Alternative Transport Fuels and Technologies in Victoria – Options for the Next Ten Years

Prepared for EPA Victoria

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Potential for impact on total GHG emissions by each major vehicle type

The approximate distribution of road transport vehicle GHG emissions across the major vehicle types, both within Victoria and nationally, is shown in Table 1.1. The majority of road transport GHG emissions at the State and national levels result from the use of Passenger Motor Vehicles (PMVs). Light Commercial Vehicles (LCVs) and Trucks each produce less than a quarter the emissions of PMVs, with buses accounting for only two percent of the State and national totals. Note that these figures are for fuel energy usage only and do not consider the exbodied GHG emissions from the manufacture, distribution and disposal of the vehicles themselves.

Also indicated in Table 1.1 is the proportion of GHG emissions contributed at the national level by each of the four major fuel and engine technology types presently in use, across each vehicle type. Table 1.2 provides an indication of relative GHG emissions for each of the four major fuel types. These figures were derived from data for PMVs and so should be regarded as a rough indication only for other vehicle types. Compression Ignition (CI) engines running on Low Sulphur (LS) diesel fuel provide the greatest fuel economy and lowest GHG emission potential of the four major fuel and engine technology pairings presently in use on Victorian roads. It is believed CNG engine technology has the potential to at least match LS diesel performance for GHG emissions by 2010.[1]

The data in Table 1.1 and Table 1.2 has been used to derive the data in Table 1.3. Table 1.3 provides an illustrative sketch of the relative potential for reduction of GHG emissions within each vehicle type, and the relative scope for each vehicle type to contribute to total road transport GHG emission reductions. This analysis is based on a hypothetical shift from the current mix of fuels and propulsion technologies to a fleet based entirely on the least greenhouse-intensive mainstream option currently available, CI engines running on LS diesel. It must be stressed that this analysis is intended to provide a very rough sketch of potential only. Social, technical, economic, environmental and political factors involved in such a shift are not considered. In particular, a proposal such as this would have to be considered highly contentious on the basis of air quality impact alone. This simply represents a blue-sky vision for present-day GHG emissions from road transport based on current technology, considered in isolation from all other considerations.

Given that CI engines currently offer the best available fuel efficiency, it is of note that there is not greater penetration in the PMV and LCV fleets. This supports the position of Green and Schafer, in the report *Reducing Greenhouse Gas Emissions from U.S. Transportation*, that fuel efficiency is not a dominant driver in the development of light vehicle propulsion technologies.[2] The data from Table 1.1 and Table 1.2 has been used to estimate the theoretical reduction in road transport vehicle usage GHG emissions that might be possible if the entire fleet comprised CI ICE vehicles running on LS diesel fuel. The estimated emissions are 24% lower than the total for the current mix of fuels and technologies, based on the National GHG inventory for 2001. The basis for this estimate is presented in Appendix D.

The CSIRO report *Energy and Transport Sector: Outlook to 2020* states that 'Transport accounts for 41% of Australia’s domestic energy consumption and 14% of greenhouse gas emissions. New technology should be focused on road transport fuels and vehicles, especially cars and light vehicles.'[3] The above analysis strongly supports this position. It is clear that PMVs offer by far the greatest potential for reduced GHG emissions, both within the PMV type and, more importantly, from the perspective of the contribution to the road transport total for all vehicle types. LCVs also offer significant potential for reductions. Given that LCVs and PMVs often share a common vehicle platform and are in many instances similar in size, it is expected that the development of improved fuel and propulsion technology pairings for PMVs will directly benefit LCVs, reducing the need for dedicated attention in the LCV area.

The predominance of diesel fuel and technology use in the truck fleet reflects the strong influence of fuel efficiency considerations on owners and operators of these vehicles. This suggests that in the short term, limited scope may be available for reducing GHG emissions from trucks given that vehicle manufacturers are already motivated to reduce fuel use and, as a consequence, GHG emissions.[4] It should be expected though, that manufacturers will continue to seek efficiency improvements, so while a step change in performance may be less technically viable than for other vehicle types, steady reductions in emissions are almost assured.

On the other hand, projects under way to develop hybrid electric propulsion systems for trucks have the strong added incentive of improved economic performance for goods transport fleet operators. In terms of the potential for impact on overall GHG emissions from road transport, the small proportion of current emissions attributable to this vehicle type make it a less attractive area for the focus of reduction efforts. This provides less incentive for trading off criteria other than GHG emissions in order to make improvements. Improvements to GHG emission performance will need to be balanced by improvements in economic and other environmental areas in order to justify the uptake of alternative fuels and propulsion technologies.

Buses have an order-of-magnitude lower impact on total GHG emissions than trucks. Any efforts applied here to reduce GHG emissions must be very carefully weighed against social, technical, economic, political and other environmental factors. For example, it may be more appropriate for fuel security issues and improvement of environmental performance with regard to particulate matter (PM) emissions to take priority over GHG emission performance. Transit buses though, because of their size, limited territory of use and fleet-type operation, do provide an effective platform for the development of heavy vehicle propulsion technologies and fuel systems. Opportunities for integration of development initiatives for buses and other vehicle types should be considered where appropriate. There seems to be little incentive for stand-alone technology and fuel-based GHG reduction programs specifically for buses. In Victoria, the fact that transit bus fleets are privately owned and operated will also militate against developments in this area. Opportunities may exist for individual operators to benefit from developments in other States, where State owned and operated fleets provide better economies of scale for advancements in GHG reduction measures.

	CO_2-eq	Vehicle type emissions as a proportion of National road transportation total	Vehicle type emissions as a proportion of Victorian road transportation total[5]	Fuel type emissions as a proportion of vehicle type GHG emissions - national basis
	(Gg)	%	%	%
National road transportation total	68176.63			
Passenger Motor Vehicles	**42458.75**	62.28	67.00	
Petrol	37915.55			89.30
Diesel	1489.48			3.51
LPG	3015.66			7.10
Natural Gas	38.27			0.09
Light Commercial Vehicles	**9650.81**	14.16	15.00	
Petrol	5789.41			59.99
Diesel	2840.69			29.43
LPG	1013.31			10.50
Natural Gas	7.19			0.07
Trucks	**14030.99**	20.58	16.00	
Petrol	313.11			2.23
Diesel	13652.97			97.31
LPG	57.48			0.41
Natural Gas	4.11			0.03
Buses	**1795.40**	2.63	2.00	
Petrol	64.69			3.60
Diesel	1467.24			81.72
LPG	62.53			3.48
Natural Gas	200.94			11.19

Table 1.1: Vehicles types and fuels as proportion of national total GHG emissions in 2001.[6]

Fuel and vehicle emission standard	Indicative exbodied GHG emissions (CO_2-eq g/km)	Relative GHG emission weighting factors for fuels, normalised against LS diesel
ULP, Euro 3	0.35	1.52
LS diesel, Euro 4	0.23	1.00
LPG Autogas, 2nd generation	0.30	1.30
CNG	0.26	1.13

Table 1.2: Indicative exbodied greenhouse gas emissions from a typical Passenger Motor Vehicle.[7]

Note: The 2nd generation LPG Autogas GHG emission value has been chosen over the 3rd generation figure on the assumption that this will be more representative of the current fleet mix.

	CO_2-eq	Equivalent GHG emissions for switch to 100% LS diesel fleet, as a proportion of GHG emissions from current fuel/tech mix	Relative scope for reduction of GHG emissions within each vehicle type by switch to 100% LS diesel fleet, normalised against PMVs	Relative scope for reduction of overall road transport GHG emissions for each vehicle type by switch to 100% LS diesel fleet, normalised against PMVs
	(Gg)	%	%	%
National road transportation total	68176.63			
Passenger Motor Vehicles	**42458.75**	67.72	100.00	100.00
Petrol	37915.55			
Diesel	1489.48			
LPG	3015.66			
Natural Gas	38.27			
Light Commercial Vehicles	**9650.81**	76.97	71.33	16.21
Petrol	5789.41			
Diesel	2840.69			
LPG	1013.31			
Natural Gas	7.19			
Trucks	**14030.99**	99.11	2.75	0.91
Petrol	313.11			
Diesel	13652.97			
LPG	57.48			
Natural Gas	4.11			
Buses	**1795.40**	96.66	10.34	0.44
Petrol	64.69			
Diesel	1467.24			
LPG	62.53			
Natural Gas	200.94			

Table 1.3: Relative scope for impact on greenhouse gas emissions within each vehicle type and relative scope for impact on total road transport greenhouse gas emissions by each vehicle type (National basis).

2 Appendix B: Policy Review

2.1 Background and Summary

The focus of this research summary is on key government policies, initiatives, and research reports supporting and/or advising policy, related to alternative fuels and technologies in the coming decade at the Australian and state government levels.

A rising commitment to the exploration of alternatives in Australian transport fuels and technologies is evidenced through the number of (in some cases, world leading) initiatives and research projects commenced in Australia in response to the greenhouse challenge. Within this burgeoning arena, there is much debate, a lot of experimentation, and varying analyses. However, several consistent themes are emerging within the Australian context and research and policy efforts are beginning to show returns.

It is now accepted that alternative approaches to road transport are required that: reduce greenhouse gas emissions and other environmental pollutants; decrease negative effects on urban quality of life and human health in general; incorporate multiple energy sources for security purposes; and achieve economic viability and social acceptance.

Several preferred transport fuel and technology mixes have emerged from a policy standpoint in response to this understanding. Accompanying these is recognition of the need to consider long time frames for assessing policy options, the importance of addressing transport GHG emissions through mode and demand management, and the need for a whole-of-government approach to address many of the issues involved.

The core strategic directions for alternative transport fuels and technologies in the Australian context are:

- *Financial incentives and funding* from government may be required in certain situations for the development, promotion and use of alternative transport fuels and technologies and the infrastructure required for these;
- *Biofuels*, namely ethanol blends know as E10 and the proposed E20 standard, are important contributors to existing fuel supplies, although the small production amounts means their overall impact is limited;
- *Research and infrastructure investment in CNG*, and to a lesser degree LPG, is required for all vehicle types, predominantly heavy vehicles and notably though pilot-trial/promotion programs in public transport fleets;
- *Best practice leadership by Government Fleet purchases* of hybrid vehicles in particular, and lower emission and more fuel efficient vehicles (including via lower weight) in general, is required;
- *Increasing regulatory constraints* on fuel quality, vehicle emissions and fuel efficiency with an openness to including alternative fuels and technologies may need to be implemented;
- An *openness to further research and development* in line with an expected use of gaseous fuels (LNG, CNG and LPG) in an evolving range of vehicle technologies (more efficient and clean internal combustion engines, through hybrids to fuel cells and related combinations) is required; and

- A *growing* expectation of, and focus of research and planning on, the development of a hydrogen economy which could be spearheaded by *a hydrogen based transport sector* is emerging.

2.2 Introduction

Over the past two decades the composition of Australia's transport fuels and technologies has been rising in significance. In this time leaded petrol has been phased out of use and liquefied petroleum gas (LPG) has gained around eight percent of the vehicle energy supply market, giving Australia the highest LPG consumption by population in the world.[8] Increasing environmental, human health and energy security concerns have motivated the Australian Government to further this evolution of transport fuels and technologies to achieve more sustainable outcomes and produce a multiplicity of benefits.

In line with its involvement in several international agreements[9], the Australian Government confirmed its commitment to alternative transport fuels and technologies (ATFT) through its 1998 National Greenhouse Strategy (NGS).[10] NGS Module Five: Efficient Transport and Sustainable Urban Planning (NGS-M5) has been developed to provide a comprehensive approach to improving transport in Australia under the banner of reducing greenhouse gas (GHG) emissions.

Each State and Territory Government has also contributed to the advancement of the transport agenda. After six years of increasing effort by Australian Governments, and various independent industry bodies, research and development institutions and community groups, a coherent picture of Australia's future ATFT is beginning to emerge.

This independently produced, desktop research summary will focus on outlining some of the key elements that are shaping Australia's ATFT strategic direction. First, a review of efforts at the national level presents the majority of policy directions. Then an overview of the progress of state and territory governments reveals a number of other policy emphasises and supporting research. Finally, the Victorian Government's ATFT policy initiatives and programs are addressed.

2.3 The Australian Government and Transport

The Australian Greenhouse Office (AGO) established under the Department of Environment and Heritage (DEH) is the world's first agency dedicated to reducing GHG. The AGO's *GHG Inventory 2001* recognised transport as one of the main contributors to GHG emissions at 14% nationally. It is also the fastest growing sector, with an increase of 25% in net emissions between 1990 and 2001.[11] Table 2.1 below shows the contribution of the transport sector as a whole, road transport, and passenger cars respectively to National GHG emissions and net transport sector emissions in Australia.

Mode	**GHG emissions (% of the National total in 2001)**	**% of net transport GHG emissions**
Total Transport	14%	100%
Road Transport	13%	88%
Passenger cars	8%	62%

Table 2.1: Contribution of the Transport Sector to National GHG Emissions

In an effort to offset the projected ‘business as usual’ increases in transport GHG emissions for 2010, the AGO's NGS-M5 has incorporated a broad range of strategies, with an emphasis on passenger car use and ATFT. Overall, the aims of the strategies reflect:

> '…the major policy directions for dealing with pollution and greenhouse gas emissions from vehicles: to reduce their use, to clean up their emissions and to make them more fuel efficient.'[12]

A review of the current outcomes of these strategies appears below. For logical presentation, related government initiatives and programs are also included in this summary where appropriate. It should be noted these programs may have been either initiated or implemented by government departments other than the AGO and, where publicly available, indication of this has been included. Key areas of government policy initiatives have been highlighted in **bold** and particular programs and reports appear in *italics*.

2.3.1 The Greenhouse Strategy Module Five

The Greenhouse Strategy Module 5.1 (M5.1) resulted in the production of the *Greenhouse Policy Options for Transport* by the Bureau of Transport and Regional Economics (BTRE) and commissioned by the Australian Transport Council (ATC) in 2002.[13]

The report is primarily concerned with assessing the comparative merits, in terms of GHG emissions and economic costs, of various transport policy options to reduce the number of vehicle kilometres travelled, based on international experience. The breadth of the report's analysis merits its summarised conclusions being quoted at length:

> 'A limited set of measures can improve economic efficiency, while also reducing greenhouse gas emissions: road congestion pricing; conversion of some of the fixed costs of car use to variable costs, so ensuring that motorists face more accurate prices; removal of parking-related distortions (e.g. regulations on the minimum number of spaces for new buildings and underpricing of employer-provided spaces); and reducing passenger motor vehicle tariffs to encourage uptake of newer, more fuel efficient cars.
>
> Road congestion pricing would see significant reductions in transport greenhouse emissions. For further reductions, as may be required to meet international commitments, economy-wide approaches would minimise the Greenhouse Policy Options for Transport impact on living standards, by allowing abatement activity to flow to those areas that can achieve the abatement at least cost. Of the two available alternatives, tradable emissions permits [a program recently scrapped by the Federal Government] have greater international momentum in the Kyoto environment than carbon taxes, which have often assumed a role of industry assistance or a general revenue source.
>
> Many other transport initiatives (e.g. enhanced public transport and high occupancy vehicle lanes) have been promoted for their greenhouse benefits, while being primarily aimed at transport and other environmental objectives. Greenhouse benefits are often smaller than might be expected, in part because measures that succeed in shifting vehicles off unpriced congested roads create capacity that is filled by new journeys.'

The reports conclusion regarding ATFT is that 'in view of rapid changes in technology, there is a case for policies that avoid designating preferred fuel types but instead ensure that fuel prices reflect the greenhouse emission externalities associated with each fuel type.'[14]

While important to the overall NGS-M5 and the development of National and State ATFT related policy, its treatment of ATFT is necessarily sparse and based on a macro-economic perspective that can obscure important details.

The M5 is a comprehensive approach to the transport sector, and it is appropriate to understand its strategies that while not directly addressing ATFT are closely related to them in practice. In addition to the broad economically focused policy options outlined above, the M5 encourages State and Territory Governments to:

- '**Integrate land use and transport planning**' (M5.2-4)[15] by coordinating public transport planning, higher residential and commercial density in key urban areas, and by providing research to improve outcomes in urban planning generally, a reduction in transport demand and increased efficiency of transport usage are the expected outcomes;
- Promote '**travel demand and traffic management**' programs (M5.5-6)[16] like local '*car pooling*' and by removing barriers to '*telecommuting*.' It promotes programs '**encouraging greater use of public transport, walking and cycling**' (M5.7-9)[17] such as the '*Travel Smart Australia*,' and '*park and ride*' programs; and encourages the provision of '**information programs on efficient vehicle use**' to the public (M5.13),[18] to reduce the overall amount of transport volume; and,
- Improve **freight and logistics systems** (M5.14-15) through research and '*intelligent transport systems*' planning of sea, road and rail freight activity, to achieve a more efficient commercial transport sector that also uses less pollution intensive means.[19]

M5.10-12 has focused more specifically on ATFT in relation to GHG emissions. M5.10 is concerned with creating an '**environmental strategy for the motor vehicle industry**' (ESMVI) and through collaboration with numerous government agencies and their programs has produced the following significant outcomes:

- Established *Australian Design Rules for Vehicle Emission Standards* requiring all new vehicles to reach reduced GHG and pollutant emissions when new, and throughout their life time;
- Instituted *mandatory GHG emissions and fuel consumption labelling* of all new passenger and light commercial vehicles up to up to 2.7 tonnes gross vehicle mass (GVM).[20] This is in addition to the continued publication of the *Consumer Fuel Consumption Guide* (its 23rd publication being in 2002-03); and,
- Set *National Average Fuel Consumption targets* (NAFC) with industry for new light vehicles up to 3.5t GVM, representing an anticipated 18% reduction in emissions and pollutants by 2010 from 2002 levels.[21] Targets for the Commonwealth Government Fleet have also been set out in the '*Green Fleet Guide*,' with a range of targets, the highest expecting from 18% to 28% reductions by 2005 from 2002 levels.[22] *Fuel consumption modelling to 2010* and the key influences have also been researched.[23]

M5.11 is specifically related to '**fuel quality and vehicle emissions**,' and has included the prominent outcome of:

- Introducing the *Fuels Quality Standards Act 2000*. The key impacts being to bring forward the phase out of leaded fuel as of 2002, reduce the sulphur content of diesel fuels, and gradually harmonise Australian standards with international standards (Euro 2-4). The Act and its associated regulations are aimed at facilitating 'the adoption of better engine and emission control technologies and allowing the more effective operation of engines;'[24]

- In addition, the 2001 *National Environmental Protection Measure (Diesel Vehicle Emissions)* set further requirements, in particular for in-service diesel vehicles, reducing their overall pollutant emission levels;[25] and,
- Several State Governments, notably Victoria (VIC), Queensland (QLD) and New South Wales (NSW), have established an Environment Protection (Vehicle Emissions) Regulations 2003 to address Summer Petrol Volatility. These built on, for example, the previous *Reduction of Summer Petrol Volatility: Memorandum of Understanding* with fuel providers in 1999 'aimed at reducing the emissions of reactive organic compounds.'[26]

M5.12 is focused on '**increasing the use of alternative fuels.**' Implemented under the AGO's *Alterative Fuels Program* it has involved numerous other government departments:

- The *Diesel and Alternative Fuels Grants Scheme Act 1999* (DFAGS) that replaced the off-road diesel fuel rebate scheme and the on-road diesel and alternative fuels grants scheme on 1 July 2003 and comes under the broader *Energy Grants Credits Scheme*, administered by the Australian Taxation Office (ATO). Most relevant to rural businesses operating vehicles of at least 4.5t GVM, the grant provides credits for the use of the following fuels: diesel, LPG, CNG, ethanol, liquefied natural gas LNG, and biodiesel. Importantly, the Act makes provision for the addition of additional alternative fuels in the future;
- Research by the CSIRO, commissioned by the AGO, on a *Comparison of Transport Fuels*, their energy efficiency, and GHG and pollution emissions. Two studies concerning heavy vehicles have been completed with a light vehicles study currently being finalised with the assistance of the Victorian Government;[27]
- The $7.6 million *Compressed Natural Gas Infrastructure Program* (CNGIP) has reportedly only established 3 CNG refuelling stations, mainly in Sydney. While approval for grants would have brought the national total to 31 CNG refuelling stations, with 19 assisted by CNGIP, including sites in Victoria, most have not been realised.[28] This is explained by an industry perception of a lack of demand;[29] and,
- The *Alternative Fuels Conversion Program* (AFCP) commenced in 2000 and is allocated $75 million to assist operators and manufacturers of vehicles greater than 3.5t GVM to receive between 50% and 70% (dependant on percentage of GHG emissions reductions) of the conversion cost to CNG or LPG fuels. The program is also provides for the offset of new purchase costs to affect conversion to these fuels;[30] As of June 2003 however, the allocated funding has been revised to $71.4 million, with 40 projects having received approval, representing only $14.9 million of approved grants. The slow uptake of the grants has been 'primarily explained by the substantial market constraints to the acceptance of program objectives, and low consumer and industry confidence for CNG and LPG in heavy vehicles. While industry was consulted prior to the introduction of the program, there has been essentially no demand for program funds for trucks operating on compressed natural gas;'[31]

It is important to note that this is not an exhaustive account of the NGS-M5 implementation. It represents a summary of information publicly available in early 2004, with the interpretive focus on the strategic direction of ATFT in Australia.

Another important document for consideration in the formulation of any policy and initiatives by the Victorian Government related to ATFT is the March 2004 Australian National Audit Office report on seven of the AGO's key funding programs under the NGS. The AGO is in general agreement with the reports findings and recommendations.

The ANAO concluded that the programs have 'been characterised by substantial administrative challenges.' The report highlights that 'the primary lesson learned is that priority must be given to performance measurement and comprehensive risk management at the design stage.' Further improvements could include:

- 'Refining performance measurement that should include the use of intermediate measures and/or assessments to gauge progress towards longer term objectives;
- A more consistent approach to project appraisal and selection would also assist in improving the transparency of decision-making; and,
- Finally, improvements to performance reporting are necessary to enable Parliament to come to a more informed view on the progress and effectiveness of the AGO in implementing programs of national significance.'[32]

2.3.2 Related to ATFT

Beyond the NGS-M5 the Federal Government has initiated several other programs related to ATFT. Those with continuing relevance to the future of ATFT include:

- Biofuels initiatives:
    - In July 2003 the ethanol *fuel standard of E10* was introduced, and to complement this in March 2004 mandatory labelling became effective (under the Fuel Quality Standards Act 2000), and consumer information has been provided identifying suitable vehicles for ethanol blend usage. In addition the Federal Government has established an *Ethanol Confidence Working Group* and received a report from a 'facilitator for the ethanol industry' in 2003 (still 'under consideration'), addressing industry development and market uptake barriers;[33]
    - Building on the Government's 2001 election policy 'biofuels for cleaner transport' in 2002 (for ethanol) and 2003 (for all biofuels) *a ten year excise relief programme* was budgeted. These measures will see no excise for biofuels until 2008, when over five years an excise is gradually introduced for biodiesel (19.1c/l), mid energy content alternative fuels (such as LPG, LNG and ethanol at 12.5 c/l) and other alternative fuels used in internal combustion engines. In addition, new alterative fuels will receive a 50% discount upon 'entering the excise net.' For comparison these excise rates are less than half that of petrol and diesel (38.143 c/l). Afterwards it is expected that the excise amount will continue to be set in relation to the energy density per volume of the alternative fuels;[34]
    - An objective to reach at least 350 million litres of biofuel contribution to Australia's total fuel supply by 2010. A research report into the '*Appropriateness of 350 Million Litre Biofuels Target*' was completed in January 2004 by CSIRO with BTRE and the Australian Bureau of Agricultural and Resource Economics (ABARE) and was commissioned by the Department of Industry Tourism and Resources (DITR). The study concluded that while small benefits in regional employment, reductions in GHG emissions and other environmental pollutants could be achieved, and that the 'waste' based production appears economically viable without Government support, the dedicated growth of source materials is not;[35]

  - The *Biofuels Capital Grants Program*, administered by Invest Australia, allocated $37 million in 2003 to fund one-off capital grants to establish or expand biofuels production plants, requiring that they produce a minimum of 5 million litres of biofuel and can project economic viability in a post-excise relief environment. The program received applications totalling $1.1 billion worth of potential investment, with the final grants yet to be announced at the time of this study;[36]
  - *A Biofuels Market Barriers Study* is currently being completed by DEH, with $5 million in funding. Included in the scope of the study is an assessment of the appropriateness of a proposed *Biofuels Mandate*, a *Tradeable Certificate System for Biofuels*, the technical viability of an *E20 ethanol fuel standard*, and a comprehensive research and consultative process investigating the market up-take barriers for biofuels;[37]
  - A small but significant element of the Federal Government's 2004 Sugar Industry Reform Programme includes '$75 million for competitive regional and community projects to assist the industry to restructure, revitalise and diversify,' including into ethanol production;[38]
- Australian Transport Council (ATC) initiatives:
  - The ATC commissioned the now defunct National Transport Secretariat to produce a short *Lowering Emissions from Urban Traffic - An Integrated National Action Plan* (4 pages) in 2000. Building off stage one of the NGS-M5, it essentially summarised the M5 strategies into outcome statements;[39]
  - The ATC produced an industry based consultative report, the *Transport and Transport Infrastructure Working Group Report 2003*, which generally conformed to existing initiatives, policies and programs under the M5 relating to ATFT;[40]
- In light of pre-existing and expected changes in the petroleum industry's economic and regulatory environments a *National Downstream Petroleum Products Action Agenda* was finalised in 1999 and its initiatives completed in 2001;[41]
- The DEH report *The State of Air*,[42] released in April 2004, accompanied by indications from the Minister that fuel and vehicle emissions standards would be increasing, several more pollutants might be added to the monitoring and regulation table and possibly included in the 2008 air quality targets set out in the 1998 (amended in 2003) *National Environment Protection Measure for Air Quality Standards;*[43] and,
- Another high level Federal Government report concerning transport was contained in the December 2003 Prime Minister's Science, Engineering And Innovation Council Ninth Meeting – Agenda Item 5: *Beyond Kyoto Report* (housed in the Department of Education, Science, and Training - DEST).[44] The report made the following recommendations concerning the reduction of transport emissions:
  - Identify and evaluate options to accelerate the adoption in Australia of technologies to improve fuel efficiency;
  - Promote and encourage reduction of emissions through the deployment of intelligent transport systems technology, in particular for management of central city congestion through pricing arrangements;
  - Assess Australia's future transport fuel mix options and associated infrastructure requirements;[45]

  In reviewing the state of Alternative fuels in Australia the report concluded that:

  - 'There is scope for Australia to alter its fuel mix with a view to reducing vehicle emissions. Such a move could include a shift from petrol to diesel which offers potential reductions in emissions of up to 17% (although a more widespread use of diesel will require particulate emissions to be controlled, in view of potential adverse health implications). Other options include the use of non-petroleum based fuels including compressed natural gas, ethanol, liquid natural gas, methanol and hydrogen. However while the emission reduction benefits of diesel are well established there is less certainty about the overall environmental benefits of non-petroleum based fuels. The use of some alternative fuels may also poses problems in terms of the need for new infrastructure.'[46]

There are many other Federal Government research reports, policy statements and briefs relevant to ATFT, however, most are in support of, or references to, the above mentioned policy initiatives and programs. One further area of policy research that is significant is the category of futures studies.

2.4 Transport Futures Studies

Several futures studies have been undertaken by a range of government agencies due to the long time frames involved in making ATFT policy decisions. The following discussion outlines the nature of these studies, and their importance to both state and federal government policy.

The BTRE has produced two related futures studies. The first is the 2002 *Greenhouse Gas Emissions from Transport: Australian Trends to 2020* for the AGO produced to update the 'business-as-usual' projections of transport GHG emissions. The work updates previous BTRE projections published in Bureau of Transport and Communications Economics (BTCE) Report 88 (Greenhouse Gas Emissions from Australian Transport: Long-term projections) and BTCE Report 94 (Transport and Greenhouse: Costs and options for reducing emissions). Importantly, the modelling forecasts that the current policy measures, such as the CNGIP, AFCP, ESMVI and DAFGS mentioned above, are 'estimated' to reduce a likely 47% growth in GHG emissions by 2010, by only 7% (to 40%).

The second BTRE futures study is the 2003 Working Paper 52: *Greenhouse Gas Emissions from Australian Transport: A Macro Modelling Approach*, to complement the 'bottom up' modelling of the related prior BTRE publication. The study is BTRE's first using a new 'computable general equilibrium model in the area of transport emissions' that can now be used to assess the 'economy-wide impact of a range of environmental policies.'[47]

In 1999 the AGO commissioned ACIL Consulting to conduct a *Study on Factors Impacting on Australia's National Average Fuel Consumption Levels to 2010*, and *Additional Modelling of Scenarios for NAFC to 2010*, as a background to establishing the NAFC under NGS-M5.10. The scenarios are still relevant for comparison of the 'business as usual' projection and assessment of the state of the various predicted drivers of fuel consumption. They also provide insight into the possible consequences of various policy measures, including increased fuel efficiency and quality, planned changes to taxation and import tariffs, and possible variations to the on road vehicle mix.[48] The report presents numerous possible outcomes from each main variable in the form of scenarios, and concludes that changes in local manufacturing practices present the most realistic and significant opportunity to improve Australia's NAFC. These include:

- Encouraging Australian vehicle manufacturers to adopt 'existing, and generally well established, technology'. Many of the benefits of adopting such technologies are incremental in nature. In isolation, each potential improvement is not dramatic, but the cumulative benefits could be significant;[49]

- Encourage 'technology on the horizon' such as 'gasoline direct injection' (GDI) that could improve NAFC by up to 20% and be used to 'boost performance' to provide the 'launch feel' customers seem to prefer;[50]
- Stimulate development and promotion of vehicles through the incentive of providing for alternatively fuelled vehicles to be included separately in Corporate Average Fuel Consumption (CAFC) calculations;[51]
- *The Australian Transport Energy Data and Analysis Centre* (ATEDAC) was established in early 2002 as 'the first centre of excellence to analyse energy end-use data for the transport sector.' ATEDAC has support from Federal and State Governments, and private agencies in various States and Territories. Although not established with a public face as yet, ATEDAC's 'purpose is to significantly improve stakeholder knowledge of transport energy use, supply patterns, and emissions.' The NSW Ministry of Energy, Utilities and Sustainability reports in its Annual Report 2002-2003 that 'Two reports: Australian Transport Facts 2001 and NSW Transport Facts 2001 have been prepared by the ATEDAC during 2002–2003. The reports provide detailed information on transport (passenger and freight) tasks, energy consumed and emissions by transport mode and fuel type since 1984–85 and projections to 2012.'[52]
- DITR's *Energy Futures* focus (including an *LPG Action Agenda*, *Renewable Energy Action Agenda* and *Transport Fuels Policy*) and the 2003 *National Hydrogen Study* are also of relevance to ATFT in terms of supporting technologies, infrastructure and fuel standards. These efforts support the CSIRO's work in the same direction and indicate an interest in transitioning through LPG and CNG to hydrogen ATFT in the long term.[53]

2.4.1 CSIRO Transport Futures

In addition there are several CSIRO research publications worth considering in relationship to other government policies and programs:

- In late 2002 the CSIRO published an *Energy and Transport Sector Outlook to 2020* to provide direction to their work in the energy and transport sectors for 2003-2005. As a high level summary based on other research the projections provide useful synthesised 'roadmaps' of ATFT development to 2020. For example they highlight that ABARE's demand projection for oil needs estimates that Australia will have to import up to 60% of its supplies by 2010 resulting in 'a $7 billion balance of payment consequence.' In contrast they propose a 20-30 year full transition time is realistic to change the basis of the transport sectors energy supply away from petroleum, given sufficient policy-supported investment. In addition their summary of the public's acceptance as an influencing factor in any ATFT uptake is noteworthy:

  > '…the public are exceptionally price-sensitive and react negatively in a political sense to small price changes. However, history has shown that behavioural changes such as reducing demand or moving to smaller vehicles does not occur unless price changes are significant. For example, the price shocks in the late 1970's saw an abrupt shift in vehicle size. The public also has expectations concerning travelling range and convenience of access to fuels, maintenance costs and health and safety. A major issue concerns the substantial life expectancy of the existing stock of vehicles;'[54]

- The Outlook 2020 roadmaps have been picked up in the Energy Futures Program, the CSIRO's National Research Flagship, *Energy Transformed*, launched in October 2003 with significant funding from the NSW Government and NSW Sustainable Energy Development Authority (SEDA). The research themes include aims to develop 'innovations that enable transport systems to contribute to the achievement of our emissions targets and place Australian transport on a path to the hydrogen economy.'[55] Their focus on enabling the transition through gas (LPG, CNG etc) to hydrogen-based ATFT in particular is noteworthy. In concert, the CSIRO *Energy Technology* research group is focusing on hybrid technologies that will 'prepare the way for hydrogen fuel;'[56]

- In relation to understanding the Federal Government's 350 Million Litre Biofuels target for 2010, the CSIRO Resource Futures 2001 working paper *Developing a Biofuel Economy in Australia by 2025* contains valuable insights. The study presents a multifaceted scenario with achievable benefits with recommended policy support and particular implementation/use methods. Although the program has recently been discounted as economically unviable (see the *Appropriateness of 350 Million Litre Biofuels Target* discussed above), the rigorous physical modelling methodology justifies quoting the findings at length:

  > 'The solutions tested in this study involve the progressive establishment of biomass plantations over the next 50 years that cover between 15 and 30 million hectares of Australia's croplands and high rainfall pasturelands. These biomass feedstocks could produce methanol and ethanol to progressively replace the declining stocks of domestic petroleum reserves. The deep rooted perennial production systems could help control hydrological problems currently responsible for dryland salinity, they could help create employment in rural Australia, they could replace future energy imports and thus help with trade issues such as international balance of payments. The parallel evolution of domestic transportation systems from internal combustion engines to methanol powered fuel cells could require less land area to underpin the biofuels transition. Alternatively, the same land stock could provide a surplus of bio-alcohol fuels for export to affluent consumer markets where carbon neutral transportation fuels will underpin part of national strategies to meet international greenhouse gas emission obligations.'[57]

- The 2002 CSIRO Sustainable Ecosystems report *Future Dilemmas: Options to 2050 for Australia's Population, Technology, Resources and Environment*, commissioned by the Department of Immigration, Multicultural and Indigenous Affairs (DIMIA), models important physical limitations relating to 'the future of energy' production (focusing on the need to transition from non-renewable to renewable energy supplies in chapter five) and the design and use of 'the urban environment' (focusing on how to minimise energy resource use wastage in chapter three) each of which have impacts on the foundation of any ATFT policy.[58]

2.4.2 Queensland Transport Futures

At the State Government level there have also been several different futures studies, some closely tied in with transport policy. While many transport plans now feature longer term time horizons in their titles, few actually involve futures studies per se. On the other hand, there are numerous research reports which involve a long term perspective, but this isn't clearly articulated in terms of reputable futures research methodologies. The Queensland (QLD) Government has published two reports that are based on sound futures methods and actively include long time frames:

- The first is the QLD *Transport Planning Scenarios 2000-2025: 4seeable Futures*, developed through collaboration between the QLD Departments of Transport and Main Roads. An extensive development process resulted in significant knowledge gains for the departments involved and while the scenarios cover the transport sector as a whole, there are relevant considerations of ATFT at a surface level within each scenario, and their relationship to social, technological, environmental, economic and political factors can be deduced. The scenarios provide a useful model for futures studies on transport in Australia, and could possibly be used as a comparative assessment tool for other Government policy research projects. The ATFT noted in the scenarios research include, in a progression of expectation of realisation, hybrid electric vehicles, Hyper Car (a combination of extremely light GVM, hybrid electric propulsion system, and other energy saving and emissions reducing technologies), and hydrogen fuel cells;[59] and,

- The second is the leading futurist Sohail Inayatullah's *Alternative Transport Futures* paper delivered to a Queensland Transport Conference on integrated transport futures. Inayatullah assesses the merits of the 4seeable Futures scenarios, and introduces a deeper frame of reference, that of the different 'worldviews' and social forces acting on transport futures Inayatullah contends the deeper approach is needed to meaningfully consider the range of alternative possibilities for transport in QLD and Australia generally. Any serious future transport policy development process would be greatly enhanced by reviewing and including some of the approaches suggested.[60]

The futures work conducted in QLD provides a valuable context for the following section in which the research, programs and policies developed by other State Governments are canvassed.

2.5 State and Territory Governments and Transport

Each of the State and Territory Governments is party to many of the above-mentioned Federal Government initiatives. In particular this includes the NGO-M5, as each State and Territory has developed its own response or particular greenhouse strategy in relationship to it. There are some important differences however, and these will be highlighted along with other significant measures related to ATFT.

2.5.1 Queensland

Drawing heavily on the influences of dedicated futures studies QLD has developed the following policies, initiatives and supporting research documents relating to ATFT:

- The QLD Environmental Protection Agency, through its *Energy Innovation Fund* (QSEIF) conducted a *Diesohol for Road Transport Case Study* in 2003 which is being used to promote broader diesohol uptake in QLD;[61]
- The 1999 inter-departmental *South-East Queensland Regional Air Quality Strategy*, while emphasising that its boundaries are at the edge of other state and national GHG strategies, carries dedicated support for many of the NGS-M5 strategies (chapter four), including the development and promotion of ATFT;[62]
- The *Transport Portfolio Environmental Framework 2002* is a broad synthesis of environmental impacts from transport and outlines the general strategic direction with regard to evolving environmentally sustainable transport for QLD. It confirms broad support for localised NGS-M5 style strategies;[63]
- Transport *2007* sits within the broader QLD *Integrated Transport Planning Framework* 2003 which has an explicit 'alternative futures,' sustainability and 'future generations' focus. Neither of the documents evidence a commitment to ATFT;[64] and,
- The QLD *Transport Directions: Strategic Plan 2003-2007*, while promoting a comprehensive and whole-of-government approach to transport planning, focuses on electronic technologies and doesn't include any reference to ATFT.[65]

2.5.2 Western Australia

Western Australia (WA) has made more progress with ATFT research papers, programs and policy initiatives than any other state in Australia. There are two key reasons for this: firstly, a recognition of WA's substantial transport fuel needs, its abundant alternative fuel resources, and the need for alternative future economic and transport fuels development; and, secondly a derivative policy direction that intends to move the State from 'oil vulnerability' to a hydrogen economy future. The *Sustainability Policy Unit* in the Department of the Premier and Cabinet, under the direction of Professor Peter Newman from the Institute for Sustainability and Technology Policy at Murdoch University WA, has been acknowledged as world leading in its research and policy development.

The 1999 Transport, Urban Land Use and Planning Working Group Report to the WA Greenhouse Council: *A Western Australian Implementation Plan for the National Greenhouse Strategy in the Areas of Transport, Urban Land Use and Planning*, includes an analysis of conflicting outcomes in the Federal Government's policies and actions under the NGS-M5 in relation to ATFT. Overall it boasts wide ranging support for, and engagement with, the strategy.

In addition, the *WA Sustainability Strategy 2003*, in Section 2: Contributing to Global Sustainability, and the December 2003 released *WA Draft Greenhouse Strategy*, recognise the following initiatives related to ATFT:[66]

- A *Sustainable Transport Energy Program* (STEP) in the Department of Planning and Infrastructure (DPI) was established in January 2003. STEP has outlined a broad, long term roadmap of ATFT trials supporting a transition timeline through LPG and CNG fuels to Hydrogen fuels, using a combination of vehicle technologies (graphical representation is available in Appendix A):[67]
    - Bus Fleet: Transperth is *trialling biofuels(100,000 litres) and three hydrogen powered fuel cell buses* in Perth during 2004 and 2005. It has also made the commitment to only purchase CNG-fuelled buses. Two case studies which outline the history and benefits of these fuels are available;[68]
    - *Government Fleet*: Focusing on replacing six-cylinder cars with four-cylinder cars. They have already purchased 20 Toyota Prius hybrid cars;[69]
    - The subsidiary *Transport Energy Strategy Committee* (TESC), involving industry, community, university and government expertise, released its *Interim Report* in July 2003 in broad agreement with this strategic direction and affirmed the place of hybrid technologies and LNG, LPG and CNG fuels as transition ATFT towards a hydrogen-powered economy and transport sector. The report is expected to significantly guide the WA Government's *Transport Energy Strategy* currently under development; and,[70]
    - DPI is also hosting the *International Hydrogen and Fuel Cell Futures Conference* (and trade show) in Perth in September 2004.[71]
- Considerable research and consultation regarding WA's future economic and transport energy fuel supplies has been conducted through the Sustainability Policy Unit, notably including:
    - *Global Oil Vulnerability: the Australian Situation;*[72]
    - *Evolution Towards a Sustainable Transport Energy Source*;[73]
    - *Gas as a Transition Fuel: Western Australia's Natural Alternative;*[74]
    - *The Hydrogen Economy*; and,[75]

  - *Sustainability and the Hydrogen Economy in Western Australia*.[76]

- The *Perth Air Quality Management Plan 2002*, along with inclusion of numerous aspects reflecting the NGS-M5 Initiative 2: Vehicle Emissions Reduction, has included an evaluation of CNG and LPG for light and heavy vehicles, and has reiterated implementation of NGS-M5 style strategies;
- Through the WA Department of Industry and Resources a $2 billion support project for the establishment of the *Sasol Chevron Global Joint Venture: Barrow Island — Gas to Liquids Fuels* (expected total $10 billion infrastructure development) is being considered. This project would produce environmentally clean diesel fuel from natural gas for both Australian supply and regional export;
- Considering 'periodic vehicle licensing and emissions testing' and the introduction of a green licence for PMV owners with the fees going towards geo-sequestration activities to mitigate GHG emissions,[77] and,
- In addition to specific support for NGS-M5 strategies, WA has set an objective to 'reduce per capita transport greenhouse gas emissions by 20 per cent by 2020.'[78]

2.5.3 New South Wales

New South Wales (NSW) has approached sustainable transport and ATFT from several directions, and while information is not always readily available from NSW Government websites, the following information about these approaches is available:

- The NSW Road and Traffic Authority's one page *Transport Environmental Policy* makes no mention of ATFT. The RTA has also purchased *18 Toyota Prius hybrid electric/petrol vehicles* for their fleet;[79]
- The status of the NSW EPA's Protection of the *Environment Operations (Clean Air - Motor Vehicles and Motor Vehicle Fuels) Regulation 2002* is currently unknown;[80]
- The NSW Ministry for Transport's *Action for Transport 2010* notes that two diesohol buses were trailed in 1998 in Sydney,[81] and the purchase of a fleet of 300 CNG buses is in process (the EPA reports that State Transit has completed 200 CNG conversions, and a further 200 were planned by the end of 2002), and indicates support for new fuels research;[82]
- The NSW *Cleaner Vehicles Action Plan*[83] is intended to 'hasten the uptake of new vehicle technologies' through promoting the Federal initiatives under the NGS-M5 for vehicle standards (as *Clean Car Benchmarks*[84]) and consumer information (as *the Green Car Guide*[85]), travel demand management, and adopting similar *fleet standards* and purchasing directions. This includes subsidising 10 hybrid vehicle leases in their managed fleets, and requiring 1% of all government fleets to be hybrid petrol/electric vehicles. The single stand out initiative is the proposed introduction of *alignment of vehicle stamp duty payments to environmental outcomes*;[86]
- The 1998 NSW EPA (now the Department for Environment and Conservation) report *Action for Air Strategy: The NSW Government's 25 Year Air Quality Management Plan*[87] (and 2002 Update[88]), with regards to transport, outlines the same general strategies as the NGS-M5, and indicates openness to researching and introducing ATFT through state government fleets (Objective 3 Strategy C: Promote Cleaner Fuels). Grants by the EPA's *Clean Air Fund* in 2003 included two biodiesel trials measuring emissions: one in a Newcastle plant using 20% biodiesel and the other, a comparative study of two council operated garbage trucks with one using petrol and the other 100% biodiesel;[89] and,

- Newcastle City Council has Australia's first complete biofuels fleet, with the introduction of B20 fuel (80% petroleum diesel and 20% biodiesel) for the Council's 228 diesel-powered vehicles. The decision was made after an 18 month trial with Council operated tip trucks, with results from emissions monitoring indicating a 33% reduction in carbon monoxide emissions and a 26% reduction in black smoke. The Council is receiving $95,000 from the NSW DEC (formally EPA) for the purchase of the fuel and the NSW RTA is providing additional funds (through Environment Australia) to conduct emissions testing on 13 vehicles (mixed design and size) while using diesel, filtered diesel and biodiesel fuels. It is expected that the B20 introduction will reduce the Council's GHG emissions by 600 tonnes per annum.[90] Interestingly the Council is also researching the use of Automated People Movers and Personal Rapid Transit (PRT) systems for limited public transport locations that may further reduce the Council's use of fuels. The PRT for example reportedly uses '75% less energy compared to a private car.'[91]

2.5.4 South Australia

South Australia (SA) is currently developing a comprehensive and proactive response to sustainable transport, including significant attention to ATFT. This can be seen in:

- The Energy SA *Draft Alternative Fuels Strategy*, representing a whole-of-government approach involving Transport SA, the Passenger Transport Board (PTB), and Fleet SA, outlines significant interest in investigating and promoting the use of a range of alternative fuels, but in particular CNG, and providing investment in new technologies. A 'watching brief' on ATFT is also mooted, specifically fuel cells, hydrogen and hybrid vehicle systems;[92]
- Through the State Energy Research Advisory Committee (SENRAC) the SA Government is supporting industry research into *LPG Fuel Injection Systems for IC Engines*, and is promoting the use of CNG by Local Government heavy vehicles;[93]
- *Transport SA* has 213 CNG buses, or approximately 28% of its fleet, and with a significant proportion of new diesel buses, the majority of the bus fleet reports emissions performance lower than Euro 3 legislated requirements. In addition, with the support of SENRAC, a 20% *biodiesel bus trial* was conducted in 2002 which returned results of up to 5-% reductions in particulate emissions. Further, a 100% biodiesel trial is currently in progress. The diesel and CNG mixed bus fleet is justified on the basis of limited availability of refuelling stations for CNG and security concerns over single fuel dependency;[94] and,
- The research paper *Sustainable Energy and Transport* by the executive director of Energy SA provides an overall appraisal of ATFT in the SA context and confirms the reasoning behind the above initiatives.[95]

2.5.5 Australian Capital Territory

The Australian Capital Territory Greenhouse Strategy echoes most points in the NGS-M5. The December 2003 *Draft Sustainable Transport Plan for the ACT* includes measures such as conversion of the entire bus fleet to CNG and increased purchases of low GHG emission and more fuel efficient vehicles in the government fleet. The strategy notes that vehicle registration fees are based on GVM, and further reduced registration fees apply for vehicles using alternative fuels.

2.5.6 Tasmania and The Northern Territory

The Northern Territory (NT) and Tasmania, while both actively involved in several aspects of the NGS-M5, show limited focus on ATFT. The Northern Territory's *Transport Plan June 2003* includes a reference to improving GHG emissions by address Government Fleet performance, and the Territory's public bus fleet had converted five buses to dual diesel/LPG use in 2003.[96]

The March 2003 report from the Tasmanian Standing Committee's Environment on Resources and Development *The Use of Compressed Natural Gas as a Vehicle Fuel in Tasmania* concluded that in light of recent completion of a natural gas pipeline to onshore Tasmania, CNG vehicle use is now possible and highly desirable economically and environmentally. They have recommended a rapid uptake scenario to the government. Regarding other ATFT the Government refers its website visitors to a private company that sells relevant information (http://www.tasmanenergy.com.au/)

2.6 The Victorian Government and Transport

The Victorian Government, through the *Victorian Greenhouse Strategy 2002* (VGS)[97], like other Australian states, closely echoes the NGS-M5 with regard to sustainable transport. This can be seen in measures such as travel mode and demand management programs, integrated planning, community information campaigns and the setting of aggressive Government fleet emissions targets (10% reduction by 2005 from 2002 levels), and exemplifying best practice leadership through using cleaner vehicles (through VicFleet, the Government vehicle provider, see below).[98]

- In relation to ATFT this research summary forms a part of VGS *Action 7.5: Determining Victoria’s role in promoting the use of alternative fuels/technologies.* In addition the following represent important initiatives, policy directions and research programs that any Victorian ATFT strategy would need to consider:
- The Department of Sustainability & Environment's *Melbourne 2030 Implementation Plan* for the development of Melbourne's transport infrastructure and services (Chapter 8: Better Transport Links) which indicates an intention to 'encourage sustainable transport;'[99]
- The Premier & Cabinet's requested *Transport Infrastructure Planning Report recommendation 29: Implement an integrated incentives scheme* (to achieve sustainability) and recommendation *34. Substantially upgrade public transport*, and then the Victorian Government response *Investing For Our Future: Growing Victoria Together* on 'promoting sustainable development' addressing the same recommendations;[100]
- The Victorian Department of Infrastructure's *Linking Victoria* might be considered, however their Investment Appraisal and Evaluation Guidelines, particularly the *Estimation and Valuation of Environmental And Social Externalities Table* could provide a significant policy development criteria analysis framework;[101]
- Under the *Greener Cities* policies of the Victorian Government, VicFleet is committed to 'use less polluting fuel efficient vehicles.' VicFleet is currently exploring the development of a '*Government Vehicle Specific Environmental Policy*,' which could include considerations such as 'vehicle selection choice, new technology vehicles, alternative fuels, travel demand management, environmentally efficient vehicle repair, vehicle manufacturers' environmental manufacturing policy, driver training, and vehicle service and maintenance.'[102]

- Aimed at reducing GHG emissions, long term cost savings and best practice promotion through leadership, VicFleet has also initiated a range of trials under a *Green Vehicle Pilot Program* which started in 2001 and included: [103]

  - *Hybrid vehicle trials* with 18 Toyota Prius from December 2001 for two years and trial of the Honda Insight. The Prius trial reported reductions of up to 43% lower emissions than similar PMVs. Subsequently in January 2004 the Victorian Government committed to purchase 50 second generation Prius vehicles for its fleet, with a further 50 to be purchased as replacement vehicles in the next few years;[104]
  - *Optimax Fuel Testing* in 2001 which concluded that 'on a cost benefit basis Optimax is only marginally not appropriate for use in existing Government vehicles and its use could not be supported at current prices. The situation will continue to be monitored for any changes in fuel price and improved engine technology;'
  - A 2001 *Ford LPG Vehicle Trial* of 20 dedicated LPG vehicles by VicFleet has resulted in their 'considering the introduction of dedicated LPG vehicles into the Victorian Government fleet to achieve reduced running costs and environmental benefit in reducing emissions of greenhouse gases and some air pollutants;'
  - *Improved Diesel Vehicle Testing* (emissions) resulting in a proposal for improved maintenance and testing procedures; and,
  - A Compressed Natural Gas (CNG) vehicle trial is proposed, however, while the cost of CNG is now comparatively favourable, greater refuelling infrastructure is required.
- Of note in Victoria is the inclusion in Ventura Bus Lines' fleet of three ethanol fuelled buses. These commenced service in 2000. Two other bus operators are also using biofuels in pilot programs.[105]

2.7 International Highlights

There are many advances in ATFT policy, regulatory measures and other government initiatives in other Western countries. A small sampling of some of these is provided for their potential adoption within the Australian and Victorian context.

2.7.1 United States of America

The United States of America (USA) has introduced a range of ATFT policies and legislative measures designed at moving their transport sector towards a more sustainable composition, including:

- *Zero Emission Vehicle Legislation* – In 2003 the USA states of California, New York, and Massachusetts introduced the Zero Emission Vehicle (ZEV) regulation requiring that 4% of all new vehicles (approximately 65,000) be ZEV. It further requires that another 6% be 'extreme-low-emission cars' for which each manufacturer receives credits towards tax deductions;[106]
- *Clean Vehicle Tax deductions* – The USA has also introduced tax deductions for the purchase or conversion to qualified 'clean' vehicles. The Energy Policy Act of 1992 (EPAct Public Law-102-486, Title XIX-Revenue Provisions, Sec. 179A). The tax deduction varies according GVM, class of vehicle and 'the value of the vehicle's clean fuel vehicle property, which refers to tailpipe emissions;'[107]
- *National Energy Security Act 2001* – The introduction of the National Energy Security Act 2001 is to encourage to purchase and use of electric modes of transport. The legislation contains a range of tax deductions.[108] In addition President Bush has proposed a temporary tax credit for certain hybrid and fuel cell vehicles;[109]

- *Hydrogen Research Grants and Vehicle Trials* – The US Energy Department announced US$350 million in grants on April 29th 2004 for 130 organisations to assist in achieving the widespread introduction of hydrogen-fuelled cars into the road transport sector by 2015.[110] Private investment is expected to contribute another US$225 million over the next five years. According to Reuters, DaimlerChrysler is planning to trial 37 fuel cell cars in US fleets this year and Ford plans to build around 30 fuel cell latter this year;[111] and,
- *Californian Hydrogen Infrastructure* – California Governor Arnold Schwarzenegger has committed an estimated US$100 million for the establishment of a network of around 200 hydrogen fuelling stations by 2010. California already has 17 established Hydrogen refuelling stations.[112]

2.7.2 Europe

The European Union (EU) has a rapidly developing ATFT sector, and the following measures are of note:

- *Draft Biofuels Taxation* – The EU is considering draft taxation measures that would see all the original 15 EU Member States required to use 2% biofuels by 2005, 5.75% by 2010, and 8% by 2020 in their transport sectors. In addition to legislating for environmental and energy supply changes, the proposal highlights that differentiated excise rates can assist developing the biofuel industry and offset the high costs of manufacturing biofuels compared to fossil fuels;[113]
- *Transport Sector Education* – The EU Energy Policy: Intelligent Energy for Europe, provides for EUR32 million grants between 2003-2006 for transport sector awareness raising and training regarding ATFT through a program called STEER;[114] and,
- More Information – There are numerous sources of more information on the EUs ATFT development, including:
  - European Transport Policy and Projects at http://www.nottingham.ac.uk/sbe/planbiblios/bibs/sustrav/refs/ST36.html;
  - European Environment Agency has statistics on the uptake of ATFT for 2002 at http://themes.eea.eu.int/Sectors_and_activities/transport/indicators;

Other European countries have also made significant initiatives in research and development including:

- *Nordic Energy Research Programme* – The Scandinavian countries Denmark, Finland, Norway and Sweden have a significant Government and EU funded Nordic Energy Research Programme, which assists 100 fuel cell and hydrogen related organisations who employ around 560 people;[115] and,
- *UK Fuel Cell Grants* – On April 27th 2004 a £3 million funding package was announced for the development of fuel cell technology.[116]

2.7.3 Biodiesel in an International context

Biodiesel has received a rapid uptake in overseas countries. The following review is quoted at length from a WA review of Biodiesel due to its breadth and succinctness:[117]

> 'Biodiesel is currently commercially produced in Germany, Italy, Austria, the Czech Republic, Malaysia and the United States, and is most advanced in the United States and

Europe, which currently produce 2 billion and 1 billion litres of biodiesel per year respectively.[118]

In the US, a bill was passed ensuring that all heavy transporting companies source 2% of their fuel from biodiesel. A number of bus and truck companies are trialling a B20 (20% blend of biodiesel and diesel), and the US Army now require new tanks and trucks to be compatible with biodiesel. In 2001 a US Department of Agriculture study concluded that an increase of 195-260 million gallons of biodiesel by 2010 was feasible. The predominantly soy-based biodiesel (due to a surplus of soy-oil) would also boost the total crop cash earnings by US$5.2 billion with an average net income increase for farmers of $300 million per year.[119]

Use of biodiesel is most advanced in Europe. B100 or pure biodiesel is now widely available in Germany, Italy and Austria. In Germany there are over 1000 outlets where biodiesel is cheaper than standard diesel. France, currently the largest user of biodiesel in the world, has a minimum mix of 5% in all diesel sold, with B50 becoming more common and popular.8

In both Europe and the US some diesel car manufacturers have extended their warranties to cover biodiesel. Unfortunately in Australia use of biodiesel in diesel engines usually voids the warranty, despite the fact that biodiesel made to appropriate standards (DIN 51606), is not harmful to modern diesel engines, and has in fact been shown to have benefits such as enhanced lubrication.[120]

Although in Australia only a very small percentage of cars are diesel, overseas the percentage is far greater and increasing. In 1990, about 3% of British cars were diesel, today this figure is almost 20%. Other European countries are equally high - 28% in France and 39% in Belgium.[121]

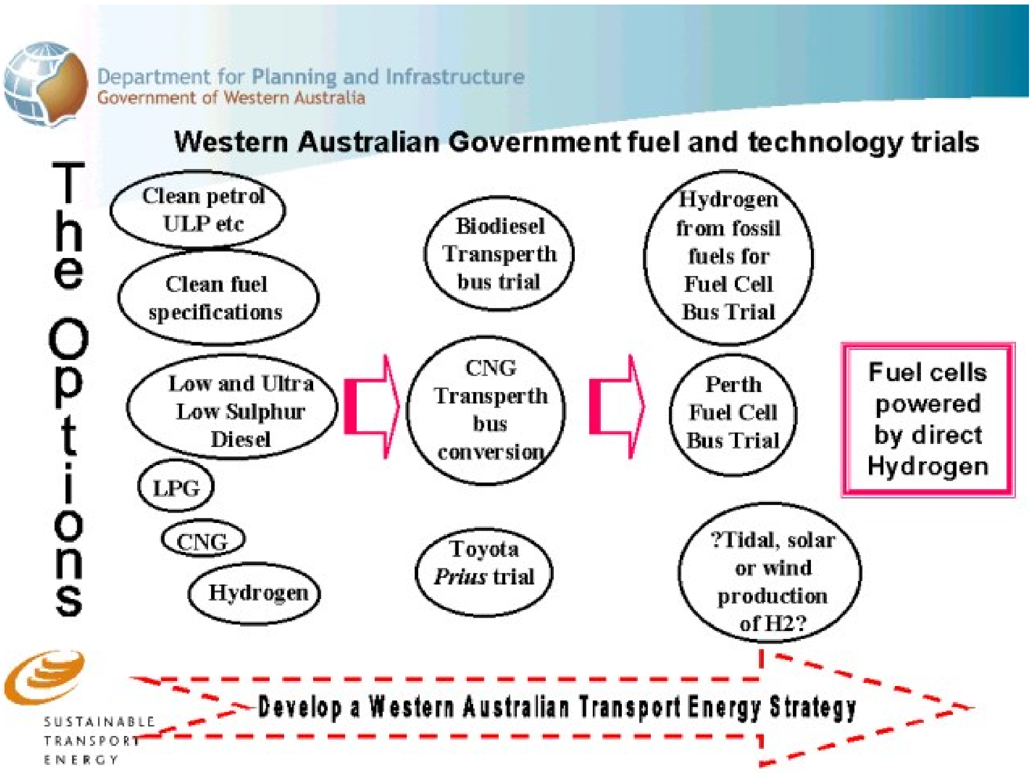
2.8 Conclusion: Strategic Directions

A significant breadth of policies and supporting initiatives and research has been canvassed in this section, and a number of core strategic directions for alternative transport fuels and technologies in the Australian context have emerged. These include:

- *Provision of financial incentives and funding* in certain situations for the development, promotion and use of alternative transport fuels and technologies and the infrastructure associated with these is required;
- *Biofuels*, namely ethanol blends know as E10 and the proposed E20 standard, are important contributors to existing fuel supplies, although the small production amounts means their overall impact is limited;
- *Research and infrastructure investment in CNG*, and to a lesser degree LPG, is required for all vehicle types, predominantly heavy vehicles and notably though pilot-trial/promotion programs in public transport fleets;
- *Best practice leadership by Government Fleet purchases* of hybrid vehicles in particular, and lower emission and more fuel efficient vehicles (including via lower weight) in general, is required;

- *Increasing regulatory constraints* on fuel quality, vehicle emissions and fuel efficiency with an openness to including alternative fuels and technologies may need to be implemented;
- An *openness to further research and development* in line with an expected use of gaseous fuels (LNG, CNG and LPG) in an evolving range of vehicle technologies (more efficient and clean internal combustion engines, through hybrids to fuel cells and related combinations) is required; and
- A growing expectation of, and focus of research and planning on, the development of a hydrogen economy which could be spearheaded by *a hydrogen based transport sector* is emerging.

2.9 WA ATFT Roadmaps



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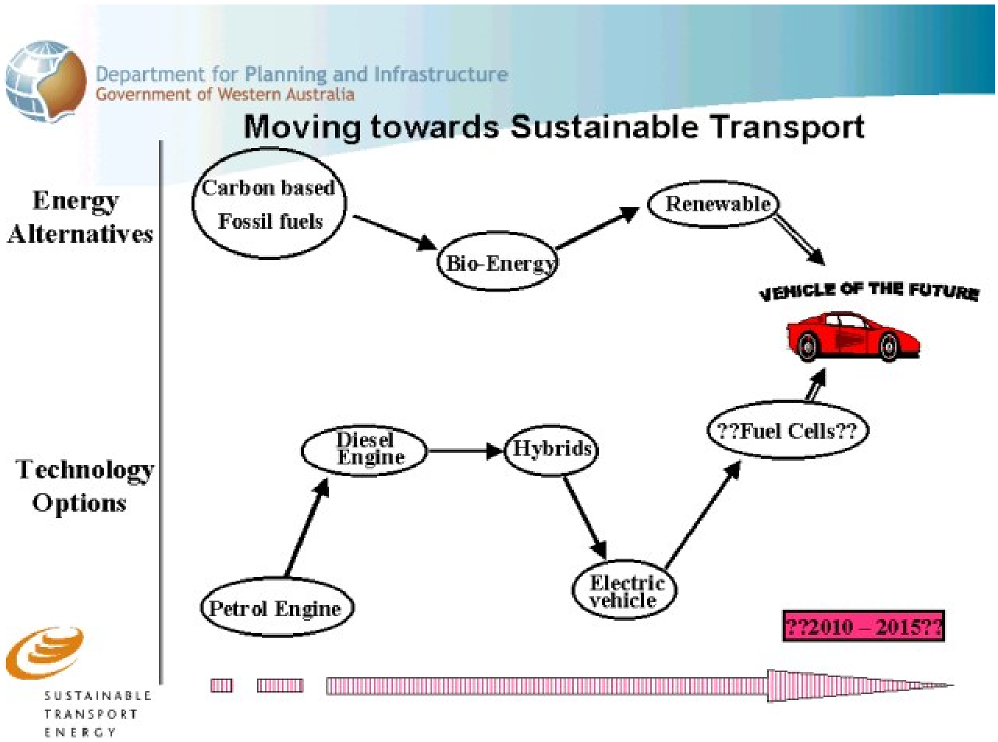

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3 Appendix C: Stakeholder Consultation

3.1 Background, Method and Summary

The perspectives of industry and non-government stakeholders on the future of alternative transport fuels and technologies are of particular importance to this study. Uptake of alternative transport fuels and technologies is highly influenced by the willingness of stakeholders to adopt such technologies. In addition, the views of stakeholders in this study have provided many insightful recommendations for the future trajectories of use of alternative fuels and technologies and associated policy options.

In conjunction with EPA Victoria, a list of relevant stakeholders was identified and invited to participate in this study via two methods. First, participants were invited to respond to an emailed questionnaire regarding the appropriateness of various alternative transport fuels and technologies (ATFT), and the role of the Victorian Government with regards to ATFT. The questionnaire canvassed input on:

- Transport fuels and vehicle technologies most likely to reduce greenhouse gas emissions and improve air quality;
- Aspects most likely to assist the uptake of these "preferred" fuels/technologies;
- Roles the Victorian government might play to promote these fuels/technologies; and
- Barriers to adoption, and how these might be removed or prevented.

In addition, stakeholders were invited to submit a brief position statement for inclusion in the public report (see Appendix B for the submitted statements). They were also provided the option of submitting any supplementary information they considered pertinent to the study.

The stakeholder responses were subsequently collated and analysed, and a synthesis of the recommendations appears below under two headings: those responses related to alternative transport fuels and technology specifically, and those concerned with potential Victorian Government approaches and policies.

3.1.1 Alternative Transport Fuels and Technologies

1. It may be unrealistic to see major reductions in vehicle emissions or uptake of alternative fuels and technologies within a ten year time frame. Planning must therefore cast much further forward than ten years in order to identify policies aligned with long term goals within the coming ten years;
2. Particular alternative fuels may need to be introduced for particular vehicle types, rather than a ‘one size fits all’ approach;
3. Both the purpose of policy (either for GHGs or air pollution), and the locality of the focus, are important in ensuring that policies which reflect appropriate targets are developed. E.g. the purpose of liveable cities (air pollution) might require restricted access to cities by all vehicles, rather than an across the board focus on marginal reductions in vehicle emissions (GHGs), within a ten year time frame;
4. For each vehicle type, a trajectory of most appropriate fuel usage over a time period may be most appropriate (phasing in and out of particular fuels) (e.g. transition to a hydrogen economy through the use of LNG and CNG);

5. External factors, such as the increasing price of oil and the associated reduced supply will encourage the uptake of alternative fuel technologies;
6. Fuel efficiency, rather than engine/car size and power, must be promoted as a buying priority for both government and the general public; and,
7. Current wisdom suggests that a pathway toward a hydrogen economy should be investigated.

3.1.2 The Victorian Government's Role

8. The Victorian government's most effective role may be to 'lead by example' in the adoption of alternative fuels, e.g. promotion for its own fleet;
9. The Victorian government may undertake a lobbying role to the Federal government in conjunction with industry to encourage alternative fuels uptake and initiatives should complement and not duplicate or conflict with Commonwealth measures;
10. Incentives and regulations are seen as important policy options to encourage adoption of alternative fuels, particularly with PMV's. Particular examples appear below. The Victorian government may need to be aware of policies that establish potential barriers to adoption, particularly for industry;
11. The Victorian government may encourage alternative fuel adoption through partnerships with industry, e.g. to increase LPG use in buses;
12. A lack of uniform policies leads to little action with regards to alternative fuel promotion and adoption. Establishment of a National Alternative Fuels portfolio investigating very long to long term strategies (in excess of 50 years) would ensure integration across departments/industries, and more foresighted government policy;
13. Lack of infrastructure, such as public refuelling stations is a barrier to uptake; and,
14. A reduction in greenhouse emissions may be better achieved through the implementation of walking, cycling and public transport initiatives than through the use of alternative fuels and technologies.

3.1.3 Policy Options

A number of specific policies for the Victorian government were suggested by stakeholders in addition to the general propositions outlined above. The full details of these suggestions appear in a table later in this chapter. However, the nature of the recommendations has been summarised below.

Government incentives and market based mechanisms:

- Vehicle registration subsidies;
- Petrol taxes/levies;
- Use of petrol taxes to fund other initiatives (particularly infrastructure provision);
- Car purchase subsidies;
- Toll way exemptions;
- Provision of access/cheaper access to areas and resources (e.g. city parking); and

- Subsidies for industry/fleet vehicle uptake.

Government regulations:

- Fuel efficiency criteria/standards.

Public Education:

- Benefits of alternative technologies.

Government infrastructure provision:

- Refuelling sites; and
- Gas pipeline and network of refuelling sites.

Government 'leading by example:'

- Conversion of government fleets to alternative fuels.

3.2 Detailed Stakeholder Recommendations

The range of perspectives and views put forward by stakeholders is outlined in more detail below.

3.2.1 Alternative Fuels and Technologies

3.2.1.1 It may be unrealistic to see major reductions in vehicle emissions or uptake of alternative fuels and technologies within a ten year time frame.

Industry representative:

The next ten years is too short a time-frame to see major or widespread new infrastructure constructed to produce and distribute new types of fuel. For one thing, in this period, there will still be a number of technology barriers to the use of some fuels, eg electric batteries, fuel cell, and hydrogen. Also, there is unlikely to be an easy way of producing these fuels from renewable energy sources, given the existing requirement to use renewable energy sources to replace electricity from the burning of brown coal. This substitution is essential to reduce the impact on the environment from greenhouse emissions of CO_2*.*

This suggests that planning must cast much further forward than 10 years in order to understand the policies that will be necessary to develop and implement within the coming ten years.

3.2.1.2 Stakeholders recommend the introduction of particular fuels for particular vehicle types – and within particular industries.

Isuzu Motors Japan and IGM both consider that diesel has a medium-long term future as the primary fuel of choice for heavy commercial vehicles [with CNG and later Hydrogen as PMV's].

This perspective contrasts with a focus upon change to a particular type of alternative fuel for all vehicle types and industries. For example, several stakeholders advocated the approach of adopting (pure) ethanol for buses, with LPG and CNG for passenger motor vehicles.

3.2.1.3 Stakeholders highlighted the importance of locality and purpose in addressing alternative fuel use issues.

Two Industry representatives:

> *We believe that even with lower emissions per vehicle, the projected increases in traffic volumes will make our cities unliveable in this [ten year] timeframe. This [cities] is where the emphasis must be.*
>
> *The federal government has chosen to subsidise CNG vehicles through the Australian Greenhouse Office (AGO), which imposes a strict GHG reduction criteria on eligible CNG vehicles. The air quality benefits of using CNG Vehicles far outweigh the GHG benefits. Therefore, [this stakeholder] considers that subsidies and incentives for CNG vehicles should be instigated by State EPAs.*

A significant number of stakeholders highlighted that it may be more appropriate to restrict vehicle access altogether from certain hot spots (like cities) than to assume that a small reduction in fuel emissions from new technologies will offset the immense air pollution projected in cities into the future. Such a policy may also have the effect of reducing overall GHG emissions, though this is not necessarily the case. The purpose or focus of emission reduction therefore becomes important.

3.2.1.4 The types of alternative fuels that may be appropriate to shift to in the short term to reduce GHGs for particular vehicles/industries may not be the ones that would be appropriate in 10, 20 or 50 years time.

> Industry Representative:
>
> *Natural Gas engine technology is now into its 2nd or even 3rd generation, compared to "early development work" for most of the others. By contrast, most industry commentators predict that Hydrogen Fuel Cells, while offering potentially the best environmental outcomes, are at least 30 years from being commercially viable in heavy transport vehicles… Refuelling infrastructure established for CNG can later be adapted for use as Hydrogen refuelling. Thus, CNG is the natural "stepping stone" towards the ideal world of H_2 fuel cells.*

This suggests that for each vehicle type, there be a trajectory or time line of particular phasing in and out of appropriate fuels. This time line would be related to the determined 'market mix' of alternative fuels at each time period.

Another Industry Representative:

> *Natural Gas is the most sustainable path to the Hydrogen economy and the most efficient source of hydrogen. Infrastructure established to service Natural Gas vehicles can very easily be adapted to service hydrogen vehicles, either via on-board or supply-side reforming.*

Therefore the next step must be to phase out high carbon fossil fuels for diesel vehicles, replacing them with biofuels where no substitute for long chain hydrocarbons is possible. Where fuel type substitution is permissible as in many gasoline engined vehicles, the use of LPG, Propane, and finally and best of all, Natural Gas would seem to be the best solution.

3.2.1.5 Current wisdom suggests that a pathway toward a hydrogen economy should be investigated.

Many stakeholders advocate the need to move toward a hydrogen economy through various methods, including the development and promotion of hydrogen fuel cell hybrids.

Industry Representative:

Hydrogen fuel cells present the most viable long term option for the reduction of greenhouse gases and sustainability of transport options into the future.

3.2.1.6 External factors, such as the increasing price of oil and the associated reduced supply will encourage the uptake of alternative fuel technologies.

Two stakeholders suggested that the most appropriate alternative transport fuels and technologies have been developed, yet particular external factors will dictate their adoption and use.

Industry Representative:

Expected increases in the price of oil, from higher demand and reduced supply can be expected to boost the price of fuel and hence the attractiveness of such vehicles.

3.2.1.7 Fuel efficiency, rather than engine/car size and power, must be promoted as a buying priority for both government and the general public

Stakeholders suggest that larger vehicles with poor fuel efficiency are promoted in Australia by both government and industry. This is primarily due to 'Australian made' government buying preferences, and vehicle 'power' being promoted by vehicle companies. Fuel efficiency must replace these preferences as a matter of priority, which may require public education.

Industry Representative:

…the preference to Australian-made vehicles in government purchasing means that fuel inefficient vehicles with larger motors are commonly bought, as smaller vehicles are usually imported. The market power of government buying might be the catalyst to get things started. Following this, anything that government does to make a vehicle type more attractive to the public will add to the momentum. Reliability awards and publicity of positive experiences with hybrid vehicles might be useful.

3.2.2 The Victorian Government Role

3.2.2.1 Stakeholders believe that the Victorian government's example in relation to alternative fuels and its own fleet is the most or highly important.

Industry Representative:

> *The Government has a lead role in influencing public and community perceptions through its own initiatives to improve air quality and the environment… The most effective driver to uptake of LPG as an automotive fuel would be the adoption by the Victorian government of a prescriptive policy with government transport vehicles such as buses and with the government fleet that specified the use of LPG buses and vehicles in appropriate circumstances.*

Stakeholders suggest that the Victorian Government can show market leadership by enhancing its current policy of vehicle purchase, and stipulate that at least 60% of government transport vehicles need to be LPG vehicles manufactured locally. In the case of buses, some recommend that a mix of natural gas and LPG buses should be used to meet appropriate infrastructure efficiencies.

3.2.2.2 Stakeholders see a strong promotion and lobbying role for the Victorian government in relation to the Federal government to encourage the use of alternative fuels.

Particular stakeholders highlighted the dependence of the Victorian Government on national commitment to alternative transport fuels and technologies. In this case, it was suggested that the Victorian government lobby the Australian Government to initiate change in relevant policies and initiatives. The Victorian government initiatives should also complement and not duplicate or conflict with Commonwealth measures.

Industry Representative:

> *Unfortunately, I think that this scenario is probably out of the hands of the Victorian Government, and it should really be a national initiative led by the federal government. I think that it is most unlikely that a single state could go it alone and simultaneously set up the infrastructure and build suitable vehicles for the program.*

3.2.2.3 Incentives and regulations are seen as important policy options to encourage adoption of alternative fuels, particularly with passenger motor vehicles.

Stakeholders recognised the usefulness of government incentives (particularly for passenger motor vehicles in the form of rebates for alternative fuel use) and regulations (for example, charges to enter the CBD are lowered for those using LPG in London and other parts of Europe).

Stakeholders also highlighted the importance of government policies as potential barriers to uptake of alternative fuels:

Industry Representative:

A recent barrier to adoption of LPG as a vehicle fuel was temporarily removed with the Federal government decision to postpone implementation of excise on alternative fuels until July 2011.

Other specific policy recommendations put forward by stakeholders appear in the Table 10 below.

Measure	Type of Policy	Policy
Government Incentives and Market-based mechanisms	Vehicle registration subsidies	Issuing green registration plates or reduced registration costs for alternative fuel vehicles as part of an incentive program for private motorists
	Petrol taxes/levies	It is important that government not reduce fuel taxes on petrol. An argument can be made that government should increase the taxes on diesel to make its use less attractive and to partially offset the public health costs of its use.
		Work towards introduction of some form of levy based on the fossil originated carbon content of fuel. There should be a signal to the market that use of high GHG emission fuel is an offence. Biodiesel could be exempted from the penalty, acknowledging its GHG neutral potential. Fuels derived entirely from renewables must carry a reward for their use, and not a penalty as at present.
	Petrol taxes as funding source for other initiatives	Initiatives could be funded by a levy of 0.5 cents per litre on petroleum fuels. The entire program would be budget neutral, and would cost the average motorist no more than $5.00 - $10.00 per year.
	Car purchase subsidies	A financial subsidy against the cost of purchase of the best CO2/km vehicles/fuels could be considered. Also, products such as MECU's 'goGreen Car Loan'.
	Toll exemptions	Granting approved CNG vehicles exemption from Citylink tunnels and other road tolls (almost zero particulate and smoke emissions)
	Access to areas and resources	Providing priority access and parking in CBD areas to CNG vehicles
	Subsidies for industry/fleet vehicle uptake	Support and subsidy programs for taxi operators, local government councils, and fleet-operated passenger and light commercial vehicles to encourage conversion to NGVs.
		Support for the uptake of natural gas buses in Melbourne and regional centres.
		Discourage use of legislation and regulation to compel compliance to some standard or another. The choice of fuels should be guided by well directed application of price controls, carbon taxes, rebates, excise and so on.
Government Regulations	Fuel efficiency criteria	"[This industry representative] would like to see the state government adopt a mandatory fuel consumption criterion in its purchasing policies. If the government, a major purchaser of vehicles, were to specify a maximum fuel consumption, then there would be economies of scale in manufacturing and importing such vehicles"
	Standards	"[This Industry Representative's position] is not support the implementation of Euro 5 emission standards for heavy trucks until such time that it can be demonstrated through expert opinion and analysis that this option is the most cost effective

		and equitable means for the trucking industry to achieve pre-determined NO_x abatement targets."
Public Education	Benefits of alternative technologies	From another industry representative: "With respect to technologies, hybrid vehicles are already available and at not a high premium to conventional vehicles (about 15-25% dearer). Anything that convinced the potential users of the viability of the technologies would be useful. They need experience and anecdotal evidence of the value (reliability, reparability, cost of ownership) of the products."
Government Infrastructure Provision	Refuelling sites	Sponsoring a network of public CNG refuelling sites around Melbourne
		Lack of a public refuelling infrastructure is a major barrier to uptake of alternative fuels.
		A partial subsidy program for the development of a publicly-accessible infrastructure program for CNG and LNG. Victoria already has an advanced gas distribution network, and the rollout of public refuelling would be easy and cost-effective.
	Gas Pipeline	"The best way to prepare for this transition would be to link some of the northern gas fields to the eastern states and SA by pipeline and set up a network of CNG filling stations. It would also require some incentives for the importation of efficient CNG vehicles and for the conversion of existing vehicles," recommends one industry representative.
Government 'lead by example'	Vic Govt's own fleet conversion	An incremental proportion of the Victorian government's own fleet should be CNG or LNG fuelled vehicles, with a target of 20% NGVs by 2010.

Table 3.1: Specific Victorian Government Policy Recommendations from Stakeholders

3.2.2.4 Partnerships between government and industry are seen by stakeholders as being of importance.

Industry Representative:

The most effective drivers to increase uptake of LPG as an automotive fuel would be joint action between the industry and Victorian Government.

Another barrier to utilisation of LPG as an automotive fuel is the lack of knowledge by the general public and fleet owners of the safety, economy and clean air benefits of LPG. The industry's own market development and promotion programs are designed to address many of these concerns.

3.2.2.5 A lack of uniform policies leads to little action with regards to alternative fuel promotion and adoption.

Stakeholders believe that little progress is being made with alternative fuels in Australia as there are too few uniform policies to indicate that alternative fuels and transport management are a priority for government.

Stakeholders see the need for "a National Energy & Resource Folio, geared toward a 50, 100, 500 and 1000 year program." This is to ensure integrated and long term thinking, rather than a sector by sector treatment of the issues determined by sectional and departmental interests and constituents.

Industry Representative:

In addition to the initiatives outlined above, the Victorian government should establish an ongoing alternative fuels task force to promote a "whole of government" approach to supporting the introduction of clean fuel strategies throughout the state.

3.2.2.6 Lack of infrastructure, such as public refuelling stations is a barrier to uptake.

Industry Representative:

The primary barrier to the adoption of natural gas as a mass-market fuel is the lack of a widespread public refuelling infrastructure.

Stakeholders saw a strong role for government in the establishment of infrastructure to support uptake of alternative transport technologies and fuels.

3.2.2.7 A reduction in greenhouse emissions may be better achieved through the implementation of walking, cycling and public transport initiatives than through the use of alternative fuels and technologies.

Particular stakeholders questioned the importance of government incentives to promote the use of alternative transport fuels and technologies, given that a greater decrease in GHG emissions may be achieved through the development of new transport planning objectives that encourage alternatives to individual vehicle use.

3.3 Official Stakeholder Position Statements

3.3.1 Ventura Bus Lines

Ventura Bus Lines in Melbourne have been operating three ethanol powered buses since 2000. These buses were introduced into Ventura's fleet of 200 buses as they have half the greenhouse gas emission of a standard diesel bus. The fuel is totally renewable and sustainable unlike fossil fuels. These buses service many major universities and schools to help educate our next generation that there is a cleaner alternative to using fossil fuels in vehicles.

Ventura is encouraged by the performance of these buses and is hoping that the Federal Government recognize the importance of this fuel for the future.

3.3.2 Environment Victoria

Environment Victoria's priority is to reduce greenhouse emissions, the total quantity of petrol and diesel fuel used in Australia, and the total distance travelled. We believe that many car journeys *could be substituted by alternative transport modes, leading to a healthier population and environment. These alternative modes include walking, cycling, and public transport.*

Government studies have shown that excessive car use leads to an overweight indolent population. New fuels and vehicle technologies will not make our cities more livable. Even if zero emissions could be achieved, the anticipated future traffic levels will, in themselves, cause ill-health.

In addition, road freight is heavily subsidised by the transfer of costs to other road users and the general population. A true accounting would lead to a diversion of a lot of freight from road to rail.

The use of petrol and diesel fuels is widespread in our society and offers only limited opportunity to reduce CO_2 emissions without major engine design work. We accept that CO_2 emissions, within petrol and diesel classes, are related to the volume of fuel consumed by a vehicle and this has a direct relationship to its engine size.

Alternative power sources, such as fuel cells and hydrogen, have been proposed. These solutions are still many years away from delivering significant savings in greenhouse and toxic emissions. We look at the complete lifecycle of that fuel and do not consider a fuel to be 'clean' (eg hydrogen) if it originates in the burning of coal to make electricity or the inefficient conversion of another fuel.

Finally, we support the use of fuel-efficient hybrid technologies, but suggest that the emission problems are inherent in the widespread (over)use of road.

3.3.3 Isuzu GM

Isuzu-GM Australia (IGM) is the importer and distributor of Isuzu-branded heavy commercial vehicles (trucks) for Australia. IGM has been the overall truck market leader (that is, vehicles above 3,500 kg Gross Vehicle Mass) in Australia for over 15 years. All of the truck sales during this time have been fuelled by diesel.*

Isuzu Motors Limited (Japan) is IGM's primary supplier. Isuzu is a world leader in diesel engine production, manufacturing over one million diesel engines in 2003. While being primarily a truck and diesel engine specialist, Isuzu Motors has committed significant research and development resources to studying alternative fuel technologies. In particular, Isuzu has been a leader in supplying trucks into the Japanese market fuelled by Compressed Natural Gas (CNG). Several Isuzu CNG truck models are available for sale on the Japanese market, and Isuzu has registered in excess of 6,000 sales of CNG trucks in Japan since 1998. Isuzu has committed to developing CNG engines to improve emissions levels and efficiencies even further than the already clean results achieved.

Isuzu believes that the long-term future for transport fuels is hydrogen. However, commercially viable hydrogen fuel cell trucks are considered to be at least 30 years into the future. Until fuel cells are a reality, Isuzu considers that both CNG and diesel hybrid vehicles will be developed and sold to provide the correct balance of performance, productivity, affordability and low emissions that is demanded in the world.

IGM is committed to promoting CNG trucks in Australia, and has committed to a federal government supported project in the Greater Sydney area which will see sixteen CNG trucks sold *and operated during 2004. Following a successful project, IGM plans to introduce more CNG trucks for sale to the Australian market in 2005.*

** Source: ERG Truck Tracker retail sales 1989 to April 2004*

3.3.4 Future Enterprises

We anticipate the demand for fossil fuels around the world continuing to rise, while production does so at a lesser rate, so price increases are probable. In conjunction with a carbon levy and a formula for representing and applying the externalized costs of fossil fuels, price adjustments should initiate a widespread shift to less polluting sources of transport energy over the next ten years. However, there is no energetically efficient new fuel likely to become widely adopted over that timescale, so the strategy must be one of encouraging a transition to existing low but non-zero carbon fuels such as CNG, and making them readily available to the motorist. Also, biofuels such as ethanol and biodiesel, grown where possible with the minimum of fossil energy subsidy, can be introduced for suitable vehicles, which must be able to use them without damage.

In the longer term these will be phased out for truly zero carbon fuels. There are three possible types, and the disadvantages of each will ensure that there will be no dominating fuel for the foreseeable future. Biofuels will be produced from crops grown without fossil energy subsidy, hydrogen obtained by electrolysis or photocatalysis of waste water, and electricity produced from renewable sources.

Whatever the scenario, the use of legislation and regulation to compel compliance to some standard or another is to be discouraged, and the choice of fuels should be guided by well directed application of price controls ([carbon] taxes, rebates, excise and so on).

3.3.5 PTUA

The PTUA recognises a legitimate role for low emission fuel and vehicle technologies. Frequently stopping vehicles such as garbage trucks, which makes trips that cannot be replaced by public transport, should be converted before passenger cars. We also have no objections to buses being converted, provided reliability, speed, safety and operational economy are not compromised.

However we believe that the environmental benefits of new fuel and vehicle types are often over-stated. Though individual cars may be getting 'cleaner', rises in overall car use can offset these benefits. In these discussions, the point that car use has higher pollution emissions per capita than 'green' transport modes is often lost. Also, unlike public transport, new fuels and engines have no potential to meliorate other consequences of car dependence, such as accidents, increased living costs, congestion, reduced urban amenity, etc.

Tackling car dependency should be at the core of any policy to reduce transport's share of air pollution and greenhouse gas emissions. This means replacing car trips with walking, cycling and public transport. To increase patronage, public transport must be made attractive for today's travel needs, rather than be the last resort people use if they don't have a car. This requires the diversion of resources from projects that entrench car dependence (such as freeways) and the construction of a network of frequent, interconnected train, tram and bus services that provides a 'go anywhere anytime' public transport capability throughout Melbourne.

Further information appears in our publication "It's Time to Move", available from the PTUA office.

3.3.6 ExxonMobile

1. Over the next ten years improvements in conventional transport fuels (petrol, diesel and, possibly, LPG) will make the most significant contribution to improvements in air quality and greenhouse gas reductions. Alternative fuel sources such as hydrogen offer great potential in theory but face considerable technical and commercial challenges.

2. Hybrid petrol or diesel engined vehicles are available and provide additional air quality and greenhouse gas benefits, particularly for urban use. In city driving, hybrid vehicles are capable of delivering a fuel economy improvement of up to 50% versus current petrol engined vehicles.

3. As has been noted by AIP, existing and currently mandated (or expected by the end of the decade) fuel standards for petrol and diesel will already have a significant impact on urban air quality and emissions from motor vehicles. Most of the vehicle emission benefits will come from new additions to the on- road fleet rather than from existing, pre-2005 vehicles.

4. There is scope for the State Government to look at complementary measures which improve fuel efficiency and reduce emissions from the current vehicle fleet, e.g. reduced congestion through improved road design and other traffic management measures, "in service" emissions testing, etc.

5. There is also an opportunity for the State Government to consider the impact of off-road vehicle/equipment engines (cranes, excavators, etc), many of which are used in urban areas and contribute significantly higher per unit emissions than on-road vehicles. Given current and future fuel quality there is potential to retrofit exhaust emission reduction measures to such engines and gain substantial air quality benefits.

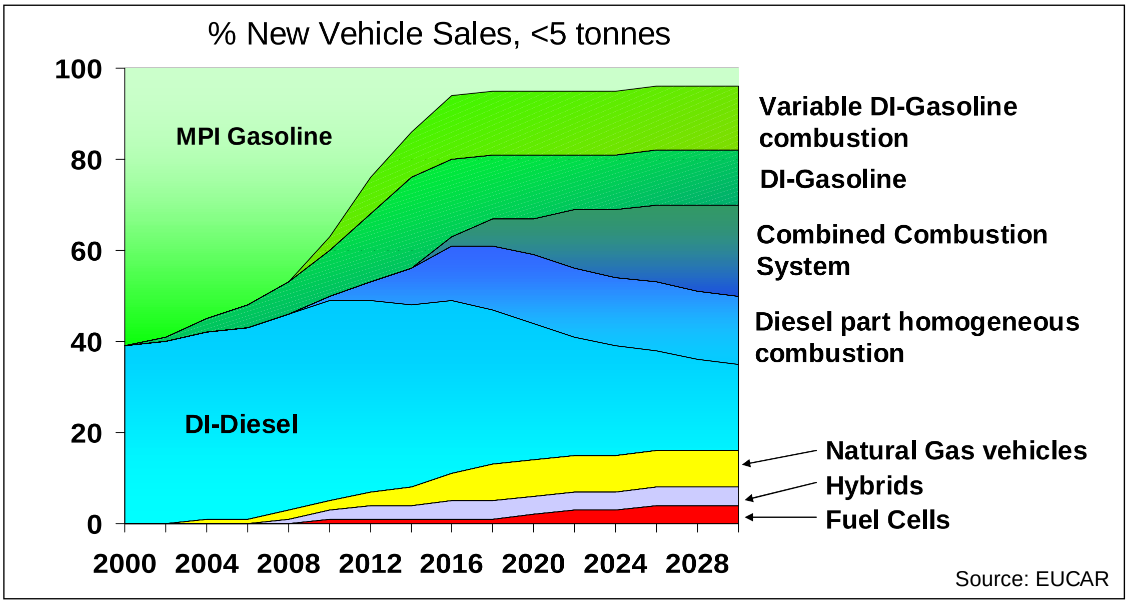
6. To deliver mandated improvements in transport fuel quality, Victorian refiners will use more fuel and generate higher emissions (including greenhouse) per unit output and this will partly offset the benefits gained from use of these cleaner fuels. In particular, we seriously question whether there is a net greenhouse benefit, on a "well to wheels" basis, in taking petrol sulphur level down below 50 ppm. This will result in significantly increased refinery greenhouse gas emissions, whereas the number of vehicles which actually depend on such quality fuel to deliver improved fuel efficiency is expected to be quite low for some years.

7. As the recent US National Research Council report concluded, realizing the potential for commercialisation of hydrogen fuel cells for transport use is decades away. A number of hydrogen production, delivery, storage and use challenges must be overcome if hydrogen is to be widely used as a transport fuel and this technology has no potential to deliver greenhouse or other environmental benefits within the next ten years. The handling and use of hydrogen poses significant safety problems compared to conventional fuels and other potential alternatives such as biofuels. Hydrogen is not available in the natural state and must be produced using other energy sources - depending on what those sources are use of hydrogen may or may not deliver any net greenhouse emission benefit. Huge investment in new infrastructure is likely to be required to supply hydrogen for general transportation purposes unless on-board vehicle reforming of conventional liquid fuels into hydrogen proves practicable.

8. ExxonMobil globally is actively engaged in a range of short, medium and long term research activities and technological initiatives that are improving existing fuels technologies as well as addressing the longer term challenges associated with hydrogen and alternative fuels.

Attached are a couple of charts which provide further information which may be useful to you. The first of these provides an assessment of likely trends in the European vehicle/fuel technology mix over the next couple of decades. The key message from this chart is that by the year 2030 conventional petrol and diesel engines are still expected to power some 85% of the European vehicle fleet. Note also that diesel is a much more significant part of the vehicle/fuel mix. Diesel engines do offer substantial fuel efficiency and greenhouse benefits over petrol engines but some effort would be required to convince Australian motorists to shift to diesel. The second chart provides a US-based comparison of "well-to-wheel" costs (excl taxes) and CO2 emissions for a range of conventional and advanced vehicle and fuel technologies. The key takeaways from this chart are the substantial costs associated with generating hydrogen from natural gas or via electrolysis. While use of hydrogen generated from natural gas offers lower greenhouse emissions than other technologies it does so at a significant fuel cost penalty. Generation of hydrogen by electrolysis is unattractive on both counts. The diesel internal combustion engine and hybrids offer both fuel cost and CO2 emission benefits versus today's gasoline (petrol) engine, while on-board reforming of gasoline to produce hydrogen is even better. Diesel and hybrid engines are, however, currently disadvantaged by higher manufacturing and operating costs (excl fuel) and on-board reforming will add further costs to the vehicle so there are some challenges ahead to make these options more commercial.

The Vehicle Mix is Evolving

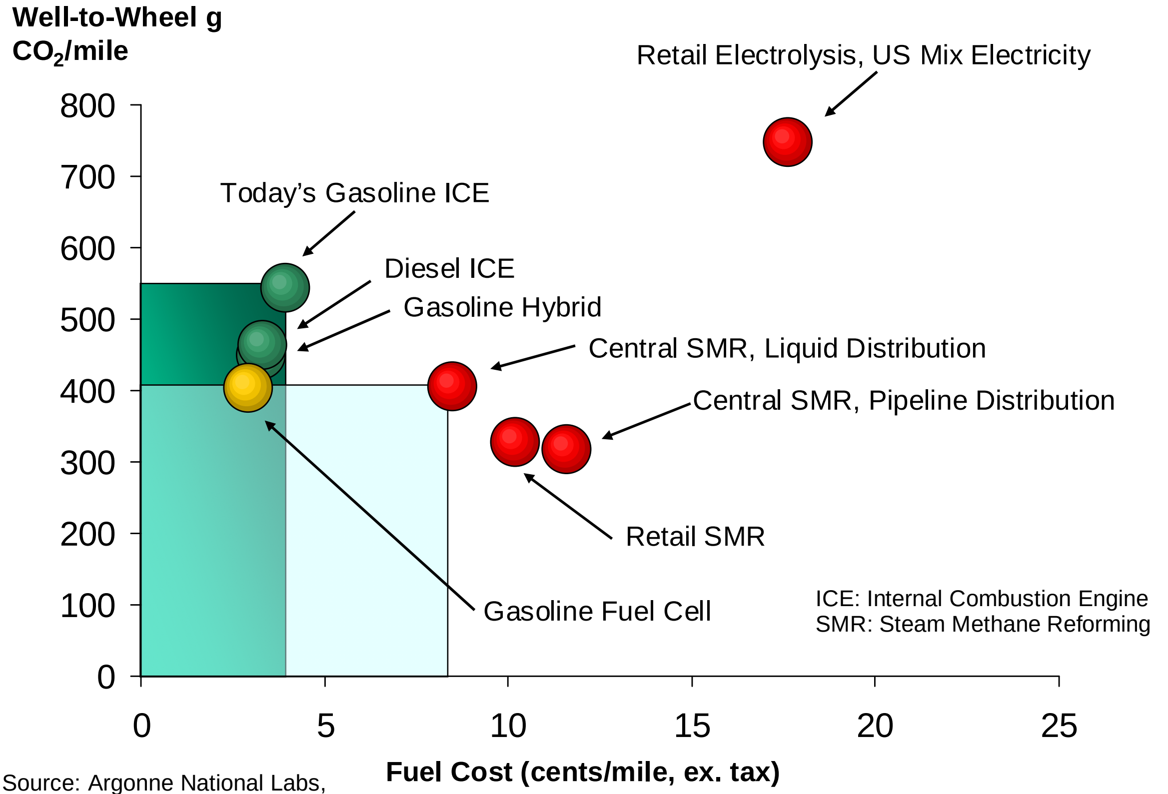


- ***Steady growth of advanced ICE, hybrid and fuel cell technology***

ExxonMobil

6/28/2004 1

Advanced Vehicles: WTW and Fuel Cost Comparison



Source: Argonne National Labs,
SFA Pacific

ExxonMobil

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3.3.7 BP Australia Pty Ltd

I preface these comments by noting that BP has a strong commitment to the environment and to greenhouse:-

- *we have led the industry on clean fuels (both the debate and their introduction) in Australia*
- *we are trialling ethanol in Qld*
- *we recently received a GGAP grant to try to develop efficient LPG fuelled engines for trucks*
- *we are trialling H2 around the world - specifically in aus, our Perth refinery is providing H2 for a bus trial to be launched next month*
- *as a Group, we conducted our internal abatement program, aiming at a 10% reduction on our 1990 emissions by 2010. We reached this target in 2002 or 3*
- *we have introduced a program called Global Choice which offers commercial customers the option of partially/wholly offsetting their GHG emissions from the use of the fuel*
- *we have one of the world's largest PV solar companies - with an operation in Sydney.*

For the next 15-20 years, liquid hydrocarbons will be the dominant transport fuel. They comprise circa 95% now and this is likely to continue. Therefore, any GHG reduction program or clean fuels program needs to focus on that.

In this regard, cleaner diesel and petrol (apart from improving air quality in their use) are facilitators for new, more efficient engine technology. The Comm government has recognised this by introducing a regime of post 06 incentives and standards which will encourage such fuels. Just two weeks ago, Env Minister Campbell announced that 10 ppm S diesel will be the standard as from 1/1/09, and all 95 RON or higher petrol must have less than 50 ppm S as from 1/1/08. The Government will be offering incentives for companies to "go early" on these - with an incentive of about 1 cpl for 10 ppm s diesel as from 1/1/07; and around 1.1 cpl for the cleaner petrol as from 1/1/06.

This follows government industry discussions with the auto and oil industry which looked at future clean fuels/air quality/ghg issues.

The importance of these cleaner fuels is that they faciliate new engine technologies eg GDI which allow for greater fuel efficiency (and hence GHG emission reduction). and indeed there is to be further examined whether we go to 10 ppm S petrol (for 95+RON) in 2010.

Associated with all of this is the Govt target for National average fuel economy imporivement from 8.3 l per 100km to 6.8 l per 100 km by 2010.

And preceding all of this has been the Fed Government's moves to cleaner gasoline and petrol through to 2006 -including the incentive for early introduciton of Ultra Low sulphur Diesel (50 ppm S or less)prior to its regulation in 2006.

We support these improvements and the "carrot and stick" methods of their introduction.

LPG (or autogas) is the next major fuel. It is a clean fuel. There may be some improvements in efficiency to be utilised.

Regarding other fuels, there is some GHG reduction in the use of ethanol provided it is produced as a by product and its production minimises its GHG emissions. CNG is not a significant contributor. Hydrogen is many years away at this stage.

Engine technology improvements are important. A move to diesel engined autos would seem to hold real potential. The fuel economy of the some of these is very impressive (circa 3.5 l per 100km). Hybrid vehicles will also assist here.

Major Federal policies - supported bilaterally - are in place. Where Victoria may have a role could be in adopting a system like the UK registration system which encourages the uptake of cleaner, more fuel economy vehicles. Vic Government could also look at take up of policies such as our own Global Choice for fuels consumption to offset GHG emissions.

3.3.8 The Australian Institute of Petroleum

AIP and its member companies share the community objectives for clean air and reduction in greenhouse gas emissions. AIP believes that all initiatives in these fields should be based on sound science.

With regard to State initiatives to promote fuels and vehicle technologies that reduce greenhouse gas emissions and improve tailpipe emissions, AIP believes strongly these initiatives should complement and not duplicate or conflict with Commonwealth measures. The Commonwealth is already moving to implement measures on vehicle technology and conventional fuel standards that will by the end of the decade:

- *Improve tail pipe emissions to the point that all reasonable air quality objectives are met. Further changes to the engine technologies and fuel standards will have a diminishing marginal impact.*
- *Improve vehicle fuel efficiency (and so greenhouse gas emission performance) through the Introduction of tighter new vehicle fuel consumption targets.*

Following these developments, conventional and currently-known alternative fuels will have equivalent overall environmental performance. There is therefore little reason for States to further promote alternative fuels for environmental reasons. Alternative fuels should be allowed to develop their own sustainable market niches. The three key criteria for these must be:

- *Reliability and sustainability of long term supply;*
- *Cost competitiveness of the fuel against other fuels;*
- *Acceptance by customers.*

AIP believes that there are potentially some significant greenhouse and air quality benefits to be gained from States introducing more holistic demand-side measures, such as traffic congestion management, urban planning, and in-service emissions control.

3.4 Participating Stakeholders

The following stakeholders have chosen to participate in this study:

- Australian Liquefied Petroleum Gas Association Ltd (ALPGA)
- The Australian Institute of Petroleum (AIP)
- Automotive Alternative Fuels Registration Board
- The Australian Trucking Association
- BP Australia Pty Ltd
- The Bus Industry Confederation
- Clean Air Refuelling (C.A.R.)
- CNG Transport Fuels and Technology
- Chris Mardon (Independent)
- CRC for Advanced Automotive Technology
- Croydon Bus Service
- Environment Victoria
- ExxonMobil
- Future Enterprises
- Greenfleet Australia
- Isuzu-General Motors Australia Limited, (IGM)
  Public Transport Users Association (PTUA)
- Royal Automobile Club of Victoria (RACV)
- Solar Hydrogen Research Pty Ltd (created and administered by HEC consulting)
- Ventura Bus Lines

4 Appendix D: Scientific Review

'There are large uncertainties about how all these technologies will develop, especially fuel cells, and especially over longer time horizons. Therefore, all our assessments are correspondingly uncertain. Important uncertainties are not confined to energy and GHG results. They extend to cost, to diesel ICE tailpipe emissions, to other performance attributes of FC vehicles, and to customer acceptance. Successful development and penetration of new technologies requires acceptance by all major stakeholder groups: private-sector fuel and vehicle suppliers, government bodies at many levels, and ultimate customers for the products and services. Therefore, the economic, environmental, and other characteristics of each technology must be assessed for their potential impacts on each of the stakeholder groups.'[122]

4.1 Passenger motor vehicle (PMV) analysis

Propulsion technology and fuel grouping steEp factor summary

Results of analysis presented earlier (in Appendix A) indicated that the greatest potential for reducing road transport GHG emissions is to be found in the PMV fleet. This potential dominates that existing for all other sections of the overall fleet. On this basis, the technology and fuel options examined for this study are generally considered in the context of PMV application. The research dimensions incorporate social, technical, economic, environmental and political factors that are likely to most significantly affect the uptake of the propulsion technology and fuel groupings (PTFG) considered. These factors are referred to collectively by the acronym 'steEp'. For the purpose of the present study, the central focus on environmental concerns has been emphasised. The steEp factors generally represent the basic set of exterior, systems-oriented criteria of interest in any foresight-type study. The following summary for PMVs is generally applicable to LCVs and to trucks and buses. Brief consideration to significant departures for vehicle types other than PMVs will be given in a later section.

4.2 Morphological analysis of GHG emissions

Reducing GHG emissions for the road transport vehicle fleet will involve a combination of the following measures:

1. Improving the overall efficiency of vehicles - changing fleet vehicle technology profile;
2. Deriving the energy to power vehicles from sources that, over their life cycle, emit less GHG to the atmosphere - changing fleet-wide fuelling profile;
3. Reducing the GHG emissions exbodied in the manufacture of vehicles;
4. Overall fleet size and fleet changeover rate, taking into account the contribution to overall GHG emission made by vehicle manufacture and distribution (given only brief consideration in this study as it does not relate solely or specifically to alternative fuels and technologies); and
5. Changing vehicle usage patterns (external to the scope of the present study).

Measure (1) above (improving the overall efficiency of vehicles) can be achieved by a combination of two independent approaches[123]:

a. Reducing the power output required for vehicles to perform their transport tasks; and,

b. Increasing vehicle drive train efficiency.

Approach (a) can be achieved by such methods as reducing vehicle mass, reducing aerodynamic drag and reducing rolling resistance. In addressing approach (b), the drive train can be further subdivided into:

i. Engine; and,

ii. Transmission.

Several means are available to improve the efficiency of each drive train component. The overall morphology described above is shown graphically in Figure 4.1. This shows details of the family of options available in each morphological branch being considered in this study.

Figure 4.1 is a summary of the vehicle propulsion technology and fuel groupings (PTFG) considered in this study. These groupings apply to each of the road transport vehicle types. Most discussion here will, however, be oriented towards PMVs on the basis of the earlier analysis indicating the far greater potential for impact on overall GHG emissions available for this vehicle type.

Overall GHG emission intensity of vehicle use (CO_2-eq). Expressed as g/km (PMVs), g/tonne-km (LCVs and Trucks), g/person-km (Buses)																					
1. Overall vehicle efficiency									2. Fuel type and fuel processing pathway, which together determine the life cycle GHG intensity of fuel (CO_2-eq). Expressed as g/MJ												
a. Overall drive train efficiency						b. Overall power output required															
i. Engine type			ii. Transmission type																		
Compression Ignition	Spark Ignition	Fuel Cell	Direct Electric	Hybrid Electric	Advanced conventional	Reduced mass	Reduced rolling resistance	Reduced aerodynamic drag	ULSD	Diesohol	Aquadiesel	Biodiesel	Petrol (PULP)	LPG	Petrohol E10P	Anhydrous Ethanol E85P	CNG	LNG	Hydrogen (from NG)	Hydrogen (electrolysis with renewable electricity)	Diesel from NG (GTL [Fischer-Tropsch] processing)
■					■	■	■	■	■	■	■										
■					■	■	■	■				■									
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Figure 4.1: Morphological table for indicating factors contributing to road transport vehicle GHG emissions and describing PTFG under consideration.

Notes for Figure 4.1:

1) Each row represents a propulsion technology and fuel grouping (PTFG), with some groupings suitable for multiple fuels (eg Compression Ignition engines can use ULSD, Biodiesel, Aquadiesel or Diesohol).
2) Advanced conventional transmission type refers to a convention mechanical transmission between the engine and drive wheels using technology such as constant velocity transmissions (CVT) or microprocessor-controlled gearbox.
3) ICE hybrid electric vehicles in studies consulted for the current work generally employed some combination of hybrid electric transmissions and advance mechanical transmissions as described in note 1) above. On this basis, the cells for both hybrid electric and advanced conventional transmission types are shaded for these vehicles.

4.3 Comparison of GHG emissions from PTFG

Measures to reduce the required power output for a given transport task are viewed as evolutionary and are not discussed here beyond noting their potential to contribute to overall GHG emission reductions independently of other measures. Reduction of the PMV fleet's average vehicle mass has the potential to significantly impact on total GHG emissions. Measures aimed at encouraging the reductions to vehicle size and mass would be an effective means of reducing GHG emissions within the limits of incumbent vehicle technology and fuel systems. But, as observed by Green and Schafer, 'if market trends continue to favour ever heavier and more powerful vehicles, technologies that could be used to increase fuel economy will instead be needed just to hold it constant.'[124]

The contribution to life-cycle GHG emissions of vehicles from their manufacture and distribution is not depicted in Figure 4.1. Meaningful comparison of vehicle technology and fuel combinations requires consideration of the full life-cycle emissions including vehicle manufacture and distribution. Six landmark studies provided primary input to the research phase of this work. Three of the studies consider well-to-wheel fuel use, and two consider well-to-wheel fuel use plus the entire vehicle manufacture and supply process in determining the GHG emissions for each vehicle technology and fuel grouping. These studies have all been conducted for PMVs. The studies are listed in Table 4.4.

Study title and participating organisations	Release date	Study scope	Study type
Life-cycle Emissions Analysis of Alternative Fuels for Light Vehicles: Report (HA93A-C837/1/F5.1F) to the Australian Greenhouse Office, CSIRO Atmospheric Research, CSIRO Environmental Risk Network, RMIT Centre for Design, University of Melbourne Department of Mechanical and Manufacturing Engineering (Australia)[125]	2004	Australia, 2004	Well-to-wheel for fuel, considering a range of currently available PMVs, expanded to include family-size petrol and diesel hybrids.
Comparative Assessment of Fuel Cell Cars, Massachusetts Institute of Technology Laboratory for Energy and the Environment (USA)[126]	2003	US, 2020	Well-to-wheel for fuel plus vehicle life cycle (cradle-to-grave)
On the Road in 2020: A life-cycle analysis of new automobile technologies, Massachusetts Institute of Technology Energy Laboratory (USA)[127]	2000	US, 2020	Well-to-wheel for fuel plus vehicle life cycle (cradle-to-grave)
GM Well-to-wheel Analysis of Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems - A European Study, General Motors, L-B-Systemtechnik GmbH, BP, ExxonMobil, Shell and TotalFina Elf (Germany)[128]	2002	Europe, 2010	Well-to-wheel for fuel (based on a particular PMV)
Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems - North American Analysis, General Motors Corporation, Argonne National Laboratory, BP, ExxonMobil and Shell (USA)[129]	2001	US, 2005 onwards	Well-to-wheel for fuel (based on a particular PMV)
Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context, 'WELL-TO-WHEELS Report', version 1b, January 2004, European Commission Directorate-General Joint Research Centre[130]	2004	Europe, 2010 and beyond	Well-to-wheel for fuel (based on a particular PMV)

Table 4.4: Key reference studies for PMV PTFG.

Figure 4.2 summarises the GHG emission results from the MIT well-to-wheel plus vehicle production studies.[131] In examining this data, it should be kept in mind that several of the broad technology options are capable of operating with a number of the fuels under consideration in the present work (see Figure 4.1). In practice, some modifications would be required in some cases to allow a specific real-world vehicle to operate on more than one of the fuels. For example, storage tanks, evaporators and different refuelling infrastructure would be required to run a vehicle on LNG that was designed specifically for CNG. While the results are specifically for PMVs, they provide an appropriate basis for comparing options for LCVs and similarly provide an indicative basis for heavy vehicle technology and fuel grouping performance.

In terms of steEp factor analysis this obviously presents a partial picture only. The intention is to provide an illustration of the various options to meet the primary aim of the Victorian Greenhouse Strategy, the reduction of GHG emissions, as a 'first screen' prior to considering subsidiary assessment criteria.[132]

The relative ranking of GHG emissions for PTFG under consideration in the current study is shown in Table 4.5.[133] It should be noted that the MIT studies present projected performance for 2020, a timeframe that includes the particular period of interest for this study. It is particularly significant that technology based on the internal combustion engine (ICE) and conventional liquid fuel is seen as remaining competitive on a GHG emission basis for at least the next fifteen years. In summarising their findings the MIT Laboratory for Energy and Environment states that 'if it is important to make significant reductions in fleet energy use and GHG emissions during the next 20 years, then *improved ICE vehicles offer the quickest and easiest technology options* for realizing those objectives.'[134] [*emphasis added*]

Several of the PTFG indicated in Figure 4.1 have been omitted from Table 4.5. For the CI ICE biodiesel option, the fuel production pathway has a large impact on the overall GHG emissions. Emissions range from around 0.005 kg CO_2-eq/MJ for biodiesel from waste oil to as much as 0.05 kg CO_2-eq/MJ from tallow, compared with around 0.09 kg CO_2-eq/MJ for LS diesel.[135] A PTFG utilising biodiesel is clearly attractive from the point of view of GHG emissions. However, as will be discussed later, fuel availability constrains this option to niche applications. The SI ICE Anhydrous Ethanol (E85P) option has also been omitted on the grounds of fuel production pathway variability and overall fuel availability for any particular path. Anhydrous Ethanol also provides the potential for significant GHG emission reduction and would be attractive in niche applications within the timeframe of this study. The SI ICE LNG option offers potential GHG emissions slightly higher than SI ICE CNG due to the extra energy required compressing the fuel to a liquid. In terms of the overall ranking of this option, it could be considered equivalent to SI ICE CNG. SI ICE LNG is omitted from the table on the grounds that it is not specifically covered in the main references.

The results from the MIT studies are largely supported by the GM European Well-to-Wheels study and the GM North American Well-to-Wheels study, particularly with regard to the major trend of Hybrid ICE vehicles performing as well as FC vehicles using hydrogen from reformed natural gas (NG).[136] The GM North American study concludes that 'Compared to the gasoline SI (conventional), the gasoline SI and diesel CIDI HEVs, as well as the diesel CIDI (conventional) yield significant total system energy use and GHG emission benefits.'[137] The main differences are small changes to the relative performance of CNG as a result of differences between drive cycles and local compositions of NG. Overall, though, it is expected that SI engines running on NG have significant scope for efficiency improvements that will lead to them outperforming CI engines running on petroleum diesel in the long term.[138]

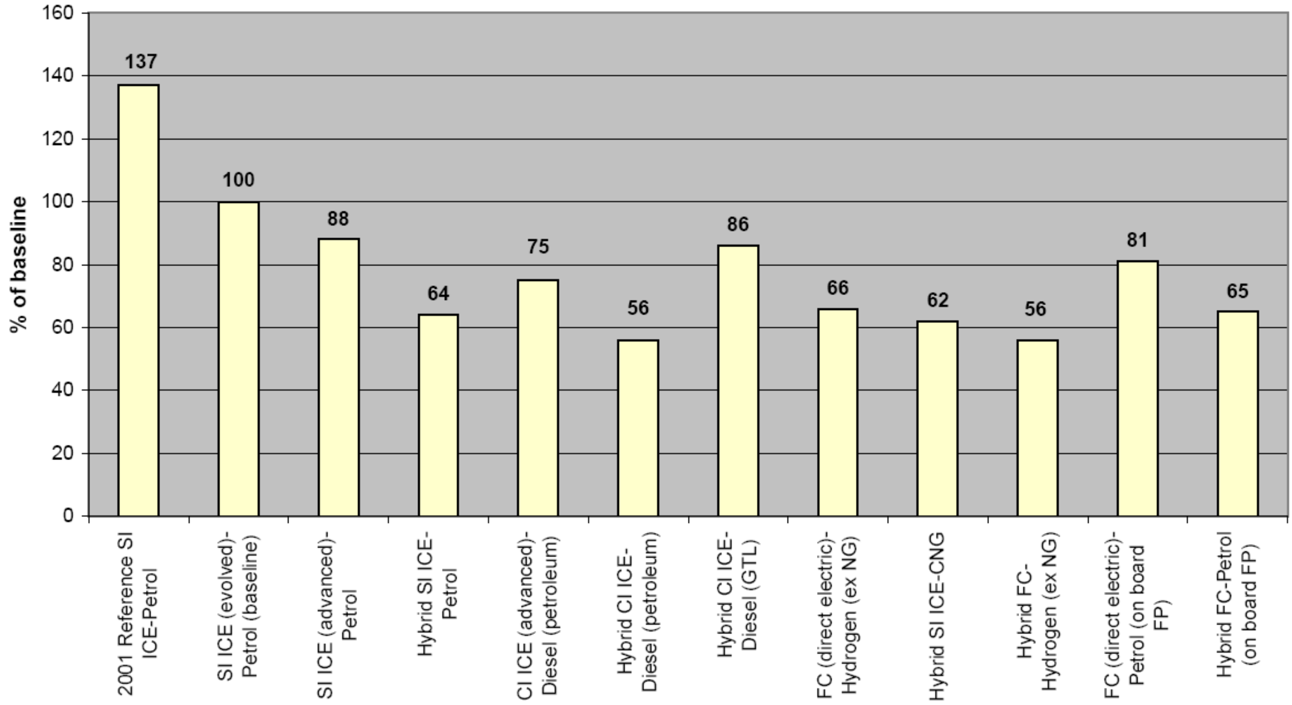


Figure 4.2: Relative life-cycle GHG emissions for PMV PTFG, based on projections to 2020. Adapted from results of MIT studies.[139]

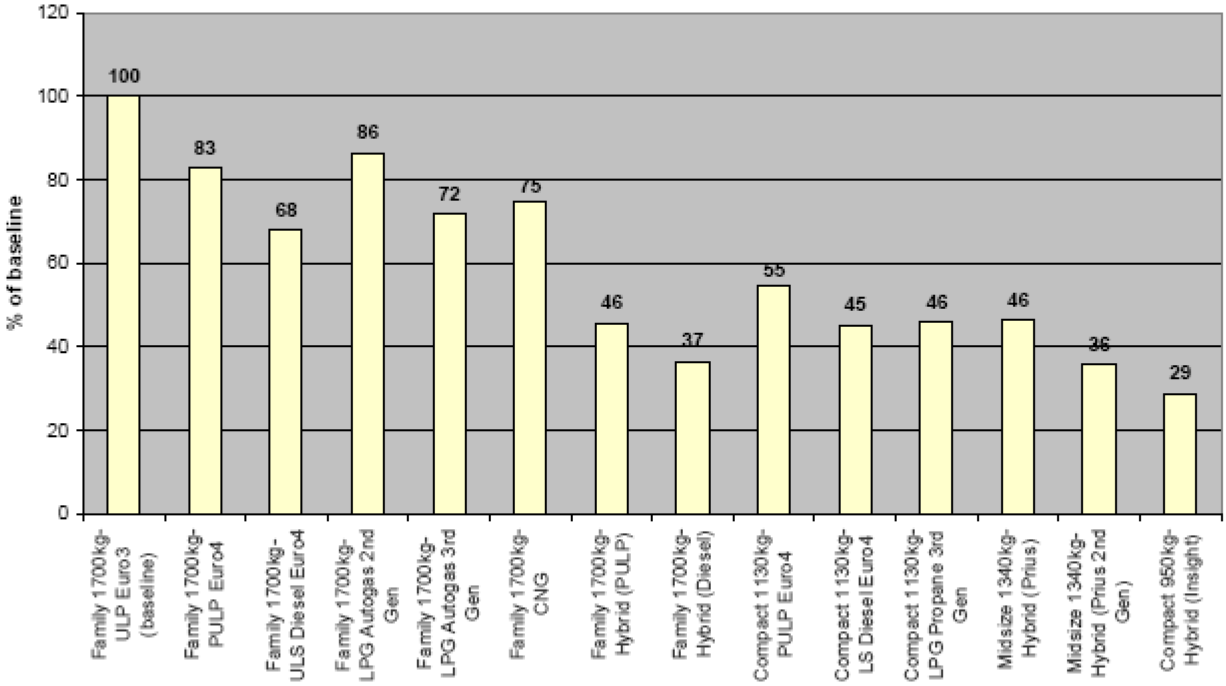


Figure 4.3: Exbodied GHG emissions from a range of currently available PMVs (European drive cycle). Adapted from study by CSIRO *et. al.* into life cycle emissions of light vehicle fuels.[140]

Relative ranking (lowest to highest GHG emissions)	Propulsion technology and fuel grouping description
1	Hybrid FC-Hydrogen (electrolysis with electricity from renewable source, or NG reformation with geosequestration of CO_2)*
2	Hybrid SI ICE-CNG
3	Hybrid CI ICE-Diesel (petroleum), Hybrid FC-Hydrogen (NG reforming)
5	Hybrid SI ICE-LPG*
6	Hybrid SI ICE-Petrol, Hybrid FC-Petrol (on board reforming)
8	FC (direct electric drive)-Hydrogen (NG reforming), Hybrid CI ICE-Diesel (GTL)
10	SI ICE (advanced)-CNG*
11	CI ICE (advanced)-Diesel (petroleum)
12	SI ICE (advanced)-LPG*
13	SI ICE (advanced)-Petrol
14	CI ICE (advanced)-Diesel (GTL)
15	CI ICE (evolved)-Diesel (petroleum)*
16	SI ICE (evolved)-Hydrogen (NG reforming)*
17	SI ICE (evolved)-LPG*
18	SI ICE (evolved)-CNG*
19	SI ICE (evolved)-Petrol*

Table 4.5: Relative ranking of PTFG from Figure 4.1, primarily based on data from the MIT studies, but drawing on other sources where appropriate.

* PTFG not specifically indicated in the MIT study results above. Ranking is based on interpolation from references in Table 4.4 and from available data from a recent Australian study.

The study recently completed by CSIRO *et. al.* (see Table 4.4) supports the relative GHG performance ranking for the major hydrocarbon fuels when used in conventional and hybrid ICE vehicles, and emphasises the influence of vehicle mass.[141] It should be noted that this study is based on existing vehicle design and performance and so is not directly comparable with the MIT data, which makes projections to 2020. The MIT study includes the exbodied emissions attributable to vehicle manufacture, while the recent Australian study does not. This presents some significant challenges to integration of the various data sources. Data adapted from the CSIRO *et. al.* study's report is shown in Figure 4.3.

Some disagreement is found for the relative performance of CNG, which performs in this study more poorly than diesel. The study's authors note that the relative performance of CNG and diesel are sensitive to the drive cycle assumed for the analysis, and that use of an alternate cycle in fact resulted in CNG outperforming diesel.[142] On this basis, and given that the figures in the available data are for current technology, the ranking in Table 4.5 has been left 'as is' on the assumption that projected improvement of CNG SI ICEs relative to Diesel CI ICEs are likely to be realised within the next ten years. The report adds information for LPG, which is absent from the MIT and GM studies. The study places LPG GHG emissions between diesel and petrol. The relative ranking of LPG ICE vehicles in Table 4.5 is based on this data. The ranking of the 'evolved' vehicles is based on the information in Figure 4.3, taking account of the relative performance of the 2001 reference vehicle shown in Figure 4.2. The evolved vehicles are those that are currently available or expected to be available in the immediate future. The term 'evolved' is intended to denote vehicles that have benefited from incremental improvements experienced as part of conventional development processes, without the application of revolutionary technology breakthrough. This introduces a temporal dimension to the ranking, from the present time to 2020. The table represents the plausible range of vehicles that is likely to comprise the overall fleet mix over the ten-year timeframe of this study.

The significant potential for GHG emissions reductions presented by the uptake of currently available hybrid petrol vehicles is clearly apparent. Given their use of the existing fuel infrastructure and the commitment already shown by major manufacturers, this PTFG option appears to offer many clear benefits.

Of particular note in Figure 4.3 is the performance of LS diesel Euro 4 and LPG 3rd generation vehicles compared with the petrol hybrid. This illustrates the significance of reduced vehicle mass coupled with efficient, but conventional, engine technology. This is important in considering appropriate migration paths to reduced fleet GHG emissions.

4.3.1 Comparison of air pollutant and GHG emissions from currently available PTFG

The GHG emission performance comparison presented in the previous section is the first tier screen for this study. While a key aim is to investigate the potential for alternative fuel and technology pathways to contribute to the GHG reduction goals of the Victorian Greenhouse Strategy, any positive contribution will need to take place within the context of the wider environmental, social and economic concerns of the State of Victoria. On the basis of EPA Victoria's overall environmental mandate and road transport's high impact on air quality, air pollution considerations represent the most important second tier screening criteria for the study. Broadly stated, any change trajectory embarked upon to lower GHG emissions from road transport in Victoria must be considered in light of its correlative impact on air quality. Any pathway that could potentially reduce GHG emissions but that threatened to negatively impact on air pollutant levels would have to be considered as significantly compromised, if not excluded from consideration outright. In addition, any attractive option for GHG reduction must be considered in light of future restrictions on air pollutant emissions. The most appropriate alternative fuel and technology options would, while meeting overall GHG reduction aims, offer corresponding improvements in air quality.

The landmark US and European studies listed in Table 4.4 cited in relation to well-to-wheels and cradle-to-grave GHG emissions do not specifically consider air pollutant emissions. The CSIRO light vehicle fuels life cycle comparison provides comprehensive analysis of major air pollutant emissions from PMVs.[143] Performance of family and compact-size PMVs is considered with regard to particulate matter (PM[10]), oxides of nitrogen (NO_x), carbon monoxide (CO) and non-methane volatile organic compound (NMVOC) emissions. While all major PMV fuels are considered, caution is required in integrating this data with the findings of the other studies in Table 4.4.

Those studies all consider vehicle performance over a time frame ranging from the near-term future out to 2020, whereas the recent Australian study focuses on present-day technology and near-future. Consideration is not given to potential future developments in, for example, PM filtering and NO_x catalyst technology, that could alter the situation portrayed here. This is particularly relevant to diesel vehicles. The recent Australian study highlights that while diesel vehicles were found to have the lowest exbodied GHG and CO emissions, their PM emissions exceed every other fuel class.[144] Hybrid diesel vehicles exhibit PM(10) emissions that far exceed that of the baseline petrol-fuelled vehicle in the CSIRO light vehicle study.

Figure 4.4 to Figure 4.7 has been adapted from data in the CSIRO light vehicle study. The emission estimates are based on a European drive cycle. The good overall pollutant emission performance of hybrid petrol, third generation LPG vehicles and CNG vehicles stand out here as promising, particularly when considered against their GHG emissions performance. Hybrid LPG and CNG appear to offer the potential for significant reduction in both GHG and major air pollutants per vehicle, although, as will be discussed later, fuel supply infrastructure may limit this potential at the level of the overall fleet.

The improved emissions performance of the second generation Toyota Prius over the first generation version reflects the improved GHG performance. This illustrates well the strong potential for petrol hybrid vehicles to provide ‘no compromise’ atmospheric improvements relative to the present fleet average, and the scope for ongoing improvements.

Both conventional and hybrid diesel vehicles are attractive from the perspective of GHG reductions, particularly considering that conventional diesel vehicles are already established in the market, are well supported overseas manufacturers (particularly European manufacturers) and use a readily available conventional fuel. However the appropriateness of a large-scale shift to diesel vehicles in the PMV fleet would have to be regarded as highly questionable in light of their very high PM(10) emissions. Such a shift could be expected to have a significant detrimental affect on urban air quality and subsequent increase in severity and extent of a range of respiratory illnesses. Declining air quality would seem to be an inappropriate tradeoff for reduced GHG emissions, particularly when readily available options to reduce both GHG and air pollutant emissions are open to us.

While this is so, some mention should be made here of the *potential* for reducing PM emissions from diesel vehicles through tailpipe filtering. Tailpipe filtering is discussed in some detail in section 4.3.5.1.1. If tailpipe filtering does prove to be a viable means of reducing the epidemiological impact of the road transport fleet to a level that we are able to accept as a society, then diesel PMVs, especially where combined with hybrid technology, would offer an important pathway for reducing road transport GHG emissions. In the heavy vehicle classes, where diesel-fuelled vehicles already dominate, pursuit of improved diesel technology, including development of hybrids, would have the dual benefit of reducing GHG and particulate matter emissions.

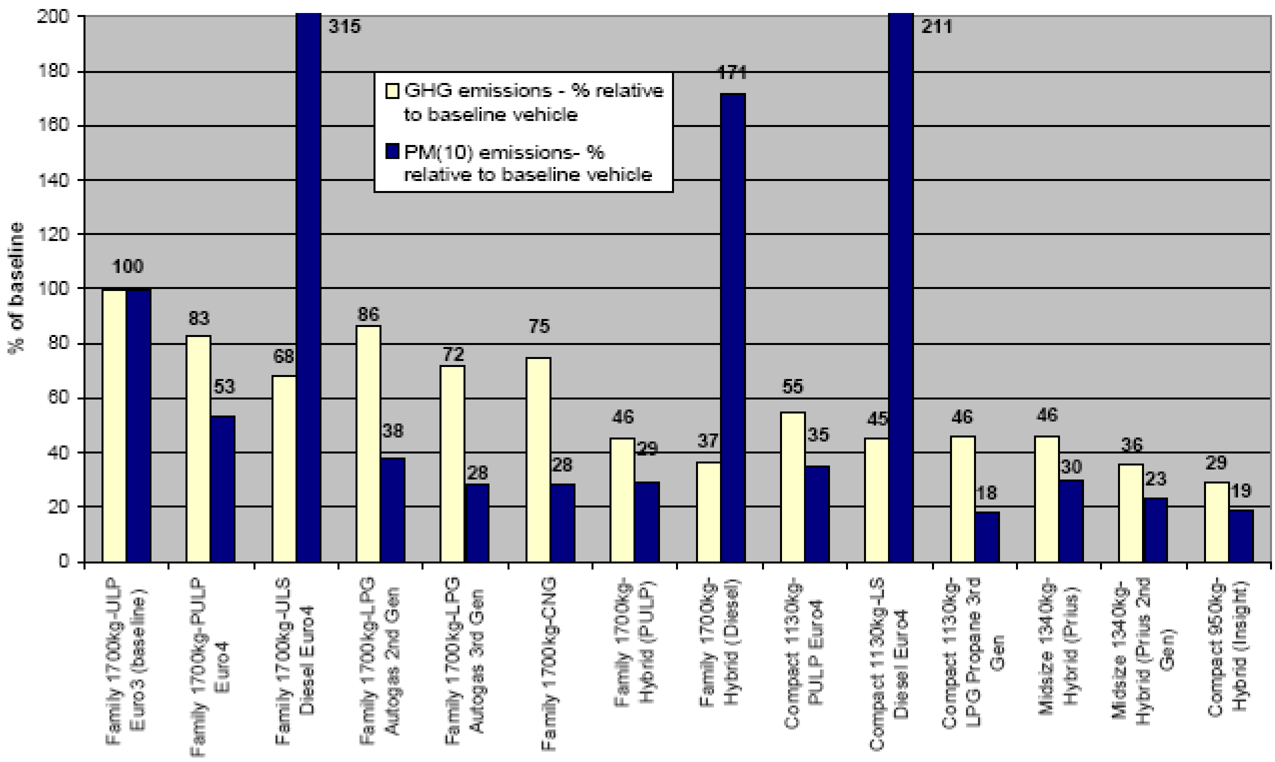


Figure 4.4: Relative GHG and PM(10) emissions for a range of currently available PMVs. Adapted from the CSIRO light vehicle fuel emissions study draft report.[145]

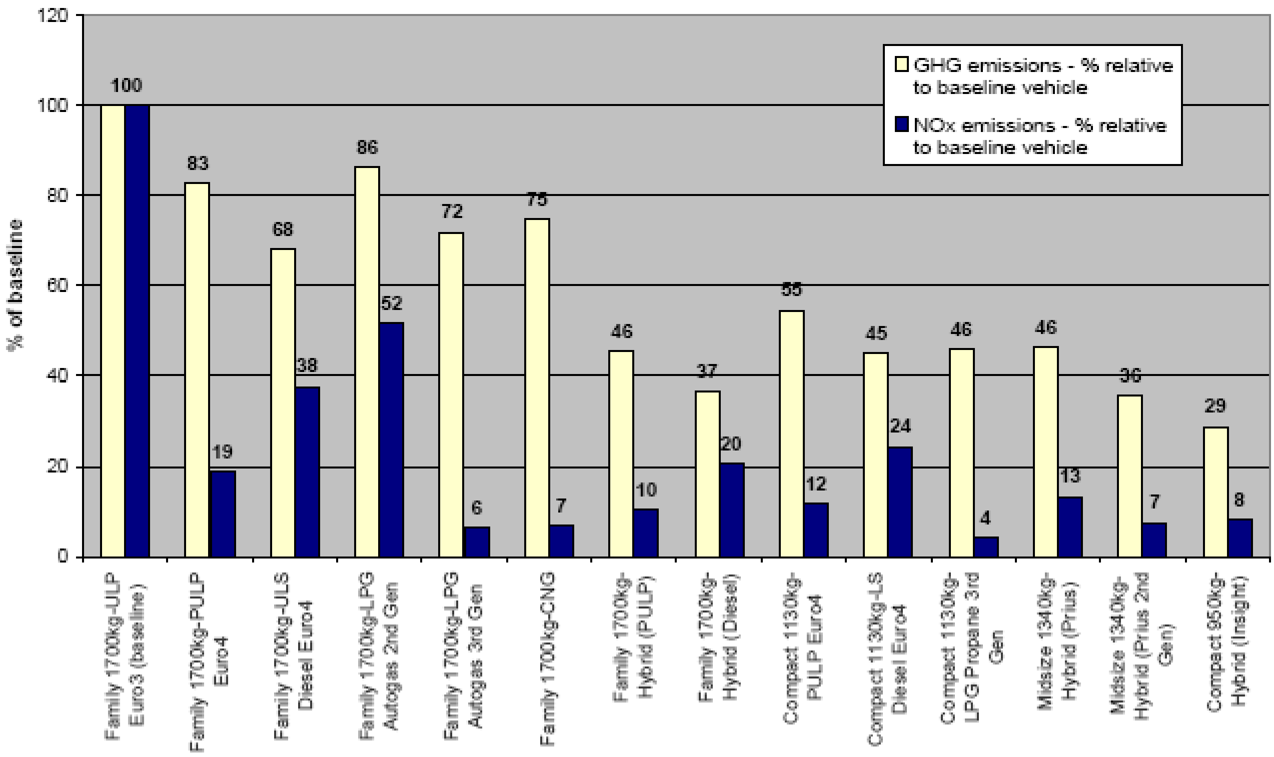


Figure 4.5: Relative GHG and NOx emissions for a range of currently available PMVs. Adapted from the CSIRO light vehicle fuel emissions study draft report.[146]

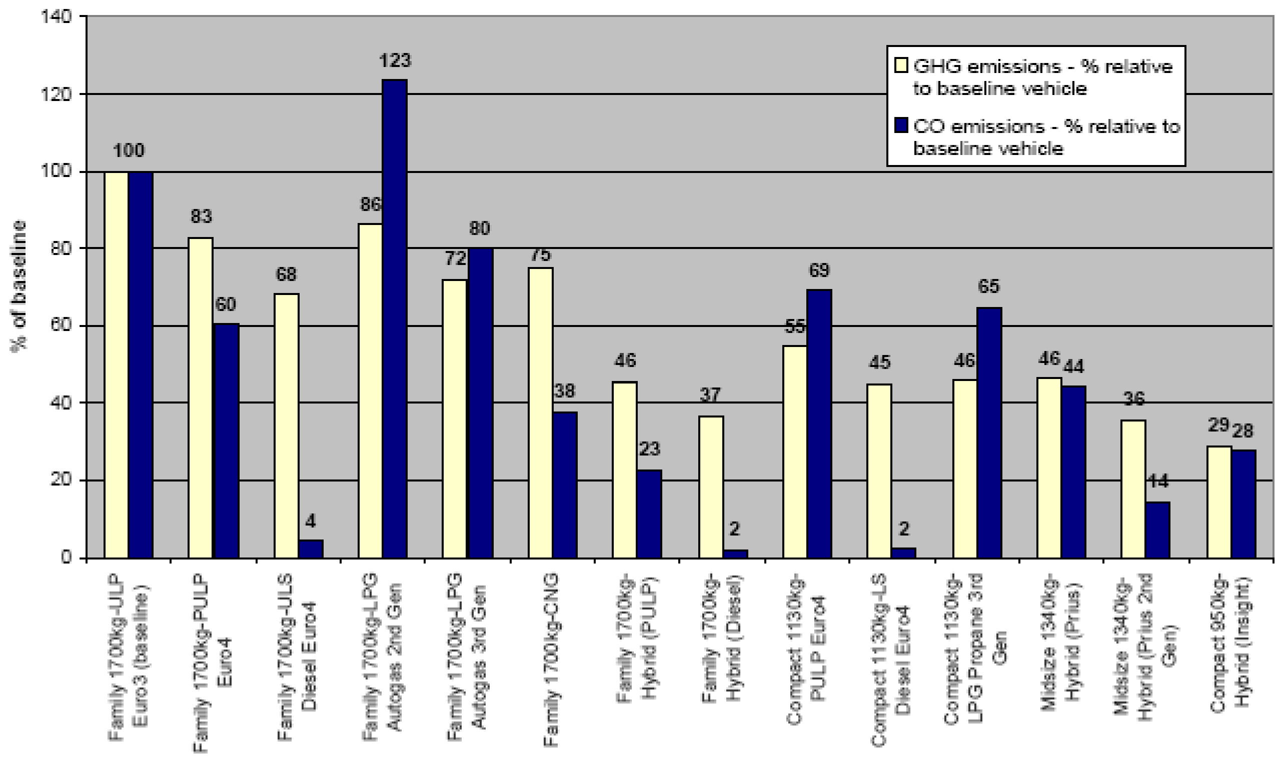


Figure 4.6: Relative GHG and CO emissions for a range of currently available PMVs. Adapted from the CSIRO light vehicle fuel emissions study draft report.[147]

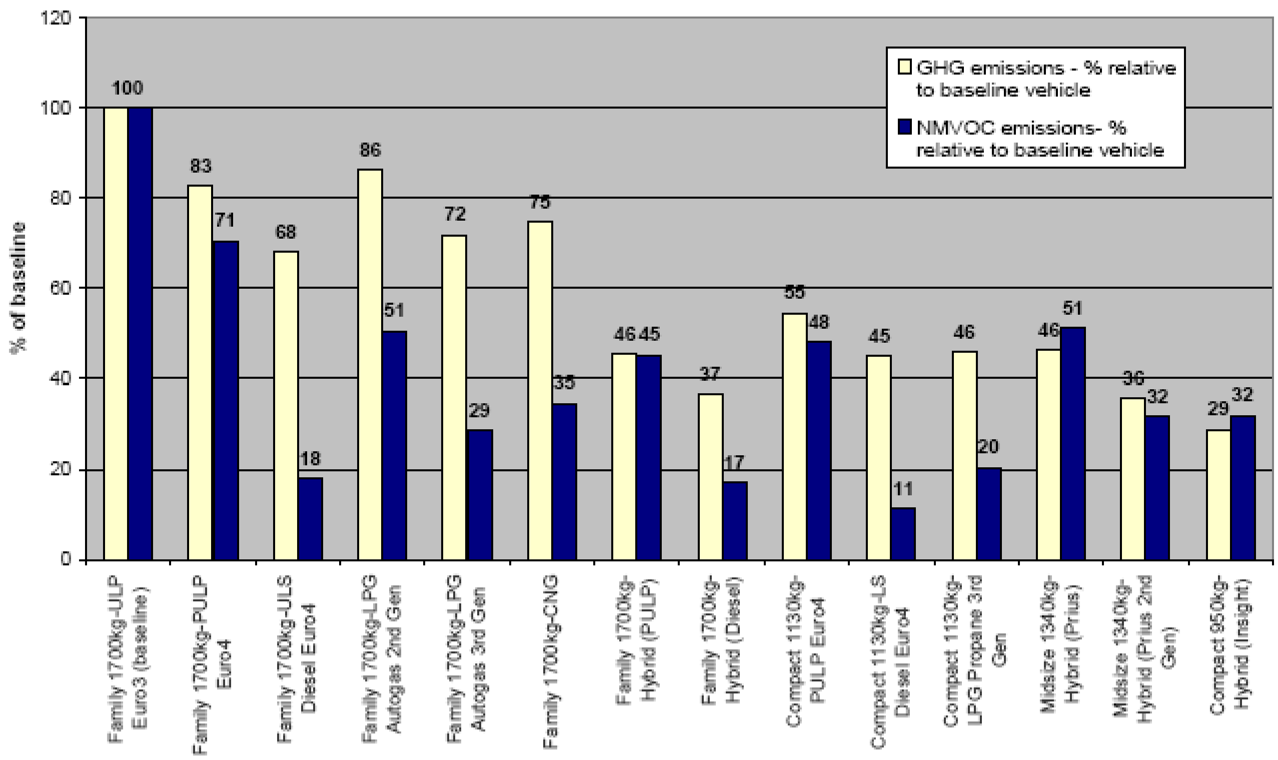


Figure 4.7: Relative GHG and NMVOC emissions for a range of currently available PMVs. Adapted from the CSIRO light vehicle fuel emissions study draft report.[148]

4.3.2 Energy use and GHG emissions comparison

Figure 4.8 shows total energy use for PTFG in addition to GHG emissions. This data is based on projections to 2020. This data indicates that, in general, life cycle energy use correlates closely with GHG emissions. While GHG emission reduction is the prime consideration of this study, performance against the GHG indicator does need to be considered in light of total energy consumption and availability. *CSIRO Energy and Transport Outlook to 2020* provides a useful graphic depiction of the relationship between GHG emissions and energy consumption for a number of major PTFG and generally supports the information in Figure 4.8. This is reproduced here in Figure 4.9.

The long-term sustainability of any PTFG must be weighed against its capacity for reduction of GHG emissions. Fischer-Tropsch Diesel and, to a lesser extent CNG, differ somewhat from the general trend of matched reductions in GHG emissions and energy use. The indication that ethanol fuels may have a negative impact on overall energy consumption is also of note. These observations should be accounted for in considering concerns around fuel security and energy equity. The attractiveness of options involving the use of natural gas in ICEs, either as CNG directly, or after a gas-to-liquid (GTL) process with carbon geosequestration may be moderated somewhat by the characteristic depicted here. It would seem appropriate to consider these issues in developing Government policy options for GHG reduction from road transport.

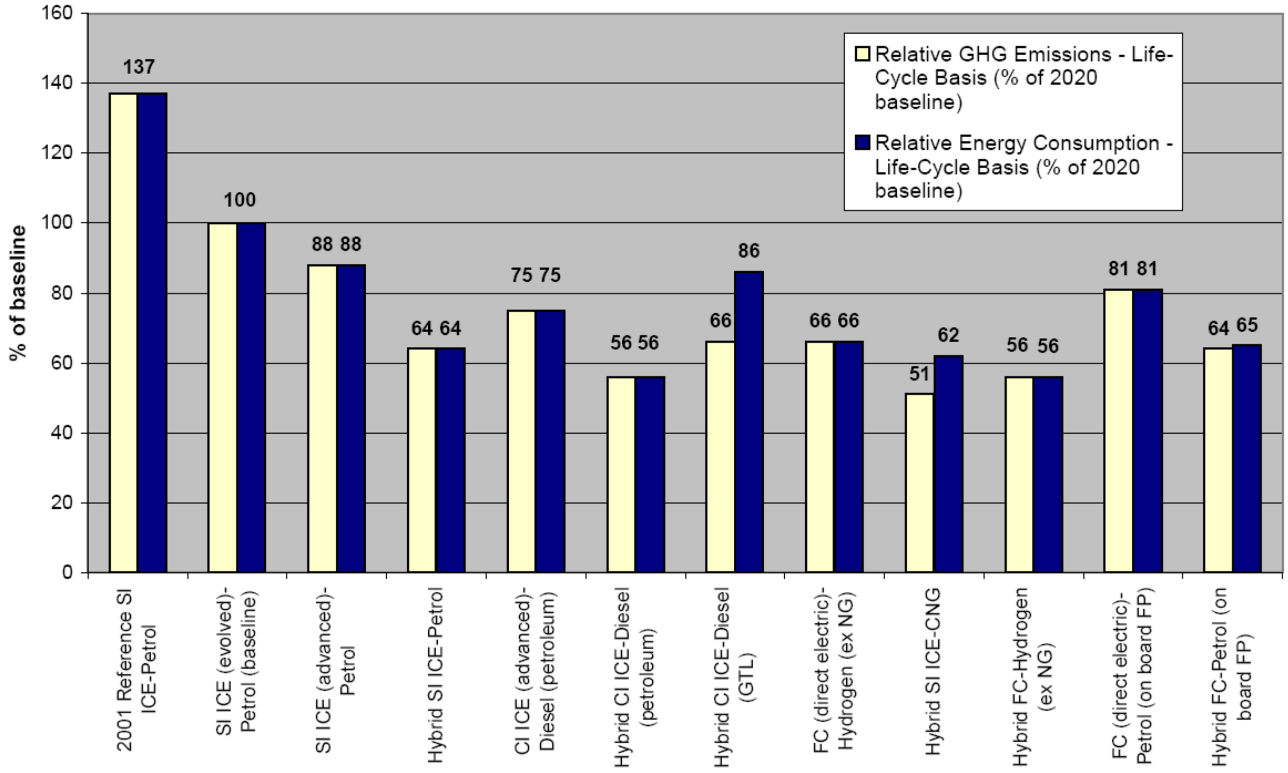
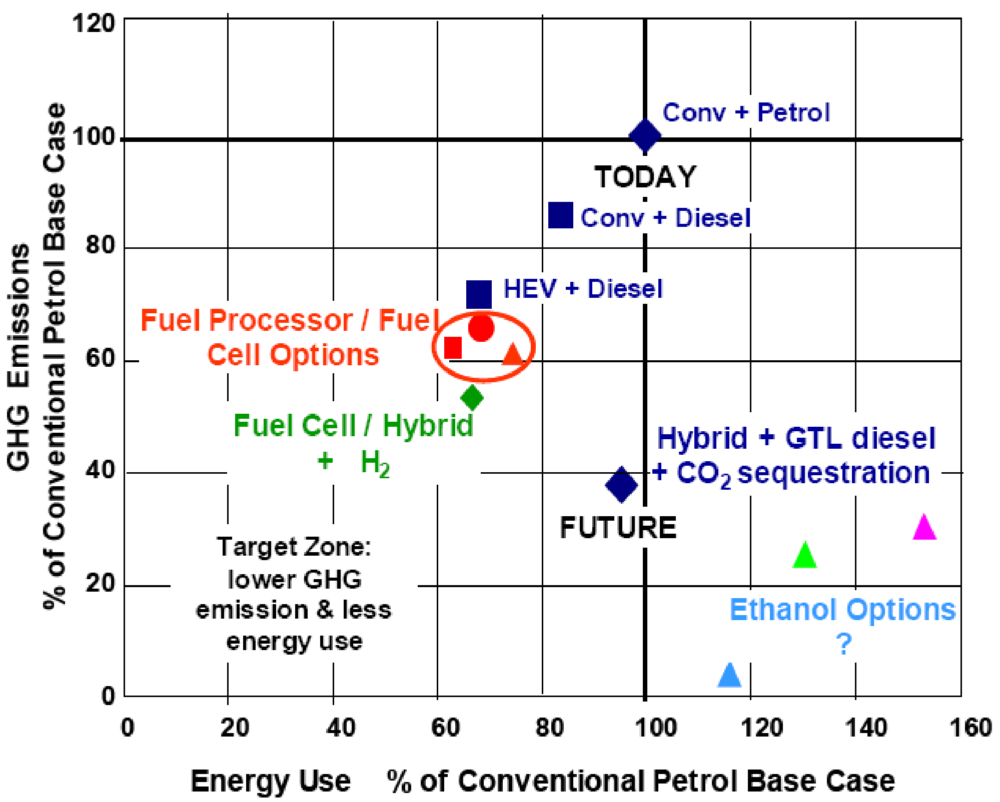


Figure 4.8: Relative GHG emissions and energy consumption estimates for a range of PMV PTFG in 2020. Adapted from MIT study data.[149]



Note: This figure is reproduced as presented in the original source document. No legend was provided for the various shapes used to represent the options under consideration. In interpreting the information presented, the text descriptor colour has been matched with the adjacent shape to determine the GHG and energy use correlations.

Figure 4.9: GHG emissions vs energy use for PTFG - reproduced from *CSIRO Energy and Transport Sector Outlook to 2020*.[150]

4.3.3 Relative technical challenge of PTFG

Table 4.6 ranks the major technology and fuel options on the basis of present day technical viability. This is based on analysis presented in the report *CSIRO Energy and Transport Sector Outlook to 2020*. Comparison of the technical viability ranking with the GHG emission reduction ranking in Table 4.5 will provide useful input into the scenario development process.

Technology challenge ranking - lowest to highest	Propulsion technology and fuel	Status
1	Conventional SI ICE-Petrol and CI ICE-Diesel	Incumbent vehicle base, existing
2	Hybrid SI ICE-Petrol and Hybrid CI ICE-Diesel	Petrol hybrids already on sale, diesel hybrids presented at major car shows
3	Hybrid FC-Petrol (on board reforming to hydrogen)	Being piloted, suffer from weight problems
4	Hybrid FC-Hydrogen	Being piloted, significant challenges with handling and storage of hydrogen

Table 4.6: Relative technology challenge to be overcome in introducing major propulsion technology and fuel groupings.[151]

4.3.4 Economic Comparison of PTFG

A comparison of relative estimated retail price projections for 2010 are presented in Figure 4.10. This covers the full range of technology options under consideration. This is based on information presented in the CONCAWE / EUCAR report *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context.*

Retail price and operating cost comparisons for the PTFG based on projections to 2020 are shown in Figure 4.11 and Figure 4.13.
Figure 4.11 adds comparative data on the relative projected retail price per unit mass. This data is adapted from the MIT study *On the Road in 2020*. The MIT study estimates retail price for the US context. This is of particular importance with regard to the impact of fuel price, and general taxation implications. This information will be of most benefit in providing a rough relative comparison of the economic impact of PTFG options on the end-user.

Relative price data for the PMV PTFG common to Figure 4.10 and Figure 4.11 is used to derive the indicative trends in Figure 4.12. It should be carefully noted that data specific to the European context and the US context is compared here, from two separate studies. The CONCAWE/EUCAR study make reference to the calculation method in the MIT study, and so it may be reasonable to assume that the basis for the projections in the two studies would allow broad comparison. Nonetheless, this should be treated as an indicative illustration only, describing a very general set of trends. The relative convergence of FC and Hybrid ICE vehicle prices towards 2020 is of note. This, however, appears to be of very limited significance within the time frame of the present study.

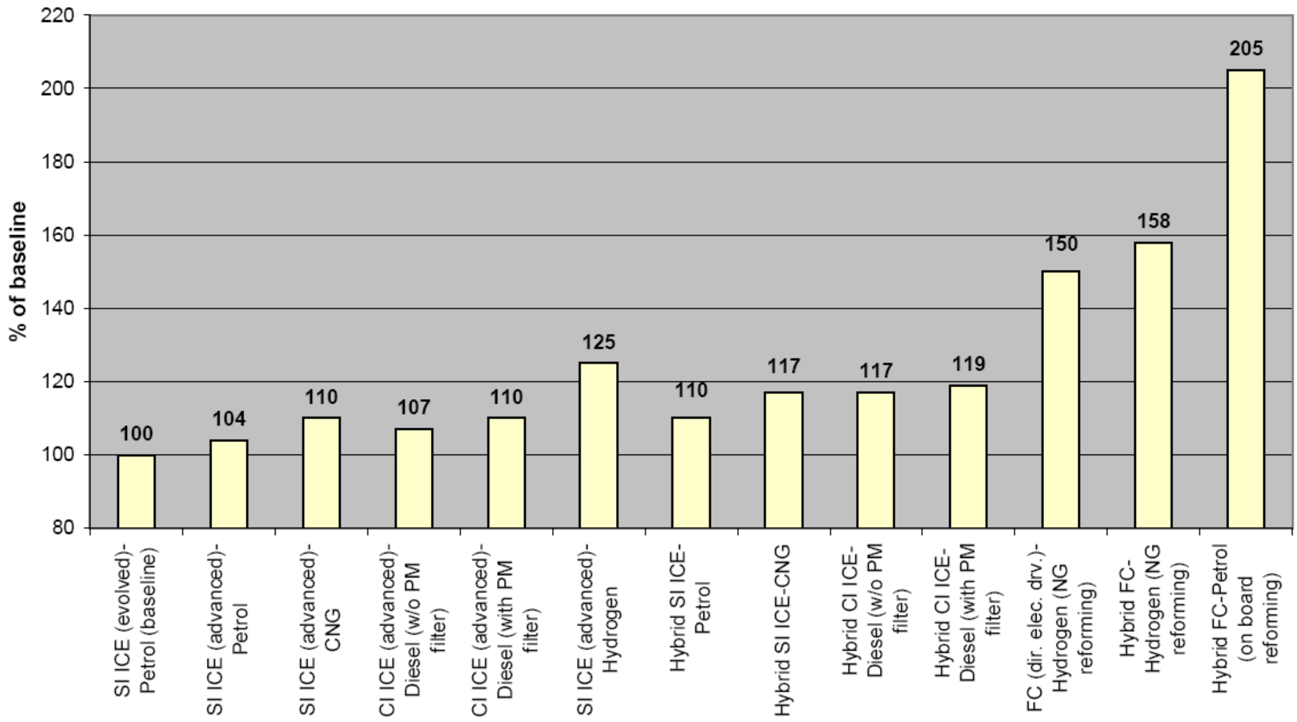


Figure 4.10: Comparison of relative retail price estimates (2010 PMVs). Adapted from data presented in the CONCAWE/EUCAR study.[152]

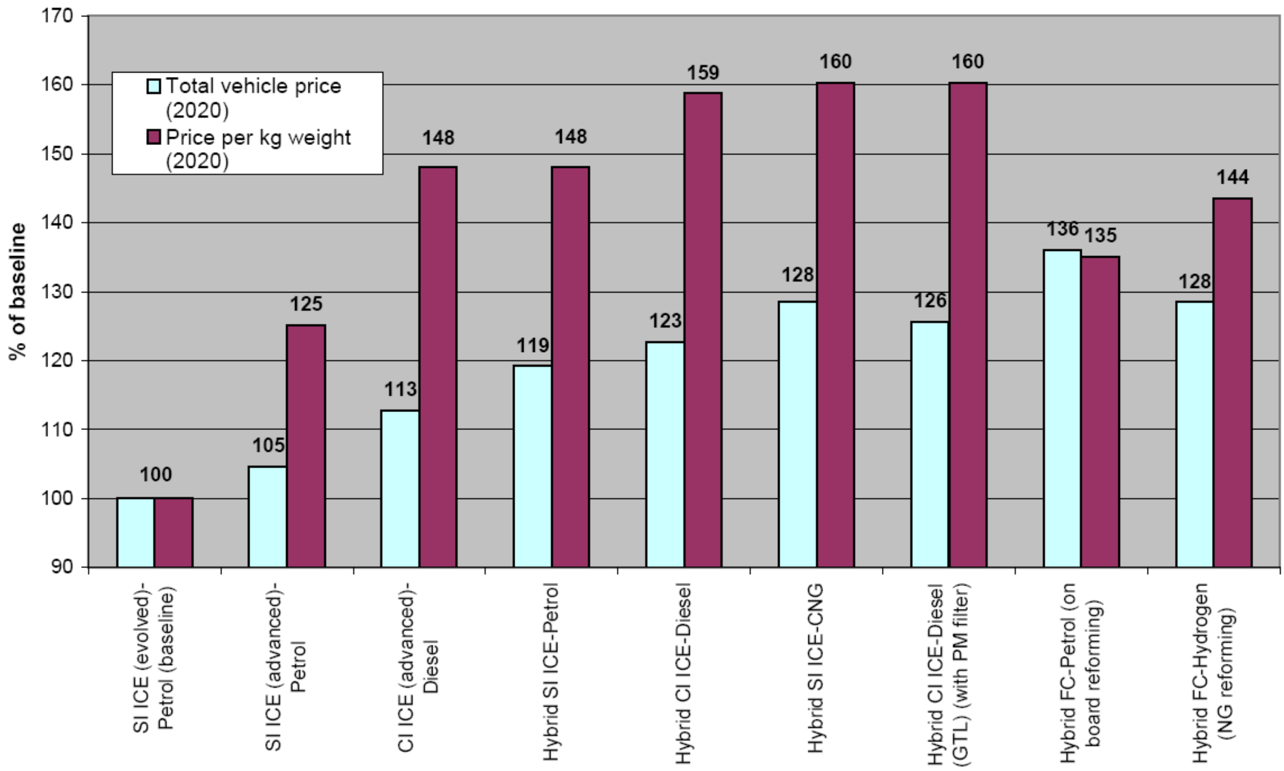


Figure 4.11: Comparison of relative retail price estimates (2020 PMVs). Adapted from data presented in MIT study *On the Road in 2020*.[153]

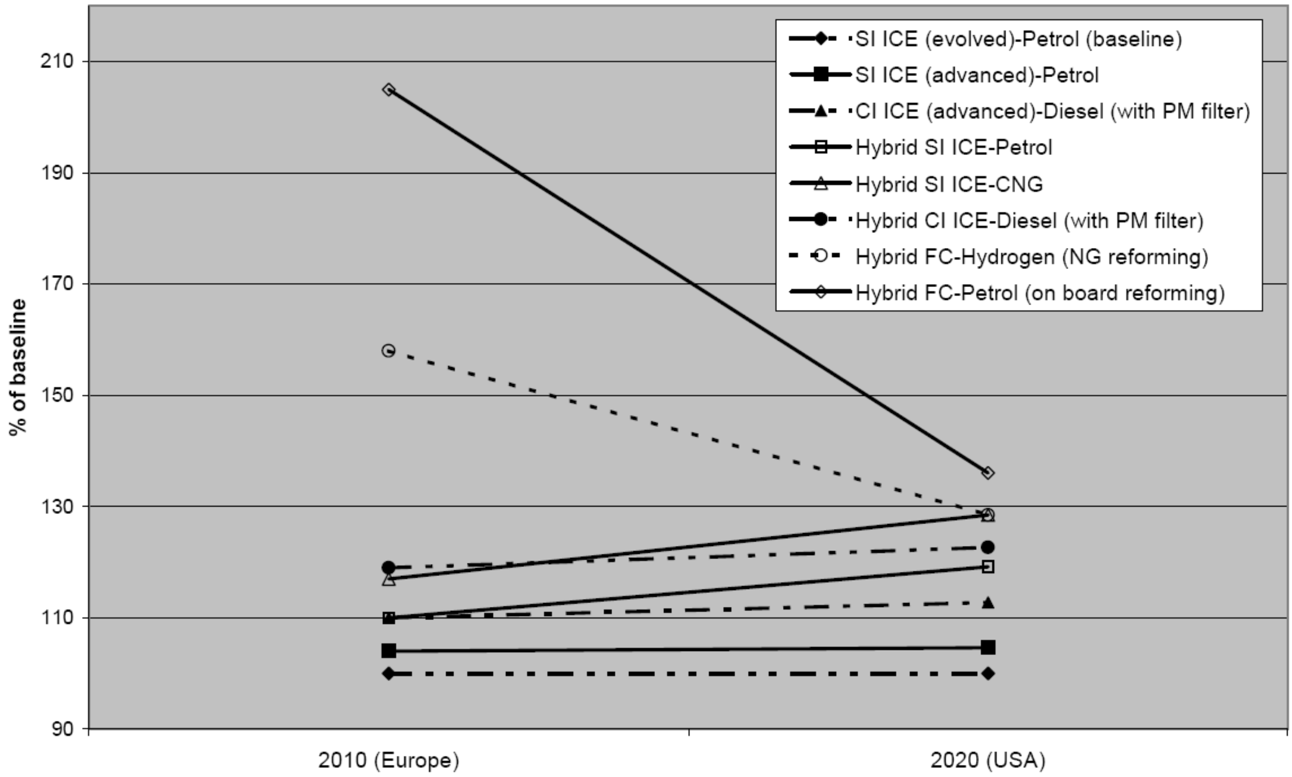


Figure 4.12: Indicative change in relative price for PMV PTFG - 2010 (Europe) to 2020 (USA)

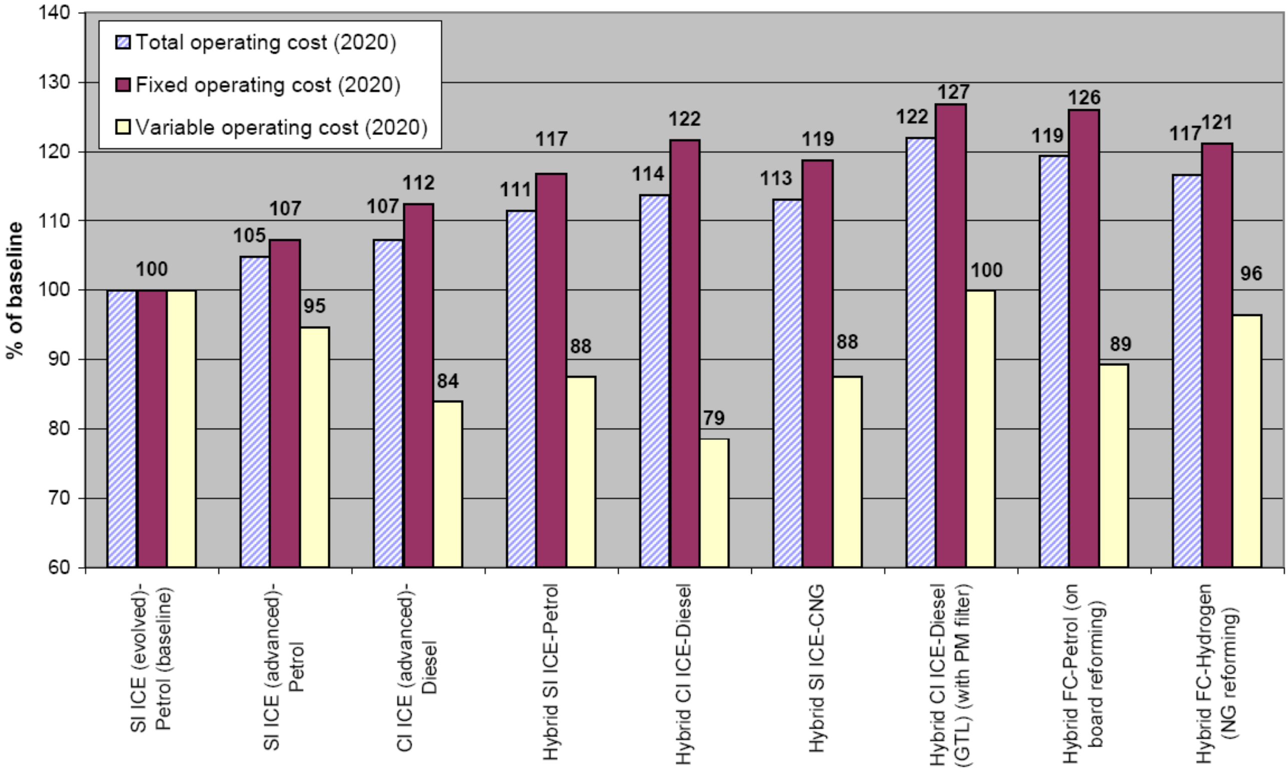


Figure 4.13: Comparison of relative operating cost estimates (2020 PMVs). Adapted from data presented in MIT study *On the Road in 2020*.[154]

Notes: (1) Figures above are based on vehicles driven 20,000 km/year. (2)Variable cost includes fuel cost, which is based in the original source on US fuel pricing, including, in particular, US fuel taxes.

The data presented above is for production vehicles, taking into account the scale effect of mass manufacturing. Particularly with regard to hydrogen FC vehicles, this should be borne in mind when considering references elsewhere in the report to sources mentioning the extremely high cost of FC vehicles as a barrier to development. Current prices mentioned in relation to FC technology often reflect the developmental nature of the vehicles under consideration. With the most advanced vehicle programs at, in the best case, pilot stage, vehicle prices might be expected to be as much as orders of magnitude greater than retail prices for mass-produced versions.

4.3.5 General steEp considerations impacting on PTFG

Attention will now be given to steEp factors impacting on the viability of particular PTFG by presenting barriers, challenges and disadvantages, and incentives, opportunities and disadvantages associated with the major pathways. The focus will generally remain on steEp factors associated with the vehicle and its viability independent of issues such as fuel availability, health and environmental aspects of fuel production, and supply and fuel delivery infrastructure. Key findings from the preceding sections that impact significantly on PTFG viability will be repeated below for clarity and emphasis. Much of the information presented below is drawn from secondary sources that synthesise a wide range of data and expert insight.

4.3.5.1 Internal Combustion Engine technology

Internal combustion engines (ICEs) are the incumbent technology for road transport vehicles. ICEs convert chemical energy stored in an appropriate fuel to mechanical energy via a combustion reaction with oxygen from air that generates expanding gas to drive reciprocating pitons. Significant potential exists for improving the efficiency of ICE technology through developments such as turbo charging, infinitely variable valve timing, direct fuel injection, cylinder deactivation under part load and continuously variable transmissions.

ICEs can be divided into two broad categories. Spark Ignition (SI) ICEs, as the name suggests, rely on an electrically generated spark to initiate combustion of the fuel air mixture. SI ICEs can be designed for a range of liquid and gaseous fuels including petrol, LPG, CNG and LNG, ethanol and ethanol/petrol blends, and hydrogen. With Compression Ignition (CI) ICEs the increased temperature resulting from compression of the fuel/air mixture initiates the combustion process. CI ICEs can utilise fuels including petroleum-derived diesel fuels Fischer-Tropsch diesel from natural gas, biodiesel, blends of petroleum diesel and biodiesel, ethanol, and emulsions of petroleum diesel and ethanol.

Due to the increased compression ratio achievable with CI ICEs, CI ICEs are inherently more thermodynamically efficient than SI ICEs. Amongst the various SI ICE PTFG, CNG and LNG allow operation at higher compression ratios than can be achieved for petrol, facilitating higher thermodynamic efficiency. In practice, the lack of development attention given to CNG SI ICEs has meant that the theoretical potential for improved efficiency has not been maximised. Thus, in theory CNG SI ICEs have significant scope for improvement relative to the incumbent technologies. A similar situation, though lesser in magnitude, exists with regard to the relative efficiency of petrol SI ICEs and diesel CI ICEs. As efficiency has not been as highly prized in petrol SI ICEs as in diesel CI ICEs, in principal the former have greater scope for improvement.

4.3.5.1.1 Tailpipe filtering of particulate matter from ICE exhaust gas streams

Combustion of all hydrocarbon-based fuels results in emission of fine solid particles known as particulate matter (PM). In general, liquid hydrocarbon fuels produce much higher PM emissions than gaseous fuels. In particular, diesel vehicles produce the highest PM emissions of any road transport vehicles. Particulate matter can aggravate respiratory and cardiovascular disease and has been linked also to decrease in lung function, exacerbation of asthma and alteration of the body's defence and lung clearance mechanisms.

Tailpipe filtering of exhaust gases to capture particulate matter is often regarded as an appropriate measure for reducing the air quality impact of road transport vehicles, particularly those using diesel fuel. While tailpipe filters may perform as designed when in 'as new' condition, in practice, performance over the vehicle life cycle is compromised by issues such as corrosion of the filter. Some people consider that one of the advantages of reduced sulfur levels in fuel is that resultant reduction of sulfur compounds in exhaust gases may lead to increased viability of tailpipe filters and subsequent improvement in air quality. Whether this will be born out in practice is, however, highly uncertain. Any failure of a vehicle's filter system would potentially result in increased PM emissions, and it seems very likely that filter performance would be strongly linked to adequacy of maintenance.

The conventional approach to assessing the PM emissions performance of vehicles is based on measuring the mass of solid matter emitted. On this basis, removing from the exhaust stream one large particle with a mass greater than the combined mass of, say, one thousand much smaller particles, would appear as effective as removing those one thousand smaller particles. However, epidemiological evidence is now suggesting that it is the number of air borne particles, not the total mass of particles, that is most significant in determining the health impact of particulate matter emissions. Tailpipe filtering relies on capturing particles above a given minimum size This size is limited by the physical characteristics of the filter system. If particles are below this size, they will pass through the filter and be emitted to atmosphere. It is of particular note that the smallest particles emitted are considered to be the most dangerous in terms of health impact. It is possible that a vehicle fitted with a new tailpipe filter which is performing as designed could emit a significantly reduced mass of PM relative to the same vehicle without the filter, but that the proportionate reduction in the *number* of particles emitted would be far less significant.

While it seems appropriate to continue to consider the role of tailpipe filtering in reducing diesel vehicle PM emissions, it must be kept in mind that this does not represent a 'magic bullet' solution. Advances in filtering technology may have the capacity to improve performance. Developments in this area should certainly be monitored, but considered from a critical perspective.

4.3.5.1.2 CI ICE-Diesel

4.3.5.1.2.1 Barriers, challenges and disadvantages:

- NO_x and PM emissions must be reduced to meet future standards (US perspective);[155]
- PM(10) emissions are much higher than incumbent PMV technology.
- Fischer-Tropsch (GTL) diesel, while potentially facilitating better tailpipe PM capture, results in a substantial well-to-wheel GHG emission increase;[156] and,

- Increased vehicle cost and reduced efficiency if emerging emission technology measures are employed to overcome emission problems. [157]

4.3.5.1.2.2 Incentives, opportunities and advantages:

- High penetration of European market (forty percent of vehicle sales), creating important economies of scale and incentive for further development;[158]
- Recent progress has been made in the development of particulate filters and NO_x reduction catalysts, and the introduction of ULS diesel fuel (containing less than 50 ppm sulphur) in 2006 will assist with lowering emissions;[159] and,
- Strongly supported by incumbent infrastructure for maintenance and fuel supply.

4.3.5.1.3 SI ICE-CNG

(Generally applicable to LNG also)

4.3.5.1.3.1 Barriers, challenges and disadvantages:

- Low energy density of fuel requires very large fuel tank for acceptable range. This makes CNG unattractive for the PMV (and probably LCV) market. Trucks and buses, with their larger overall size relative to fuel tank size hold greater potential for application of the option.

4.3.5.1.3.2 Incentives, opportunities and advantages:

- 16% improvement in GHG emissions expected by 2010, compared with 2% improvement in diesel engines likely to see CNG as the lowest GHG ICE fuel option.[160]

4.3.5.1.4 SI ICE-Hydrogen

4.3.5.1.4.1 Barriers, challenges and disadvantages:

- Poor efficiency - Well-to-tank efficiency is very low for hydrogen produced from natural gas, SI ICE is the lowest efficiency propulsion technology considered (although hybridising could improve this somewhat);[161]
- Well-to-wheel GHG emissions are higher than petrol or diesel ICE vehicles;[162] and,
- High NO_x emissions.[163]

4.3.5.1.4.2 Incentives, opportunities and advantages:

- May accelerate early development of hydrogen infrastructure.[164]
- Extremely low (or zero) tailpipe particulate emissions.

4.3.5.2 Fuel Cells

Fuel cells convert chemical energy stored in an appropriate fuel directly to electrical energy, via an oxidation reaction involving the fuel and oxygen from air. This electrical energy can then be stored in a battery system (hybrid system) or used to drive the vehicle directly via an electric motor (non-hybrid system). The fuel for the fuel cell can either be stored on board, or can be produced on board as needed from a source such as petrol, using a fuel processor. Fuel cell development for road transport is focussed on use of hydrogen fuel.

4.3.5.2.1 FC-Hydrogen (Hybrid & Non-Hybrid)

4.3.5.2.1.1 Barriers, challenges and disadvantages:

- Fuel cell vehicles are currently extremely expensive (although this may include the affect of their developmental nature), and are projected to remain relatively expensive compared to alternatives for at least 10 to15 years;[165]
- Require new infrastructure for vehicle manufacturing and maintenance, and for producing and distributing hydrogen fuel, therefore market acceptance and rapid penetration difficult;[166]
- Requires commitment of government and industry to appropriate codes and standards;[167]
- Many experts expect that market penetration is still a decade or more away;[168]
- Vehicle manufactures, which need incentives to transfer from current technology, hold the power in determining advancement. ICE hybrids are currently reported to be favoured over fuel cell vehicles;[169]
- Fuel cell stacks are facing durability problems, with operating lives reportedly significantly below current expectations for vehicle propulsion systems;[170] and,
- Adequate on board hydrogen storage is a major unresolved issue and may be a showstopper on the path to successful commercialisation.[171] Range, packaging, weight and cost are cited as issues yet to be addressed.[172]

4.3.5.2.1.2 Incentives, opportunities and advantages:

- Quieter than alternatives;[173]
- Lower non-GHG tailpipe emissions;[174]
- US Government appears committed to long term hydrogen fuel cell strategy;[175] and,
- Costs are expected to fall dramatically as vehicles enter production on a large scale.[176]

4.3.5.2.2 Fuel Processor (FP) FC-Petrol

4.3.5.2.2.1 Barriers, challenges and disadvantages:

- Excessive weight; and,
- Added propulsion system complexity, potentially compromising reliability, and shifting capital and maintenance costs to the vehicle owner.

A strong consensus has reportedly formed recently around the use of direct hydrogen for fuel cell vehicles, as opposed to on board reformation of liquid fuel.[177]

4.3.5.2.3 Hybrid FC-Hydrogen

Note: Battery included in propulsion system

4.3.5.2.3.1 Incentives, opportunities and advantages:

- Reduced fuel cell size and therefore cost;
- Potential extension of fuel cell operating life due to reduced peak performance demand;
- Amelioration of on board hydrogen storage issues; and,
- Ability to employ regenerative braking.

A general consensus that fuel cell vehicles will be hybridised is reported to have formed, centred on the above advantages.[178]

4.3.5.3 Hybrid ICE/electric vehicles

Hybrid vehicles use either a CI or SI ICE to convert chemical energy from an appropriate fuel to mechanical energy. Some portion of this mechanical energy (in some cases, this may be all of the mechanical energy) is then converted to electrical energy, which is then used to drive the vehicle. Hybrid vehicles facilitate storage of energy when the vehicle is operating at part load, allowing the ICE to be operated within its most efficient speed range, or shut down when not required. Hybrids also allow recovery and storage of energy during braking. The ICEs utilised in hybrid vehicles can benefit from all of the efficiency improvements anticipated for conventional ICE vehicles.

4.3.5.3.1 All hybrid ICE PTFG

4.3.5.3.1.1 Barriers, challenges and disadvantages:

- Significantly higher cost than vehicles based on conventional technology;[179] and,
- Increased complexity, limited maintenance infrastructure.

4.3.5.3.1.2 Incentives, opportunities and advantages:

- Benefits as for Hybrid FC, amplified for ICEs relative to FCs;[180]
- Two prototypes developed in Australia, two production models on the market in Australia already;[181]
- Car manufacturers play a powerful role in determining technology direction, and are reported to favour ICE Hybrids over FCs at present;[182] and,
- Ability to offer added value to consumers, such as electrical power outlets.[183]

4.3.5.3.2 Hybrid SI ICE-petrol

4.3.5.3.2.1 Barriers, challenges and disadvantages:

- Petrol fuelled SI ICE engine is inherently less efficient than diesel CI ICE or CNG SI ICE.

4.3.5.3.2.2 Incentives, opportunities and advantages:

- Current and growing market presence (three vehicles in 2002, two available in Australia in 2004).[184]

4.3.5.3.3 Hybrid SI ICE-CNG

4.3.5.3.3.1 Barriers, challenges and disadvantages:

- Low fuel energy density therefore low vehicle range;
- Very limited refuelling infrastructure; and,
- GHG emission performance is dependent on the extent of fugitive hydrocarbon emissions. May be affected by vehicle design, quality of manufacture, adequacy of maintenance, and vehicle age.

4.3.5.3.3.2 Incentives, opportunities and advantages:

- Best performance of any vehicles with regard to GHG emissions (excluding FC using hydrogen from electrolysis with renewable electricity).[185]

4.3.5.3.4 Hybrid CI ICE-diesel

4.3.5.3.4.1 Barriers, challenges and disadvantages:

- More expensive than SI ICE-Petrol PTFG;[186] and,
- Higher NOx and much higher PM emissions than equivalent petrol vehicles.

4.3.5.3.4.2 Incentives, opportunities and advantages:

- Highest well-to-wheel energy efficiency of any technology path;
- Highest tank-to-wheel energy efficiency of non-FC technology paths;
- Technology of choice for all hybrid cars in the 2001 Frankfurt Motor Show;[187] and,
- Fischer-Tropsch (GTL) diesel fuel with geosequestration of CO_2 can potentially provide advantages of CI ICE with greatly improved air quality performance, by improving viability of

tailpipe PM filtering. This is perhaps of greatest significance in heavy vehicles, where air quality improvements may be considered to outweigh life-cycle energy efficiency performance, or even GHG emission performance where geosequestration is not viable.

4.3.6 Fleet changeover issues

4.3.6.1 PMV market barriers to fuel economy

Reduction of the Victorian PMV fleet average GHG emissions requires not only that vehicles with potential for lower emissions be offered by manufacturers, but that the market responds by taking up such vehicles. Where reduction of GHG emissions requires that consumers place significant value on lifetime fuel savings, a market barrier to the uptake of new vehicle technology may exist. As is discussed earlier, an overall reduction in GHG emissions requires that propulsion system efficiency improves in real terms, not just relative to vehicle power and size requirements. If the market demands heavier and more powerful vehicles, as has been the general trend in recent years, then gains from technology development will be undermined. In the United States, no improvement to light vehicle fuel efficiency has been seen for fifteen years.[188] The Green and Schafer cite a study indicating that from the consumer's perspective, value is only placed on the first three years of fuel savings.[189] The report *CSIRO Energy and Transport Sector Outlook to 2020* observes that, while consumers 'react negatively in a political sense to small price changes', price changes must be more significant in order to drive a shift towards more fuel efficient (and hence less GHG intensive) vehicles, as was seen in the wake of the 1970's oil crisis.[190]

On the other hand, one source reports that adoption of new technology accelerates rapidly once a certain market penetration threshold is reached. For the US context, this level is between 10% and 20% of annual vehicle sales.[191] It may then be necessary for technology options with the potential to reduce GHG emissions to be promoted on their ability to meet other market demands in order to achieve rapid market acceptance.

Reduction of GHG emissions is regarded as a 'public good externality', and as such it seems unreasonable to expect that consumers and businesses acting in their own self-interest will bring about the required change. Collective action is required - market approaches must be assisted with regulatory measures.[192] A comprehensive strategy approaching the issue simultaneously on multiple fronts is called for.[193] Examples include cleaner fuel regulations, tighter design regulations, infrastructure initiatives and taxation measures for vehicles and fuels.[194,195]

4.3.6.2 Local vehicle manufacturing industry

It should be kept in mind that the global nature of the transport vehicle and fuel industries will require that in Victoria, and Australia generally, we align our interests with deeper currents.[196] A real advantage exists in deciding locally how to ride the wave of global developments.

Worldwide developments in vehicle technology will need to be considered in the local manufacturing industry if it is to remain competitive, particularly in the export market.[197] The aXcess car project and development of the ECOmmodore show a local capacity and willingness for this.[198] From the Government perspective, the Automotive Competitiveness and Investment

Scheme, with its $2.8 billion assistance to the industry over the five years to 2006, suggests strong support.[199]

4.3.6.3 Fleet changeover time

The time taken for incumbent technology to be replaced with less GHG intensive technology is strongly influenced by vehicle life expectancy and normal design cycle inertia. The Pew Centre report indicates that the average fleet energy efficiency improvement is expected to be around half that for new vehicles by 2015, corresponding with a GHG emission reduction (for the US) of around 11%.[200] The complete transition away from liquid petroleum fuel based road transport is seen as having a thirty-year time frame.[201]

In considering the effect of fleet changeover time on GHG emissions reductions, it is important to also bear in mind the following issues:

1. In addressing the reduction of net GHG emissions from road transport in Victoria, the total vehicle fleet and fuel system life cycles must be considered;
2. A significant proportion of a particular vehicle's life-cycle exbodied GHG emissions is accounted for by the time the vehicle leaves the showroom floor;[202] and,
3. Environmental problems linked to GHG emissions are of a global systemic nature and scope. There is no advantage to be gained by geographically relocating emissions or by shifting the distributions of emissions between vehicle and fuel life-cycle stages unless a true, systemic net reduction is achieved.

Point (2) above should be considered in light of the effect of increased vehicle manufacture that would be needed to bring about a technology-driven impact on GHG emissions, at least until the fleet average is significantly lowered. Measures aimed at reducing GHG emissions that involve accelerated fleet changeover may be counter-productive in the short term. On the other hand, one study has found that, for tailpipe emissions, 'stringent emission controls are successful in decreasing atmospheric loads in the short term, as old vehicles are replaced by newer vehicles with lower emissions. In the longer term all of the vehicle fleet consists of lower emission vehicles and then the increase in passenger car numbers and in VKT [Vehicle Kilometres Travelled] leads to an increase in atmospheric loads.'[203]

Measures that encourage the use, in existing vehicles, of new fuel sources with scope for reduced GHG emissions might be considered. For example, the production of diesel fuel from natural gas with geosequestration of CO_2 from the gas-to-liquid (GTL) process may be considered. Similarly, if the FC route were to be pursued, hydrocarbon-based fuel system approaches that allow for the capture of CO_2 may warrant encouragement. This would militate against on-board fuel processor (FP) systems, and may reduce the viability of fuelling station based FP systems.

CSIRO researchers Foran and Poldy, in discussing future energy use in Australia, consider the inter-sectoral rebound effect, or Jevons Paradox. This effect suggests that at the level of the overall economy, 'increases in energy efficiency may catalyse increases in energy usage, rather than allowing more production for the same or less energy usage'.[204] This should be kept in mind in developing Victoria's GHG emissions approach as it pertains to vehicle technology and fuels. Any GHG emissions reduction measures that might result in increased PMV consumption and use should be avoided. In formulating policies aimed at promoting fleet changeover to more fuel efficient vehicles this should be considered. In any case, it must be born in mind that the adequacy of our GHG emissions reduction measures is entirely dependent on the quality of our total systems analysis and understanding. We can ill afford to engage in isolated activities that waste vital resources and precious time through failure to recognise macro-level effects.

4.3.6.4 PMV fleet operation

- Centrally owned or managed vehicle fleets may offer the greatest potential for GHG emissions, for all vehicle types including PMVs, given that the effect of influencing a single decision maker or decision making body to reduce emissons is multiplied by the number of vehicles in the fleet. Conversely, for a given GHG emission reduction, a smaller number of individuals must be influenced to change[205];
- The requirement that business-based PMV fleets accrue sufficient usage in order to avoid fringe benefits tax acts as a perverse incentive that undermines efforts to reduce GHG emissions; and,
- The fleet market currently provides little incentive for local vehicle manufacturers to reduce the size (and hence the fuel consumption and GHG emissions) of the PMVs they produce.[206]

4.4 Issues Specific to Other Vehicle Types

While the PTFG steEp factor summary for PMVs is largely applicable to other vehicle types, many issues are specific to intended vehicle usage and fleet scale. In this section, brief notes are presented outlining considerations specific to LCVs, Trucks and Buses, grouped into *Incentives, opportunities and advantages* and *Barriers, challenges and disadvantages*.

4.4.1 Light Commercial Vehicles (LCVs)

4.4.1.1 Incentives, opportunities and advantages:

- Fleet-type operation where refuelling and maintenance is centralised at a fleet depot may incline LCVs towards use of niche fuels or alternative fuels for which distributed infrastructure is unavailable. For example, delivery vehicles that only operate within the metropolitan area or over fixed, short-distance routes, might be suited to the use of a fuel such as CNG for which there is only very limited refuelling infrastructure at present;
- The lower noxious and particulate emission from LPG and CNG relative to diesel make the gaseous fuels well suited to LCVs operating in urban environments;[207] and,
- The US Department of Energy 21st Century Truck program is aiming for a 50-70% improvement in fuel efficiency for LCVs.[208]

4.4.2 Trucks

See the section 'Fuel Type steEp Factors' for comparison of relative GHG emissions and air pollutants for trucks.

4.4.2.1 Barriers, challenges and disadvantages:

- While CNG has the greatest potential for GHG emission reductions from trucks, problems such as fugitive fuel emissions and tailpipe hydrocarbon emissions mean that this potential is not always realised;[209]
- Due to the impact of fuel costs on road freight, development of large truck engines has been strongly motivated by fuel efficiency concerns for a long time. Lower potential therefore exists for further improvement;[210]
- Technology that could significantly improve efficiency must overcome emission quality hurdles;[211]
- Costs of efficiency improvements may be excessive; and,
- FC prospects for long-distance truck propulsion are poor due to high efficiency of incumbent diesel technology. Limitations in hydrogen storage and refuelling infrastructure would also hinder application in this market.[212]

4.4.2.2 Incentives, opportunities and advantages:

- High volume fuel consumption and an imperative to reduce air pollution, combined with the fleet advantage described for LCVs above, are seen as strong incentives for application of the SI ICE-CNG PTFG to trucks;[213]
- For long-distance trucks, aerodynamic resistance presents significant potential for efficiency improvements. Reductions of greater than 20% to aerodynamic resistance may be possible;[214]
- Idling of truck engines at standstill to maintain power to auxiliary systems accounts for a significant proportion of total GHG emissions. Dedicated auxiliary power units have the potential to greatly reduce GHG emissions in this regard.[215] FC systems are being developed for this purpose; and,
- US Department of Energy 21st Century Truck Program is aiming for 50-70% fuel efficiency improvement.[216]

4.4.3 Buses

For a comparison of relative GHG and air pollutant emissions for heavy vehicles, see the section 'Fuel Type steEp Factors'. The charts presented are based on data adapted from truck results, but are applicable to buses in a general sense.

4.4.3.1 Barriers, challenges and disadvantages:

- Bus fleets in Victoria are privately owned and operated, reducing scale incentives for development and uptake of alternative propulsion technology and fuel systems. Little probability exists that fleet operators would cooperate on industry-wide developments unless significantly encouraged by government;[217]
- Questions remain around the durability of FC systems, a problem exacerbated for heavy vehicles which require a longer operating life than PMVs, and very limited market size;[218] and,
- Hybrid CI ICE-Diesel technology is highly suited to the stop-and-start type operation required for transit buses. Potential for improvement to fuel efficiency is reported at between 25% and 70%, up to 50% improvement is already reported.[219]

4.4.3.2 Incentives, opportunities and advantages:

- Fischer-Tropsch (F-T) diesel may be an appropriate fuel for transit buses in urban areas. Higher GHG emissions may be acceptable as a trade off for improved urban air quality, given buses' low overall contribution to the transport sector's GHG emissions. F-T diesel potentially facilitates lower PM emissions through improving the viability of particle traps. Minimum scale for viability of F-T diesel production process would need to be considered;
- LPG and CNG would offer benefits,[220] if infrastructure establishment problems could be overcome, perhaps through Government assistance;
- Local transit buses may be able to benefit from FC bus developments currently under way elsewhere (Perth for example), following commercialisation;
- Operation of buses in densely populated areas would favour the zero tailpipe emissions of FC technology;[221] and,
- There are indications that FC technology for transit buses will be viable around five years ahead of that for PMVs.[222]

4.5 Fuel type steEp factors

Consideration of fuel issues has so far been restricted mainly to their direct impacts on the viability of vehicle technologies. Data in the following section is organised by fuel type. This allows consideration of steEp factors for the fuels themselves, including production and supply influences. Consideration will also be given to substitute fuels such as biodiesel and petrohol, not specifically addressed in relation to PTFG. Information is generally organised into *Barriers, challenges and disadvantages* and *Incentives, opportunities and advantages*. This section draws extensively on CSIRO *et al.*'s report to the Australian Greenhouse Office *Comparison of Transport Fuels*.[223] An important primary reference for biofuels is CSIRO *et al.*'s report to the Department of Industry, Tourism and Resources, *Appropriateness of a 350 ML Biofuels Target*.[224]

4.5.1 Dominance and inertia of liquid petroleum-based fuels

Existing fuel supply systems and road transport infrastructure based on liquid fuels provide any options for the reduction of GHG emissions that employ liquid petroleum-derived fuels with a very significant advantage. This must be closely considered in any change strategy.[225] Continued operation of the existing system, estimated to have twenty to thirty years' inertia, will need to be carefully integrated into the transition plan to new road transport fuels.[226] In the US high energy density, low cost, and adaptability to environmental constraints are cited as contributing to the failure of alternatives to displace petroleum fuel to any significant degree. This is despite efforts to bring about more significant use of alternatives over the past twenty-five years.[227]

The study *Comparison of Transport Fuels* highlights that 'even if one argues that the fossil fuel economy is economically efficient, it is more difficult to argue that it encourages equity or ecological integrity.'[228] Overwhelming though the task may seem there is a widely held motivation to overcome the inertia of our incumbent road transport fuel system.

4.5.2 GHG and air pollutant emission comparison for light vehicle and heavy vehicle fuels

Figure 4.14 to Figure 4.17 present comparisons of relative GHG and air pollutant emissions for light vehicle fuels containing or based on ethanol, and PULP, representing the incumbent light vehicle fuel. This information is adapted from data presented as part of CSIRO *et al.*'s 2001 study comparing life cycle emissions of heavy vehicle fuels. The data represents emissions for a generic light vehicle powered by an SI ICE. This data illustrates both the wide variation in emissions between the various ethanol feed stocks and production pathways, and the relatively minor impact of ethanol when used in its most realistic role as a blending agent. The two ethanol options shown here represent the production pathways and analysis methods with maximum and minimum GHG emissions respectively for the range of options examined in the original study. Ethanol from molasses (economic allocation analysis) and ethanol from wood waste effectively bound the GHG emissions for the complete set of options. They have not been chosen here as 'preferred options' or 'most favourable' alternatives from the wider set. They simply illustrate the degree of variation that occurs due to feed stock, production route and analysis approach.

It should also be noted that updated emission estimates for E10P were derived for the study *Appropriateness of a 350 ML Biofuels Target*. This study indicated slightly improved performance compared with the data presented in *Comparison of Transport Fuels*. In considering the use of E10P in PMVs, lifecycle GHG emissions were found to be between 5.1% and 1.7% lower than for ULP, based on ethanol production from molasses using cogenerated energy and production from wheat respectively.[229] The results from in *Comparison of Transport Fuels* have been retained in the figures presented in this report to ensure that contextual consistency is maintained as closely as possible with other fuels (for example, results for E85P are not presented in *Appropriateness of a 350 ML Biofuels Target*).

Figure 4.18 to 4.21 present comparisons of relative GHG and air pollutant emissions for heavy vehicle fuels when specifically applied to a heavy vehicle transport task. The information is also adapted from CSIRO *et al.*'s life cycle comparison of heavy vehicle fuels, specifically the emissions for a generic truck cycle in emissions per tonne-kilometre. The stand out feature of this data is the across-the board emission improvement indicated for CNG, both in terms of GHG emissions and air pollutants. The comments made with regard to the representative ethanol production pathways and analysis methods depicted for the light vehicle fuels also apply to the heavy vehicle fuels.

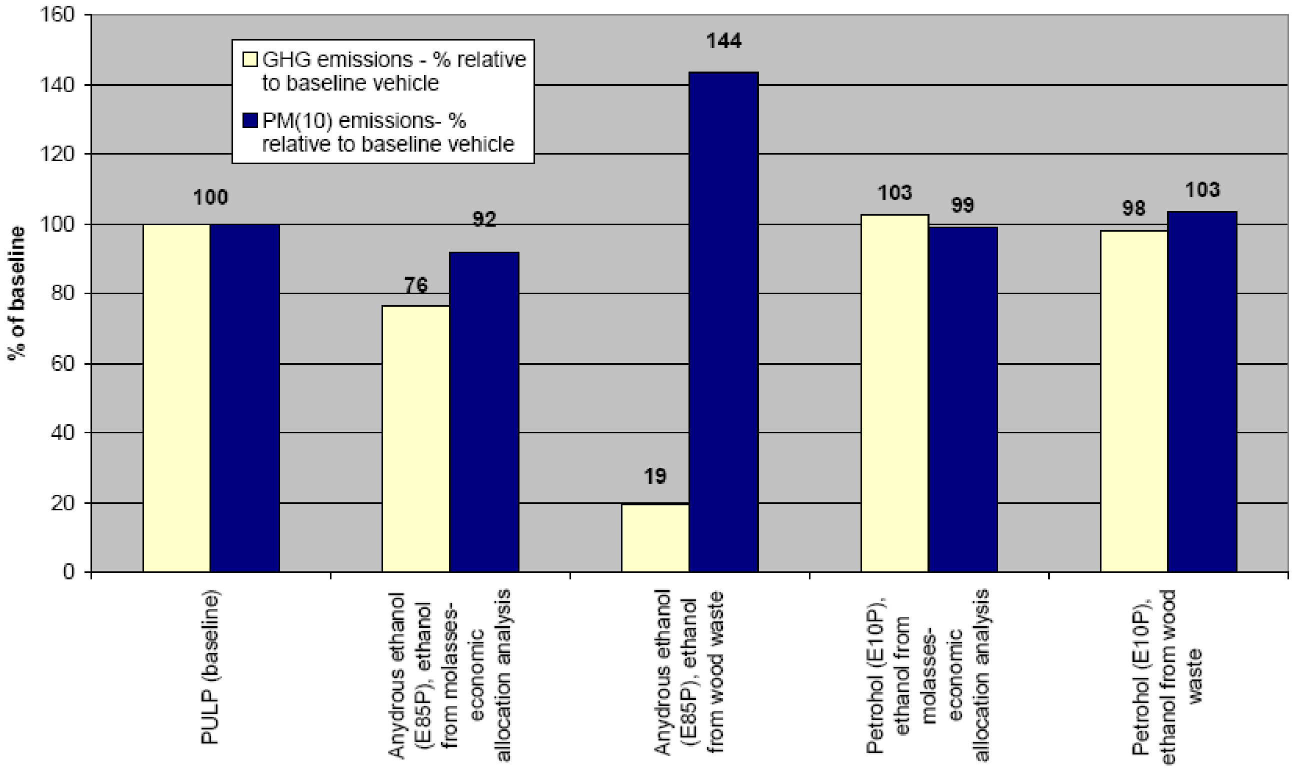


Figure 4.14: Relative GHG and PM(10) emissions for light vehicle fuels. Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[230]

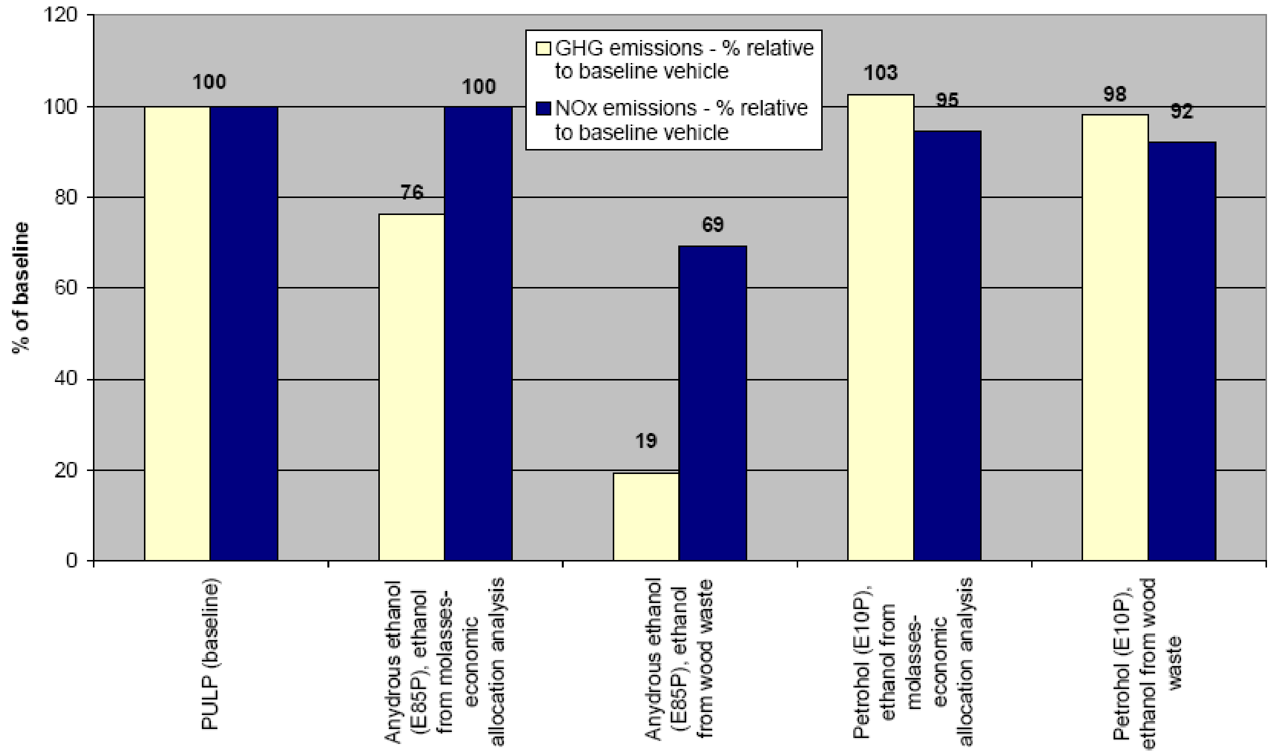


Figure 4.15: Relative GHG and NOx emissions for light vehicle fuels. Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[231]

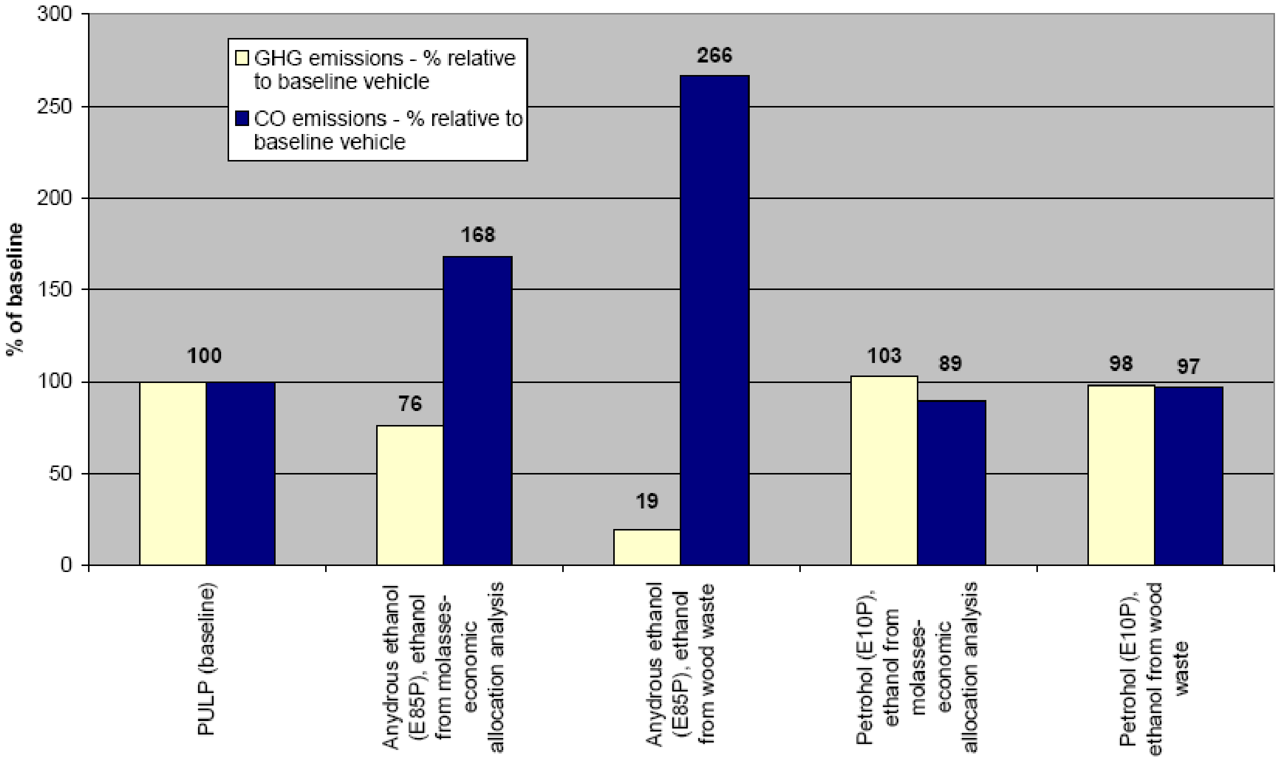


Figure 4.16: Relative GHG and CO emissions for light vehicle fuels. Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[232]

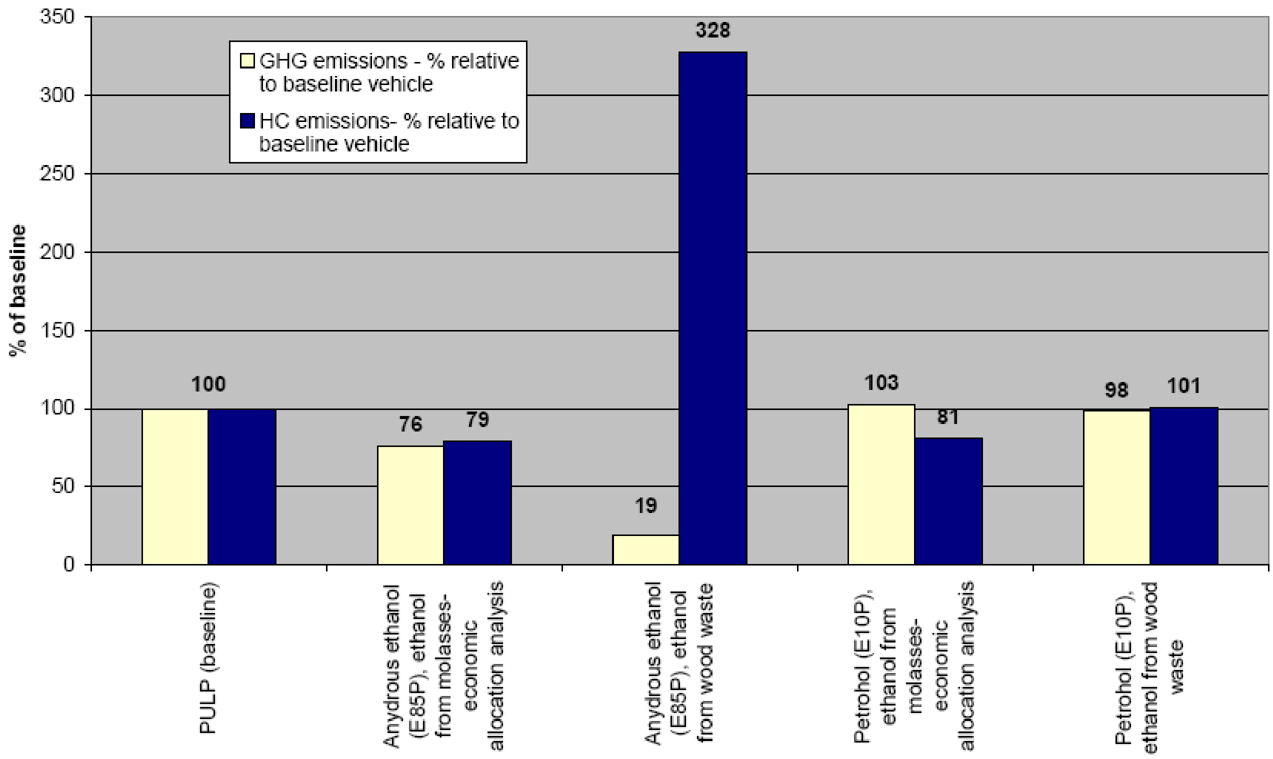


Figure 4.17: Relative GHG and HC emissions for light vehicle fuels. Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[233]

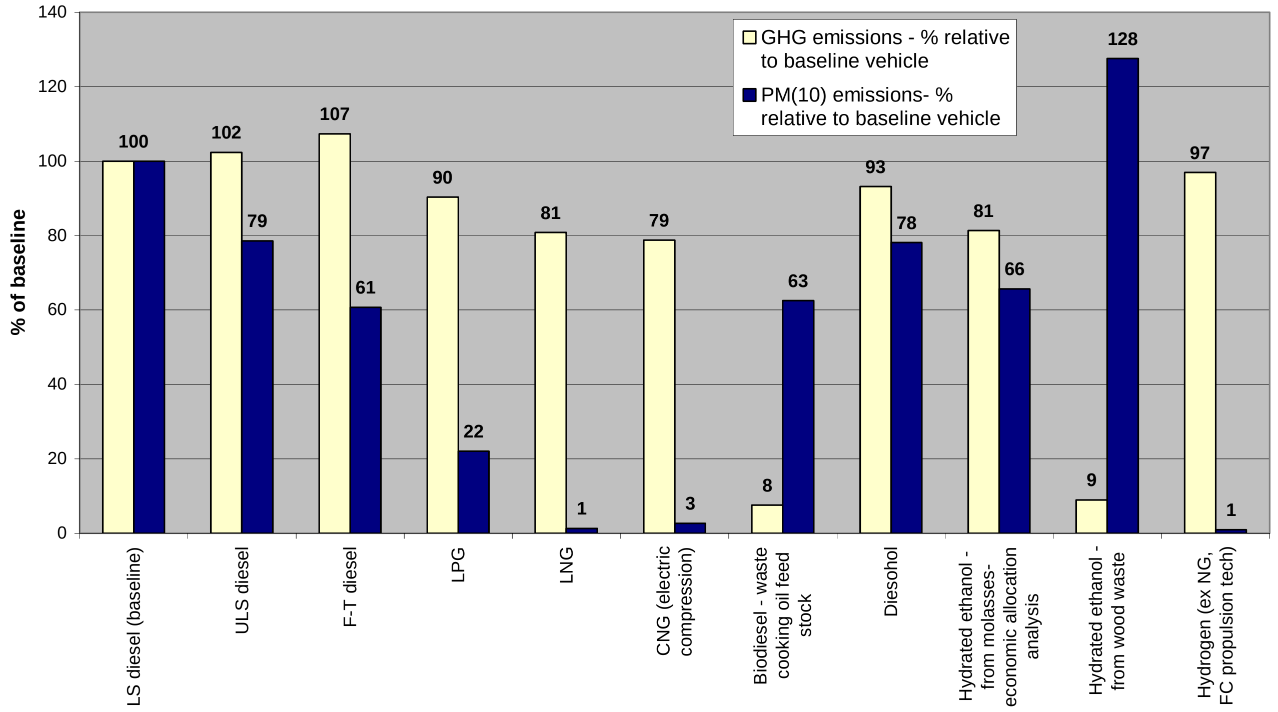


Figure 4.18: Relative GHG and PM(10) emissions for heavy vehicle fuels (emissions per t-km for trucks). Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[234]

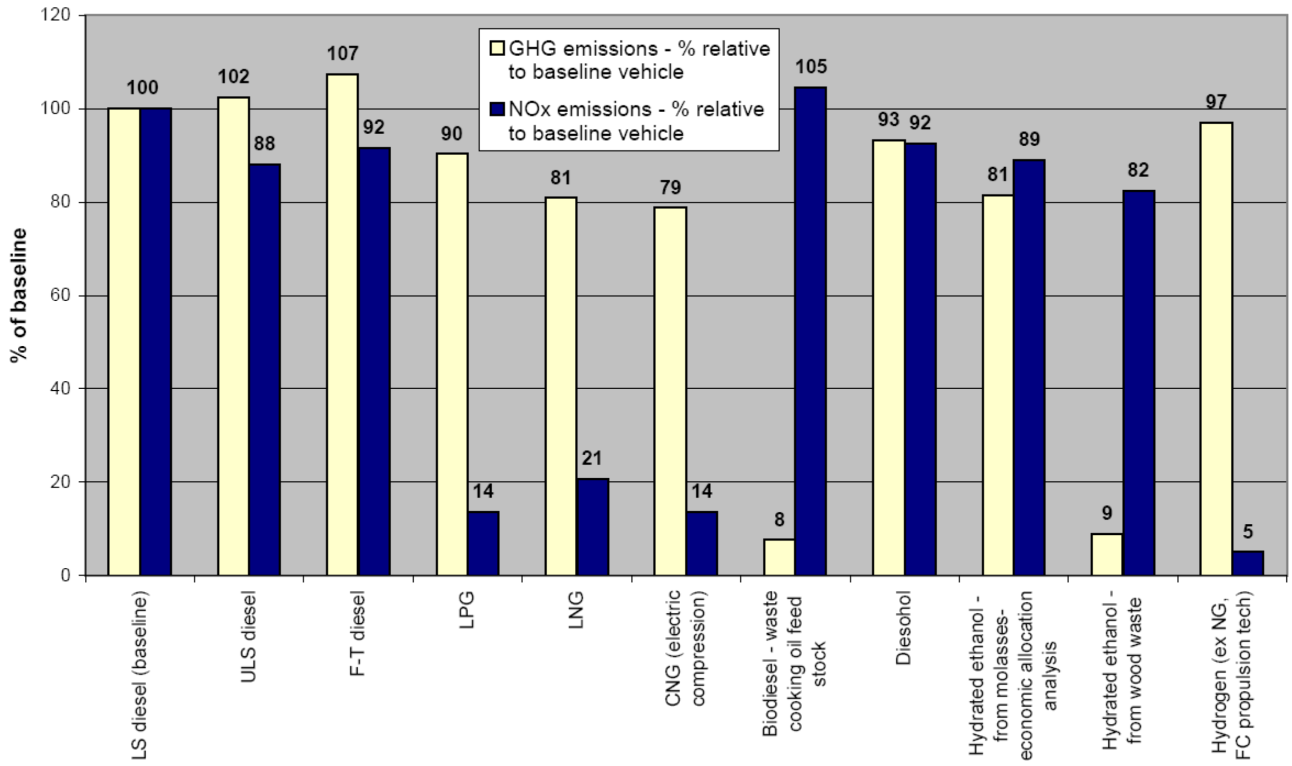


Figure 4.19: Relative GHG and NOx emissions for heavy vehicle fuels (emissions per t-km for trucks). Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[235]

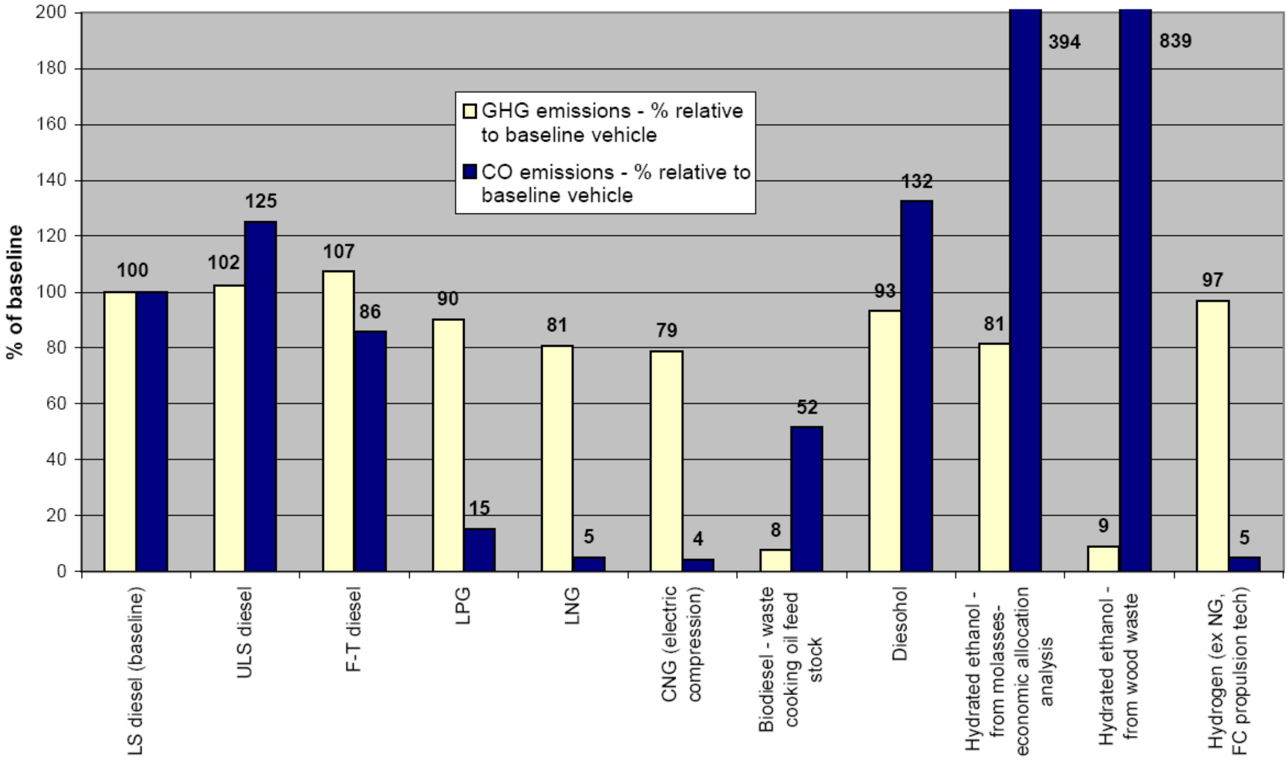


Figure 4.20: Relative GHG and CO emissions for heavy vehicle fuels (emissions per t-km for trucks). Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[236]

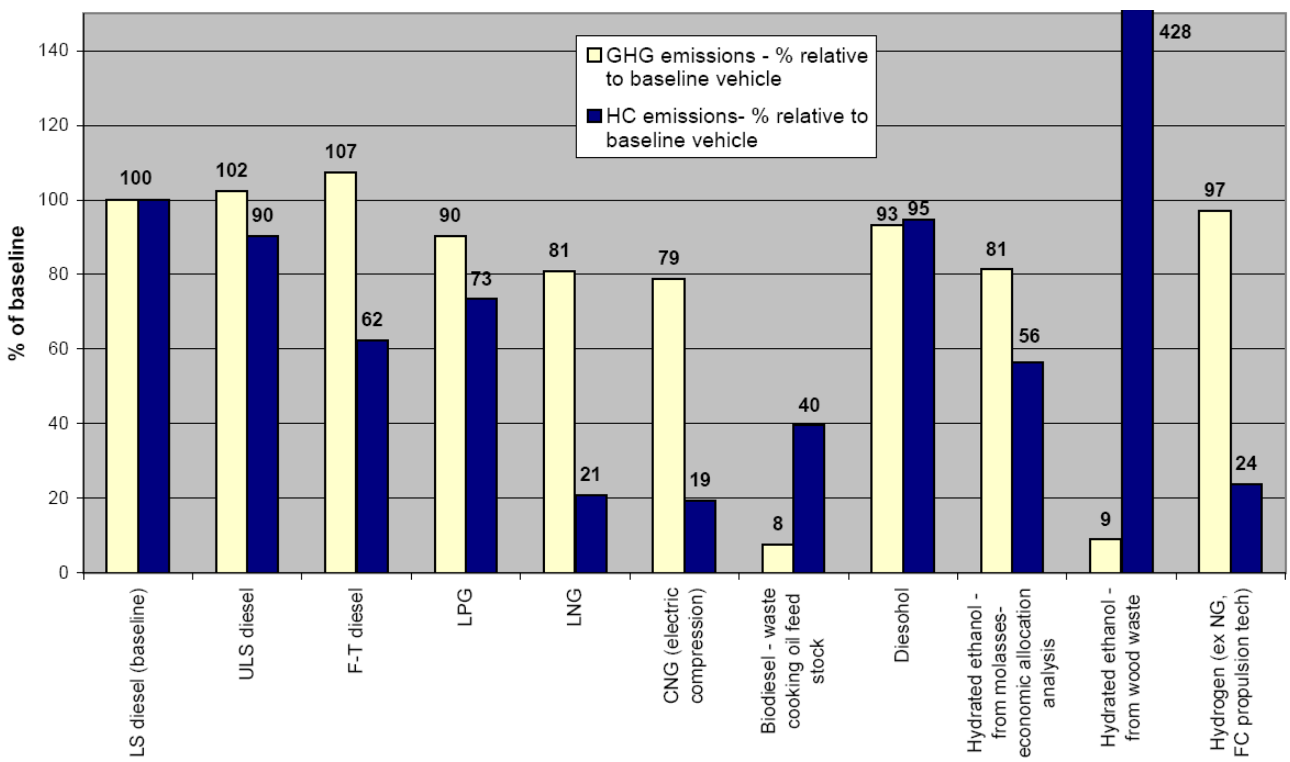


Figure 4.21: Relative GHG and HC emissions for heavy vehicle fuels (emissions per t-km for trucks). Adapted from data presented in Part 2 of CSIRO *et al.*'s comparison of heavy vehicle fuels.[237]

		GHG emission reduction (CO_2 equiv. LCA)	Emissions savings			
			VOCs	CO	NO_x	PM
Baseline - Diesel (LS)	short-term emission outlook	REFERENCE	REFERENCE	REFERENCE	REFERENCE	REFERENCE
ULS diesel	long-term ADR compliance outlook	=	~+	-	++	++
LPG	short-term emission outlook	+	+	++	++	++
	long-term ADR compliance outlook	expected same as above	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs
LNG	short-term emission outlook	+	++	++	++	++
	long-term ADR compliance outlook	expected same as above	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs
CNG	short-term emission outlook	+	++	++	++	++
	long-term ADR compliance outlook	expected same as above	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs	expected to meet all future ADRs
Hydrogen	short-term emission outlook	=	++	++	++	++
	long-term ADR compliance outlook	++	no long-term regulation compliance issues foreseen	no long-term regulation compliance issues foreseen	no long-term regulation compliance issues foreseen	no long-term regulation compliance issues foreseen
Biodiesel	short-term emission outlook	++	~+	+	-	~+
	long-term ADR compliance outlook	expected same as above	expected same as above	expected same as above	May not meet Euro3 and Euro4 stds	May not meet Euro3 std
Hydrated ethanol	short-term emission outlook	++	+	-	~+	=
	long-term ADR compliance outlook	expected same as above	May slightly exceed Euro3 and Euro4 stds	Expected to meet all future ADRs	Expected to meet all future ADRs	Expected to meet all future ADRs
Emulsified diesel (Diesohol)	short-term emission outlook	+	=	-	=	+
	long-term ADR compliance outlook	expected same as above	May slightly exceed Euro3 and Euro4 stds	Expected to meet all future ADRs	Expected to meet all future ADRs	Expected to meet all future ADRs
Emulsified diesel (Aquadiesel)	short-term emission outlook	~+	-	+	+	+

Table 4.7: Comparative emissions performance for heavy vehicle fuels.[238]

Note: ULS diesel is being introduced to facilitate technology introduction to meet Euro4 specifications. This fuel is not expected to compromise the compliance of vehicles with gazetted ADRs.

		GHG emission reduction (CO_2 equiv. LCA)	Emissions savings			
			VOCs	CO	NO_x	PM
Baseline - PULP	**short-term emission outlook**	REFERENCE	REFERENCE	REFERENCE	REFERENCE	REFERENCE
Anhydrous ethanol (E85P)	**short-term emission outlook**	++	=	=	=	=
	long-term ADR compliance outlook	expected same as above	May slightly exceed Euro3 and Euro4 stds	Expected to meet all future ADRs	Expected to meet all future ADRs	Expected to meet all future ADRs
Petrohol (E10P)	**short-term emission outlook**	=	=	~+	=	=
	long-term ADR compliance outlook	expected same as above	Expected to meet all future ADRs	Expected to meet all future ADRs	Expected to meet all future ADRs	Expected to meet all future ADRs

Table 4.8: Comparative emissions performance for light vehicle fuels.[239]

Note: PULP is assumed to comply with all future ADRs relevant to light vehicles.

4.5.3 Fuel Type Summaries

Table 4.7 and Table 4.8 present a comparative assessment of emissions reductions for GHG and pollutants for heavy vehicle and light vehicle fuels respectively (as examined in *Comparison of Transport Fuels*), summarising at a glance the data presented in the light vehicle and heavy vehicle fuel comparison charts. The legend for interpreting these tables is presented in Table 4.6. Other factors are examined in the following sections, where each fuel is considered on a case-by-case basis. Information from Table 4.7 and Table 4.8 is repeated where particularly relevant.

--	Significant negative impact relative to reference fuel
-	Negative impact relative to reference fuel
=	Neutral impact relative to reference fuel
~+	Slight positive impact relative to reference fuel
+	Positive impact relative to reference fuel
++	Significant positive impact relative to reference fuel

Table 4.9: Legend for fuel emissions comparison Table 4.8 and Table 4.9.

4.5.3.1 Premium unleaded petrol (PULP)

Unleaded petrol is the predominant fuel used in PMVs and LCVs in Victoria. It is a product of the crude oil refining process.

4.5.3.1.1 Barriers, challenges and disadvantages:

- Considered more hazardous than diesel by Worksafe Australia;[240]
- Extreme flammability rating;[241]
- Extreme chronic effect rating;[242]
- With declining Australian oil reserves, petrol's sustainability is dependent on global oil supplies;[243] and,
- Environmental hazard posed to bird and marine life by transport of crude oil, and by spillage of petrol during production, transport and refuelling.[244]

4.5.3.1.2 Incentives, opportunities and advantages:

- Particulate matter (PM) emissions are lower than for diesel; and,
- Dominance of incumbent infrastructure, particularly for distribution to vehicle users.

4.5.3.2 Diesel (LSD & ULSD)

Diesel is the predominant fuel used in trucks and buses in Victoria. It is a product of the crude oil refining process. Low sulfur diesel (LS diesel) contains less than 500 ppm sulfur. This is a fuel that meets either the Euro 2 standard, or the Commonwealth mandated standard introduced in December 2002. Ultra low sulfur diesel (ULS diesel) contains less than 50 ppm sulfur. This is a fuel that meets either the Euro 4 standard, or the Commonwealth mandated standard due for introduction in 2006.

4.5.3.2.1 Barriers, challenges and disadvantages:

- High overall PM emissions (diesel exhaust is treated as an air toxic by the US EPA);[245]
- Diesel fuel sustainability is dependent on global crude oil supply;[246] and,
- Extra processing energy required for ULSD results in higher GHG emissions than LSD.[247]

4.5.3.2.2 Incentives, opportunities and advantages:

- LS and ULS diesel vehicles generally have lower GHG emissions than petrol vehicles.
- ULS diesel combined with Euro 4 engine technology will provide significant improvements in vehicle PM emissions;[248]
- ULS diesel can be used in engines designed for LS diesel, with marginal reduction of PM emissions;[249]
- ULS diesel will result in more efficient oxidation catalyst performance, with reduced NO_x emissions;[250]
- Incumbent infrastructure can use ULSD without significant changes; and,

- Diesel fuels are generally regarded as relatively safe.[251]

4.5.3.3 Aquadiesel

Aquadiesel is an emulsified diesel fuel manufactured and distributed in Australia by Shell. Aquadiesel comprises 84-85% LS diesel, 12-13% water and 2-3% 'CFT Additive' (an emulsifying agent):[252]

- Life cycle PM, CO and NO_x emissions are lower than LS diesel and biodiesel,[253] but higher than for CNG;[254]
- Life cycle hydrocarbon emissions are higher than for LS diesel, biodiesel and CNG;[255]
- Life cycle GHG emissions may be very slightly lower than for LS diesel;[256]
- Life cycle GHG emissions are higher than for biodiesel;[257]
- Life cycle GHG emissions are higher than for CNG;[258] and,
- Capital expenditure is required in changing from LS diesel to CNG, whereas immediate change from LS diesel to Aquadiesel can be made without capital outlay.[259]

4.5.3.4 Fischer-Tropsch (GTL) diesel

Production of Fischer-Tropsch (F-T) diesel involves conversion of natural gas to a liquid fuel suitable for use in compression ignition engines. The upstream processing required means that energy use and hence GHG emissions are considerably higher than for diesel fuel derived from crude oil. F-T diesel is discussed here mainly in light of the future possibility that geosequestration of carbon dioxide from the gas-to-liquid (GTL) process may make this fuel more attractive from a GHG emission perspective.[260] The sequestration process requires additional energy input, and it generates additional greenhouse gases.[261] Fischer-Tropsch diesel offers the potential for reduced tailpipe PM emissions and extension of the existing diesel vehicle and fuel distribution infrastructure through exploitation of a primary energy source that would otherwise require a major transition to enable its widespread implementation for transport use.[262] While the GTL process is proven and viable, carbon dioxide geosequestration viability is less certain. Realisation of potential PM emission reduction requires the use of particle traps, improved implementation of which is facilitated by the close to zero sulfur level in F-T diesel fuel. Sulfur in diesel fuel can cause rapid decay of particle traps.[263]

4.5.3.5 Liquefied petroleum gas (LPG Autogas)

LPG used in Victoria is produced by processing of natural gas. LPG Autogas has exbodied GHG emissions lower than LS diesel but higher than CNG.[264]

4.5.3.5.1 Barriers, challenges and disadvantages:

- Low energy content per unit volume;[265]
- Ignites more easily than petrol, presenting a greater safety hazard;[266]

- Financial incentives to switch to LPG, available for heavy vehicles, have not been extended to PMVs and LCVs;[267]
- Further growth in demand for LPG is ultimately limited to an increase of 50%, based on existing, known resources.[268]

4.5.3.5.2 Incentives, opportunities and advantages:

- Reduced noise and improved engine durability;[269]
- Easily transported and stored, requiring minimal support infrastructure;[270]
- Low particulate emissions relative to diesel;[271]
- Increased demand for LPG is easily satisfied, although, as a by-product of natural gas production and crude oil refining, this is ultimately limited;[272]
- Existing widespread use means that significant infrastructure is already available.[273] Australia has the most extensive LPG infrastructure, distribution and retail network in the world;[274]
- Factory-built LPG vehicles have been available in Europe, USA and Japan and are now becoming available in Australia;[275]
- Financial incentives to switch to LPG are in place for heavy vehicles;[276]
- Existing SI ICE vehicles running on petrol can be modified to use LPG, with GHG reductions of 10-15% possible for PMVs and LCVs;[277] and,
- The LPG refuelling process is very simple, requiring low pressure pumping only from storage to vehicle fuel tank.[278]

4.5.3.6 Compressed natural gas (CNG)

Natural gas is a mixture of hydrocarbon gases, but mainly consists of methane. It is recovered in Australia from gas wells and from crude oil wells. Natural gas is distributed throughout Australia by a network of pipelines. For use as a road transport fuel it is first compressed to 25 MPa, for on board storage at 20 MPa.[279]

CSIRO Energy and Transport Sector Outlook to 2020 concludes that 'Given its range and infrastructure problems, it does not appear an attractive mainstream option, but can be attractive for particular applications where infrastructure challenges can be readily satisfied.'[280]

4.5.3.6.1 Barriers, challenges and disadvantages:

- Significant variation in composition depending on source;[281]
- Limited range due to lower energy content per unit volume.[282] CNG requires a 300 litre tank to store the same energy as a 75 litre petrol tank;[283]
- Special refuelling stations required.[284] Needs high pressure compressors and largely limited to urban areas due to need for proximity to pipelines;[285]
- Small changes in emissions of methane have a relatively large impact on GHG emissions;[286]
- Suffers from lower energy efficiency than liquid hydrocarbon fuels;[287] and,
- Lack of policies to promote natural gas vehicle industry has seen Australian industry stagnate and fall into decline.[288]

4.5.3.6.2 Incentives, opportunities and advantages:

- All advantages above for LNG apply also to CNG;[289]
- CNG exbodied GHG emissions are lower than for LNG due to LNG's liquefaction energy requirements;[290]
- Lighter than air, therefore safer than spilled diesel;[291]
- CNG ICE technology development is estimated to achieve 16% efficiency improvement by 2010 compared with 2% for diesel;[292]
- Well suited to LCVs and transit buses due to low particulate and noxious emissions;[293]
- Potential to alleviate dependence on imported crude oil;[294]
- More inflow of natural gas vehicle technology required;[295] and,
- Natural gas vehicle industry is reported to be growing rapidly internationally.[296]

4.5.3.7 Liquefied natural gas (LNG)

LNG is produced by refrigerating natural gas to below its liquefaction temperature. Natural gas liquefies at -161^{o}C and is generally refrigerated to -180^{o}C in the LNG conversion process. It must then be stored in cryogenic vessels.[297]

4.5.3.7.1 Barriers, challenges and disadvantages: [298]

- Low energy content per unit volume results in limited range relative to conventional fuels;
- Suitable only for fleet operation due to requirement for cryogenic liquid handling and special refuelling facilities;
- Energy required for liquefaction of natural gas results in higher exbodied GHG emissions than for CNG;
- Refuelling time is longer than for diesel; and,
- Relatively high tailpipe emissions of the GHG methane, compared with LS diesel.

4.5.3.7.2 Incentives, opportunities and advantages: [299]

- Low carbon to hydrogen ratio produces very low particulate emissions;
- Quieter engine operation than for diesel fuel, a benefit for operation in urban areas;
- Lower NOx emissions than diesel fuel; and,
- Safer than diesel due to its higher ignition temperature.

4.5.3.8 Hydrogen

Hydrogen may be used as a transport fuel in either SI ICE or FC vehicles. The efficiency of energy conversion is inherently much higher when used to fuel FCs.

Most hydrogen is presently produced by reforming of natural gas. Hydrogen can also be produced by electrolysis of water.

One particular passage from the *Future Wheels II: A Survey of Expert Opinion on the Future of Transportation Fuel Cells and Fuel Cell Infrastructure*, reporting on a study by Northeast Advanced Vehicle Consortium, provides important context for consideration of hydrogen's potential for near-zero GHG emissions:

> 'But, is using renewably generated electricity to produce hydrogen for transportation the most efficient use of that resource? One expert offered the following viewpoint on the wisdom of using renewable sources for hydrogen:
>
> *'The government should focus on how to make hydrogen without CO_2…Any renewably generated electricity should first be used to offset less clean electricity generation. It doesn't make sense to generate hydrogen from it because that will reduce the gain had by generating electricity from a renewable source.''*[300]

4.5.3.8.1 Barriers, challenges and disadvantages:

- Refuelling time can be up to ten times that of petrol vehicles;[301]
- Evaporating hydrogen must be extracted during refuelling to avoid explosions, tanks must be adequately protected to prevent damage in collisions;[302]
- Production of hydrogen by natural gas reforming is difficult to justify on grounds of ecological sustainability;[303]
- Use of renewable electricity to produce hydrogen by electrolysis and subsequent use of that hydrogen for personal transport in PMVs is a highly contentious application of limited GHG reducing resources. Strong arguments can be mounted that any hydrogen produced using renewable electricity would, in combating GHG emissions, be much more effectively used to displace conventional stationary energy sources via industrial or domestic fuel cells;
- Infrastructure and technology barriers are expected to prevent hydrogen from having a strong presence, let alone reducing GHG emissions, before 2020 according to one source at least;[304]
- Hydrogen produced by electrolysis using electricity generated from brown coal would result in very significant increases in GHG emission;[305]
- Entirely new infrastructure is needed for producing, distributing, storing, and retailing hydrogen fuel;[306] and,
- Transition to a hydrogen-fuelled road transport system will require closely coordinated commitments and intensive planning involving all levels of government, numerous industry stakeholders and the general public.[307] Appropriate codes and standards are also required.[308]

4.5.3.8.2 Incentives, opportunities and advantages:

- Hydrogen rises when released into air, after which safety is similar to conventional fuels;[309]
- The possibility may exist to produce hydrogen on large scale by electrolysis using electricity generated from tidal energy in Australia's north-west;[310]
- Centralised generation of hydrogen from hydrocarbon-based primary energy sources would in principle allow geosequestration of carbon dioxide, improving the GHG emission performance of hydrogen-fuelled road transport, although net energy consumption would increase significantly;[311]

- In the very long term (thirty to fifty years) hydrogen is the only presently conceived fuel source that offers truly decreased GHG emissions for road transport - provided of course that the primary energy source is not hydrocarbon based or allows adequate geosequestration of carbon dioxide;[312]
- Hydrogen has the largest variety of pathways from primary energy source to vehicle fuel tank;[313]
- The US Government has indicated its commitment to a long-term hydrogen strategy for energy distribution, suggesting strong support in overcoming obstacles;[314]
- Sources suggest that fuel distribution infrastructure could be set up on a modular basis, using reformation of hydrocarbon fuel at the site of the refuelling station, overcoming the need for a nation-wide hydrogen distribution network;[315]
- Initial restriction of hydrogen vehicles to fleet-type operations would allow the establishment of a wide but sparse fuel distribution network that would form the infrastructure backbone for the 'early adopter' private PMVs;[316] and,
- Demonstration infrastructure is already being implemented (eg Perth fuel cell transit bus trial and a proposed Kimberley area demonstration of a hydrogen based economy and transport sector).[317]

4.5.3.9 Biofuels - general

Biofuels circumscribe the broad class of fuels suitable for road transport vehicles produced from plant-based, or more rarely, animal-based feed stocks.

Presented below are the key findings most relevant to the present study taken directly from the report *Appropriateness of a 350 ML Biofuels Target:*[318]

- 'The costs of implementing a policy of assisting the Australian biofuels industry to meet a 350 ML biofuels target are estimated to exceed the benefits;'[319]
- 'The benefits of biofuels in terms of improving energy security are minimal. 350 ML of biofuels represents only 1.1 per cent of Australia’s total motor vehicle fuel demand;'[320]
- 'Under the target scenario, greenhouse gas emissions are estimated to be 268,000 tonnes lower in 2010 (about 0.3 per cent of transport GHG emissions);'[321]
- 'Particularly with the prospect of significantly cleaner petrol and diesel in use in the vehicle fleet by 2010, the net environmental impacts of increased biofuels, while positive, are small, in overall terms;'[322]
- 'Savings in health costs of meeting a biofuel target are estimated to be $3.3 million in 2010 (in 2003 dollars);'[323]
- 'The cost of each direct job created is is estimated to be between $492,000 and $516,000 (in terms of lower GDP) or from $164,000 to $172,000 for each direct and indirect job created in biofuels and related industries;'[324]
- 'Regional employment impacts of biofuels production are commonly overstated and are difficult to predict as they will be plant and location specific. Some regions will benefit; however, given the mobility of labour, not all of these jobs would represent additional employment. Benefits will be localised and are likely to be concentrated in parts of Queensland and New South Wales;'[325] and,

- 'Assisting the biofuels industry to meet a 350 ML target is estimated to reduce GDP by between $71 and $74 million in 2010 (in 2003 dollars).'[326]

The conclusions above essentially present a steEp overview of biofuels for road transport in Australia. For the purpose of the present study, if a first-pass screening criteria is applied to any future road transport technology and fuel option on the basis of GHG emissions impact, then it is clear that biofuels, with the potential to reduce emissions by around 0.2 percent (70 percent of 0.3 percent), offer little relief. At the production levels envisaged, any biofuels would have to be regarded as suitable only for niche applications or as additives.[327] This is what is being seen in practice with high profile local council vehicle fleets for example, but at the overall system level is achieving low GHG emission impact. However, the potential for consciousness raising on GHG issues via these programs is perhaps of far greater significance than the physical impact.

Biomass-derived fuels are dependent on a diffuse production system subject to high variability depending on such factors as cultivation method, fertiliser use, soil quality and climate conditions.[328] It is also important to consider whether use of water resources and productive farmland to provide fuel for an extremely inefficient personal transport system (the vast majority of transport energy is used to move cars, not people) is justifiable in the context of overall resource allocation. This is especially so where the usage of land and water is displacing food production.

Biofuel production appears particularly appropriate where the fuel is derived from the waste stream of existing processes, and where opportunity exists for net GHG emission reduction by making use of that waste stream. Examples include the manufacture of biodiesel from waste cooking oil. Specific biofuels and biofuel blends are considered below.

4.5.3.10 Biodiesel[329]

Biodiesel is produced by the estrification of vegetable oil, or by processing tallow. Biodiesel can be used in CI ICEs without modification. GHG and air pollutant emissions for biodiesel depend on the fuel feed stock and production pathway, with significant variability. It is perhaps of particular note that biodiesel can be produced from waste cooking oil. Such use could divert this oil from landfill disposal.

4.5.3.10.1 Barriers, challenges and disadvantages:

- Limited possibility for contribution to total road transport fuel supply;
- Increased production from dedicated crops would have negative land use impacts, including production of the GHG N2O;
- Requires modified fuel injection systems due to high kinematic viscosity;
- Relatively high NOx levels are produced during combustion;
- Contact with humid air must be avoided due to hygroscopic nature;
- Lack of standardisation may lead to equipment problems, for example seal failures and blockage of fuel system components;
- Lower volumetric energy density than petroleum diesel; and,
- Modified refuelling infrastructure is required.

4.5.3.10.2 Incentives, opportunities and advantages:

- Life cycle GHG emissions are lower than for petroleum diesel;
- PM emissions lower than petroleum diesel are expected;
- Non-toxic and biodegradable nature means that fuel is safer than petroleum diesel; and,
- Can improve lubricity when blended with LS diesel.

4.5.3.11 Hydrated ethanol

Hydrated ethanol is ethyl alcohol that contains around 5 percent water.[330] Ethanol production on large scale would require ligno-cellulosic feedstock (trees and shrubs) rather than sugar and wheat. One source cited claims that 90 percent of Australia's petroleum requirement could be met by establishment of biomass plantations over a fifty-year period. Plantations would cover 19 million hectares of cropland and high rainfall pasture.[331] Australia currently has around 53 million hectares of arable land, pasture land is more extensive. Such a transition is regarded here as disadvantageous due to the need to displace other crops.

Ethanol can be produced from a wide range of feed stocks, and the particular production pathway leads to significant variation in GHG emissions. Air pollutant emissions are also affected by the production pathway.

It is possible to use hydrated ethanol as a fuel directly in modified CI ICEs, or in an emulsion with petroleum diesel in unmodified CI ICEs.

4.5.3.11.1 Barriers, challenges and disadvantages:

- Use in diesel engines requires modification of fuel or 'extensive engine adaptations;'[332]
- A full systems analysis of ethanol production from corn in the United States indicates that production and use of ethanol fuel provides no net energy gain and is environmentally and socially unsustainable;[333]
- Ignition improvers may contain harmful chemicals;[334] and,
- Ethanol may have an odour problem;[335]
- Contribution to GHG emission reductions restricted by limited production scale;
- Increased production from dedicated crops would have negative land use impacts, including production of the GHG N_2O.

4.5.3.11.2 Incentives, opportunities and advantages:

- Easily blended with petrol;[336]
- GHG accounting rules result in no tailpipe emissions for ethanol combustion, producing very low GHG emissions results overall for vehicles fuelled with ethanol;[337]
- Large scale ethanol production for transport fuel, using sugar cane as feedstock, has been successful in Brazil for several decades;

- PM emissions are lower than for conventional fuels;[338] and,
- Sulfur level is lower than conventional fuels.[339]

4.5.3.12 Diesohol

Diesohol is a blend of 84.5% petroleum diesel fuel, 15% hydrated ethanol and 0.5% emulsifier from Australian company APACE Research. [340]

4.5.3.12.1 Barriers, challenges and disadvantages:

- Chemical emulsifiers in equivalent fuels overseas contain harmful chemicals. The chemical emulsifier used in the APACE fuel apparently contains only hydrocarbons and oxygen, making its toxicity equivalent to diesel fuel.[341]

4.5.3.12.2 Incentives, opportunities and advantages:

- Blending with a renewable fuel reduces GHG emissions;342 and,
- NOx and PM emissions are lower than for LS diesel.[343]

4.5.3.13 Anhydrous ethanol (E85P)

Anhydrous ethanol is produced by passing hydrated ethanol through an additional processing stage, resulting in a 100% ethanol product. Anhydrous ethanol can either be blended with petrol or used as a fuel on its own in SI ICEs. In practice, it is almost always blended with petrol in the ratio 85% ethanol-15% petrol to improve ignition.[344]

4.5.3.13.1 Barriers, challenges and disadvantages:

- Not a direct substitute for petrol, as is the case for blends limited to a maximum of 10% ethanol;
- Low energy content per unit volume.

4.5.3.13.2 Incentives, opportunities and advantages:[345]

- Lower CO_2 emissions than conventional fuel;
- Tailpipe emissions of NOx and PM may be lower than for conventional fuels on average (depending on feed stock and production pathway); and
- Air toxic levels except for aldehydes are lower than for conventional fuels.

4.5.3.14 Petrohol (E10P)

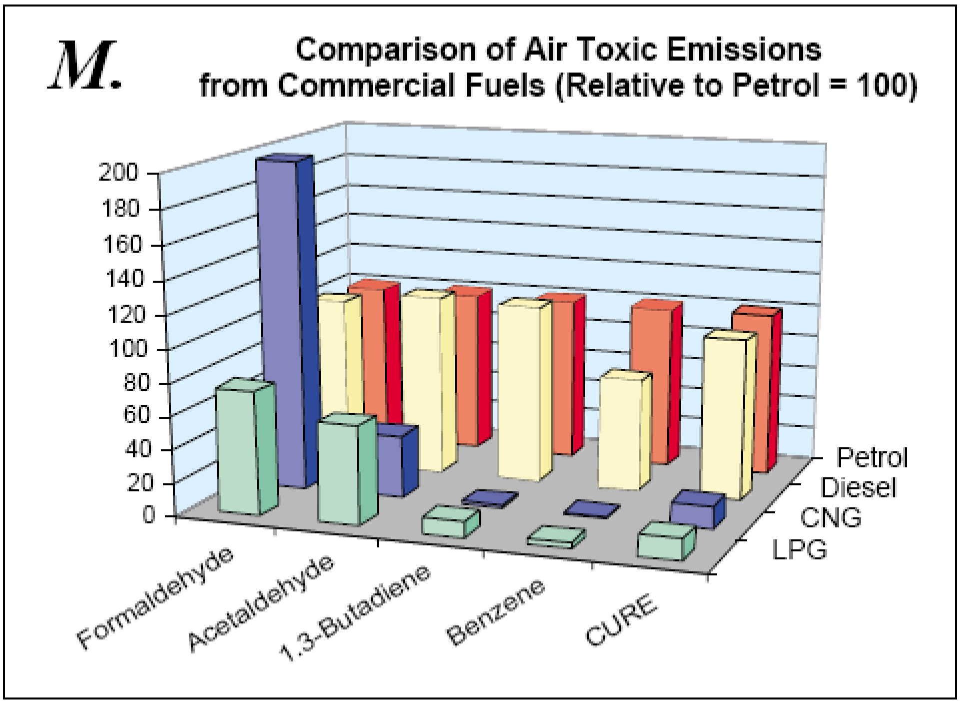
Petrohol is a blend of 10% anhydrous ethanol and 90% petrol.

- Exbodied GHG emissions are only slightly lower than for PULP;[346]
- Other air quality measures are similar to PULP,[347] although 'CO and HC emissions appear to be lower on average;'[348] and,
- High hydrocarbon evaporative emissions.[349]

4.5.4 Air toxic emissions

Information on air toxic emissions for a small subset of the fuels considered above is presented in Figure 4.22. This data is based on research conducted by Argonne National Laboratory, USA. The air toxics considered are formaldehyde, acetaldehyde, 1.3-butadiene and benzene. Also included in the chart is data for Cancer Unit Risk Estimate (CURE).

The relative performance of LPG compared to diesel and petrol for all of the air toxic emissions considered clearly stands out. Overall air toxic emissions for CNG are also lower than both diesel and petrol, although the significantly higher formaldehyde emissions compromise this result to some extent.



Note: CURE = Cancer Unit Risk Estimate, defined as "the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent (eg. chemical) at a concentration of 1 microgram per cubic metre in air or 1 microgram per litre in water". Hence the higher the CURE number, the higher the human cancer risk.

Figure 4.22: Air toxic data for petrol, diesel, CNG and LPG, reproduced from *LPG- The Clean Transport Fuel: Presenting the Environmental Case*[350]

5 Appendix E: Analysis Outcomes

5.1 Summary

Stage Two of the EPA Victoria’s *Study The Future of Alternative Transport Fuels and Technologies in Victoria* involved outlining and applying criteria of analysis to the PTFG and ATFT Policy options identified in Stage One. The steEp analysis criteria are derived from the Stage One research and the original study brief provided by the Victorian EPA. The complete set of PTFG from Stage One were subjected to a summary analysis and screened to identify a subset presenting the most viability for contribution to minimised road transport GHG emissions in Victoria over the next ten years. This subset of significantly viable PTFG were then subjected to further analysis according to broader variables set within a ten year time horizon of possible change. Barriers to the uptake of the most viable PTFG options are identified and existing policy directions that might contribute to overcoming those barriers are noted in brief. A fuller discussion of policy options related to the PTFG is provided in Stage Three of this study.

5.2 Introduction

Stage Two of EPA Victoria’s *Study The Future of Alternative Transport Fuels and Technologies in Victoria* involved analysis of the Stage One research outcomes to identify the most viable subset of Propulsion Technology and Fuel Grouping (PTFG) options in the Victorian context. The analysis process served to clarify the findings documented in the Stage One Technical and Policy steEp Summaries (steEp being an acronym for social, technical, economic, environmental and political variables, with emphasis on the environmental variables) in accordance with the fuel and technology option assessment criteria outlined in the project brief. The resulting subset of PTFG and their key features provides the input into this study's Stage Three scenario generation process.

The first step in the analysis process was defining Triple Bottom Line (TBL) assessment criteria in terms of the steEp factors that circumscribed the Stage One research process. A summary analysis of each PTFG considered in Stage One is presented in relationship to the steEp criteria. The PTFG summaries are then subjected to a general assessment screening using a numerical scoring system based on the steEp criteria. The intent was to identify a subset of PTFG that appear to hold the most viability to, and greatest potential for, contributing to the minimisation of road transport GHG emissions over the next ten years in the Victorian context. The 'most viable' subset of PTFG are then examined in more detail in relationship to four broader, or cross-cutting, analysis variables. This examination includes discussion of the main drivers of change that are expected to affect the viability and related uptake of the PTFG. It also addresses the potential barriers to uptake, fleet operation issues and opportunities, and possible policy-based outcomes and measures for encouraging the uptake of each PTFG.

5.3 Assessment criteria

The PTFG assessment criteria were derived primarily from the EPA Victoria’s study brief. As understood in the brief's terms of reference, the areas of analysis needed to be refined during the research and analysis process. Particular assessment criteria have become more detailed, while others have been summarised, in light of the Stage 1 research. The criteria have been designed to facilitate the screening of the PTFG to identify the most viable options for promotion by the Victorian Government within the next ten years.

The assessment criteria are based on the initial steEp research dimensions, are summarised within more generalised TBL criteria. While additional criteria might be conceived, these constitute a sufficiently broad set to allow reliable identification of the most viable subset of PTFG options.

5.3.1 steEp criteria

Each of the steEp research dimensions encompass several key variables. Table 1 identifies a range of important variables and summarises them as 'criteria questions'. Each criteria question addresses a different 'capability' for which each PTFG can be assessed in considering the development of any Government ATFT policy. Some of the variables are relevant to multiple steEp dimensions, and are included in each for completeness.

steEp Dimension	Capability	Criteria Question	Key Variables	Description of Variable Factors
Technical	Viability	Is production scale possible?	Viability	Technical viability at production scale. This assessment considers issues such as whether or not major technical barriers need to be overcome for particular system components in order for option to be viable at production scale, without considering whether or not the particular option is already supported by manufacturers. For example, hybrid LPG vehicles, while not currently available in the vehicle market, would not require developments beyond currently available technology, where as hydrogen fuel cell vehicles have significant technical hurdles to overcome at production scale.
			Safety	Safety considerations related to vehicle use and accidents, and fuel storage, transport and refuelling.
			Maintenance	Availability of technical skills, specialised equipment, and parts required for vehicle maintenance, both locally and inter-state; and overall vehicle complexity and reliability. Issues related to interstate refuelling are also addressed here.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	Public, fuel supply and automotive industry infrastructure development required to facilitate uptake of the PTFG.
			Retail and operating cost	Retail price and life cycle operating cost for vehicle owners and fuel suppliers.
			Scale	Issues impacting the scale of PTFG uptake, and perception thereof, required to support local manufacture, fuel infrastructure and maintenance suppliers including the potential for imports to meet local demand.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions	Well-to-wheel GHG emissions, based on CO_2-equivalent mass per transport task unit. Described relative to nearest 'competitor' option (eg hybrid petrol is described relative to conventional petrol, hybrid LPG is described relative to hybrid petrol).
			Air Pollution	Well-to-wheel PM, NOx, CO and VOCs, based on emissions per transport task unit. Descriptions as for GHG emissions.
			Resource Consumption	Large-scale road transport usage impact on primary energy source for fuel.
Political	Compatibility	Does it fit existing policy?	Security	Capability of fuel to contribute to diversification of primary energy sources; effect of increased fuel-type usage on crude oil reliance; and ability to make use of domestic energy sources.
			Regulations	Consideration of current and anticipated fuel quality standards and vehicle emissions regulations.
			Initiatives	The existing policy measures and initiatives of Governments in support of the uptake of various ATFT.
Social	Acceptability	Will the market accept it?	Demand	Anticipated market response to PTFG availability.
			Image	Anticipated market perception of the PTFG utility in providing product performance and social desirability.
			Function	Availability and ease of use in terms of vehicle refuelling, general operation, and suitability for vehicle type end-use.

Table 5.1: steEp Criteria Generation.

5.3.2 TBL criteria

The above steEp capabilities and guiding assessment questions can be further summarised in relationship to the common TBL performance assessment categories. Table 2 presents this grouping with general, orienting assessment questions posed for each TBL category.

TBL		steEp		
'Bottom Line' Category	**Orienting Question**	**Dimension**	**Capability**	**Criteria Assessment Question**
Economic	*Is it possible?*	Technical	Viability	Is production scale possible?
		Economic	Feasibility	Do benefits out weigh costs?
Environment	*Does it help?*	Environmental	Sustainability	Does it minimise emissions?
Social	*Is it wanted?*	Political	Compatibility	Does it fit existing policy?
		Social	Acceptability	Will the market accept it?

Table 5.2: TBL and steEp Summary Assessment Questions.

5.3.3 Broader assessment variables

Following the initial screening process, four additional dimensions of analysis warranted further attention for each of the most viable PTFG options. The following four dimensions cut across many of the steEp assessment criteria, forming broader assessment variables:

- *Vehicle Class* – The primary PTFG screening is conducted with PMVs as the primary focus. While many of the assessment criteria are generally applicable to LCVs, trucks and buses also, some variation between vehicle classes does occur. Where the PTFG assessment criteria are dependent on, or significantly influenced by, application in particular vehicle class, different barriers and opportunities arising need to be addressed;
- *Fleet Operations* – Performance against some assessment criteria is significantly influenced by whether vehicles are operated individually or as part of a fleet. The primary screening process generally considered individual operation. The different barriers and opportunities presenting in the context of fleet adoption of the various PTFG need to be considered;
- *10 Year Time Horizon 'Change Variables'* – Some assessment criteria, and the summary assessments presented in this study, may change within the next ten years. Where significant potential for changes impacting the viability of different PTFG is in evidence, these changes need to be outlined. This includes consideration of any widely held expectations regarding development of particular PTFG options. It is also likely that some variables will change over longer time frames (eg 15, 20 or 30 years), and where these might hold value in the consideration of current policy decision making regarding ATFT these need to be indicated; and,
- *Uptake Barriers & Related Policy Options* – While the criteria outlined above also facilitate barrier identification and analysis, other barriers may also exist that could be addressed through a range of policy options. These possible policy outcomes and measures need to be identified.

5.4 Propulsion technology & fuel groupings analysis

A summary of the analysis outcomes for each PTFG identified in Stage One, in relationship to the above steEp criteria, is presented below. Subsequently the range of PTFG was reduced through a high level, generalised steEp assessment process, where a subset of the most viable PTFG are highlighted for further consideration. This process does not represent a rejection of the utility of any of the PTFG omitted from the 'most viable' subset. Rather, the screening process indicates that some options present greater potential benefit according to this study's assessment criteria, where the emphasis is on minimising GHG and air pollutant emissions from Victorian road transport over the next ten years. Following the general screening process, the most viable PTFG are assessed in terms of the broader assessment variables outlined above.

5.4.1 Individual PTFG assessment summaries

The following tables summarise the overall findings for each of the PTFG considered in Stage 1 in terms of the steEp assessment criteria. The analysis focused on the key issues concerning the viability of each PTFG within the Victorian context. The analysis process was tailored for this purpose and subsequently the summary results presented should not necessarily be taken as exhaustive or exacting. The analysis outcomes are presented, where appropriate to aid ease of comparison, as descriptions of PTGF performance relative to either conventional vehicles or likely competitors. For further details, the reader is advised to consult Stage One of this study. The relative GHG and air pollutant emissions are discussed, along with social, technical, political and other environmental factors that either make the option particularly attractive, or that are considered to be impediments to implementation. The analysis outcome summaries form the basis for subsequent general screening to arrive at a subset of most viable PTFG options. It is important to note that the general focus is on applicability to PMVs.

Note that Aquadiesel and diesohol, and petrohol (E10P), are generally covered by the summaries for CI ICE-diesel and SI ICE-petrol respectively. These alternative fuels may be used as direct substitutes for conventional diesel and petrol fuels without any vehicle modification. Compared with other alternative fuels, steEp criteria analysis indicates performance relatively similar to the conventional fuels. As such, they are considered here as a subcomponent of the overall diesel and petrol supply. It is expected that they will remain present as a proportion of the overall fuel supply pool within the timeframe of the study, but with comparatively limited capacity for GHG and air pollutant emissions reduction.

steEp Dimension	Capability	Criteria Question	Key Variables		**Table 5.4.1.1 PMV CI ICE (advanced)-Diesel (petroleum)** (incorporating the diesel substitutes Aquadiesel and diesohol)
Technical	Viability	Is production scale possible?	Viability		Currently in widespread use in Europe, and imports available in small numbers in Australia.
			Safety		Fuel handling safer than petrol.
			Maintenance	General	Availability of labour and replacement parts specific to PMVs would need to be increased, but would be readily implemented. CI ICE generally more reliable than SI ICE.
				Inter-State	No issues foreseen.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	No major issues foreseen, but refer to maintenance and fuel industry impacts.
				Auto Industry	No local manufacture. For significant fleet penetration, local manufacturing probably required. Widely available in Europe, some increased demand could be met by imports.
				Fuel Industry	Strongly supported by local industry. Significant shift from petrol to diesel fuel would necessitate expanded fuel production, distribution and retail infrastructure.
			Operation	Retail Price	Higher than petrol equivalent.
				Op. Cost	Lower than petrol equivalent.
			Scale		Significant uptake would be required to support local manufacture, however initial demand could be stimulated on the basis of imports.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than petrol equivalent.
			Air Pollution	PM	Very significantly higher than petrol equivalent, scope may exist for relative improvement through tailpipe filtering tech. development.
				NOx	Higher than petrol equivalent.
				CO	Significantly lower than petrol equivalent.
				VOCs	Significantly lower than petrol equivalent.
			Resource Consumption		Crude oil, production of which is likely to increase in cost and energy intensity in the mid to long term, perpetuates dependence on a non-renewable energy source.
Political	Compatibility	Does it fit existing policy?	Security		Continued dependence on crude oil, demand for which will increasingly need to be met by imports.
			Regulations		Additional technology development will be essential to meet expected tighter emissions standards.
			Initiatives		Diesel fuel rebate only for heavy vehicles.
Social	Acceptability	Will the market accept it?	Demand		Low demand in PMV market.
			Image		Diesel unpopular outside 4WD market, but may be possible to improve through promotion of 'advanced technology' aspect.
			Function		As for current petrol technology.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.2 PMV CI ICE-Biodiesel
Technical	Viability	Is production scale possible?	Viability		Currently in use, can be used in conventional vehicles without engine modifications.
			Safety		Fuel handling much safer than for petrol.
			Maintenance	General	Similar to petroleum diesel vehicles.
				Inter-State	Limited by fuel availability.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Would require very large infrastructure investment, at high cost.
				Auto Industry	Fuel system components need to be compatible with fuel, but not a significant issue.
				Fuel Industry	Existing industry is very small, expansion would require very large investment. Specialised refuelling infrastructure required - may be best suited to fleets. Attractive where fuel source is waste stream from existing process eg cooking oil.
			Operation	Retail Price	Higher than petroleum diesel equivalent.
				Op. Cost	Expected to be same as for petroleum diesel, on the basis that fuel must be competitive in that market. If biodiesel is perceived as a premium product in niche markets, operating cost may be higher than petroleum diesel. Lower than petrol equivalent. Lower excise than petroleum diesel.
			Scale		Limited fuel availability, fixed high production cost and thus limited scope for expansion.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Much lower than petrol equivalent, lower than petroleum diesel equivalent. Actual GHG emissions vary depending on production pathway and feedstock.
			Air Pollution	PM	Higher than petrol equivalent, lower than petroleum diesel equivalent. Actual emissions vary with production pathway and feedstock.
				NOx	Higher than petroleum diesel equivalent. Actual emissions vary with production pathway and feedstock.
				CO	Lower than petroleum diesel equivalent. Actual emissions vary with production pathway and feedstock.
				VOCs	Slightly lower than petroleum diesel equivalent. Actual emissions vary with production pathway and feedstock.
			Resource Consumption		Renewable production base, but land use impacts can be significant depending on feedstock source.
Political	Compatibility	Does it fit existing policy?	Security		Diversifies fuel supply, but quantity is not significant. Locally produced, so reduces need for imports. Scale of effect very small though.
			Regulations		Reduction in tailpipe air pollutants will need to be addressed to meet increasingly tight emissions and fuel standards.
			Initiatives		Current Federal Government initiative in place to expand biofuels industry, including biodiesel.
Social	Acceptability	Will the market accept it?	Demand		Niche demand, mainly in Government fleets, bus fleets and limited demand in LCV fleets.
			Image		Highly regarded in small niche market segments.
			Function		Comparable to diesel, interchangeable with petroleum diesel, although fuel system impacts must be considered.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.3 PMV Hybrid CI ICE-Diesel (petroleum)
Technical	Viability	Is production scale possible?	Viability		No major issues foreseen.
			Safety		Diesel generally safer to handle than petrol.
			Maintenance	General	Vehicle complexity increased, limited maintenance facilities (more of an issue for hybrid transmission than for CI ICE, but expanded CI ICE facilities would also be required for significant uptake). CI ICE generally more reliable than SI ICE.
				Inter-State	No fuel issues. National maintenance network required for hybrid vehicles, already being established with introduction of petrol hybrids but will take some time to expand.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Not a major issue, but maintenance and fuel industry impacts anticipated.
				Auto Industry	No local or overseas manufacturing commitment, although demonstration vehicles have been presented at European motor shows. Significant fleet uptake would require commitment from local manufacturers. Hybrid diesel PMVs may be available as imports from Europe in the future. This availability might stimulate local demand sufficient to encourage local manufacture.
				Fuel Industry	Strongly supported by fuel industry. Significantly increase would require increased fuel production and expansion of fuel distribution and retailing facilities.
			Operation	Retail Price	Significantly higher than conventional petrol and diesel, higher than petrol hybrid.
				Op. Cost	Lower than for conventional petrol and diesel, slightly lower than for petrol hybrid.
			Scale		None foreseen for fuel. Fleet needs to be large enough to support adequate maintenance facilities, threshold for local manufacture might be met initially by imports from Europe.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Much lower than petrol equivalent, best present option and expected to be similar even to Hydrogen FC beyond timeframe of present study.
			Air Pollution	PM	Significantly higher than Hybrid SI ICE Petrol and non-hybrid diesel, but significantly lower than non-hybrid diesel. Future developments in tailpipe filtering may improve performance relative to petrol, however there is significant uncertainty surrounding this.
				NOx	Higher than petrol equivalent and non-hybrid advanced petrol technology.
				CO	Significantly lower than petrol equivalent.
				VOCs	Lower than petrol equivalent.
			Resource Consumption		Reduced resource usage, but still reliant on limited and volatile crude oil supply. Crude oil, production of which is likely to increase in cost and energy intensity in the mid to long term, perpetuates dependence on a non-renewable energy source.
Political	Compatibility	Does it fit existing policy?	Security		Continued dependence on crude oil - demand will increasingly need to be met by imports.
			Regulations		Air pollution emissions will need to be addressed by technology development to meet expected tighter emissions and fuels standards.
			Initiatives		No specific current initiatives.
Social	Acceptability	Will the market accept it?	Demand		None at present, if Europe and US markets drive up availability at appropriate cost, demand may be easier to stimulate in Australia.
			Image		Diesel vehicles unpopular outside 4WD PMV market. Very popular in Europe (40% PMV market). Hybrid 'high tech' perception may offer opportunity to improve image.
			Function		As for current petrol equivalent.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.4 PMV CI ICE (advanced)-Diesel (GTL with CO2 geosequestration)
Technical	Viability	Is production scale possible?	Viability		No automotive technology issues foreseen.
			Safety		As for petroleum diesel.
			Maintenance	General	As for petroleum diesel vehicles.
				Inter-State	As for petroleum diesel vehicles - fuel is a direct substitute for petroleum diesel.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Would require establishment of processing and geosequestration infrastructure, at significant cost. Uncertain if infrastructure would be established within ten years.
				Auto Industry	Fuel is an alternative to petroleum diesel, requiring no vehicle modifications. GTL has no impact on the automotive industry. Otherwise, as for petroleum diesel vehicles.
				Fuel Industry	Availability dependent on commitment from fuel industry and development of geosequestration capability. Large investment required. Investment likely to depend on relative price of petroleum diesel, as GTL is a direct competitor. Situation would be very sensitive to issues such as introduction of carbon taxes and crude oil supply.
			Operation	Retail Price	Vehicle price unaffected by fuel pathway. Higher than petrol equivalent.
				Op. Cost	Expected to be high due to energy costs of fuel production and CO2 geosequestration, but must be considered relative to cost of petroleum diesel. Unlikely to be available unless cost is comparable with petroleum diesel.
			Scale		Dependent on cost differential with petroleum diesel.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Potentially significantly lower than petrol and petroleum diesel equivalent, but entirely dependent on technology development. Without geosequestration, higher than for petrol.
			Air Pollution	PM	Markedly lower than petroleum diesel vehicles without particle traps and potentially lower than petrol, provided a particle trap is employed in the vehicle exhaust system. Extremely low sulfur in F-T diesel potentially facilitates improved performance of exhaust particle traps.
				NOx	Higher than for petroleum diesel.
				CO	Assumed same as for petroleum diesel.
				VOCs	Lower than for petroleum diesel.
			Resource Consumption		Based on more plentiful natural gas supplies, but still a limited, non-renewable natural resource. Cost and energy intensity of production is likely to increase significantly in the mid to long term.
Political	Compatibility	Does it fit existing policy?	Security		Significant improvement to fuel security, as Australia has large NG reserves. This use would divert NG from other end uses or would increase depletion rate for reserves.
			Regulations		Same basic vehicle developments required to meet tailpipe emissions standards.
			Initiatives		No major government initiatives.
Social	Acceptability	Will the market accept it?	Demand		Essentially dependant on opportunity cost and market concern with sustainability.
			Image		As for petroleum diesel vehicles.
			Function		As for current diesel vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.5 PMV Hybrid CI ICE (advanced)-Diesel (GTL with CO2 geosequestration)
Technical	Viability	Is production scale possible?	Viability		No major issues foreseen.
			Safety		As for petroleum diesel.
			Maintenance	General	As for petroleum diesel hybrid vehicles.
				Inter-State	As for petroleum diesel hybrid vehicles - fuel is a direct substitute for petroleum diesel.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Would require establishment of processing and geosequestration infrastructure, at significant cost. Uncertain whether infrastructure development would be likely within ten year timeframe.
				Auto Industry	Fuel an alternative to petroleum diesel requiring no vehicle modifications. GTL has no impact on the automotive industry. Otherwise, as for petroleum diesel vehicles.
				Fuel Industry	Availability dependent on commitment from fuel industry and development of geosequestration capability. Large investment required. Investment likely to depend on relative price of petroleum diesel, as GTL is a direct competitor. Situation would be very sensitive to issues such as introduction of carbon taxes and crude oil supply.
			Operation	Retail Price	Vehicle price unaffected by fuel pathway. Higher than petrol equivalent.
				Op. Cost	Expected to be high due to energy costs of fuel production and CO2 geosequestration, but must be considered relative to cost of petroleum diesel. Unlikely to be available unless cost is comparable with petroleum diesel anyway.
			Scale		Dependent on cost differential with petroleum diesel.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Potentially much lower than for petrol and lower than for petroleum diesel equivalent.
			Air Pollution	PM	Markedly lower than for petroleum diesel vehicles without particle traps and petrol equivalents, provided a particle trap is employed in the vehicle exhaust system. Extremely low sulfur in F-T diesel potentially facilitates improved performance of exhaust particle traps.
				NOx	Higher than for petroleum diesel equivalent.
				CO	Assumed same as for petroleum diesel equivalent.
				VOCs	Lower than for petroleum diesel equivalent.
			Resource Consumption		Based on more plentiful natural gas supplies, but still a limited, non-renewable natural resource, although reduced usage due to hybrid propulsion system. Cost and energy intensity of production is likely to increase significantly in the mid to long term.
Political	Compatibility	Does it fit existing policy?	Security		Significant improvement to fuel security, as Australia has large NG reserves. This use would divert NG from other end uses or would increase depletion rate for reserves.
			Regulations		Same basic vehicle developments required to meet tailpipe emissions standards.
			Initiatives		No major government initiatives.
Social	Acceptability	Will the market accept it?	Demand		Essentially dependant on opportunity cost and market concern with sustainability.
			Image		As for petroleum diesel vehicles.
			Function		As for current diesel vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.6 PMV SI ICE (advanced)-Petrol (incorporating the petrol substitute petrohol [E10P])
Technical	Viability	Is production scale possible?	Viability		Business as usual development – no issues.
			Safety		As for current vehicles.
			Maintenance	General	No issues, although tech advancements will need to be matched by appropriate equipment and training.
				Inter-State	No issues.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	No issues.
				Auto Industry	Strongly supported by auto industry, expect that advanced technology would be readily incorporated into new vehicles as and when available, provided price implications are not severe.
				Fuel Industry	Strongly supported by fuel industry.
			Operation	Retail Price	Baseline for comparison. Relative price increase may occur with implementation of advanced SI ICE technology.
				Op. Cost	Baseline for comparison, expected to reduce relative to existing vehicles.
			Scale		No issues.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than for current petrol vehicles - ultimate baseline for comparison.
			Air Pollution	PM	Lower than for current petrol vehicles - ultimate baseline for comparison.
				NOx	Lower than for current petrol vehicles - ultimate baseline for comparison.
				CO	Lower than for current petrol vehicles - ultimate baseline for comparison.
				VOCs	Lower than for current petrol vehicles - ultimate baseline for comparison.
			Resource Consumption		Crude oil, production of which is likely to increase in cost and energy intensity in the mid to long term, perpetuates dependence on a non-renewable energy source.
Political	Compatibility	Does it fit existing policy?	Security		Continued dependence on crude oil, demand for which will increasingly need to be met by imports.
			Regulations		Expected to evolve in line with, and significantly influence, the levels of fuel quality and vehicle emissions standards.
			Initiatives		Extensive manufacturing financial support.
Social	Acceptability	Will the market accept it?	Demand		Primary market purchase based on availability and cost.
			Image		As for current vehicles, provided increased price is seen as justified by technology improvements.
			Function		As for current vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.6 PMV SI ICE (advanced)-Anhydrous Ethanol (E85P)
Technical	Viability	Is production scale possible?	Viability		Currently in use overseas, particularly Brazil. Requires engine management and fuel system modifications, but Flexible Fuel Vehicles that can run on any blend from 0 to 85% ethanol are widely available in the USA.
			Safety		As for current vehicles.
			Maintenance	General	As for petrol vehicles.
				Inter-State	Limited by fuel availability.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Limited infrastructure at present, large-scale investment required for fuel availability.
				Auto Industry	Would require industry support in form of provision of modified fuel system components.
				Fuel Industry	Small industry at present, with limited scope for expansion due to restricted feedstock. High level of investment required to expand industry. Very limited capacity for displacement of petroleum fuel.
			Operation	Retail Price	Expected same as for petrol, but may be some price implications in modifying fuel systems for E85P.
				Op. Cost	Expected to be similar to petrol, on the basis that ethanol would need to be competitive in that market. If perceived as a premium product in niche markets, demand could increase cost due to limited supply.
			Scale		No issues foreseen on basis that small scale relative to petroleum fuel sees any increase in production readily taken up, provided pricing is competitive.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Significantly lower than petrol equivalent, varies depending on fuel production pathway.
			Air Pollution	PM	Similar to petrol.
				NOx	Slightly lower than petrol.
				CO	Slightly higher than petrol.
				VOCs	Similar to petrol.
			Resource Consumption		Dependant on feedstock. Renewable resource, but potential land use impacts depending on feedstock supply.
Political	Compatibility	Does it fit existing policy?	Security		Improves fuel diversity, even though magnitude of effect is very small. Displaces crude oil imports, again at very small scale.
			Regulations		Supported by current Federal Government initiative as blending agent, but current regulations restrict content of blend to 10% ethanol. Expected introduction of 20% blend in coming years.
			Initiatives		Effective 0% excise relief until 2008, numerous Federal Government manufacturing infrastructure funding support options, currently reviewing commitment to 350ML production by 2010.
Social	Acceptability	Will the market accept it?	Demand		Low demand generally, some niche markets favourable.
			Image		Ethanol vehicles have poor image due to perceived negative impact on existing vehicles. Mitigated for purpose-built vehicles. Image is good in niche markets particularly interested in reduced GHG emissions.
			Function		As for current vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.7 PMV SI ICE (advanced)-LPG
Technical	Viability	Is production scale possible?	Viability		Currently in widespread use, particularly in fleets.
			Safety		As for current vehicles.
			Maintenance	General	No issues foreseen.
				Inter-State	No issues foreseen.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Significantly increased uptake requires increased fuel supply.
				Auto Industry	Development of LPG vehicles has not kept pace with petrol vehicles, however technology improvements in Europe could be readily implemented locally. Ford currently produces a dedicated LPG version of the Falcon. Increased local industry commitment required.
				Fuel Industry	Well supported by fuel industry. Significantly increased uptake of LPG vehicles would require increased fuel production and distribution, but this is expected to be easily accommodated relative to other fuels. LPG can be sourced both from crude oil refineries and from natural gas production (the major source in Australia).
			Operation	Retail Price	Expected to be slightly higher than for equivalent petrol vehicle.
				Op. Cost	Significantly lower than for equivalent petrol vehicle, based on current excise rate.
			Scale		Threshold market penetration already achieved, increase ultimately limited by LPG availability (ALPGA indicates 50% increase from current production is readily achievable).
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than for petrol equivalent.
			Air Pollution	PM	Lower than for petrol equivalent.
				NOx	Lower than for petrol equivalent.
				CO	Lower than for petrol equivalent.
				VOCs	Lower than for petrol equivalent.
			Resource Consumption		Based on extensive but ultimately finite domestic NG supplies. Continued dependence on non-renewable fuel supply.
Political	Compatibility	Does it fit existing policy?	Security		Increased uptake would represent a significant improvement to fuel security, as Australia has large NG reserves. This use would divert NG from other end uses or would increase depletion rate for reserves.
			Regulations		Adequate for existing and projected fuel quality and vehicle emissions standards.
			Initiatives		Lower tax relative to petrol, and conversion funding for heavy vehicles (this is a Commonwealth initiative).
Social	Acceptability	Will the market accept it?	Demand		Currently at 8% of PMV fleet.
			Image		Widely accepted in PMV market, particularly in fleet operations (taxis for example).
			Function		As for current vehicles although slightly more vehicle space is taken up by fuel tank.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.8 PMV Hybrid SI ICE (advanced)-Petrol
Technical	Viability	Is production scale possible?	Viability		Currently in production.
			Safety		As for existing vehicles.
			Maintenance	General	Increased complexity, requires maintenance facilities and capabilities specific to hybrid drive train.
				Inter-State	Adequate maintenance facilities required.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Adequate maintenance infrastructure required
				Auto Industry	Worldwide, auto industry is making a solid commitment to petrol hybrids. Current availability based on imports only. For significant local uptake, local manufacturers would need to follow suite. Technical viability has been demonstrated locally, but this has not been backed up by production commitment. Continued competitiveness of local industry may require hybrid development.
				Fuel Industry	None foreseen, except for noting slightly reduced fuel supply requirements with widespread uptake.
			Operation	Retail Price	Higher than for equivalent non-hybrid vehicles.
				Op. Cost	Lower than for equivalent non-hybrid vehicles.
			Scale		Increased availability of imports could act as stimulus for local market uptake. This might encourage manufacture by local industry.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Significantly lower than for non-hybrid petrol vehicles.
			Air Pollution	PM	Lower than for non-hybrid petrol vehicles.
				NOx	Lower than for non-hybrid petrol vehicles.
				CO	Lower than for non-hybrid petrol vehicles.
				VOCs	Lower than for non-hybrid petrol vehicles.
			Resource Consumption		Crude oil, production of which is likely to increase in cost and energy intensity in the mid to long term, perpetuates dependence on a non-renewable energy source. Lower impact than non-hybrid. Battery disposal/recycling must be addressed.
Political	Compatibility	Does it fit existing policy?	Security		Continued dependence on crude oil, demand for which will increasingly need to be met by imports.
			Regulations		Expected to easily meet current and projected vehicle emissions standards.
			Initiatives		VIC Government PMV fleet has set target for uptake of petrol hybrids. Federal Government committed to maintaining competitiveness and export potential of local manufacturing industry.
Social	Acceptability	Will the market accept it?	Demand		Demand greater than current supply. This initial rapid uptake is dominated by Government fleet purchases, and is yet to be tested in the broader market.
			Image		Already in market, and appear to be well accepted, although price differential compared with non-hybrids may be a disincentive to uptake. Manufacturers perceive need to maintain adequate power-to-weight to achieve wide acceptance.
			Function		As for existing vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.9 PMV Hybrid SI ICE (advanced)-LPG
Technical	Viability	Is production scale possible?	Viability		None currently available as production vehicles, but in principle any petrol-fuelled ICE vehicle can be modified to run on LPG, either via an aftermarket conversion, as an ex-factory option or as a production-level model variant.
			Safety		As for current vehicles.
			Maintenance	General	Increased complexity, requires maintenance facilities and capabilities specific to hybrid drive train and LPG, but if follows petrol hybrid uptake, then no major issues foreseen.
				Inter-State	No issues foreseen, provided adequate maintenance facilities available.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	None foreseen, although major increase in uptake would require increased fuel supply.
				Auto Industry	See comments for non-hybrid LPG vehicles and hybrid petrol vehicles. No hybrid LPG vehicles are currently on offer, however potential may exist for aftermarket conversion of hybrid petrol vehicles. Market demand might encourage hybrid petrol manufacturers to offer LPG versions of existing vehicles.
				Fuel Industry	Well supported by fuel industry. Significantly increased uptake of LPG vehicles would require increased fuel production and distribution, but this is expected to be easily accommodated relative to other fuels. LPG can be sourced both from crude oil refineries and from natural gas production (the major source in Australia).
			Operation	Retail Price	Price could be expected to be higher than for petrol equivalent.
				Op. Cost	Significantly lower than for petrol equivalent, based on current excise rate.
			Scale		No significant issues foreseen, if following on from hybrid petrol vehicles.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than for petrol equivalent.
			Air Pollution	PM	Lower than for petrol equivalent.
				NOx	Lower than for petrol equivalent.
				CO	Lower than for petrol equivalent.
				VOCs	Lower than for petrol equivalent.
			Resource Consumption		Based on extensive but ultimately finite domestic NG supplies. Continued dependence on non-renewable fuel supply. Lower resource consumption impact than non-hybrid.
Political	Compatibility	Does it fit existing policy?	Security		Increased uptake would represent a significant improvement in fuel security, as Australia has large NG reserves. This use would however, divert NG from other end uses or would increase depletion rate for reserves.
			Regulations		Expected to meet projected tightening in fuel quality and vehicle emissions standards.
			Initiatives		Supported by lower tax relative to petrol.
Social	Acceptability	Will the market accept it?	Demand		Expected to be a welcomed alternative if overall LPG technology is updated.
			Image		Likely to be similar to perception of non-hybrid LPG vehicles, although additional 'green technology' likely a plus.
			Function		As for current vehicles.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.10 PMV SI ICE (advanced)-CNG
Technical	Viability	Is production scale possible?	Viability		Currently in use in heavy vehicle fleet in small numbers. Diesel vehicles can be converted to CNG with addition of appropriate engine management, fuel handling and spark ignition systems. Fuel system and engine management modification required for PMV conversion. Reported to have 16% PMV fleet share in Argentina, based on conversion of petrol vehicles.
			Safety		No issues foreseen.
			Maintenance	General	No significant issues foreseen, although skill base would need to be developed for CNG SI ICE technology.
				Inter-State	Dependent on availability of refueling infrastructure. CNG would not be viable for vehicles intended for use inter-state without national infrastructure development.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Significant fuel distribution and retail infrastructure would be required to ensure viability, needing large investment.
				Auto Industry	CNG engine development has lagged behind petrol and diesel, but is expected to improve significantly relative to incumbent technology over the next ten years. Ex-factory CNG vehicles are not widely available at present, and viability would require commitment from local manufacturers. Most CNG vehicles (particularly PMVs) are converted from petrol.
				Fuel Industry	Significant commitment from fuel industry required to ensure viability.
			Operation	Retail Price	Expected to be higher than for petrol equivalent.
				Op. Cost	Similar to petrol equivalent, although this is uncertain.
			Scale		Fuel distribution and retail infrastructure, and market acceptance required.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than for petrol equivalent.
			Air Pollution	PM	Lower than for petrol equivalent.
				NOx	Significantly lower than for petrol equivalent.
				CO	Significantly lower than for petrol equivalent.
				VOCs	Significantly lower than for petrol equivalent, provided fugitive emissions during fuel delivery are kept sufficiently low
			Resource Consumption		Based on extensive but ultimately finite domestic NG supplies. Continued dependence on non-renewable fuel supply.
Political	Compatibility	Does it fit existing policy?	Security		Significant improvement to fuel security, as Australia has large NG reserves. This use would however, divert NG from other end uses or would increase depletion rate.
			Regulations		Expected to meet fuel quality and vehicle emissions standards for the next 10 years.
			Initiatives		Supported by Federal Government vehicle conversion and fuel supply manufacturing funding, although refueling station development has stalled.
Social	Acceptability	Will the market accept it?	Demand		Vicious circle of low infrastructure development due to low demand, due to no refuelling infrastructure.
			Image		Expected to be poor due to fuel tank size issue.
			Function		Very significantly affected for PMVs by size of fuel tank required for adequate range. Lack of refueling infrastructure would also have a significant negative impact on ease of use. Longer refueling time than for liquid fuels.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.11 PMV SI ICE (advanced)-LNG
Technical	Viability	Is production scale possible?	Viability		Significant heavy vehicle technical viability, technically viable in PMV market, but technical limitations on range.
			Safety		Storage and handling of cryogenic liquid may be an issue.
			Maintenance	General	Would require appropriate maintenance infrastructure development.
				Inter-State	Unlikely to be suitable due to refuelling issues (cryogenic fuel handling is required, making it suitable for depot-based vehicles only).
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Significant fuel distribution and retail infrastructure would be required to ensure viability, needing large investment.
				Auto Industry	LNG engine development has lagged behind petrol and diesel, but is expected to improve significantly relative to incumbent technology over the next ten years. LNG vehicles are not readily available at present, and viability would require commitment from local manufacturers.
				Fuel Industry	Significant commitment from fuel industry required to ensure viability.
			Operation	Retail Price	See CNG equivalent, cryogenic fuel storage may increase price.
				Op. Cost	Expected similar to CNG.
			Scale		Fuel distribution infrastructure required, market acceptance would be required.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Slightly higher than for CNG.
			Air Pollution	PM	Very similar to CNG.
				NOx	Slightly greater than for CNG.
				CO	Assumed similar to CNG.
				VOCs	Slightly less than for CNG, provided fugitive emissions during fuel delivery are kept sufficiently low.
			Resource Consumption		Based on extensive but ultimately finite domestic NG supplies. Continued dependence on non-renewable fuel supply.
Political	Compatibility	Does it fit existing policy?	Security		Significant improvement to fuel security, as Australia has large NG reserves. This use would divert NG from other end uses or increase depletion rate for reserves.
			Regulations		Expected to meet fuel quality and vehicle emissions standards for the next 10 years.
			Initiatives		Supported by Federal Government vehicle conversion and fuel supply manufacturing funding.
Social	Acceptability	Will the market accept it?	Demand		Vicious circle of low infrastructure development due to low demand, due to no refuelling infrastructure.
			Image		Expected to be poor due to fuel tank size issue.
			Function		Very significantly affected for PMVs by size of fuel tank required for adequate range. Lack of refueling infrastructure would also have a significant negative impact on ease of use.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.12 PMV Hybrid SI ICE (advanced)-CNG
Technical	Viability	Is production scale possible?	Viability		Significant heavy vehicle technical viability, technically viable in PMV market, but technical limitations on range.
			Safety		No issues foreseen.
			Maintenance	General	No significant issues foreseen, although skill base would need to be developed for CNG SI ICE technology. Prior establishment of hybrid maintenance facilities is assumed for petrol vehicles.
				Inter-State	Dependent on availability of refuelling infrastructure.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Significant fuel distribution and retail infrastructure would be required to ensure viability, needing large investment.
				Auto Industry	See comments for non-hybrid CNG vehicles. Hybrid CNG vehicles are not presently available, nor are any known to be in the pipeline. They are considered here as a plausible development of hybrid petrol and diesel vehicle technology.
				Fuel Industry	Significant commitment from fuel industry required to ensure viability.
			Operation	Retail Price	Expected to be higher than for petrol equivalent.
				Op. Cost	Similar to petrol equivalent, although this is uncertain.
			Scale		Fuel distribution and retail infrastructure required, commitment from auto industry (Europe or US and local) would be required, market acceptance would be required.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lower than for petrol equivalent.
			Air Pollution	PM	Lower than for petrol equivalent.
				NOx	Significantly lower than for petrol equivalent.
				CO	Significantly lower than for petrol equivalent.
				VOCs	Significantly lower than for petrol equivalent, provided fugitive emissions during fuel delivery are kept sufficiently low.
			Resource Consumption		Based on extensive but ultimately finite domestic NG supplies. Continued dependence on non-renewable fuel supply.. Uses less fuel than non-hybrid.
Political	Compatibility	Does it fit existing policy?	Security		Significant improvement to fuel security, as Australia has large NG reserves. This use would divert NG from other end uses or would increase depletion rate for reserves.
			Regulations		Expected to meet fuel quality and vehicle emissions standards for the next 10 years.
			Initiatives		Supported by Federal Government vehicle conversion and fuel supply manufacturing funding, although refueling network development has stalled.
Social	Acceptability	Will the market accept it?	Demand		Vicious circle of low infrastructure development due to low demand, due to no refuelling infrastructure.
			Image		Expected to be poor due to fuel tank size issue.
			Function		Significantly affected for PMVs by size of fuel tank required for adequate range, although increased fuel economy for hybrid will mitigate this issue somewhat relative to non-hybrid. Lack of refuelling infrastructure would also have a significant negative impact on ease of use. Longer refuelling time than for liquid fuels.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.13 PMV SI ICE-Hydrogen (ex NG)
Technical	Viability	Is production scale possible?	Viability		Not yet practical, prototype/demonstration stage only.
			Safety		Poor safety image of hydrogen is reportedly overstated.
			Maintenance	General	Would require development of appropriate skill base and facilities, although being based on ICE technology would make this relatively straightforward.
				Inter-State	Dependent on development of nation-wide refuelling and maintenance infrastructure. Very uncertain at this stage.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Requires development of fuel production facilities and distribution network for uptake to be viable.
				Auto Industry	Limited activity around this technology. Seen only as a transition to fuel cells, so little commitment likely. No indication of local auto industry commitment. Availability would likely be dependent on imports.
				Fuel Industry	Viability requires strong commitment from fuel industry, either existing or new players.
			Operation	Retail Price	Markedly higher than petrol equivalent.
				Op. Cost	Expected to be markedly higher than petrol equivalent.
			Scale		Would require sufficient fuel availability, and vehicle availability from overseas.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Higher than petrol equivalent. With CO2 geosequestration post NG reforming, GHG emissions from fuel cycle could in theory be reduced to zero.
			Air Pollution	PM	Effectively zero (although small amount could be expected ex engine lubricants).
				NOx	Higher than for petrol equivalent.
				CO	Zero.
				VOCs	Zero.
			Resource Consumption		Dependent on large (although ultimately limited and non-renewable) domestic natural gas reserves. Usage as primary energy source for production of hydrogen ICE fuel would deplete reserves more quickly than if natural gas was used directly as ICE fuel.
Political	Compatibility	Does it fit existing policy?	Security		Positive for fuel security due to diversification of fuel sources, and use of local feedstock. Potential to displace crude oil, but scale seems unlikely to be significant within timeframe of present study.
			Regulations		Appropriate vehicle standards and regulations are required.
			Initiatives		None at present.
Social	Acceptability	Will the market accept it?	Demand		Entirely dependent on fuel availability and automotive industry commitment, prior to even considering market response to any fuel and vehicle availability.
			Image		Little present awareness, vehicle price and operating cost unlikely to be attractive.
			Function		Refuelling time longer than for liquid fuels. Range restricted by low fuel density (or very large fuel tank required). Entirely dependent on development of hydrogen distribution and refuelling infrastructure. Probably only suitable for fleet use.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.14 PMV FC (direct electric drive)-Hydrogen (ex NG)
Technical	Viability	Is production scale possible?	Viability		Not yet confirmed practical (prototype/demonstration stage only).
			Safety		Poor safety image of hydrogen is reportedly overstated.
			Maintenance	General	Requires development of facilities and skill base around FC technology. This will not transfer directly from current maintenance infrastructure. Large training commitment required. FC vehicles under development still have reliability and service life issues.
				Inter-State	Dependent on development of nation-wide refuelling and maintenance infrastructure. Very uncertain at this stage.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Requires large commitment to fuel distribution, retail and maintenance infrastructure.
				Auto Industry	Vehicles are at pilot stage only at present, and hence lag other options by a significant margin. Questions over whether manufacturers would develop non-hybrid FC vehicles, likely to go straight to hybrid version. Dependent on overseas developments. Any significant uptake likely to require commitment by local auto industry. Availability of vehicles within timeframe of present study is uncertain.
				Fuel Industry	Viability requires strong commitment from fuel industry, either existing or new players.
			Operation	Retail Price	Much higher than for petrol hybrid.
				Op. Cost	Significantly higher than for petrol hybrid.
			Scale		Would require sufficient fuel availability, and importing of vehicles.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Higher than petrol hybrid, may be as high as non-hybrid diesel. With CO2 geosequestration post NG reforming, GHG emissions from fuel cycle could in theory be reduced to zero.
			Air Pollution	PM	Approaching zero.
				NOx	Approaching zero.
				CO	Assumed approaching zero.
				VOCs	Lower than for petrol hybrid.
			Resource Consumption		Dependent on large (although ultimately limited and non-renewable) domestic natural gas reserves. Usage as primary energy source for production of hydrogen FC fuel would extend reserves relative to use in hydrogen ICEs or direct usage of natural gas as ICE fuel.
Political	Compatibility	Does it fit existing policy?	Security		Positive for fuel security due to diversification of fuel sources, and use of local feedstock. Potential to displace crude oil, but large scale unlikely within ten years.
			Regulations		Appropriate vehicle standards and regulations required.
			Initiatives		Only vehicle heavy vehicle (bus) trials in WA.
Social	Acceptability	Will the market accept it?	Demand		Entirely dependent on fuel availability and automotive industry commitment. Automotive industry likely to bypass direct drive FCs altogether in favour of hybrid system. Perth bus trial is based on direct electric drive rather than hybrid. Demand expected to be very sensitive to high relative vehicle price.
			Image		Much hype around hydrogen FC vehicles, highly visible option. Likely to be attractive to consumers, although retail price will impact significantly on this.
			Function		Refuelling time longer than for liquid fuels. Range restricted by low fuel density (or very large fuel tank required). Entirely dependent on development of hydrogen distribution and refuelling infrastructure. Probably only suitable for fleet use.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.15 PMV FC (direct electric drive)-Hydrogen (electrolysis with renewable electricity)
Technical	Viability	Is production scale possible?	Viability		As for FC (direct electric drive)-Hydrogen (ex NG). Fuel production is technically viable.
			Safety		As for FC (direct electric drive)-Hydrogen (ex NG).
			Maintenance	General	As for FC (direct electric drive)-Hydrogen (ex NG).
				Inter-State	As for FC (direct electric drive)-Hydrogen (ex NG).
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	Would require large-scale development of renewable electricity infrastructure. Large investment required.
				Auto Industry	As for FC (direct electric drive)-Hydrogen (ex NG).
				Fuel Industry	Dependent on commitment from fuel industry. May be opportunity for entirely new players to enter road transport fuel market. Fuel would be very expensive, though, likely discouraging investment.
			Operation	Retail Price	As for FC (direct electric drive)-Hydrogen (ex NG).
				Op. Cost	Very high (expected highest operating cost of any option).
			Scale		Any level of fuel production would add directly to existing hydrogen supply pool.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Zero for fuel cycle, but vehicle production and renewable electricity generation equipment will contribute some emissions.
			Air Pollution	PM	Zero from fuel cycle.
				NOx	Zero from fuel cycle.
				CO	Zero from fuel cycle.
				VOCs	Zero from fuel cycle.
			Resource Consumption		Highly contentious use of renewable electricity resources, given very limited availability at present. Perceived as poor usage of a scarce resource, particularly given low overall efficiency of end use.
Political	Compatibility	Does it fit existing policy?	Security		Potential for significant improvement to fuel security. Displaces fossil fuels. Scale would limit effect in real terms.
			Regulations		Appropriate vehicle standards and regulations required.
			Initiatives		Discussion of hydrogen production from tidal power in WA's north west should be watched.
Social	Acceptability	Will the market accept it?	Demand		Very high cost option throughout the timeframe of present study, likely to restrict any demand to the level of 'enthusiasts' at most.
			Image		As for FC (direct electric drive)-Hydrogen (ex NG).
			Function		As for FC (direct electric drive)-Hydrogen (ex NG).

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.16 PMV Hybrid FC-Hydrogen (ex NG)
Technical	Viability	Is production scale possible?	Viability		As for FC (direct electric drive)-Hydrogen (ex NG). ICE hybrid technology is currently in production and would be directly applicable to hybrid FC vehicles.
			Safety		As for non-hybrid FC
			Maintenance	General	As for non-hybrid FC, but with added complexity of hybrid drive. While this may improve the reliability of the FC itself, the overall system has more failure points.
				Inter-State	As for non-hybrid FC.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	As for non-hybrid FC.
				Auto Industry	Development lags hybrid ICE tech by a significant margin. Pilot stage only at present. Worldwide, though, the auto industry appears to be making a solid commitment to this option. Local activity, however, lags further behind, and would need to catch up if this option was to see significant uptake. In terms of the present study, uncertainty regarding timeframe of availability casts doubt over significance. On the whole, seems unlikely to be a significant player in the next ten years.
				Fuel Industry	As for non-hybrid FC.
			Operation	Retail Price	Much higher than for petrol and diesel hybrids.
				Op. Cost	Significantly higher than for petrol and diesel hybrids.
			Scale		As for non-hybrid FC vehicles.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Similar to diesel hybrid. With CO2 geosequestration post NG reforming, GHG emissions from fuel cycle could in theory be reduced to zero.
			Air Pollution	PM	Approaching zero.
				NOx	Approaching zero.
				CO	Assumed approaching zero.
				VOCs	Assumed lower than for diesel hybrid.
			Resource Consumption		As for non-hybrid FC, although improved fuel efficiency would extend life of natural gas reserves. Battery recycling/disposal must be addressed.
Political	Compatibility	Does it fit existing policy?	Security		As for non-hybrid FC.
			Regulations		No issues foreseen.
			Initiatives		Only vehicle heavy vehicle (bus) trials in WA (non-hybrid).
Social	Acceptability	Will the market accept it?	Demand		Entirely dependent on fuel and vehicle availability, but expected to be restricted by very high retail price relative to other vehicle technologies.
			Image		As for non-hybrid FC.
			Function		As for non-hybrid FC, although fuel storage issue will be mitigated somewhat by improved efficiency.

steEp Dimension	Capability	Criteria Question	Key Variables		Table 5.4.1.17 PMV Hybrid FC-Hydrogen (electrolysis with renewable electricity)
Technical	Viability	Is production scale possible?	Viability		As for non-hybrid.
			Safety		As for Hybrid FC-Hydrogen (ex NG).
			Maintenance	General	As for Hybrid FC-Hydrogen (ex NG).
				Inter-State	As for Hybrid FC-Hydrogen (ex NG).
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	As for non-hybrid, renewable pathway.
				Auto Industry	As for Hybrid FC-Hydrogen (ex NG).
				Fuel Industry	As for non-hybrid, renewable pathway.
			Operation	Retail Price	As for Hybrid FC-Hydrogen (ex NG).
				Op. Cost	Very high, mitigated somewhat by improved efficiency of hybrid tech.
			Scale		As for Hybrid FC-Hydrogen (ex NG).
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Lowest plausible GHG emission option for road transport within timeframe of study, emissions dependent on vehicle manufacture and scrapping, electricity generation equipment manufacture and scrapping. On this basis, inherently not 'zero emission.'
			Air Pollution	PM	Zero from fuel cycle.
				NOx	Zero from fuel cycle.
				CO	Zero from fuel cycle.
				VOCs	Zero from fuel cycle.
			Resource Consumption		See non-hybrid FC.
Political	Compatibility	Does it fit existing policy?	Security		As for non-hybrid, renewable pathway.
			Regulations		Non applicable.
			Initiatives		Discussion of hydrogen production from tidal power in WA's north west should be watched.
Social	Acceptability	Will the market accept it?	Demand		Very high cost option throughout the timeframe of present study, likely to restrict any demand to the level of 'enthusiasts' at most.
			Image		As for Hybrid FC-Hydrogen (ex NG).
			Function		As for Hybrid FC-Hydrogen (ex NG).

steEp Dimension	Ability	Criteria Question	Key Variables		Table 5.4.1.17 PMV Hybrid FC-Petrol (on board reforming)
Technical	Viability	Is production scale possible?	Viability		Possible in principle, not in production due to high cost, less viable than hydrogen FC.
			Safety		As for incumbent technology.
			Maintenance	General	Adds another level of complexity to hybrid FC vehicle, requiring further facility and skill development, and potentially further reducing reliability. Unattractive from maintenance perspective.
				Inter-State	No issues for fuel, but maintenance support would need to be available nation-wide.
Economic	Feasibility	Do benefits out weigh costs?	Infrastructure	General	None for fuel, see comments regarding maintenance.
				Auto Industry	Indications are that auto industry is unlikely to pursue on board fuel processing option. If this was supported, development lags significantly behind ICE-based tech. No indication of local industry activity.
				Fuel Industry	None foreseen.
			Operation	Retail Price	Very much higher than hybrid petrol ICE.
				Op. Cost	Similar to hybrid petrol ICE.
			Scale		Would require availability of imports, which seems unlikely at this stage.
Environmental	Sustainability	Does it reduce net emissions?	GHG Emissions		Similar to hybrid petrol ICE.
			Air Pollution	PM	Assumed much lower than hybrid petrol ICE.
				NOx	Assumed much lower than hybrid petrol ICE.
				CO	Assumed much lower than hybrid petrol ICE.
				VOCs	Assumed lower than hybrid petrol ICE.
			Resource Consumption		Reduced fuel usage relative to ICE vehicle, but continues dependence on non-renewable crude oil, production of which is expected to increase in cost and energy intensity in mid to long term.
Political	Compatibility	Does it fit existing policy?	Security		Continues crude oil dependence.
			Regulations		Would meet current and expected increases in fuel quality and vehicle emissions standards.
			Initiatives		None currently.
Social	Acceptability	Will the market accept it?	Demand		Expected to be highly dependent on retail price.
			Image		Little market awareness apparent, would probably be attractive on the basis of fuel availability, but very unattractive on basis of retail price.
			Function		Similar to hybrid petrol ICE, and therefore to incumbent technology.

5.5 General steEp assessment of PTFG

The results of the PTFG screening process, conducted on the basis of the analysis outcome summaries in the tables above, are shown in Table 5.4. This high level screening uses a simple numerical scoring system, based on estimated relative performance, to rank the viability of each PTFG. The outcome is a subset of the most viable PTFG that will be carried forward for more examination according to the four broader variables outlined above.

5.5.1 steEp criteria scores

The numerical scores for each steEp criteria are arrived at by estimating each PTFG option's performance according to the scale shown in Table 5.3. A colour-coding system has been adopted to aid interpretation of the results. The scoring process represents a high level assessment of each PTFG's capabilities relative to the conventional vehicle baseline, and bridges qualitative and quantitative criteria. The assessments are intended to be broadly indicative rather than exacting. This is a necessary compromise between subjective and objective methodology brought about by the wide range of variables being considered in this study.

Score	Colour	Meaning
+2	(dark green)	Significantly positive capability
+1	(light green)	Positive capability
0	(white)	Neutral
-1	(grey)	Little capability
-2	(orange)	Restricted capability
-20	(red)	Significant impediment to implementation
Relative to the SI ICE Petrol Baseline from Stage 1.		

Table 5.3: Legend for PTFG Assessment Scores.

The assessment table represents a judgement based on the technical and policy steEp research documented in Stage One, focusing on PVM and LCV vehicle types as these are the most significant contributors to net transport GHG emissions.

TBL Criteria Question	**Is it possible?**		**Does it help?**		**Is it wanted?**		**Overall steEp Assessment:**
steEp Dimension	**Technical**	**Economic**	**Environmental**		**Political**	**Social**	
steEp Capability	Viability	Feasibility	Sustainability		Compatibility	Acceptability	
steEp Criteria Question	Is production scale possible?	Do benefits out weigh costs?	Does it reduce net emissions?		Does it fit existing policy?	Will the market accept it?	
			GHG	Air			
CI-ICE (adv.)-Diesel (petroleum)	0	-1	1	-2	0	-1	☆
CI-ICE Biodiesel	0	-20	1	-1	2	0	
Hybrid CI ICE-Diesel (petroleum)	-1	-1	2	-1	0	-1	☆
CI ICE (adv.)-Diesel (GTL +Gsq)	-20	-2	2	2	-1	0	
Hybrid CI ICE-Diesel (GTL + Gsq)	-20	-2	2	2	-1	0	
SI ICE (adv.)-Petrol (Baseline)	0	0	0	0	0	0	
SI ICE (adv.)-Anhy. Ethanol (E85P)	-1	-20	2	1	2	-1	
SI ICE (adv.)-LPG	0	1	1	1	1	0	☆ ☆
Hybrid SI ICE-Petrol	0	0	1	1	1	1	☆ ☆
Hybrid SI ICE-LPG	0	0	2	2	1	0	☆ ☆
SI ICE (adv.)-CNG	-1	-2	1	1	2	-20*	☆
SI ICE (adv.)-LNG	-2	-20	1	1	1	-20	
Hybrid SI ICE-CNG	-2	-2	2	2	1	-20*	☆
SI ICE Hydrogen (ex NG)	-1	-20	0	1	1	1	
FC Hydrogen (ex NG)	-2	-20	1	2	1	1	
FC Hydrogen (renewable)	-2	-20	2	2	1	2	
Hybrid FC Hydrogen (ex NG)	-2	-20	2	2	1	2	
Hybrid FC Hydrogen (renewable)	-2	-20	2	2	1	2	
Hybrid FC Petrol (fuel processor)	-2	-20	1	1	1	1	

Table 5.4: Summary of PTFG Assessment Scores.

*The significant impediment is mitigated in the context of heavy vehicles, buses and fleet operations.

5.5.2 General assessment results

While each of the PTFG have their own particular strengths, several stand out as being more viable options for the reduction of GHG and air pollutant emissions within the next ten years. The subset that will be further examined include those with an overall steEp assessment rating of one or two stars. The PTFG omitted by the screening process (those with no stars) may still hold value, and individual fuel and/or technology components may also be of value. Within the scope of this study however, they offer less potential for GHG and air pollutant reductions. (Table 5.5 outlines the nature of the significant impediments to implementation of these PTFG.)

The inclusion of conventional and hybrid diesel PMVs in the most viable subset is strongly contingent on the success of tailpipe filtering in significantly reducing particulate matter emissions. If improvements were not made in this area, then it would seem inappropriate to increase the proportion of diesel vehicles on the grounds that air quality is likely to deteriorate with significant increase in associated health risks. Rather than making an immediate commitment to promoting this option, an approach whereby developments in this area were closely monitored for improvement prior to active promotion would perhaps be more appropriate.

The heavy vehicle fleet sectors, in which diesel technology is already established as the incumbent option, stand to benefit from uptake of advanced conventional and hybrid diesel technology. The diesel options clearly belong in the most viable subset for heavy vehicles, where overall air pollutant emissions can be expected to reduce as GHG emissions reduce.

PTFG	steEp Criteria	Nature of Impediment
CI-ICE Biodiesel	Economic	Limited fuel availability, high cost for small increase
CI ICE (adv.)-Diesel (GTL +Gsq)	Technical	Require establishment of processing and geosequestration infrastructure
Hybrid CI ICE-Diesel (GTL + Gsq)	Technical	Require establishment of processing and geosequestration infrastructure
SI ICE (adv.)-Anhy. Ethanol (E85P)	Economic	Large-scale investment required for fuel availability (limited infrastructure at present)
SI ICE (adv.)-CNG	Social	Fuel tanks would be too large for passenger vehicles (or vehicle range would be inadequate), lack of refuelling infrastructure
SI ICE (adv.)-LNG	Economic & Social	Significant fuel distribution and retail infrastructure would be required to ensure viability; Refuelling requires handling of a cryogenic liquid - suitable only for depot-based fleet vehicles
Hybrid SI ICE-CNG	Social	Fuel tanks would be too large for passenger vehicles (or vehicle range would be inadequate), lack of refuelling infrastructure
SI ICE Hydrogen (ex NG)	Economic	High vehicle costs, extremely high fuel costs
FC Hydrogen (ex NG)	Economic	Extremely high vehicle costs, extremely high fuel costs
FC Hydrogen (renewable)	Economic	Extremely high vehicle costs, extremely high fuel costs
Hybrid FC Hydrogen (ex NG)	Economic	Extremely high vehicle costs, extremely high fuel costs
Hybrid FC Hydrogen (renewable)	Economic	Extremely high vehicle costs, extremely high fuel costs
Hybrid FC Petrol (fuel processor)	Economic	Extremely high vehicle costs, extremely high fuel costs

Table 5.5: Description of significant impediments to uptake of PTFG.

Opportunities for significant benefit do exist in the cases of the CNG, LNG and hydrogen PTFG. In the case of CNG and LNG viability is significantly improved with increased vehicle size. Hydrogen FC options are expected to be more attractive over a longer timeframe. These options merit further discussion and ongoing consideration in the Stage 3 ATFT scenario process. Natural gas and hydrogen-fuelled vehicles are discussed further as two broad ATFT categories.

The significant impediments affecting biodiesel and ethanol mean that these options are not considered in any further detail. As discussed elsewhere however, the biofuels in particular are very attractive in niche applications. For more information, the reader is referred to Stage 1 and the analysis outcome summary tables above. In general, research indicates that the overall contribution to minimisation of emissions from these fuels will be very limited. They are likely to be present, but any impact is expected to be significantly limited at the level of the total road transport fleet.

GTL diesel produced from natural gas has a very uncertain future in terms of the Australian context. It might warrant mention in the scenario-generation process, but is not examined any further here.

5.6 Broader PTFG examination

The subset of most viable PTFG identified was examined according to the four broader assessment criteria:

- *Vehicle Class* – The primary PTFG screening is conducted with PMVs as the primary focus. While many of the assessment criteria are generally applicable to LCVs, trucks and buses also, some variation between vehicle classes does occur. Where the PTFG assessment criteria are dependent on, or significantly influenced by, application in particular vehicle class, different barriers and opportunities arising need to be addressed;

- *Fleet Operations* – Performance against some assessment criteria is significantly influenced by whether vehicles are operated individually or as part of a fleet. The primary screening process generally considered individual operation. The different barriers and opportunities presenting in the context of fleet adoption of the various PTFG need to be considered;
- *Ten Year Time Horizon 'Change Variables'* – Some assessment criteria, and the summary assessments presented in this study, may change within the next ten years. Where significant potential for changes impacting the viability of different PTFG is in evidence, these changes need to be outlined. This includes consideration of any widely held expectations regarding development of particular PTFG options. It is also likely that some variables will change over longer time frames (eg 15, 20 or 30 years), and where these might hold value in the consideration of current policy decision making regarding ATFT these need to be indicated; and,
- *Uptake Barriers & Related Policy Options* – While the criteria outlined above also facilitate barrier identification and analysis, other barriers may also exist that could be addressed through a range of policy options. These possible policy outcomes and measures need to be identified.

In the following tables, these four broader assessment criteria are considered in an integrated fashion along each of the steEp dimensions. The tables summarise the key capabilities, barriers and policy options related to each PTFG, highlighting the aspects that represent the most viable opportunities to minimise GHG and air pollutant emissions from Victorian road transport over the next ten years.

TBL Criteria	steEp Ability	steEp Criteria	**Broader variable assessment notes on:** **Table 5.6.1 CI ICE (adv.)-Diesel (petroleum)**
Is it possible?	Technical Viability	*Is production scale possible?*	An expanded maintenance network would be required for more CI ICE-Diesel PMVs, however this would be easily evolved from the existing diesel and petrol vehicle maintenance network in step with any market share increase of diesel PMVs.
	Economic Feasibility	*Do costs out weigh benefits?*	Diesel PMVs could be imported in greater numbers to provide for initial uptake, with possible local manufacturer follow-on. Local manufactures could be stimulated by import competition and a limited tax credits system related to lower GHG emissions and air pollutants, and/or infrastructure conversion assistance funding. Significant uptake in the PMV market might be achieved by import tariff reductions, lower purchase taxes, lower fuel price differential compared to petrol reflecting efficiency gains, a rebate scheme for commercial fleets, and lower vehicle registration costs. This would need to consider appropriate means for differentiating small diesel PMVs from large diesel PMVs such as 4WD vehicles, to avoid encouraging further uptake of excessively large vehicles which could contribute to an increase in net emissions. Any promotion of diesel PMVs should be contingent on reductions in particulate matter and NOx emissions to levels lower than the PMV fleet average.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	Developments in tailpipe filtering accompanying the introduction of ULS diesel may have the potential to significantly reduce PM emissions. This might be considered part of the normal evolutionary development of CI ICE technology. Expanded opportunities may exist to hasten development and application amongst existing fleet, predominantly LCV, trucks and buses by mandating tighter emissions standards based on available technologies, applied specifically to new vehicles, or where possible through modifications to current fleet vehicles. New technologies could be encouraged through research and development funding.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	There are no conflicts with current policies, however concern over air quality has the potential to place diesel under tighter scrutiny. Further diesel uptake could be stimulated by the current fuels grants scheme being extended and qualified to include next generation LCV diesel vehicles that demonstrate lower air pollutant emissions. Additionally, because diesel vehicles have options for use of biodiesel, a minor increase in transport sector fuel diversity and security could be achieved.
	Social Acceptability	*Will the consumer market accept it?*	Government fleet adoption may contribute to stimulated demand and improved availability of diesel vehicles (provided air pollutant emissions issues are addressed). The above mentioned technology developments, marketing of these developments on the basis of their improved 'green' image and financial incentives could all contribute to an increased share of the PMV and LCV market over the next ten years.

TBL Criteria	steEp Ability	steEp Criteria	**Broader variable assessment notes on:** **Table 5.6.2 Hybrid CI ICE-Diesel (petroleum)**
Is it possible?	Technical Viability	*Is production scale possible?*	In addition to an expanded maintenance network, new skills to handle the increase in vehicle complexity would be required, however these could be evolved gradually from within the current network within a ten year period. Given that similar skills will be required for the petrol hybrid vehicle fleet already commencing operation, no significant barriers are seen here. This technology option would offer fleet, bus, truck and LCV operators significant gains in fuel efficiency. More extensive hybrid diesel development has occurred for buses than for trucks due to greater use in urban areas and increased benefits from reducing pollution from stop start emissions.
	Economic Feasibility	*Do costs out weigh benefits?*	Increased purchase and maintenance costs would be offset by reduced fuel costs and potentially by any government incentives. LCVs, trucks and buses, will be less sensitive than PMVs to increased capital cost, provided increased fuel efficiency reduces net life cycle cost. Comments in relation to non-hybrid vehicles regarding import and local manufacture also apply here. Availability, especially for trucks, is a key issue. If the US and European market demand drives availability, and the capital cost is acceptable, rapid uptake could be expected. Policies supporting cost effective importation could be crucial.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	A significant reduction in GHG emissions from the conventional, in all vehicle classes, expected to be similar to hydrogen FC, even beyond 2014. Developments in tailpipe filtering may contribute to reduction of PM emissions. Hybrids provide significant emission improvement over conventional diesel transmissions, however PM emissions are still very significantly higher than for petrol equivalents. More stringent design rules for emissions may also encourage the development and uptake of PM filtering technologies. Any promotion of diesel PMVs should be contingent on reductions in particulate matter and NOx emissions to levels lower than the PMV fleet average.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	There are no conflicts with current policies, however concern over air quality has the potential to place diesel under tighter scrutiny. Uptake could be encouraged by imports, higher fuel price differential in relationship to petrol (especially for PMV and LCV markets) and vehicle registration financial incentives. A significant reduction in fuel usage through hybrid technology would potentially reduce the scale of crude oil imports.
	Social Acceptability	*Will the consumer market accept it?*	Government fleet adoption may contribute to stimulated demand and improved availability of diesel vehicles. The above mentioned technology developments, marketing of these developments on the basis of their improved 'green' image and financial incentives could all contribute to an increased share of the PMV and LCV market over the next ten years.

TBL Criteria	steEp Ability	steEp Criteria	Broader variable assessment notes on: **Table 5.6.3 SI ICE (adv.)-LPG**
Is it possible?	Technical Viability	Is production scale possible?	LPG vehicle technology could be improved through measures to encourage development of new vehicle design rules based on internationally available technology, use of more advanced conversion kits (starting with importation of technology) and measures to encourage local LPG vehicle production.
	Economic Feasibility	*Do costs out weigh benefits?*	With dedicated LPG vehicles now becoming available in Australia (and already being available in Europe, US and Japan), in addition to the established after market conversion industry, further uptake could be readily catered for. Increased uptake in the PMV market could be stimulated through lower import tariffs, lower purchase tax, regulation of percentage of imports, and/or lower registration costs. Further commitment from local manufactures is essential, and could be stimulated through direct development funding or tax credits for 'cleaner cars'. Fuel industry support might be appropriate to facilitate expansion of LPG production and distribution infrastructure, if demand outstripped current capacity (reported as 50% higher than present production by ALPGA).
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	With increased technology development, LPG can be expected to offer significantly lower GHG and air pollutant emissions compared with petrol and diesel.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	LPG conversion is already supported for trucks and buses. Similar assistance or financial encouragements could see a wider uptake of LPG in the PVM and LCV fleets. A slow response to the LPG conversion scheme indicates wider industry consultation is required to design appropriate measures to insure greater uptake. LPG conversions and purchase of dedicated vehicles would both be appropriate, provided best available technology and emission testing was mandatory for converted vehicles. If hydrogen-based long term ATFT policies continue to increase in their appeal, LPG (along with other NG sourced fuels) is sometimes considered as assisting transition to hydrogen.
	Social Acceptability	*Will the consumer market accept it?*	With increased technical development, promotion of LPG vehicles and policy-directed incentives for consumers, a wider uptake could be accomplished in a relatively short time frame. This could proceed both on the basis of new vehicle sales and conversion of existing vehicles. Fleet adoption is an attractive option for leading stimulation of the broader market in the uptake of LPG.

TBL Criteria	steEp Ability	steEp Criteria	Broader variable assessment notes on: **Table 5.6.4 Hybrid SI ICE-Petrol**
Is it possible?	Technical Viability	*Is production scale possible?*	New maintenance skills and infrastructure are needed, but development of these by manufacturers and their dealers, and within fleet operations with fixed bases first (an easier task) should be relatively easily evolved out into the broader current service network within ten years.
	Economic Feasibility	*Do costs out weigh benefits?*	Higher purchase and maintenance costs are expected to continue to outweigh fuel efficiency gains, and comparisons with conventional advanced petrol vehicles, even if significant market share is achieved. Supply is currently restricted by manufacturer production, much of which is taken up by Government fleet purchases. Lower import tariffs, purchase tax, and registration costs could stimulate initial uptake in both PMV and LCV market.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	Continued incremental emissions reductions are expected over the next ten years.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	Easily accommodated within current emissions reduction policies, as demonstrated by Government fleet purchases operations.
	Social Acceptability	*Will the consumer market accept it?*	While perceived as green alternatives, little uptake has occurred mainly due to lack of availability. The image of small and less powerful contrasts with the majority consumer demand of big and powerful. Education campaigns, especially relevant in congested city environments, may be of assistance. It should be noted however that demand does currently exceed supply, but as this is likely explained in Australia through fleet purchases and a small but significant consumer segment strongly motivated by environmental concerns, the broader PMV market is yet to be tested in this regard.

TBL Criteria	steEp Ability	steEp Criteria	Broader variable assessment notes on: **Table 5.6.5 Hybrid SI ICE-LPG**
Is it possible?	Technical Viability	*Is production scale possible?*	The hybrid LPG technology is yet to be established as a market ready option, although LPG conversion of petrol hybrids should not present any significant technical challenges. With Government incentives however, for development through funding and/or tax credits per vehicle sold, it seems plausible that market entry could be achieved within ten years. New maintenance skills and infrastructure are needed, but development of these by manufacturers and their dealers, and within fleet operations with fixed bases first (an easier task) should be relatively easily evolved out into the broader current service network within ten years.
	Economic Feasibility	*Do costs out weigh benefits?*	Increased purchase and maintenance costs can be expected for the next decade, however, continued price differential between LPG and petrol could allow LPG conversion to offset the increased capital cost of the hybrid vehicle.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	Development of hybrid LPG technology would facilitate significant emission reductions, provided best available technology and post-conversion emission testing is mandated for converted vehicles.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	LPG conversion is already supported for trucks and buses. Similar assistance or financial encouragements could see uptake of LPG hybrids in PVM and LCV markets, however this would best follow an increased uptake of petrol hybrids which have started developing the necessary skills and maintenance infrastructure required for hybrid vehicles. A slow uptake of the LPG conversion scheme for heavy vehicles indicates that wider industry consultation is required to design appropriate measures to insure greater uptake.
	Social Acceptability	*Will the consumer market accept it?*	With increased technical development, LPG-specific vehicle promotion and policy directed incentives for consumers, a wider uptake could plausibly be accomplished in a relatively short time frame for new vehicles, within the current sector-wide PMV fleet through established conversion services, and later through conversions of hybrid petrol vehicles. Fleet adoptions are an attractive option for leading broader market stimulation in the uptake of LPG. Realistic availability of LPG hybrids, either as aftermarket conversions or ex-factory, would most likely require significant availability and uptake of petrol hybrids.

TBL Criteria	steEp Ability	steEp Criteria	**Broader variable assessment notes on:** **Table 5.6.6 Combined CNG and LNG PTFG** **(SI ICE (adv.)-CNG, Hybrid SI ICE-CNG, Hybrid SI ICE (advanced)-CNG, and SI ICE (advanced)-LNG)**
Is it possible?	Technical Viability	*Is production scale possible?*	CNG and LNG are not considered viable in PMVs due to very large fuel tank relative to overall vehicle size (or reduced range). Hybrid CNG and LNG developments, however, may mitigate this barrier. This may also affect LCV uptake, but for small operation range fleets this may be less of a barrier if other incentives exist. Fleets with central depots are most likely early adopters. Improvement of CNG SI ICE efficiency relative to diesel may further mitigate range/fuel storage issue.
	Economic Feasibility	*Do costs out weigh benefits?*	Significant lack of fuel distribution and retail infrastructure, and corresponding vehicle availability. Appropriate only within fixed depot fleet operations currently, and likely to remain predominantly so within the next ten years due to high cost of infrastructure development. Significant increases in existing CNG Infrastructure Program funding (and possible extension to cover LNG) would be required to stimulate fuel retail industry development. In addition, commitment from local manufacturers would need to be secured through incentives such as 'clean vehicle' tax credits, development funding, or more external measures such as any incentives possible to increase imports, and thus also stimulating competition.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	Significant immediate emission reductions are available with improvements possible through technology development, chiefly affecting fuel efficiency.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	Fits with current policies, however they will need to be bolstered and further developed in consultation with industry to achieve desired outcomes. CNG and LNG present significant fuel diversification advantages with consequential improvement to fuel security, due to local resource location and fuel production infrastructure.
	Social Acceptability	*Will the consumer market accept it?*	Some fleet uptake for buses has already been achieved. Aggressive expansion of refuelling infrastructure and supported introduction of hybrid CNG and LNG could lead to broader uptake within ten year time frame by LCV and truck market. PMV market only likely once bus, tuck and LCV fleets establish maintenance and refuelling infrastructure and increase local manufacturer commitment (and even then, only if reduced range is accepted relative to present expectations).

TBL Criteria	steEp Ability	steEp Criteria	Broader variable assessment notes on: **Table 5.6.7 Combined Hydrogen PTFG** FC (direct electric drive)-Hydrogen (ex NG), FC (direct electric drive)-Hydrogen (electrolysis with renewable electricity), Hybrid FC-Hydrogen (ex NG), and Hybrid FC-Hydrogen (electrolysis with renewable electricity)
Is it possible?	Technical Viability	*Is production scale possible?*	Bus trials are currently underway in Western Australia and overseas. Many reliability issues are yet to be overcome. Unless major breakthroughs are achieved and aggressive government policies applied, there is little chance of any significant market availability of hydrogen technology within the next ten years.
	Economic Feasibility	*Do costs out weigh benefits?*	Not within the next ten years, and likely highly expensive relative to incumbent PTFG mix and other ATFT options. New refueling, manufacture, and maintenance infrastructure required.
Does it help?	Environmental Sustainability	*Does it reduce net emissions?*	Hydrogen has numerous fuel production pathways which differ significantly in their GHG and air pollution emissions. In addition, vehicle manufacture and disposal also incur emissions. In terms of tailpipe emissions however, hydrogen offers the potential for zero GHG and air pollutant emissions.
Is it wanted?	Political Compatibility	*Does it fit within existing policy?*	International efforts towards hydrogen vehicle developments could bring forward the development time line and potential for introduction into Australia transport sector. At this point, this seems unlikely to make any significant impact on GHG emissions from road transport within the next ten years. Western Australia has proposed a broad transition development path towards a hydrogen-fuelled transport sector however, and further research and development funding would assist the realisation of this vision. Nonetheless, from the point of view of minimising GHG emissions from road transport within a ten time horizon, this does not offer particular advantages over alternative pathways.
	Social Acceptability	*Will the consumer market accept it?*	It is likely that if the high costs of hydrogen technologies are compensated by financial incentives that reduce import barriers, registration fees and fuel taxes, that significant uptake could occur, however, at the earliest it is expected, this would be well beyond ten years from now. Early adopters of developing technologies could be seen in niche fleet markets such a depot based buses, and LCVs.

6 Appendix F: Victorian ATFT Scenarios

6.1 Summary

The Third and Fourth stages of the EPA Victoria's study *The Future of Alternative Transport Fuels and Technologies in Victoria* involved generating a set of scenario environments and identifying a range of viable ATFT policy options for the Victorian government related to them. The steEp research dimensions, which also served as the dominant assessment criteria and identified uptake barriers, are also seen as the main categories of drivers of change within the next ten years for the Victorian road transport policy context. Using a simplified scenario generation process a wide range of drivers were analysed to identify the two of highest impact and greatest uncertainty. These two key drivers were then used to generate four scenario environments. These scenario environments constitute the contexts for policy option development. The scenario environments have been structured around a central 'probable world'. This forms the hub from which three divergent 'plausible worlds' radiate outwards. The plausible worlds are used to ensure that policy options are informed by and sufficiently flexible to respond to emergent changes. Each of the scenarios is described from a systems perspective, and includes key event assumptions, barriers and opportunities that might affect the uptake of ATFT with the potential to minimise GHG and air pollutant emissions across the Victorian road transport sector. Finally, appropriate policy options were identified for the Victorian Government to consider in promoting viable ATFT to assist in minimising GHG and air pollution emission over the next ten years. The output from this process is a set of core policy options that is informed by contingency considerations for responding to key uncertainties and that accounts for the longer-term outlook.

6.2 Generating Scenarios

Stage 3 of EPA Victoria’s study *The Future of Alternative Transport Fuels and Technologies in Victoria* involved the generation of a small selection of scenarios for the next ten years. The scenarios are intended to build on the research and analysis of this study's Stages 1 and 2. The range of requirements for the scenario generation process has been derived from the study's brief and from results of the research, analysis and interpretation process. An appropriate scenario generation method has been formulated and applied to generate four viable ATFT policy environments for the study's ten year time horizon. In stage four, later in this document, an analysis of each scenario identifies a range of policy options suited to each, and serves to highlight the types of ATFT that can be promoted as most viable. The scenarios are not intended to convey fixed end points, or full-picture realities with high probability of realisation, rather they are intended to be used to highlight some of the most divergent plausible eventualities that Victorian ATFT policy might need to accommodate. In this way, the scenarios serve to identify some of the plausible extreme edges of the viable policy context for ATFT over the next ten years, and provide a framework in which the relevance of different policy options can be assessed.

6.3 Scenario Criteria

In order to select and apply a suitable scenario generation process, the requirements that the scenarios needed to meet were first identified. The following criteria represent general guidelines that informed the scenario generation process, and were derived form the original brief and research and analysis of Stages 1 and 2 of this study:

- *Identify Viable Policy Options* – The scenarios need to highlight viable policy options that support the uptake of ATFT within the next ten years. The focus is on highlighting the nature of the policy options and their possible outcomes in terms of the PTFG emphasised;
- *Achieve Improved Environmental Outcomes* – The PTFG that are the most viable ATFT in each scenario need to contribute to minimising GHG and air pollutant emissions from road transport within the next ten years;
- *Consider the PTFG Mix* – Each scenario needs to reflect a realistic PTFG mix in the road transport fleet. Identifying the nature of this mix would be advantageous;
- *Provide Transparency for ATFT Selection Process* – The logic of the scenario worlds need to justify the selection of the leading ATFT in each scenario;
- *Incorporate Wildcard PTFG* – The process needs to account for the possibility that some of the PTFG screened out in Stage 2 may become more viable due to changes in the transport context within the next ten years;
- *Be Engaging* – The scenarios need to be concise, and accessible to a broad audience, including Government and non-government stakeholders in the Victorian policy context; and,
- *Maintain Continued Relevance through Independence of Drivers* – The scenario drivers need to be closely aligned to current realities, and yet also be relatively independent of each other in terms of cross-impact, in order to increase their relevance for policy consideration during the ten year period.

6.4 Scenario Generation Method

One approach that can meet the criteria set out above is the rapid scenario generation process, first popularised by the Global Business Network. Focusing on the main drivers of change in the context in question, and identifying the most uncertain and highest impact drivers, leads to a scenario generation framework that produces four related but divergent scenarios. In this application, the drivers were identified during a two-stage process or systems mapping and brainstorming. The drivers of change represent the key actors and factors that will shape the context related to the guiding scenario question.

6.5 Scenario Question

The scenario driver identification, and scenario development and analysis, is guided by the following question derived from the study's brief:

What factors are likely to influence the uptake of PTFG with potential to contribute to lower GHG and air pollutant emissions in Victoria over the next ten years?

6.6 Scenario Drivers

6.6.1 Driver Identification

In response to the guiding question above a brainstorming session was conducted by the scenario team to produce a list of drivers, based on the knowledge developed during Stages One and Two of the study. It became evident during this process that the drivers mostly reflected the steEp research variables, and PTFG assessment criteria and barriers. Accordingly the drivers are presented, in Table 6.1 below, grouped according to the PTFG assessment categories.

steEp Dimension	Key Variables	Reference	Victorian ATFT Policy Context Drivers
Technical	Viability	T1 T2	▪ Improved conventional PTFG efficiency ▪ Alternative PTFG development
	Safety	T3	▪ Degree of safety
	Maintenance	T4	▪ Availability of maintenance network
Economic	Infrastructure	C1 C2 C3	▪ International production ▪ Commitment of local manufacturers ▪ ATFT infrastructure (especially fuel supply)
	Operation	C4 C5	▪ Cost of fuel ▪ Cost of vehicles
	Scale	C6 C7	▪ Oil price (absolute) ▪ Oil price (volatility)
Environmental	GHG Emissions	E1 E2	▪ Global warming ▪ Global warming induced events
	Air Pollution	E3	▪ Air quality
	Resource Consumption	E4	▪ Environmental impacts of production and use
Political	Security	P1 P2	▪ Fuel diversification ▪ Oil availability
	Regulations	P3 P4 P5	▪ International policy ▪ Fuel standards ▪ Vehicle standards
	Initiatives	P6 P7 P8 P9 P10 P11	▪ Financial incentives for consumers ▪ Financial incentives for industry ▪ Government fleet uptake ▪ Research and development funding ▪ National adoption of ATFT ▪ Promotion of ATFT
Social	Demand	S1	▪ Demand for ATFT
	Image	S2 S3	▪ Utility image of ATFT ▪ Green image of ATFT
	Function	S4 S5	▪ Perception of safety ▪ Environmental concern

Table 6.1: Victorian ATFT Policy Context Drivers.

6.6.2 Driver Systems Map

In order for the scenario generation team to better understand the realistic relationships between the different drivers in the ATFT policy context of Victoria, a systems mapping method was employed. Figure 6.1 below presents the system map that informed the definition of the drivers, and assisted in developing the internal logic of each of the scenarios. The systems map is not exhaustive in including all possible actors and factors that might be considered drivers, nor are all the possible relationship dynamics between the different drivers identified. The drivers and dynamics identified in the systems map represent the most significant that were identified during Stage 1 and 2 of this study.

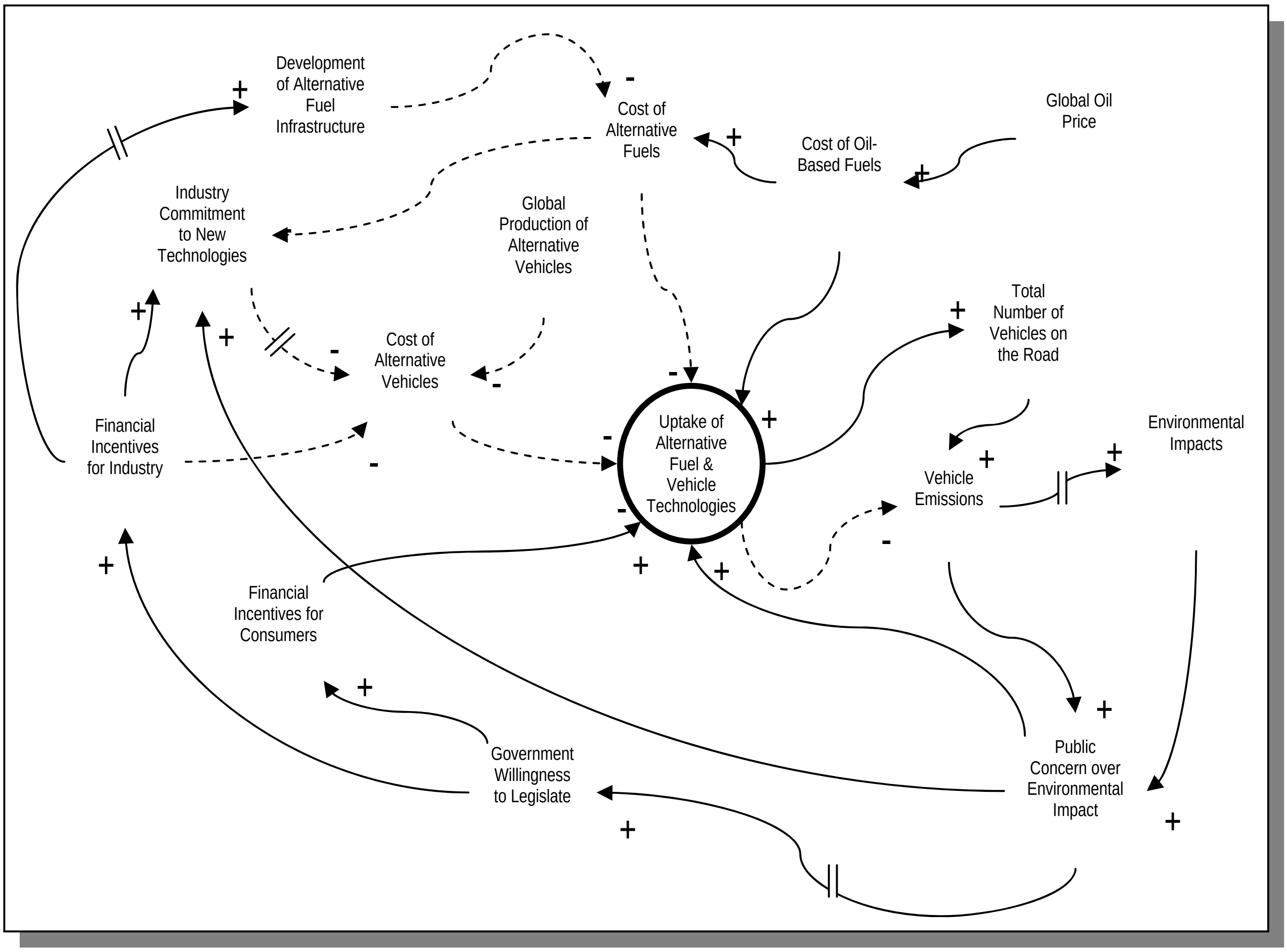


Figure 6.1: ATFT Policy Environment Systems Map.

6.6.3 Driver Analysis

The next step in the scenario generation process was to identify the drivers that represented the highest impact and greatest uncertainty of occurring, within the context of the scenario generation criteria and in response to the scenario question. The outcome of the driver analysis is depicted in Figure 6.2 below. It is important to note that the analysis was a brief and subjective assessment based on the knowledge generated during this study. A more rigorous approach to assessing each driver was outside the scope of this study. The general analysis however, serves to generally relate the drivers to the Victorian ATFT policy context in order to identify the two most important drivers in terms of policy context change. Differing driver analyses are possible, and would likely lead to alternative scenario frameworks. The analysis presented here is not intended to foreclose these alternatives, rather simply identify one set of alternatives that provide value in considering ATFT policy in light of the scenario criteria outlined above.

Low <-------------- Impact --------------> High				
	T1	C5 C4	T2 P2 P11	C6 C7 S5 C3 S1
	P1 S3	C1 P6 T4 P3	P10 P8 P7 C2	E2
	P4 P5 T3	E3 S2 E4 P9	E1	
	S4			
	Low <-------------------------------------- Uncertainty --------------------------------------> High			

Figure 6.2: Driver impact/uncertainty analysis.

6.6.4 High Impact and Uncertainty Drivers

Ref.	Driver Name	Impact (/10)	Uncertainty (/10)	Combined Score (/20)	Comments	Result
C7	Oil price (volatility)	10	10	20	Potential for major impact within 10 years	✓
C6	Oil price (absolute)	10	9	19	Driver of C6 - less uncertain	✗
S5	Environmental concern	9.5	9.5	19	Picks up social factors	✓
C3	ATFT infrastructure (especially fuel supply)	9	9	18	Result of several deeper drivers	✗
P2	Oil availability	10	8	18	Driver of C6 / C7 - less uncertain	✗
S1	Demand for ATFT	8	10	18	Result of several deeper drivers	✗
E2	Global warming induced events	7	10	17	Lower impact without public concern	✗
P11	Promotion of ATFT	9	8	17	Possible result of policy	✗
T2	Alternative PTFG development	10	6	16	Result of several deeper drivers	✗
P10	National adoption of ATFT	8	7	15	Result of several deeper drivers	✗
P7	Financial incentives for industry	7	7	14	Possible result of policy	✗
P8	Government fleet uptake	7	6	13	Possible result of policy	✗
C2	Commitment of local manufacturers	6.5	6	12.5	Relatively low score	✗

Table 6.2: High impact and uncertainty driver analysis.

6.6.5 Driver Extremes

The two drivers identified as being both high in impact and highly uncertain in occurring are 'C7-environmental concern' and 'S5-oil price (volatility).' Both of these drivers represented potentially very strong variations as increasing influences in the plausible context for Victorian ATFT policy over the next ten years. They are also relatively independent of each other's influence, and both have a broad range of impacts across the range of other drivers. The natures of the extreme variation in each driver to be considered in this study are highlighted below.

6.6.5.1 Oil Price volatility

- *Roller Coaster* – Global oil prices become significantly more volatile, causing widespread uncertainty around the future viability of fuels derived from crude oil; and,
- *Status Quo* – Global oil prices continue to fluctuate, but stay within close range of current prices.

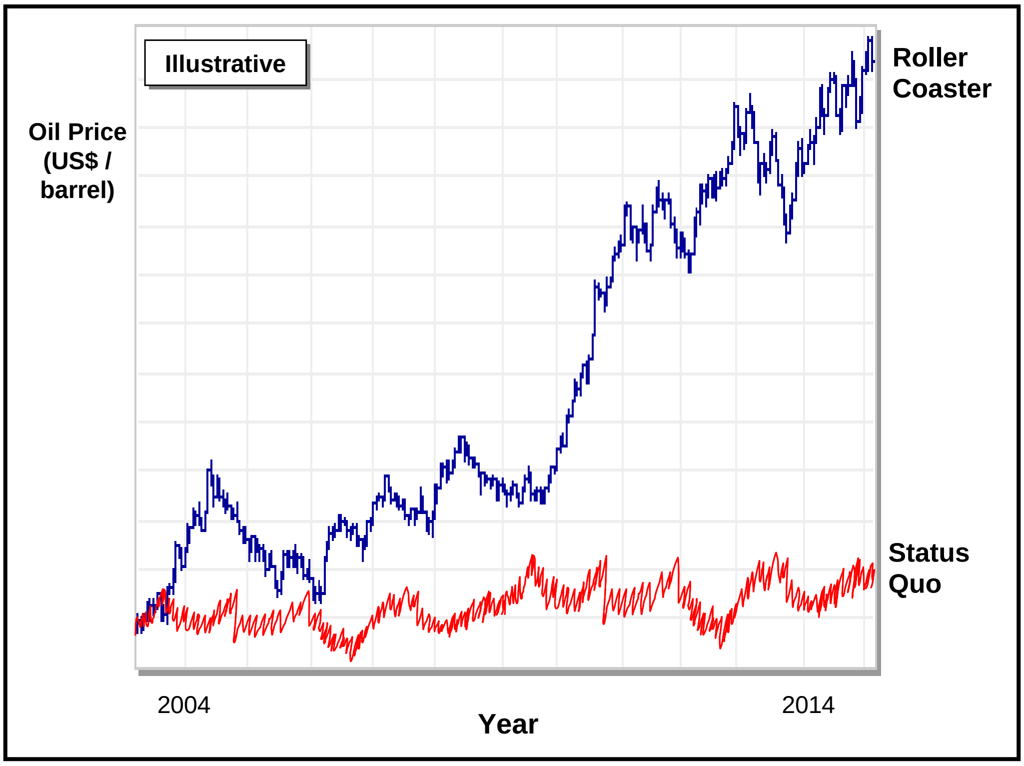


Figure 6.3: Illustrative extremes of oil price volatility driver, 'status quo' and 'roller coaster.'

6.6.5.2 Environmental Concern

- *Consensus Action* – Global warming is shown to be progressing faster than first anticipated. A range of extreme weather events such as floods and heat waves cause significant public concern. Air pollution becomes widely acknowledged as a major threat to public health. A call for consensus action becomes realised.

- *Status Quo* – The threat of global warming and air pollution does not increase in the eyes of the general public. Little or no behaviour change takes place.

6.7 Scenario Framework

By considering that each driver could, under appropriate circumstances, be represented by a 'high' state or a 'low' state, four driver-state combinations are available. These four driver-state combinations describe the scenario logic for four different 'worlds'. The four 'worlds' created by combining the two drivers identified above are depicted in Figure #. The high and low states for each driver were named appropriately to assist in conceptualising each of the scenario worlds. A name for each of the four scenarios was chosen based on a metaphor that characterises each world.

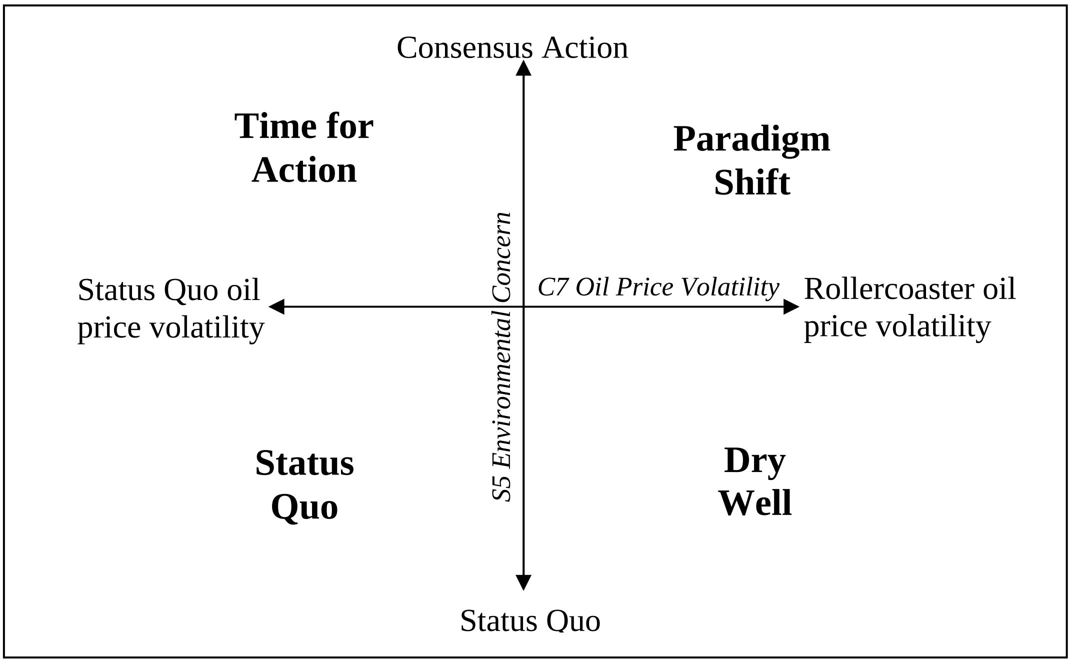


Figure 6.4: Victorian ATFT policy scenario framework.

6.7.1 Four ATFT Worlds in 2014

The four ATFT policy contexts for Victoria in 2014 can be described in brief as:

- *Status Quo:* The threat of global warming and air pollution does not increase in the eyes of the general public. While global oil prices continue to fluctuate, they stay within close range of current prices. In general, little or no behaviour change takes place.
- *Time For Action:* Society rallies together to address a number of increasingly serious environmental issues (accelerated global warming, extreme weather events, air pollution)
- *Dry Well:* Global oil prices become significantly more volatile, causing widespread uncertainty around the future viability of fuels derived from crude oil
- *Paradigm Shift:* A paradigm shift is caused by the dual pressures of serious environmental issues and increasingly volatile oil prices (combination of 'Time for Action' and 'Dry Well')

6.7.2 Futures Cone Mapping

In order to understand the relationship between the four scenarios, it is helpful to consider the likelihood of each from the context of our present situation. Figure 8 depicts the 'futures cone' which is used to map alternative futures. The set of alternative future ‘worlds’ at any time is represented by a series of concentric circles, the relative diameter of which expands as the period of interest moves further from the present. The different circles comprising the futures cone indicate ever broader contexts defined as:

- *Probable futures*, or a range of alternative 'business as usual' prospections (extrapolations of present trends). One finds here the worlds that are commonly expected, or considered 'likely' to eventuate;
- *Plausible futures*, which are less likely to eventuate but serve to ‘expand the horizons’ beyond the immediately obvious present trends. It is here that one finds the worlds that ‘could’ eventuate. form the next level of contextual breadth for considering the probable future; and,
- *Possible futures*, where eventualities are remote, and are considered alternatives that ‘might’ eventuate.

The four scenarios generated for Victorian ATFT policy consideration represent one probable scenario and three plausible scenarios. These are depicted on the futures cone in Figure 8 below.

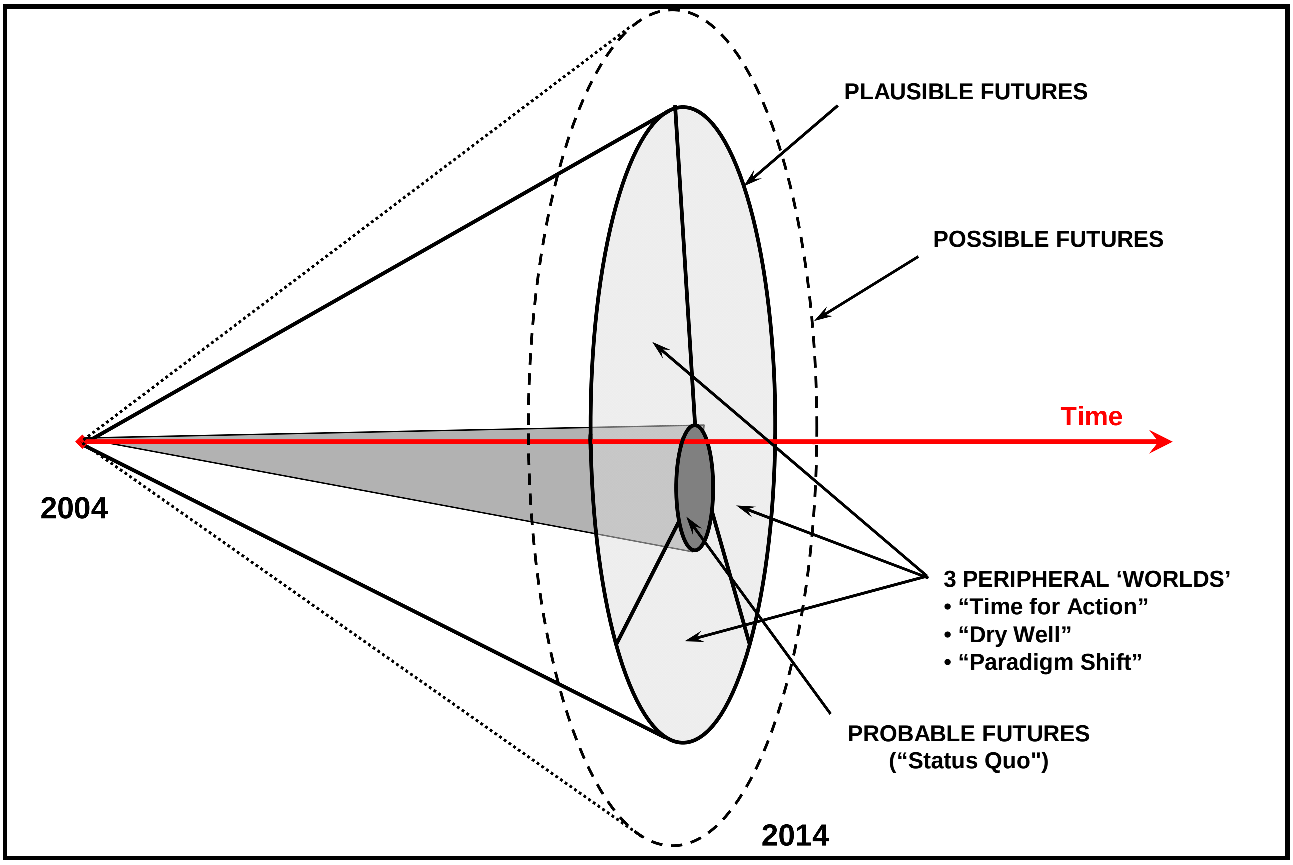


Figure 6.5: The Victorian ATFT Scenario Contexts and the Futures Cone.

6.7.3 Scenarios as Risk Management

The three plausible scenario contexts are closely related to the current status quo situation, and yet diverge in significant ways that can open up new policy opportunities or conditions.

Each of the plausible scenarios are briefly described below in terms of a 'snap shot' review of the ATFT policy context the present for Victoria in 2014. A range of policy options are then presented for each of the different contexts, highlighting some measures and initiatives that could encourage the outcomes seen as most viable in each context or, at least, provide for Victoria to be more able to adapt to the broader changes that might create these differing contexts. In this adaptation fashion, the consideration of various policy options constitute a risk analysis and mitigation process where some of the plausible dramatic changes in the policy environment can be factored into the consideration of current policy decisions.

The policy options for the three plausible scenarios are chosen in addition to the policy options offered for consideration in the Status Quo context. They are presented as additional options that would need to be supported by some of the Status Quo options. Further, it is important to note that the policy options presented are not exhaustive in a range of variety nor in means of application, but reflect the range of policy options exemplified within Australia, and to some extent internationally, as identified in Stage 1 of this study. The development of entirely new classes of possible policy options, including a fuller integration of the Stakeholder suggestions identified in Stage 1, was unfortunately beyond the scope of this study.

6.7.3.1 Development Pathways

In relating the different sets of policy options presented for each scenario below, three different developmental pathways emerge for the next ten years. Beginning now with the Status Quo scenario, it is plausible that the ATFT policy context may be affected by aspects of the changes identified in the second and third scenarios, the Times for Action and Dry Well alternative worlds. In addition it is plausible that from either of these worlds, or from the Status Quo context, changes may shift the policy context to one reflecting elements of scenario four, the Paradigm Shift. These different developmental pathways are depicted in Figure # below. The pathways can be used to group the different policy options associated with each scenario, in an accumulative manner.

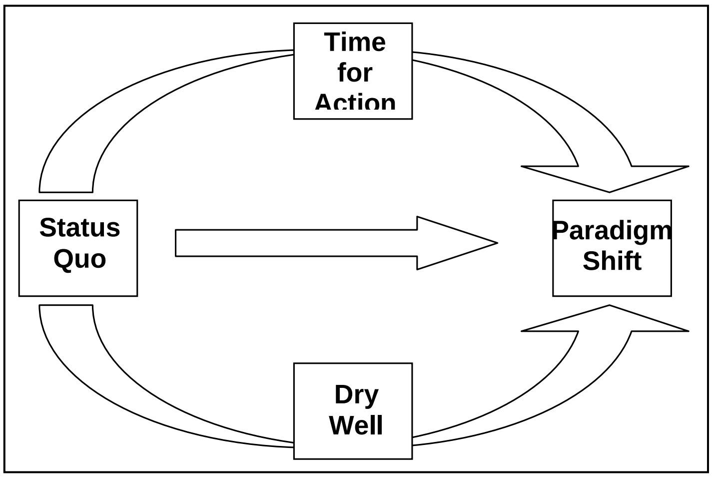


Figure 6.6: ATFT policy context development pathways.

6.8 Change Driver Analysis

The following table presents a very brief summary of the probable influence of each driver on the road transport sector in relation to the uptake of ATFT, across the next ten years to 2014, within the context of the Status Quo scenario. The descriptions are intended to provide a snap shot of the influences that might constitute the policy context of a 'status quo' world.

steEp Dimension	Key Variables	Reference	Status Quo Driver Analysis - 2014
Technical	Viability	T1 T2	▪ Conventional PTFG efficiency improves incrementally as expected, gains which are slowly fed into the new vehicle markets, mainly PMVs. The gains in fuel efficiency are mitigated by a higher proportion of larger and/or more powerful PMVs such as four-wheel drives, and Australia's traditional six-cylinder or large four-cylinder Holden and Ford family cars. ▪ Alternative PTFG development continues, though mostly by a small core of dedicated adherents. Beyond a limited number of petrol-electric hybrids, this doesn't really make any mainstream market penetration.
	Safety	T3	▪ Vehicle safety has continued its trends towards concern for personal safety through larger vehicles, continued development of anti-collision technology and so on, without overt concern for infrastructure and refuelling safety issues.
	Maintenance	T4	▪ The vehicle maintenance network remains the same, servicing the same general vehicle classes in similar proportions to the present. Niche developments do occur, and petrol hybrid vehicle dealers and fleet operators provide maintenance services, but owners of these vehicles are limited to a small selection of locations in urban centres. Stories of motorists stranded on cross-country trips are heard from time to time.
Economic	Infrastructure	C1 C2 C3	▪ International production of ATFT doesn't reach a tipping point that spills over into local market penetration or local manufacturing capacity. The few hybrid vehicles available come from overseas, but their numbers are limited because demand has been slow to grow. ▪ Commitment of local manufacturers is not gained in developing ATFT for the mass market. ▪ ATFT infrastructure (especially fuel supply) is not developed.
	Operation	C4 C5	▪ Fuel cost for conventional vehicles steadily increases, although no ‘price shocks’ occur, and environmental and social costs continue to be externalised. ▪ Cost of conventional vehicles increases in a similar manner to the previous decade, and the market seems unconcerned.

	Scale	C6 C7	▪ Oil price (absolute), steadily increases, creating no great alarm. ▪ Oil price (volatility), is relatively stable and remains within similar bounds to previous years, while the expected gradual increases in price are tolerated by the market.
Environmental	GHG Emissions	E1 E2	▪ Global warming slowly continues, with no dramatic consequences that influence the transport sector. ▪ Global warming induced events do not dramatically influence government or consumer decision making regarding road transport. While insurance underwriters continue to report increased claims for property damage related to storms and flooding, debate over the cause of this diffuses consensus on global warming impacts. Consumers and government are unmotivated to respond with more drastic action than at the turn of the century.
	Air Pollution	E3	▪ Air quality, while being monitored, deteriorates gradually, with the efforts made at reducing air pollution at best holding steady, or minimising, the increase of air pollution, except for isolated examples of improvement.
	Resource Consumption	E4	▪ Resource depletion related to production and use of road transport do not influence the mix of PTFG available, nor significantly stimulate the uptake of ATFT.
Political	Security	P1 P2	▪ Fuel diversification is not readily achieved, and remains a policy ideal. ▪ Oil, although becoming more expensive, does not show any major signs of having reached peak production – yet.
	Regulations	P3 P4 P5	▪ International policy has led to minor initiatives promoting the development of ATFT vehicles and related infrastructure. None of the efforts have significantly increased the viability of ATFT such that they change the existing mix of PTFG. ▪ Fuel standards have steadily become more stringent for new vehicles over the past decade and have contributed to minimising air pollution and GHG emissions. Design limits are being reached, however, and are not expected to offer much scope for further reductions over the coming decade. ▪ Vehicle design regulations aimed at reducing air pollutant emissions were introduced and have steadily increased for new vehicles, contributing to minimising air pollutant emissions. A debate about the extent of regulations for limiting GHG emissions through vehicle design standards has only recently been concluded, with the implications being implemented in the coming years.

	Initiatives	P6 P7 P8 P9 P10 P11	▪ Financial incentives for consumers have only included sporadic, low impact efforts, and correspondingly minor market effect. ▪ Financial incentives for industry have failed to take hold and produce any significant shift in the availability of ATFT. ▪ Government fleet uptake continues to show leadership, mainly through the use of hybrid vehicles, but this is seen as a token gesture by environmental groups, given that the bulk of the fleet still consists of large, six-cylinder vehicles, and little uptake has resulted in the broader market. ▪ Research and development funding fails to achieve any significant outcomes in terms of ATFT development and thus uptake. ▪ Federal and other State Government fleet adoption of ATFT occurs at a similar level to Victoria. ▪ Promotion of ATFT is limited to recognition of government fleet purchases, and is seen as redundant until major ATFT developments are initiated by industry.
Social	Demand	S1	▪ Demand for ATFT does not increase beyond niche markets, and fleet operations. The market has been happy to purchase ATFT but only when they are seamlessly integrated into development of existing vehicles without compromising performance and size.
	Image	S2 S3	▪ Utility image of ATFT has not improved as they are not widely available. ▪ Green image of ATFT is still in the category of hope for the future, but not yet practical.
	Function	S4 S5	▪ Perception of safety is a non-issue ▪ Environmental concern, while continuing to increase throughout the community, does not influence mainstream consensus with regard to the uptake of ATFT.

Table 6.2: Status Quo Driver Analysis - 2014

7 Appendix G: Estimation of GHG emission Reductions Potential

GHG emission reduction potential available if entire road transport fleet shifted to CI ICE technology and LS diesel.

Adapted from Appendix Table 1-2001 - Fuel combustion activities 1A-3 (sheets 1 & 2): Emissions from transport, Appendix Table 1 Energy (Including Trasnport), National Greenhouse Gas Inventory 2001, accessed 10/4/04 at http://www.greenhouse.gov.au/inventory/2001/pubs/appendixenergy2001.pdf

	CO2-eq (Gg)	Proportion of national road transportation total %	Proportion of vehicle type GHG emissions %	Energy use (PJ)	CO2 (Gg)	CH4 (Gg)	N2O (Gg)	NOx (Gg)	CO (Gg)	NMVOC (Gg)	SO2 (Gg)
National road transportation total	68176.63			961.51	63329.27	27.26	13.79	378.41	2892.89	417.72	42.19
Passenger Motor Vehicles	42458.75	**62.28**		585.38	37988.17	20.98	13.00	226.69	2340.86	153.26	10.64
Automotive Gasoline	37915.55		**89.30**	512.92	33513.99	19.76	12.86	199.37	2086.35	131.27	7.75
ADO	1489.48		**3.51**	21.35	1472.93	0.05	0.05	4.79	5.02	2.46	2.48
LPG	3015.66		**7.10**	50.45	2966.76	1.00	0.09	22.40	249.42	19.51	0.40
Natural Gas	38.27		**0.09**	0.67	34.49	0.18	0.00	0.13	0.07	0.01	0.00
Light Commercial Vehicles	9650.81	**14.16**		144.08	9451.26	3.45	0.41	53.74	408.95	31.09	6.17
Automotive Gasoline	5789.41		**59.99**	86.56	5655.74	2.97	0.23	34.50	313.94	19.75	1.31
ADO	2840.69		**29.43**	40.60	2801.60	0.09	0.12	10.38	9.47	4.65	4.72
LPG	1013.31		**10.50**	16.79	987.36	0.35	0.06	8.83	85.52	6.69	0.13
Natural Gas	7.19		**0.07**	0.13	6.56	0.03	0.00	0.02	0.01	0.00	0.00
Trucks	14030.99	**20.58**		201.64	13884.80	2.09	0.33	83.02	92.27	16.00	22.87
Automotive Gasoline	313.11		**2.23**	4.79	312.90	0.01	0.00	1.41	6.07	0.58	0.07
ADO	13652.97		**97.31**	195.80	13510.93	2.04	0.32	80.98	83.50	14.95	22.79
LPG	57.48		**0.41**	0.97	57.06	0.02	0.00	0.54	2.70	0.47	0.01
Natural Gas	4.11		**0.03**	0.08	3.90	0.01	0.00	0.09	0.02	0.00	0.00
Buses	1795.4	**2.63**		26.82	1770.03	0.47	0.05	14.59	16.46	3.76	2.47
Automotive Gasoline	64.69		**3.60**	0.98	64.27	0.02	0.00	0.64	7.99	0.57	0.01
ADO	1467.24		**81.72**	21.02	1450.48	0.06	0.03	9.17	5.39	2.92	2.45
LPG	62.53		**3.48**	1.06	62.32	0.01	0.00	0.27	2.33	0.23	0.01
Natural Gas	200.94		**11.19**	3.75	192.96	0.38	0.00	4.50	0.75	0.04	0.00

Global warming potentials (p.viii, National Greenhouse Gas Inventory 2001, accessed 10/4/04 at http://www.greenhouse.gov.au/inventory/2001/pubs/inventory2001parta.pdf)

CO2	1	HFC-23	11,700
CH4	21	HFC-125	2,800
N2O	310	HFC-134a	1,300
CF4	6,500	HFC-143a	3,800
C2F6	9,200	SF6	23,900

CO_2-eq is the sum of the products of CO_2, CH_4 and N_20 and their corresponding weighting factors

Sum of quotients of CO_2-eq (for each fuel and vehicle type) and relative GHG emission weighting factors

	CO2-eq (Gg)	GHG emissions for each fuel type divided by relative greenhouse gas emission weighting factors (ie, GHG emissions achievable by switching to LS Diesel and CI ICE tech) (Gg)	Equivalent GHG emissions for each vehicle type achievable by changing to least greenhouse intensive fuel and engine tech (Gg)	Theoretical reduction of GHG emissions achieved by changing entire fleet to LS Diesel, for each vehicle type (Gg)	Equivalent GHG emissions for switch to 100% LS Diesel as a proportion of GHG emissions from current fuel/tech mix %	Relative scope for reduction of GHG emissions within each vehicle type, normalised against PMVs %	Relative scope for reduction of overall road transport GHG emissions for each vehicle type, normalised against PMVs %	Total greenhouse gas emissions for change to least GHG intensive fuel and engine tech (as proportion of present total) %
National total	68176.63		51821.54					76.01
Passenger Motor Vehicles	42458.75		28751.27	13707.48	67.72	100.00	100.00	
Petrol	37915.55	24915.93						
Diesel	1489.48	1489.48						
LPG	3015.66	2312.01						
Natural Gas	38.27	33.85						
Light Commercial Vehicles	9650.81		7428.39	2222.42	76.97	71.33	16.21	
Petrol	5789.41	3804.47						
Diesel	2840.69	2840.69						
LPG	1013.31	776.87						
Natural Gas	7.19	6.36						
Trucks	14030.99		13906.43	124.56	99.11	2.75	0.91	
Petrol	313.11	205.76						
Diesel	13652.97	13652.97						
LPG	57.48	44.07						
Natural Gas	4.11	3.64						
Buses	1795.4		1735.44	59.96	96.66	10.34	0.44	
Petrol	64.69	42.51						
Diesel	1467.24	1467.24						
LPG	62.53	47.94						
Natural Gas	200.94	177.75						

Fuel and vehicle emission standard	exbodied greenhouse gas emissions (kg CO2-eg/km)	Relative greenhouse gas emission weighting factors for fuels, normalised against LS Diesel
ULP, Euro 3	0.35	1.52
LS Diesel, Euro 4	0.23	1.00
LPG Autogas, 2nd generation	0.30	1.30
CNG	0.26	1.13

Data from Table 1.2 in Appendix A

Estimation of GHG emission from road transport, relative to 2001 total, if fleet was entirely comprised of CI ICE vehicles using LS diesel fuel

Notes

[1] Beer, T, Grant, T and Watson, H (2004), p.87.

[2] Green and Schafer (2003), p.15.

[3] Williams (2002), p.10.

[4] Green and Schafer (2003), p.19.

[5] Figures adapted from Victorian Greenhouse Gas Inventory 1999, accessed 10/4/04 at http://www.greenhouse.vic.gov.au/files/VGGasInventory99.pdf

[6] Adapted from Australian Greenhouse Office (2003), Appendix Table 1-2001 - Fuel combustion activities 1A-3 (sheets 1 & 2): Emissions from transport, Appendix Table 1 Energy (Including Transport) and Department of Natural Resources and Environment (2002), Table 2, p.3, accessed 10/4/04 at http://www.greenhouse.gov.au/inventory/2001/pubs/appendixenergy2001.pdf .

[7] Figures based on Beer, T, Grant, T and Watson, H (2004) p.81, fig.7.1.

[8] http://www.alpga.asn.au/uses/auto.asp

[9] In particular, the initial signing of the Kyoto Protocol in 1998 and being party to the United Nations Framework Convention on Climate Change

[10] AGO (1998).

[11] AGO (2003a).

[12] Fuel Quality Standards Bill 2000, Revised Explanatory Memorandum, p.4.

[13] Martin (2002).

[14] Ibid. 'executive summary.'

[15] For detailed access to eight projects carried out under M5.3 for example, see: http://www.planning.sa.gov.au/greenhouse/cd/main.htm

[16] For example see the Australian participation in the International Cities for Climate Protection program which falls under Travel Demand Management, online at: http://www3.iclei.org/ccp-au/

[17] For example, see Travel Smart Australia online at: http://www.travelsmart.gov.au/

[18] For example, see NSW's Action for Air strategy online at http://www.epa.nsw.gov.au/air/actionforair/index.htm

[19] AGO (1998).

[20] AGO (2003b).

[21] http://www.greenhouse.gov.au/transport/env_strategy.html

[22] See the proposed Green Fleet Guide at: http://www.dotars.gov.au/mve/green_vehicles_guide.htm

[23] ACIL Consulting (1999b).

[24] Fuel Quality Standards Bill 2000, Revised Explanatory Memorandum, p.2.

[25] http://www.ephc.gov.au/nepms/diesel/diesel_intro.html

[26] For example see: http://www.epa.qld.gov.au/publications/p00697aa.pdf/Reduction_of_summer_petrol_volatility_Memorandum_of_Understanding.pdf

[27] Beer (2000), (2001) & (2004).

[28] http://www.greenhouse.gov.au/media/media_releases/2001/cng.html

[29] ANAO (2004) p.35.

[30] http://www.greenhouse.gov.au/transport/afcp/index.html

[31] ANAO (2004) pp.34-35.

[32] ANAO (2004) pp.16-17.

[33] http://www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectID=A9D9A207-0351-51FB-F20C287758203878

[34] Ibid.

[35] CSIRO (2003)

[36] http://www.investaustralia.gov.au/biofuels

[37] http://www.deh.gov.au/atmosphere/cleaner-fuels/biofuels/index.html

[38] http://www.pm.gov.au/news/media_releases/media_Release832.html

[39] http://www.atcouncil.gov.au/emissionsstrategy.pdf

[40] ATC (2003).

[41] http://www.industry.gov.au/content/itrinternet/cmscontent.cfm

[42] DEH (2004).

[43] http://www.ephc.gov.au/nepms/air/air_nepm.html

[44] http://www.dest.gov.au/science/pmseic/meetings/9thmeeting.htm

[45] P.3 http://www.dest.gov.au/science/pmseic/documents/Beyond%20Kyoto%20report.doc

[46] Ibid. pp.35-38 - 8.2 Alternative Fuels.

[47] BTRE (2003) p.ii.

[48] ACIL Consulting (2003b) p.v., and (2003a).

[49] Ibid. p.73.

[50] Ibid p.78.

[51] Ibid p.81.

[52] p33 NSW Ministry Of Energy And Utilities Annual Report 2002–2003: Energy Strategy, available online at: http://www.deus.nsw.gov.au/about/MEU%20Annual%20Report%202003%20-%20Energy%20Strategy%20-%20760KB.pdf

[53] http://www.industry.gov.au/content/itrinternet/cmsco...A-20E0-68D8-EDB550B8BD2CB714&indexType=crossindustry

[54] Williams (2002) p.14.

[55] http://www.csiro.au/index.asp?type=blank&id=EnergyTransformed_ResearchTheme3

[56] Ibid.

[40] Foran (2001) p.1.

[58] Foran (2002a & b).

[59] QT & QMR (2000).

[60] Inayatullah (2000).

[61] http://www.epa.qld.gov.au/publications?id=1098

[62] http://www.epa.qld.gov.au/environmental_management/air/air_quality_monitoring/seq_strategy/

[63] http://www.transport.qld.gov.au/qt/LTASinfo.nsf/index/environment_transportportfolioenvironmentalframework

[64] Online here: http://www.transport.qld.gov.au/framework and here http://www.transport.qld.gov.au/qt/IRTPSign.nsf/index/transport2007

[65] http://www.transport.qld.gov.au/Home.nsf/index/strategicplans

[66] The WA Sustainability strategy is available online here: http://www.sustainability.dpc.wa.gov.au/docs/Strategy.htm
The WA Draft Greenhouse Strategy is available online here: http://www.greenhouse.wa.gov.au/draft_strategy/index.html

[67] A graphical representation is available online at: http://www.dpi.wa.gov.au/sustain/images/picture1.html and http://www.dpi.wa.gov.au/sustain/images/picture2.html

[68] The case studies: Garrity (2002), Passey (2002).

[69] http://www.dpi.wa.gov.au/sustain/solutions.html

[70] TESC (2003).

[71] http://www.dpi.wa.gov.au/fuelcells/conf/index.html

[72] Robinson (2002).

[73] Hawkes (2002).

[74] Combes (2002).

[75] Garrity (2002a).

[76] Newman (2003).

[77] Strategic actions 2.5.18 and 2.4.19 respectively of the WA Draft Greenhouse Strategy, p. 57: http://www.greenhouse.wa.gov.au/draft_strategy/index.html

[78] Ibid., p.54.

[79] http://www.rta.nsw.gov.au/environment/airquality/vehicleemissions/alternativefuels.htm

[80] http://www.epa.nsw.gov.au/air/riscamvmvf.htm

[81] http://www.transport.nsw.gov.au/pubs_legal/act2010nsw.pdf

[82] http://www.epa.nsw.gov.au/air/dopahhm/organicmanagement.htm

[83] http://www.statefleet.dpws.nsw.gov.au/Greening+the+Government+Fleet/Cleaner+Vehicles+Action+Plan.htm

[84] http://www.statefleet.dpws.nsw.gov.au/Greening+the+Government+Fleet/Subsidised+Green+Vehicles.htm

[85] http://www.epa.nsw.gov.au/air/cleancars.pdf

[86] http://www.statefleet.dpws.nsw.gov.au/Greening+the+Go...ent+Fleet/Hybrid+Vehicles+in+the+Government+Fleet.htm

[87] http://www.epa.nsw.gov.au/air/actionforair/index.htm

[88] http://www.epa.nsw.gov.au/air/update.pdf

[89] http://www.epa.nsw.gov.au/air/projects2003.htm

[90] http://www.ncc.nsw.gov.au/news/archive/mrdata00_03.cfm?MID=925&M=10&Y=2003

[91] Transit Planners (2003) p.17.

[92] http://www.sustainable.energy.sa.gov.au/pages/policy/state/fuels_strategy/draft.htm

[93] http://www.senrac.sa.gov.au/

[94] http://www.transport.sa.gov.au/environment/air_greenhouse/bus_greening.asp

[95] Fong (2002).

[96] http://www.nt.gov.au/ocm/media_releases/2003/20030219_bus.shtml

[97] http://www.greenhouse.vic.gov.au/strategy/summary.htm

[98] For examples, see: http://www.greenhouse.vic.gov.au/transport.htm

[99] http://www.dse.vic.gov.au/melbourne2030online/

[100] http://www.dpc.vic.gov.au/CA256D8000265E1A/page/Listing-Publications-Infrastructure+Planning+Council+Final+Report!OpenDocument&1=60-Our%20Leadership%20Role~&2=70-Publications~&3=~

[101] Pratt (2002).

102 http://www.vicfleet.vic.gov.au/domino/web_notes/vicfleet/vicfleetsite.nsf/SP/DFA2D5349E43C2574A256B40007FE444?OpenDocument

103 http://www.vicfleet.vic.gov.au/domino/web_notes/vicfleet/vicfleetsite.nsf/SP/CDD01CCD2E1166434A256B40007FE43C?OpenDocument

104 Reported in a Press release by acting Premier John Thwaites, on Monday, 19 January 2004, 'Government Car Fleet To Be More Greenhouse Friendly.'

105 http://www.venturabus.com.au/ven_environment.html

106 http://www.bellona.no/en/energy/report_3-1999/11167.html

107 http://www.ccities.doe.gov/vbg/progs/laws2.cgi

108 For more detail see: http://www.electricdrive.org/gov/gov_murkowski_energy_bill.htm

109 http://www.electricdrive.org/pdf/BushProposesTaxCredit_Hybrid.pdf

110 http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,4330,00.html

111 http://www.just-auto.com/news_detail.asp?art=44246

112 As reported in The San Francisco Chronicle on April 21st 2004: http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2004/04/21/BAG9M683IP20.DTL

113 http://europa.eu.int/comm/taxation_customs/proposals/taxation/report_en.pdf

114 http://www.inforse.dk/europe/eu_inte-en.htm

115 http://www.fuelcelltoday.org/FuelCellToday/FCTFiles/FCTArticleFiles/Article_770_FuelCellsinScandinavia0304.pdf

116 http://www.autoindustry.co.uk/news/industry_news/news-54khm2b0kn

117 Passey (2002).

118 Ecofutures (2002) Australia's fledgling BioDiesel industry taking off in Western Australia, Ecofutures, Feb-April, 2002.

119 Campbell, J. B. (2000) Biodiesel - Will There Be Enough? New Markets For Bio-Based Energy And Industrial Feedstocks, Agricultural Outlook Forum 2000, from http://www.usda.gov/oce/waob/oc2000/speeches/campbell.txt

120 Renew (2002) Biodiesel car review, Renew Magazine, Alternative Technology Association, Issue 79, 2002.

121 Web Wombat Motoring News (2002) at http://www.webwombat.com.au/motoring/news_reports/diesel.htm

122 Weiss, Heywood, Schafer, and Natarajan (2003), p.12.

123 Weiss, Heywood, Schafer, and Natarajan (2003), p11 and Green and Schafer (2003), p.13.

124 Green and Schafer (2003), p.18.

125 Beer, Grant, Watson and Olaru (2004).

126 Weiss, Heywood, Schafer, and Natarajan (2003).

127 Weiss, Heywood, Drake, Schafer and AuYeung (2000).

128 General Motors, L-B-Systemtechnik GmbH, BP, ExxonMobil, Shell and TotalFinal Elf (2002).

129 General Motors Corporation, Argonne National Laboratory, BP, ExxonMobil and Shell (2001).

130 EUCAR, CONCAWE and JRC (2004).

131 The authors of *On the Road in 2020* emphasise that the study represents 'what *could happen* to passenger car fuel consumption over the next 20 years, and not necessarily what we judge will or ought to happen.' (Weiss, Heywood, Drake, Schafer and AuYeung (2000), p.3.28.).

[132] Tables 5.4 and 5.5 in Weiss, Heywood, Drake, Schafer and AuYeung (2000) provide summary steEp comparison of technology and fuel combinations for PMVs. For an in-depth steEp comparison, see Chapter 5A: Appendices in Weiss, Heywood, Drake, Schafer and AuYeung (2000).

[133] The rankings shown in Table 4.5 have been derived in large part from the findings of the two key MIT reports. The ranking approach has been taken to allow the formulation of a coherent overview of propulsion technology and fuel groupings across multiple assessment criteria from multiple studies. The aim here is to allow the study data to be taken forward into scenario development. It should be noted that the authors of *On the Road in 2020* issue the following caution with regard to ranking the options considered in their study: 'Although our numeric results appear to allow a ranking of the technologies evaluated against different attributes, consideration of uncertainty ranges blurs the apparent comparisons. ***Only where differences are more than these uncertainty ranges are the rankings of technologies clear.*** Our analysis does allow the effects of different options to be considered within a consistent format. We have not performed a comprehensive uncertainty analysis, so this paragraph is intended to serve as both a context and a caution about drawing too broad conclusions using technology option rankings from our representative technology system analyses.' (Weiss, Heywood, Drake, Schafer and AuYeung (2000), p.5.3.). The rankings presented in the current work are to regarded then as broadly illustrative, and not beyond qualification. They are entered into with awareness of the dangers involved.

[134] Weiss, Heywood, Schafer, and Natarajan (2003), p12.

[135] Beer, Grant, Morgan, Lapszewicz, Anyon, Edwards, Nelson, Watson and Williams (2001), p.28, fig. 4.1.

[136] General Motors, L-B-Systemtechnik GmbH, BP, ExxonMobil, Shell and TotalFinal Elf (2002), pp.23-4.

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