high cost of this technology and the lack of hydrogen refuelling infrastructure suggest that hydrogen-powered vehicles are unlikely to be available in any significant volumes in the short to medium term.

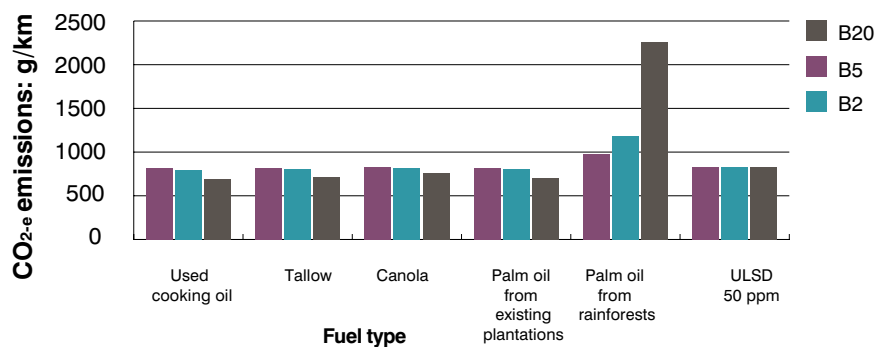


Figure 3

GHG emissions from B2, B5 and B20, various sources, compared with ultra low sulfur diesel. Source: Meyrick and Associates, based on data from *The GHG and air quality emissions of biodiesel blends in Australia*, CSIRO 2007

4. Vehicle technologies

Direct injection technologies

Direct injection technologies are an optimised type of fuel injection that has been fitted to modern diesel engines for a number of years, but is now also being fitted to some advanced petrol engines. The technology can deliver GHG emission reductions in the order of 15% when compared with equivalent-powered conventional vehicles.

This technology is typically fitted to diesel passenger cars, with current direct petrol injection systems available in Australia tending to be geared towards achieving greater power and torque performance at similar engine capacity in addition to reducing fuel consumption.

These vehicles are usually slightly more expensive than conventional petrol vehicles. While delivering improved fuel economy, the net annual fuel savings have been smaller than expected in recent years owing to the significantly higher cost of diesel relative to petrol.

When considered on a whole-of-life basis, the vehicle costs for direct injection technologies are likely to be equivalent (or marginally higher) than those for equivalent-powered conventional vehicles.

Variable cylinder technologies

First introduced successfully by Mercedes Benz in 1999, this technology allows the vehicle to select a more fuel-efficient operating mode for the engine by using inboard electronics (in the right conditions) to run the engine on half its cylinders in order to save fuel. This feature is typically provided on larger 6, 8 and 12-cylinder engines with current availability in the Honda Accord and Holden Commodore.

Potential GHG emission reductions are in the order of 5% with no significant change in emissions of other air pollutants.

In Australia, Honda introduced this system on its Accord in February 2008 with other manufacturers yet to provide this technology as a mainstream option.

5. Alternative drivetrain technologies

Hybrid electric vehicles

The term 'hybrid vehicle' in common usage refers to a car that has a combination of an electric motor and a petrol (or diesel) internal combustion engine. These cars can convert some of the kinetic energy generated during travel via regenerative braking to recharge batteries that power the electric motor. They differ from fully electric vehicles in that the electrical energy to charge the onboard batteries is drawn from regenerative braking and the combustion engine – not from the electricity grid.

Hybrid vehicles use the electric motor when the vehicle would otherwise be idling or starting up. The models currently commercially available are able to operate solely on electric power on distances of up to 21 kilometres at speeds of 100 kilometres per hour. The electric motors used in hybrid vehicles are also able to instantly switch from 'off' to 'on', which reduces wasteful revving and means the system is well suited to driving in urban areas where start-stop driving is more common. As a result hybrid vehicles generally have significantly lower average fuel consumption in city driving than conventional petrol vehicles.

Environmental performance

Hybrid vehicles generally have low average fuel consumption due to their ability to combine fuel use with internally generated electric power. According to the *Green Vehicle Guide*, the Toyota Prius and the Honda Civic Hybrid have among the lowest average fuel consumption of any vehicles on the market, producing an average of 106 and 109 grams of CO₂ per kilometre respectively.

Another feature of hybrid vehicles is generally lower noise, which may be a particular advantage in urban areas.



	Ford Focus (non-hybrid)	Toyota Prius (hybrid)	Honda Civic (hybrid)
Annual km travelled	40,000	40,000	40,000
Fuel consumption (litre/100 km)	7.1	3.9	4.6
Fuel price	\$1.45/litre	\$1.45/litre	\$1.45/litre
Total annual fuel cost (\$)	\$4,118	\$2,262	\$2,668

Operational considerations

The main operational advantages of hybrid vehicles include:

- Lower fuel costs. See Table 3 for a summary of annual fuel costs comparing the Ford Focus (non-hybrid) with the Toyota Prius and Honda Civic Hybrid. The gap in fuel costs widens proportionally with the number of kilometres driven every year and rising petrol prices. When the cars travel 40,000 kilometres per year, the Prius Hybrid can save around \$1856 in fuel costs (assuming \$1.45 per litre of petrol).
- The regenerative braking of hybrid vehicles reduces wear on the brakes and makes them particularly suited to city driving where braking is frequent
- Hybrid vehicle technology has been commercially available for more than 10 years, and so is well established as an alternative vehicle technology.

The main disadvantages of hybrid vehicles relate to the higher capital cost and the limited range of vehicle options. Hybrid cars are generally substantially more expensive than equivalent conventional petrol vehicles, so they need to travel significant distances in order to deliver a positive economic return over the vehicle's life.

Some further issues have been raised about the whole-of-life costs of hybrid vehicles. Concerns stem from the possible need to replace, and ultimately recycle, the lithium batteries to power the car's electric motor. Experience with scrapping these vehicles has so far been too limited to provide definitive conclusions.

Financial considerations

While hybrid electric vehicles offer significant fuel savings relative to conventional petrol vehicles, the higher capital cost of hybrid vehicles largely offsets these savings over the typical operating life of the vehicle.

Examining their maintenance and repair prices reveals that the cost of maintaining a hybrid vehicle is more expensive than conventional engine equivalents (RACQ 2010).

The net result of these considerations is that hybrid vehicles can deliver a small cost saving (around 5%) when considered on a whole-of-life cost basis.

Electric vehicles

While hybrid electric vehicles are now accepted as a mainstream option, the market for purely electric and 'plug-in hybrid electric' vehicles is at an earlier stage of development. While purely electric vehicle completely replace a conventional combustion engine with battery power, plug-in hybrid electric vehicles add an electric re-charging capability to hybrid electric petrol (or diesel) vehicles.

Table 3

Comparing fuel costs between a non-hybrid and hybrid vehicles. Sources: Fuel consumption figures from the Green Vehicle Guide. Unleaded petrol price based on the May 2011 national average from the Australian Institute of Petroleum: www.aip.com.au/pricing/retail/ulpl/index.htm.

Purely electric vehicle technology is improving quickly using chemical energy storage in rechargeable battery packs and employing electric motors instead of internal combustion engines. Recent innovations in battery technology, such as lithium ion batteries, can provide higher power and energy density. This allows the cars to have a greater driving range and means the batteries are less bulky.

For example, the Mitsubishi Innovative Electric Vehicle (i Miev) is a small-sized passenger electric vehicle that uses a lithium ion battery to travel up to 160 kilometres on a single charge, with a maximum (restricted) speed of 130 kilometres per hour. The Tesla Roadster is an electric sports car that is able to travel up to 350 kilometres on a single charge. In the US, Phoenix Motorcars produces sports utility vehicles and sports utility trucks with lithium titanate batteries which are capable of travelling over 160 kilometres on a single charge, with the vehicle able to be driven up to 150 kilometres per hour while carrying five passengers and a full payload.

Many of the major automotive manufacturers have electric vehicles under development with release dates as shown in Table 4.

Table 4

Planned release dates for mass-produced electric vehicles

Company	Vehicle	Commercial release date	Release location
Mitsubishi	Mitsubishi Innovative Electric Vehicle (i Miev)	2009	Japan
		2012	Australia
General Motors	Volt	2010	USA
		2012	Australia
Nissan	LEAF	2010	USA and Japan
		2012	Australia
Renault-Nissan	EV_02 plug-in hybrid electric vehicle	2010–12	Europe
Ford	Escape: plug-in hybrid electric vehicle	2012–14	USA

Environmental performance

Assessing the potential environmental benefits of electric vehicles needs to take into consideration how the electricity used to power the vehicles is derived. Australia's heavy reliance on fossil fuels to generate electricity means that the carbon dioxide emissions intensity of electricity production is significantly higher than the world average (see Figure 4).

In spite of this, research published by Curtin University's Sustainability Policy Institute has found that even when powered from the current coal dominated Australian electricity grid, electric vehicles have on average 24% lower GHG emissions per kilometre than the current Australian passenger vehicle average. Charging an electric vehicle with GreenPower (renewable energy) provides even higher GHG reductions compared to an equivalent petrol car.

Operational considerations

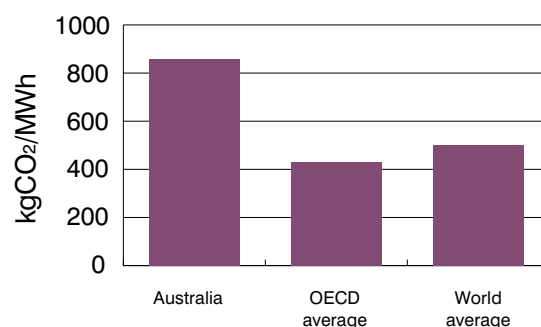
As indicated earlier, fully electric vehicles are not currently available as a mainstream option for passenger car fleets in Australia. However, models like the Mitsubishi i-Miev are increasing production from the 1,400 in 2010 to 40,000 per year from 2012; mainstream availability may not be too far away.

Any move to adopt electric vehicles for passenger cars in Australia would need to consider the following:

- Electric vehicles currently have a much smaller range than conventional petrol vehicles. Small electric vehicles have typical ranges of between 80–160 kilometres from a single overnight charge. Early experience in Australia suggests that the real-world driving range is lower than some of the more optimistic manufacturer claims.
- Electric vehicles may have lower maintenance requirements than average internal combustion engine vehicles because they have far fewer moving parts and regenerative braking.
- These vehicles are likely to be best suited to inner city operation and are unlikely to be suitable for regional travel without a significant investment in recharging infrastructure.
- In order to maximise greenhouse benefits, these vehicles need to be charged from electricity derived from renewable sources.

Figure 4

Carbon dioxide emissions intensity of electricity production, 2005. Source: Based on International Energy Agency 2007



6. Further information

Australian Bureau of Statistics, *Survey of Motor Vehicle Use, Australia, 12 months ended 31 Oct 2007*, August 2008
www.abs.gov.au/Ausstats/abs@.nsf/mf/9208.0/

Australian Government Department of the Environment, Water, Heritage and the Arts, Ethanol labelling standard
www.environment.gov.au/atmosphere/fuelquality/standards/ethanol/labelling.html

Australian Liquefied Petroleum Gas Association (2002), Liquefied Petroleum Gas as an automotive fuel – An environmental and technical perspective 2002
www.cleanairnet.org/caiasia/1412/article-58767.html

Australian Liquefied Petroleum Gas Association (ALPGA) submission to the 2008 review of the Australian Automotive Industry, 2008 (listed as 'LPG Australia')
www.ret.gov.au/energy/Documents/ewp/pdf/EWP%200100%20DP%20Submission%20-%20LPG.pdf

The Australian Transport Council and the Environment Protection and Heritage Council Vehicle Fuel Efficiency Working Group discussion paper, *Vehicle Fuel Efficiency: Potential measures to encourage the uptake of more fuel efficient, low carbon emission vehicles*,
www.environment.gov.au/settlements/transport/

CSIRO, ABARE and BTRE, *Appropriateness of 350 Million Litre Biofuels Target*. Report to the Australian Government, Department of Industry Tourism and Resources, 2003.
www.btre.gov.au/info.aspx?NodeId=16&ResourceId=133

CSIRO, *Biofuels in Australia – Issues and Prospects*, a report for the Rural Industries Research and Development Corporation, June 2007
www.rirdc.gov.au/news-&-events/news-display.cfm?article=7A3A5D3E-F1FE-4F78-AE4F-2B66ACBD572D

CSIRO, *Comparison of Transport Fuels*, Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles, Canberra, 2001, www.environment.gov.au/settlements/transport/comparison/index.html

CSIRO, *The greenhouse and air quality emissions of biodiesel blends in Australia*, Report for Caltex Australia Ltd, November 2007
www.csiro.au/resources/pf13o.html

Ford Australia, www.ford.com.au
Green Vehicle Guide,
www.greenvehicleguide.gov.au

King J, *The King Review of Low-Carbon Cars. Part II: Recommendations for Action*, HM Treasury, London, 2008
http://webarchive.nationalarchives.gov.uk/+http://www.hm-treasury.gov.uk/bud_bud08_king_review.htm

LPG Autogas,
www.lpgautogas.com.au

National Transport Commission Carbon Emissions from New Australian Vehicles, November 2009
www.ntc.gov.au/DocView.aspx?DocumentId=1921

NRMA Motoring Blog, Using premium unleaded petrol
www.mynrmacomcommunity.com/motoring/2007/10/02/using-premium-unleaded-petrol/

Rare Consulting Pty Ltd, *Transport, Greenhouse and Air Quality – a strategic framework*, report prepared for the NSW Roads and Traffic Authority, May 2007

Ross Garnaut, *The Garnaut Climate Change Review*, October 2008 www.garnautreview.org.au/index.htm

The World Bank, *A Note on Rising Food Prices*, July 2008
http://econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469372&piPK=64165421&menuPK=64166093&entityID=000020439_20080728103002



References

ABS 2010

Australian Bureau of Statistics, *Motor Vehicle Census, Australia*, 31 March 2010

www.abs.gov.au/ausstats/abs@.nsf/mf/9309.0

ALPGA 2002

Australian Liquefied Petroleum Gas Association, 2002, *Liquefied Petroleum Gas as an automotive fuel – An environmental and technical perspective 2002*

www.cleanairnet.org/caiasia/1412/article-58767.html

ALPGA 2008

Australian Liquefied Petroleum Gas Association (ALPGA) submission to the 2008 review of the Australian Automotive Industry, 2008 (listed as 'LPG Australia')

www.innovation.gov.au/automotivereview/Documents/66%20LPG%20Australia%20140508.pdf

CSIRO 2007a

CSIRO, *Biofuels in Australia – issues and prospects*, a report for the Rural Industries Research and Development Corporation, June 2007

www.rirdc.gov.au/news-&-events/news-display.cfm?article=7A3A5D3E-F1FE-4F78-AE4F-2B66ACBD572D

CSIRO 2007b

CSIRO, ABARE and BTRE, *Appropriateness of 350 Million Litre Biofuels Target*. Report to the Australian Government, Department of Industry Tourism and Resources, 2003.

www.btre.gov.au/info.

[aspx?NodeId=16&ResourceId=133](http://www.btre.gov.au/info.aspx?NodeId=16&ResourceId=133)

Customs Tariff Amendment (Taxation of Alternative Fuels) Bill 2011

www.comlaw.gov.au/Details/C2011B00079

Ford 2008

EcoLPi Falcon To Go On Sale Mid-Year, April 2011

www.ford.com.au/servlet/Satellite?c=DFYArticle&cid=1248905429430&pageid=1248884930150&pagename=wrapper&site=FOA&sub_c=DFYPage&sub_id=1248884930150&t=controller

Garnaut 2008

Ross Garnaut, *The Garnaut Climate Change Review*, October 2008 www.garnautreview.org.au/index.htm

RACQ 2010

Private Vehicle Ownership Costs 2010

www.racq.com.au/__data/assets/pdf_file/0008/55673/Private_Ownership_Costs_2010.pdf

Rare Consulting 2011

The sustainability of biofuels: An analysis of the benefits and challenges of biofuels as an alternative to conventional transport fuels in Australia, prepared for QER Limited

UNEP 2009

Towards sustainable production and use of resources: Assessing Biofuels www.uneptie.org/scp/rpanel/pdf/Assessing_Biofuels_Full_Report.pdf

The World Bank 2008

The World Bank, *A Note on Rising Food Prices*, July 2008

http://econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469372&piPK=64165421&menuPK=64166093&entityID=000020439_20080728103002



