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

Prepared for EPA Victoria

By The National Centre for Sustainability, Swinburne University of Technology

FINAL REPORT
September 3rd, 2004

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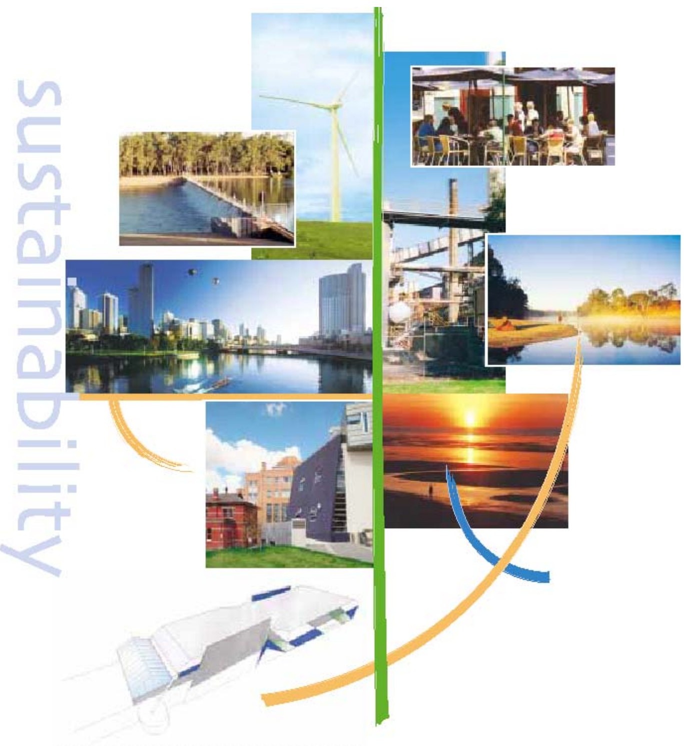

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SWINBURNE UNIVERSITY OF TECHNOLOGY

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Executive Summary

Action to address the impact of greenhouse gas emissions on climate change is increasing at the global, national and local levels. In Victoria, a broad-based response is being implemented under the Victorian Greenhouse Strategy (VGS). The VGS recognises that transport is a significant and growing contributor to the State's emissions. In 1999, transport sources accounted for 16% of Victoria's total greenhouse gas emissions. By far the most significant component of these emissions comes from road transport.

This study, which has been commissioned by EPA Victoria as part of Action 7.5 (*Determining Victoria's role in promoting the use of alternative fuels and technologies)*, aims to identify the transport fuels and vehicle technologies which should be promoted in Victoria – over the next ten years – in terms of their capacity to contribute to reduced greenhouse gas emissions and emissions of substances impacting on air quality. The results of the study will assist in the determination of the most appropriate role for the Victorian Government in the promotion of the preferred fuels and technologies.

In considering road transport propulsion technology and fuel options, this study addresses a broader range of assessment variables than any other study publicly available in Australia. The economic, technical, social, environmental and political appropriateness of different alternative transport fuels and technologies (ATFT) is considered. Scenario development (a foresight methodology) is used to assist in the creation of a range of viable forward views for the Victorian ATFT policy context over the next ten years.

The analysis shows that there is no magic bullet. Despite significant media attention, hydrogen technology is considered unattractive over the next ten years – both for economic and environmental reasons. Instead, hybrid technologies appear more to be the most attractive option – particularly hybrid petrol. Advanced LPG and hybrid LPG also appears preferable to conventional petrol technologies in the passenger motor vehicle class. Advanced diesel and hybrid diesel technologies also show promise, particularly for heavy vehicles already using petroleum diesel. In the case of passenger motor vehicles, diesel, in both its conventional and hybrid manifestations, must address particulate matter emissions much higher than the present fleet average if it is to offer large-scale benefits. Potential for such improvement may exist in the form of tailpipe filtering developments, however it is far from certain that real reductions will be delivered. With today's technology, a large shift to diesel passenger motor vehicles would result in adverse air quality impacts and associated increase in health risks. CNG and Hybrid CNG are also preferable in heavy vehicles – although fuel tank size requirements present some challenges.

In the absence of any significant incentives or encouragement, uptake of these new technologies is expected to be minimal. Perhaps the only exception is the uptake of hybrid petrol vehicles by concerned individuals and organisations keen to portray a 'sustainable' image. In order to encourage wider uptake of preferred ATFT, the Victorian Government might consider a range of measures such as:

- Modifying Government fleet policies to drive significant adoption of hybrid petrol-electric and LPG vehicles;
- Aligning registration fees with vehicle type (providing incentives for using lower emission vehicles); and,

- Lobbying the Federal Government to encourage ATFT uptake by adjusting fuel quality/vehicle emission standards, fuel taxation levels, importation tariffs and sales tax.

As a risk management measure, the Victorian Government might also consider scenarios arising from increased public concern over environmental impacts, and increased oil price volatility. Respectively, these scenarios will place increased importance on emission control measures, and alternatives to petroleum based fuels. Under these scenarios, more rapid transitions to hybrid technologies, and LGP / CNG technologies respectively, will be required – and the Government's role in supporting these transitions will become even more important.

When viewed in a broader context, even a full transition to ATFT over the next ten years is unlikely to result in a significant reduction in emission levels as compared with today. The promotion of ATFT should therefore be seen as necessary, but not sufficient, for reducing greenhouse gas emissions. Only in conjunction with a range of other measures – including demand management (for transportation and stationary energy) and migration to alternative forms of transport (including public transport, walking and cycling) – will the promotion of ATFT provide meaningful emission reductions. Acting alone, Victoria is not capable of achieving emission reductions of significance on a global scale. However, since Victoria is a progressive state in one of the world's most advanced nations, the Victorian Government has an essential leadership role to play on this vital issue. This leadership will not only promote greater awareness of environmental issues with consumers and local businesses, but also send an important message to local industry, other State Governments, the Federal Government, and other governments around the world.

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ACT	Australian Capital Territory
ADR	Australian Design Rule
ATEDAC	Australian Transport Energy Data and Analysis Centre
AFCP	Alternative Fuels Conversion Program
AGO	Australian Greenhouse Office
ANAO	The Australia National Audit Office
ATC	Australian Transport Council
ATFT	Alternative Transport Fuels and Technologies
BTCE	Bureau of Transport and Communications Economics
BTRE	Bureau of Transport and Regional Economics
CAFC	Corporate Average Fuel Consumption
CI	Compressed Ignition
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide equivalent
CNG	Compressed Natural Gas
CNGIP	Compressed Natural Gas Infrastructure Program
CSIRO	Commonwealth Scientific and Industry Research Organisation
DEH	Department of Environment and Heritage
DFAGS	Diesel and Alternative Fuels Grants Scheme Act 1999
DIMIA	Department of Immigration, Multicultural and Indigenous Affairs
DITR	Department of Industry Tourism and Resources
E10P	Petrol-Ethanol fuel blend containing 10% ethanol and 90% petrol
E85P	Ethanol-Petrol fuel blend containing 85% ethanol and 15% petrol
ESMVI	Environmental Strategy for the Motor Vehicle Industry
FC	Fuel Cell
FP	Fuel Processor
F-T (Diesel)	Fischer-Tropsch Diesel
GTL	Gas-to-Liquid
GHG	Green House Gases
GVM	Gross Vehicle Mass
HC	Hydrocarbon
ICE	Internal Combustion Engine

LCV	Light Commercial Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied petroleum gas
LS (Diesel)	Low Sulfur (Diesel)
NG	Natural Gas
NAFC	National Average Fuel Consumption targets
NGS	National Greenhouse Strategy
NGS-M5	National Greenhouse Strategy Module Five: Efficient Transport and Sustainable Urban Planning
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Oxides of Nitrogen
NSW	New South Wales
NT	Northern Territory
PM	Particulate Matter
PM(10), PM10	Particulate Matter less than 10 ÿm in diameter
PMV	Personal Motor Vehicle
PRT	Personal Rapid Transit
PTB	South Australian State Passenger Transport Board
PTFG	Propulsion Technology and Fuel Grouping
PULP	Premium Unleaded Petrol
QLD	Queensland
QSEIF	Queensland State Energy Innovation Fund
RTA	NSW Road and Traffic Authority
SA	South Australia
SI	Spark Ignition
SEDA	NSW Sustainable Energy Development Authority
SENRAC	South Australian State Energy Research Advisory Committee
steEp	Social, technical, economic, environmental and political factors, with emphasis on environmental factors. The research dimensions and assessment criteria considered in this study are broadly categorised according to these categories.
TESC	Western Australia State Transport Energy Strategy Committee
ULP	Unleaded Petrol
ULS (Diesel)	Ultra-Low Sulfur Diesel
US	United States
VOC	Volatile Organic Compounds
VGS	Victorian Greenhouse Strategy 2002
VIC	Victoria
WA	Western Australia

1 Introduction

1.1 Context

Action to address the impact of greenhouse gas emissions on climate change is increasing at the global, national and local levels. In Victoria, a broad-based response is being implemented under the Victorian Greenhouse Strategy (VGS). The VGS recognises that transport is a significant and growing contributor to the State's emissions. In 1999, transport sources accounted for 16% of Victoria's total greenhouse gas emissions, before consideration of the exbodied emissions associated with the manufacture of transport vehicles and associated infrastructure.

Within Victoria's transport sector, road transport is responsible for the majority of greenhouse gas emissions. This is reflected in the VGS's Action Module 7: *Influencing travel choices and behaviour*. Propulsion technology and fuel choice play a significant role in determining the emissions produced in accomplishing any given road transport task. This study has been commissioned by EPA Victoria as part of Action 7.5: *Determining Victoria's role in promoting the use of alternative fuels and technologies*, and aims to identify the transport fuels and vehicle technologies which should be promoted in Victoria in terms of their capacity to contribute to reduced greenhouse gas emissions and emissions of substances impacting on air quality. The results of the study will assist in the determination of the most appropriate role for the Victorian Government in the promotion of the preferred fuels and technologies.

1.2 Significance of this Study

This study is characterised by its high level, integrative nature. In considering road transport propulsion technology and fuel options, this study addresses a broader range of assessment variables than any other study publicly available in Australia. The economic, technical, social, environmental and political appropriateness of different alternative transport fuels and technologies (ATFT) is considered.

While this report is based on high quality primary and secondary sources, it extends the findings of these sources through the use of scenario development (a foresight methodology) – to assist in the creation of a range of viable forward views for the Victorian ATFT policy context over the next ten years.

1.3 Objectives

The objectives of the study were to:

- Investigate the Triple Bottom Line viability of each ATFT within the scope of this study;
- Identify current National and State Government policies that influence the uptake of these ATFT;
- In light of the above, identify the most viable ATFT that offer the greatest potential benefits for promotion over the next ten years in terms of minimising greenhouse gas emissions and air pollutants from road transport in Victoria;

- Consider industry and non-government stakeholders' views; and,
- Identify a range of policy options for promoting the uptake of ATFT over the next ten years.

1.4 Scope

This study is a multi-dimensional viability assessment of some nineteen different propulsion technology and fuel groupings (PTFG). The research dimensions include social, technical, economic, environmental and political variables. As the chart in Figure 1 shows, the passenger motor vehicle (PMV) class accounts for around sixty-seven percent of road transport greenhouse gas emissions in Victoria, and represents the greatest opportunity for emission reduction. (Full details of this analysis can be found in Appendix A.) The report therefore focuses its analysis first on PMVs, and then considers other vehicle classes where particularly significant opportunities are in evidence.

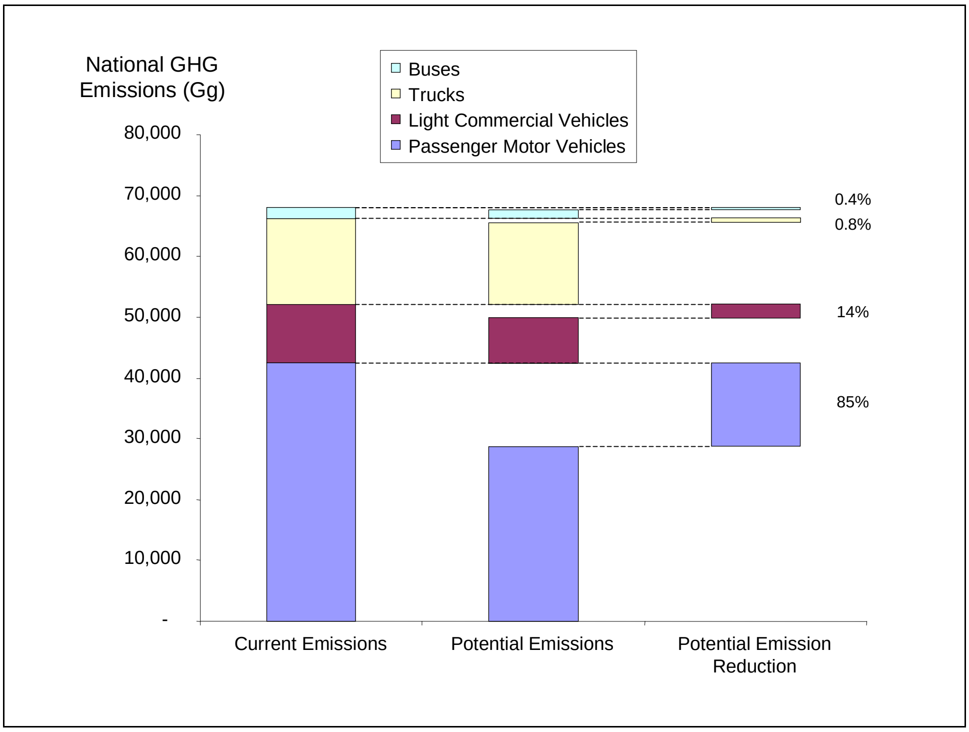

Figure 1.1: Opportunity for Emissions Reductions by Vehicle Class

2 Methodology

2.1 Introduction

A strategic foresight approach was adopted for this study due to its unique ability to synthesise the wide-ranging viability assessment criteria, stakeholder positions, and Federal and State policy initiatives under consideration. Importantly, such an approach engages with the uncertainties of the future in a manner that allows consideration of current policy development and implementation. The study methodology comprised four stages, each of which involved a key expert review process. A process overview is shown in the Figure 2.1 below. The study utilised direct (stakeholder) and desktop based (policy and scientific) research, using high quality primary and secondary research sources and publicly available government documents outlining relevant policy initiatives.

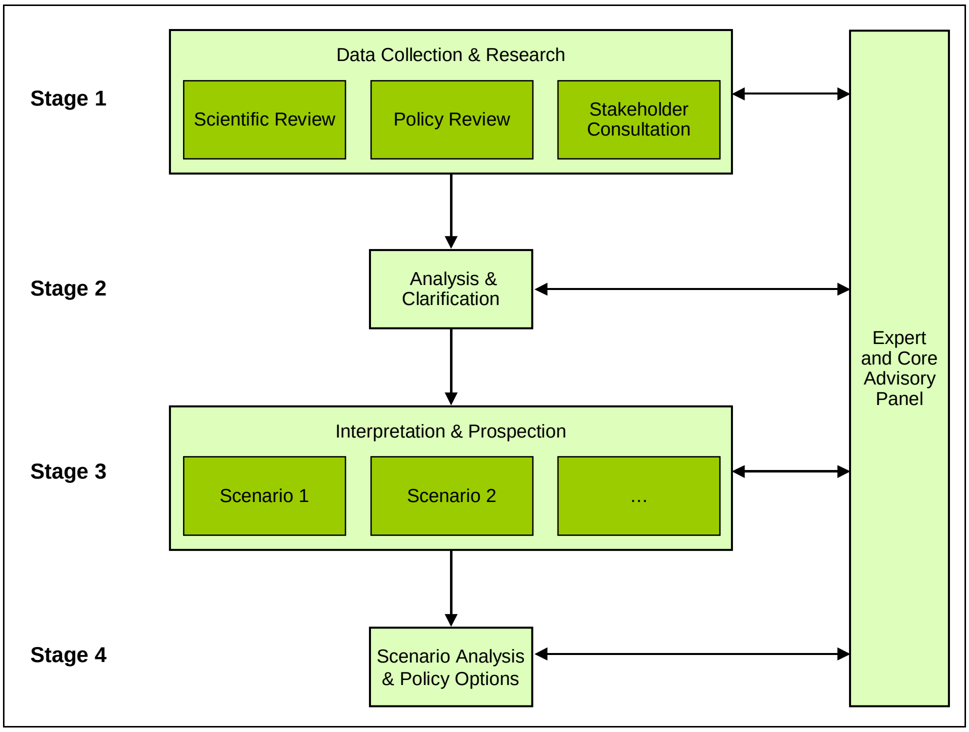

Figure 2.1: Overview of Study Process

2.2 Stage One

2.2.1 Stakeholder Consultation

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 contacted by email or phone and asked to respond to a questionnaire regarding the appropriateness of various alternative transport fuels and technologies (ATFT), and the role of the Victorian Government with regards to promoting 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. 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 included in the report.

2.2.2 Scientific Review

A wide ranging literature review was conducted to summarise the key technical information related to each propulsion technology and fuel grouping (PTFG) identified in the study's brief. The particular emphasis in this exercise was on the technical and environmental considerations of different PTFG, and the relationship of these to GHG emission reductions. Where appropriate, social, economic and political issues were also considered, particularly where these issues intersected strongly with the application of technological systems to the task of reducing GHG emissions.

2.2.3 Policy Review

A wide ranging 'desk top' policy review was conducted drawing on publicly available information sources related to ATFT policy and initiatives both within Australia and overseas. Each policy activity identified was summarised and was used to inform the study's following stages. A synthesis of the key policy highlights and strategic directions is presented in the report.

2.3 Stage Two

2.3.1 SteEp Assessment Variables

A range of PTFG 'capability' assessment criteria were derived from the objectives of this study and from the research conducted in Stage One. The assessment criteria included social, technical, economic, environmental and political (steEp) variables and were grouped according to triple bottom line (TBL) categories. These are presented in Tables 2.2 and 2.3 below.

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.
			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.
			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 2.2: steEp Criteria Generation

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 2.3: TBL and steEp Summary Assessment Questions

2.3.2 Broader Assessment Variables

A summary assessment of the PTFG addressed by the study's scope revealed a subset of most viable options which presented the greatest opportunity for emissions minimisation in Victoria over the next ten years. This subset was further analysed according to four additional criteria, each of which is influenced by multiple steEp factors:

- *Vehicle Class* – The primary PTFG screening is conducted with PMVs as the main 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 are 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 presented in the context of fleet adoption of the various PTFG are 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 are 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 are 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 are identified.

These four criteria were considered in an integrated fashion, and formed the basis of the broader assessment. This broader assessment was conducted for each of the steEp variables.

2.4 Stage Three & Four

The third stage of this study involved the generation of a set of plausible scenarios describing the Victorian ATFT policy context in ten years time. The scenarios were developed using an approach similar to the one developed by the Global Business Network (for full details, see Appendix F). The purpose of using scenarios is to provide a number of challenging yet plausible futures against which the appropriateness of potential policy options may be tested and, where necessary, refined.

The scenarios were then systematically analysed in stage four to identify the significant changes in PTFG mix. A range of policy options that could most appropriately support the uptake of ATFT within each scenario was developed.

3 Policy Review

3.1 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.[1] 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.

For this study, a wide ranging review of publicly available documents was undertaken to identify some of the key government policies, initiatives, and research reports, related to alternative fuels and technologies, at both the Federal and State government levels, and more generally internationally. A fuller summary of the documents identified, summarised and incorporated into this study's analysis is detailed in Appendix B.

The comments in this report are based on the key elements shaping Australia's ATFT strategic direction as identified in Appendix B. Appendix B contains first, a review of efforts at the national level concerning the majority of key policy directions. Second, an overview of the progress of state and territory governments reveals a number of other policy emphasises and supporting research. Third, a range of futures projects are reviewed for the unique input into the ATFT policy context. Fourth, the Victorian Government's ATFT policy initiatives and programs are addressed in some detail. Finally, a representative sample of international policy initiatives are also canvassed.

3.2 Policy Highlights

In line with its involvement in several international agreements[2], the Australian Government confirmed its commitment to alternative transport fuels and technologies (ATFT) through its 1998 National Greenhouse Strategy (NGS).[3] 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.

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 vehicle 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.'[4]

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.

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 challenge of climate change. 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.

3.3 Strategic Directions

A significant breadth of policies and supporting initiatives and research are canvassed in Appendix B, 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, predominately 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.

4 Stakeholder Consultation

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.

A synthesis of the recommendations from stakeholders 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. A fuller presentation of the Stakeholder's views informing this study, and official statements on ATFT from them, are available in Appendix C.

4.1 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

4.2 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.
7. Current consensus suggests that a pathway toward a hydrogen economy should be investigated.

4.3 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.
10. The Victorian government initiatives should complement and not duplicate or conflict with Commonwealth measures.
11. 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.
12. The Victorian government may encourage alternative fuel adoption through partnerships with industry, e.g. to increase LPG use in buses.
13. 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.
14. Lack of infrastructure, such as public refuelling stations is a barrier to uptake.
15. 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.

4.4 Policy Options

In addition to the general propositions outlined above, stakeholders also suggested a number of specific policies for the Victorian government. The full details of these suggestions appear in a table later in this chapter. However, the nature of the recommendations has been summarised below in the Table 4.1 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] does 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. Leading by example is important.

Table 4.1: Specific Victorian Government Policy Recommendations from Stakeholders

5 Scientific Review

5.1 Passenger Motor Vehicle (PMV) analysis

Propulsion technology and fuel grouping steEp factor summary

As discussed in the Introduction (and Appendix A), 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 sectors 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 of significant departures for vehicle types other than PMVs will be given in a later section.

5.2 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 the 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 the fleet-wide fuelling profile;
3. Reducing the GHG emissions exbodied in the manufacture of vehicles;
4. Changing fleet size, fleet changeover rate (taking into account the contribution to overall GHG emission made by vehicle manufacture and distribution) - this is 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 - this is beyond 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[5]:

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 5.1. This shows details of the family of options available in each morphological branch being considered in this study. These 19 vehicle propulsion technology and fuel groupings (PTFG) are also shown in Table 5.1. These groupings apply, in general, to each of the road transport vehicle types.

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 5.1: Morphological Table for Indicating Factors Contributing to Road Transport Vehicle GHG Emissions and Describing PTFG under Consideration

Notes:
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.

PTFG	Fuel	Engine	Transmission
CI-ICE (adv.)-Diesel (petroleum)	Diesel	Compression Ignition	Advanced Conventional
CI-ICE Biodiesel	Diesel (Biodiesel)	Compression Ignition	Advanced Conventional
Hybrid CI ICE-Diesel (petroleum)	Diesel	Compression Ignition	Hybrid Electric
CI ICE (adv.)-Diesel (GTL +Gsq)	Diesel (from NG)	Compression Ignition	Advanced Conventional
Hybrid CI ICE-Diesel (GTL + Gsq)	Diesel (from NG)	Compression Ignition	Hybrid Electric
SI ICE (adv.)-Petrol (Baseline)	Petrol	Spark Ignition	Advanced Conventional
Hybrid SI ICE-Petrol	Petrol	Spark Ignition	Hybrid Electric
SI ICE (adv.)-Anhy. Ethanol (E85P)	Ethanol	Spark Ignition	Advanced Conventional
SI ICE (adv.)-LPG	LPG	Spark Ignition	Advanced Conventional
Hybrid SI ICE-LPG	LPG	Spark Ignition	Hybrid Electric
SI ICE (adv.)-CNG	CNG	Spark Ignition	Advanced Conventional
Hybrid SI ICE-CNG	CNG	Spark Ignition	Hybrid Electric
SI ICE (adv.)-LNG	LNG	Spark Ignition	Advanced Conventional
SI ICE Hydrogen (ex NG)	Hydrogen (from NG)	Spark Ignition	Advanced Conventional
FC Hydrogen (ex NG)	Hydrogen (from NG)	Fuel Cell	Direct Electric
FC Hydrogen (renewable)	Hydrogen (renewable)	Fuel Cell	Direct Electric
Hybrid FC Hydrogen (ex NG)	Hydrogen (from NG)	Fuel Cell	Hybrid Electric
Hybrid FC Hydrogen (renewable)	Hydrogen (renewable)	Fuel Cell	Hybrid Electric
Hybrid FC Petrol (fuel processor)	Petrol	Fuel Cell	Hybrid Electric

Table 5.1: List of PTFG Addressed in this Study

Notes:
1) Diesel includes contributions from ULSD, Aquadiesel and diesohol.
2) Petrol includes contributions from PULP and E10P.

Note that conventional diesel, diesohol and Aquadiesel are grouped together, as are petrol and petrohol. This reflects the fact that diesohol, Aquadiesel and petrohol are all alternative fuels that can be used in conventional compression ignition and spark ignition engines respectively, without engine modification. As the research revealed, the alternative fuels also exhibited only marginally different emissions results in comparison to conventional diesel and petrol. There was little value in considering these combinations of alternative fuels and conventional technologies as separate PTFG. The analysis outcomes presented later assume that diesohol and Aquadiesel form a subcomponent of the total diesel supply, and petrohol forms a subcomponent of the total petrol supply.

5.3 Key References

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 5.2.

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)[6]	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)[7]	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)[8]	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)[9]	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)[10]	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[11]	2004	Europe, 2010 and beyond	Well-to-wheel for fuel (based on a particular PMV)

Table 5.2: Key Reference Studies for PMV PTFG

Two further Australian studies focused generally on use of the full range of fuels under consideration, with currently available propulsion technology. Scope included use of fuels in heavy vehicle applications. These are shown in Table 5.3.

A wide range of other sources is drawn on as appropriate.

Study title and participating organisations	Release date	Study scope	Study type
Comparison of Transport Fuels: Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles, CSIRO Atmospheric Research, CSIRO Environmental Risk Network, RMIT Centre for Design, CSIRO Energy Technology, Parsons Australia Pty Ltd, University of Melbourne Department of Mechanical and Manufacturing Engineering.[12]	2001	Australia, 2001	Well-to-wheel for fuel, using conventional propulsion technology.
CSIRO, BTRE and ABARE (2003) *Appropriateness of a 350 ML Biofuels Target*, CSIRO, BTRE and ABARE.[13]	2003	Australia, 2003	Well-to-wheel for fuel, using conventional propulsion technology.

Table 5.3: Key Reference Studies for Fuels, Including Heavy Vehicle Applications

5.4 Organisation of Research Findings

The full research findings are presented in Appendix D. In general, the research findings are presented within sections that correspond to one or more of the steEp factors. Findings relevant to the full range of propulsion technologies and fuel groupings are first considered in the context of PMVs. Given the significance of issues specific to fleet-based PMV operation, and the relationship of this to vehicle manufacture, a section focussing on these areas follows. Significant points of departure for other vehicle types are then considered. Finally, the full range of fuels under consideration is examined in more detail, generally based on utilisation in conventional spark ignition and compression ignition engines. Throughout the presentation of findings, full fuel lifecycle is considered. Vehicle lifecycle is also considered where data was available. Table 5.4 gives a general indication of the relationship between the report sections and the steEp assessment criteria for the range of PTFG options, and can be considered as a 'reading guide' for Appendix D. It is emphasised that this should be regarded as broadly indicative only.

steEp factor	Relevant report sections - general focus on PMVs (see appendix D)	Sections specifically relevant to vehicle types other than PMVs
social	▪ General steEp considerations impacting on PTFG ▪ Energy use and GHG emissions comparison ▪ Fleet changeover issues ▪ Fuel type summaries	▪ Issues specific to other vehicle types ▪ Fuel type summaries
technical	▪ Relative technical challenge of PTFG ▪ General steEp considerations impacting on PTFG	▪ Issues specific to other vehicle types ▪ Fuel type summaries
economic	▪ Economic comparison of PTFG ▪ Fleet changeover issues ▪ Fuel type summaries	▪ Issues specific to other vehicle types
Environmental	▪ Comparison of GHG emissions from PTFG ▪ Comparison of air pollutant and GHG emissions from currently available PTFG ▪ GHG and air pollutant emission comparison for light vehicle and heavy vehicle fuels ▪ Fuel type summaries ▪ Air toxic emissions	▪ Issues specific to other vehicle types ▪ GHG and air pollutant emission comparison for light vehicle and heavy vehicle fuels ▪ Fuel type summaries
political	▪ General steEp considerations ▪ Fleet changeover issues ▪ Dominance and inertia of liquid petroleum-based fuels	▪ Issues specific to other vehicle types ▪ Fuel type summaries

Table 5.4: Categorisation of Appendix D Sections by steEp Factors

6 Analysis

6.1 Introduction

Stage two of this study involved an analysis of the research outcomes to identify the most viable subset of PTFG options in the Victorian context. The analysis process served to clarify the findings documented in Appendices A-D.

A summary of the analysis outcomes for each PTFG considered in the research phase is presented in Appendix E. The subset of most viable PTFG was identified through a high level, generalised steEp assessment process. 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.

6.2 General steEp Assessment of PTFG

The results of the PTFG screening process, conducted on the basis of the analysis outcome summaries in Appendix E, are shown in Table 6.2 below. 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 further examination.

Note that the fuels Aquadiesel and diesohol, and petrohol (E10P), are incorporated within the CI ICE-diesel and SI ICE-petrol categories 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.

6.2.1 steEp Criteria Scores

The numerical scores for each steEp criterion are arrived at by estimating each PTFG option's performance according to the scale shown in Table 6.1. 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 6.1: Legend for PTFG Assessment Scores

The assessment table represents a judgement based on the technical and policy steEp research documented in Appendix E, 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 6.2: Summary of PTFG Assessment Scores

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

6.3 Discussion of 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 two stars:

- Advanced LPG
- Hybrid Petrol

- Hybrid LPG
- Advanced CNG (heavy vehicles only)
- Hybrid CNG (heavy vehicles only)

The options with an overall assessment rating of one star, namely conventional and hybrid diesel, warrant further consideration. Inclusion of conventional and hybrid diesel PMVs in the most viable subset is strongly contingent upon the success of tailpipe filtering in significantly reducing particulate matter emissions. If improvements are not made in this area, then it would seem inappropriate to increase the proportion of diesel vehicles in the PMV fleet on the grounds that air quality would deteriorate and associated health risks would be very likely to increase. An approach whereby developments in this area are closely monitored, rather than an early commitment to promotion, appears more appropriate. Promotion of developments to reduce particulate matter emissions may be appropriate.

In the heavy vehicle classes, where conventional diesel is the incumbent technology, advances in both conventional and hybrid technology stand to significantly reduce both GHG and air pollutant emissions. In these classes, the diesel options must clearly be included in the most viable subset.

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 6.3 outlines the nature of the significant impediments to implementation of these PTFG.)

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 6.3: 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 following ATFT scenario process.

The significant impediments affecting biodiesel and ethanol mean that these options are not considered in any further detail. As discussed previously however, the biofuels in particular are very attractive in niche applications. For more information, the reader is referred to the technology and fuel research summary Appendix D, the policy research summary Appendix B and the analysis outcome summary tables in Appendix E. In general, research indicates that the overall contribution to minimisation of emissions from these fuels will be limited. They will almost certainly remain present in the fuel mix, but their impact on GHG and air pollutant minimisation is expected to be limited at the level of the total road transport fleet.

GTL diesel produced from natural gas has a very uncertain future in the Australian context. It warrants brief mention only, on the basis that its viability may be sensitive to particular scenario contexts.

In general, the PTFG analysis outcomes presented here constitute a ‘probable future’ perspective. The context for the probable future is a world whose essential characteristics are similar to or at most, conservative extrapolations from, our current situation. A scenario generation and analysis process was carried out to mitigate the risk associated with overlooking significant departures from this assumed context that could plausibly arise over the next ten years. This process is described in detail in the following section.

7 Future Scenarios

7.1 Introduction

Following the study's initial analysis phase, a set of scenario environments were generated and used to identify an expanded range of viable PTFG and appropriate policy options for the Victorian government to consider in promoting uptake of these PTFG. These scenario environments constitute the contexts for policy option development. The scenario environments have been structured around a central 'probable world', which correlates with the contextual basis of the key references cited in the research phase. In other words, the probable future world forms the basis for the assessment filter depicted in Table 6.2, and hence for identification of the subset of most viable PTFG options that were identified.

In the scenario process, the probable world forms a hub from which three divergent 'plausible worlds' radiate outwards. This is depicted graphically in Figure 7.1. The plausible worlds expand the boundaries of the more conventional thinking that characterises the probable world, introducing factors that encourage questioning of our assumptions. The alternative contexts described by each of these worlds are used to modify the PTFG assessment filter applied in the initial analysis phase. The filter is then reapplied to identify different subsets of most viable PTFG options for each scenario world. The plausible worlds are used to ensure that policy options are informed by, and sufficiently flexible to, respond to emergent changes. The output from this process is a set of core policy options that are informed by contingency considerations for responding to key uncertainties identified from within a longer-term outlook. The complete scenario generation process is detailed in Appendix F.

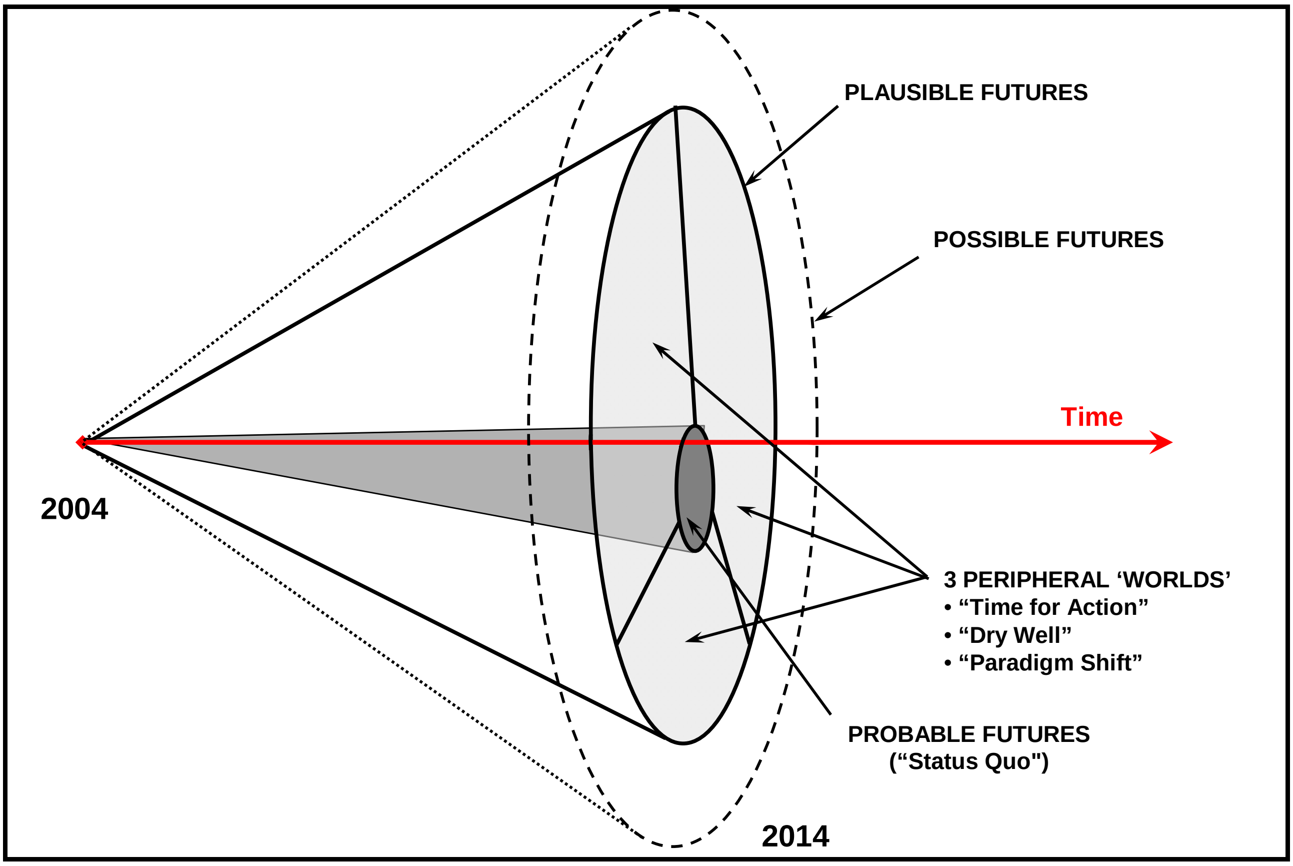

Figure 7.1: The Victorian ATFT Scenario Contexts and the Futures Cone

7.2 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 stages 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 Change Drivers* – The scenario change drivers need to be closely aligned with current realities, and yet also be relatively independent of each other in terms of cross-impact, in order to increase their breadth for considering policy during the ten year period.

7.3 Scenario Generation

To meet the above criteria the scenarios for this study were generated using a variation of the rapid scenario generation process, first popularised by the Global Business Network. A full explanation of the method and process outcomes that resulted in the scenarios presented in this study is outlined in Appendix F. The scenario development and analysis was 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?

7.3.1 Scenario Framework

The two key drivers identified during this study generate four plausible yet differing policy contexts for 2014. A name for each of the four scenarios was chosen based on a metaphor that characterises each world.

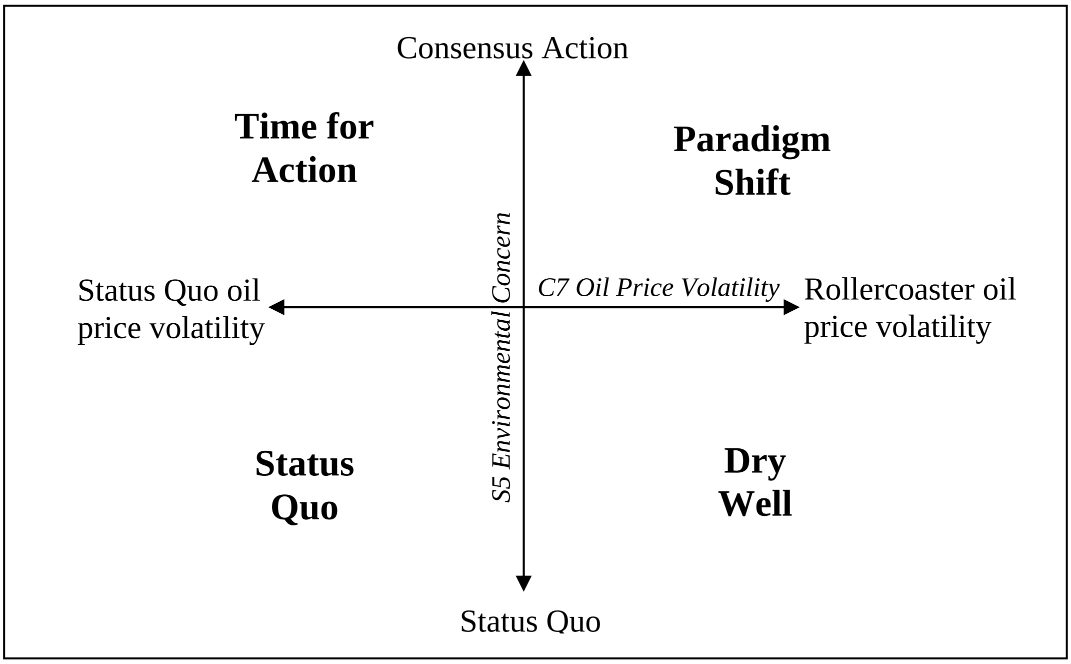

Figure 7.2: Victorian ATFT Policy Scenario Framework

7.3.2 Four ATFT Policy Contexts 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')

7.4 Interpreting the Scenarios

It should be noted that the scenarios are only briefly considered within this study and that an expanded analysis could yield further insights for policy consideration. The purpose of the descriptions and option analyses provided is to facilitate the accommodation of different policy options and developmental pathways during the Victorian ATFT policy generation process. The scenarios can serve to prompt the consideration of a broader range of plausible future eventualities impacting on the road transport policy context and ATFT in particular. In this manner the scenarios are alternative ten-year time horizon 'snap shots' that need to be interpreted with their brief nature and selective focus in mind. It is possible that PTFG other than those identified here could rise to prominence within the logic of these scenario worlds. The outcome of the scenario analysis presented here is only one approach to accommodating the requirement that the scenarios be divergent yet sufficiently plausible.

It is crucial to remember that the purpose of scenarios, as applied within this study, is not to forecast the most likely future, or predict what could actually happen. The scenarios do not represent 'reality' in this sense. The scenarios are brief outlines of some of the edges of plausibility that we can see today. These edges are defined by our current knowledge, but are not rigidly defined and certainly contain no fixed content. The value of the scenarios is in their ability to inform thinking in the present. The scenarios are intended for use as alternative contexts within which to assess the viability of different ATFT and possible supporting policy options.

7.4.1 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. In an adaptive 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 might complement the ‘Status Quo’ options.

7.4.2 Development Pathways

In relating the different sets of policy options presented for each scenario, 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 ‘Time for Action’ and ‘Dry Well’ alternate 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 7.3 below. The pathways can be used to group the different policy options associated with each scenario, in an accumulative manner.

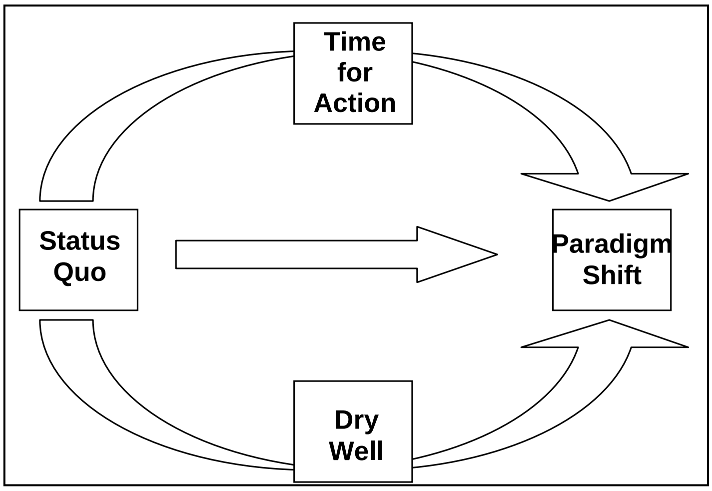

Figure 7.3: ATFT Policy Context Development Pathways

8 Findings

Once a selection of plausible scenarios had been generated, each was systematically explored in order to flesh out the nature of the scenarios' 'logic'. This led to the identification of the selection of ATFT that would be most viable in each scenario context. The likely PTFG mix served to guide the identification of policy options that could actively support the uptake of those ATFT.

It is important to note that the policy options presented are not exhaustive in terms of content or means of application, but reflect the range of policy options exampled within Australia (and to some extent internationally) as identified in the research stage of this study.

8.1 Scenario 1: Status Quo

8.1.1 Policy Environment Description

The system of interlocking forces that saw a steady increase in GHG emissions and deteriorating air quality in the 1990s, despite tighter fuel quality and vehicle emissions regulations for new vehicles, have continued in a similar pattern until today, in 2014. Consumer vehicle preferences, related manufacturer production, a continued fuel supply for which price variation has remained within limits accepted by motorists for many years, and a road transport fleet which is retained for even longer life spans per vehicle means that there is great resistance to the adoption of any ATFT beyond small niche markets. The main ATFT viably available is hybrid petrol-electric vehicles, and these are still more expensive to purchase and maintain than conventional petrol vehicles. The past decade of on-road use around the world has however, seen the continued improvement of hybrid petrol-electric technology so that overall fuel efficiency has increased without compromising power output, and availability of maintenance services and knowledge of the hybrid petrol-electric system has steadily increased. As the market penetration of petrol hybrids has increased so have ventures into hybrid diesel technology and conversion of petrol hybrids to LPG. Hybrid diesel continues to be hampered by poor PM and NOx emissions relative to its petrol equivalent, though given the very limited interest in GHG reducing PMVs, this problem causes little concern with regard to overall fleet emissions. Biofuels gain some popularity, but remain a small component of the overall road transport fuel mix. The slow introduction of hybrid vehicles into the broader market overall however, has caused market interest in ATFT to stagnate, and little will exists for more ambitious ATFT policies. The policies adopted reflect this road transport context, and continue to make minor adjustments to ATFT-related issues in an effort to minimise the increases in GHG and air pollutant emissions from the road transport sector.

Demand	Supply	Environment
▪ Consumer vehicle preferences and fleet policies continue to support traditional fuels and technologies; and, ▪ Hybrid petrol-electric vehicles remain the only viable genuinely ATFT, but enjoy limited uptake beyond a concerned minority.	▪ Hybrid petrol-electric vehicles remain more expensive than conventional vehicles, although technology improvements are helping to bridge the gap to an extent.	▪ Despite tighter fuel quality and vehicle emissions regulations for new vehicles, GHG and air pollution emissions continue to increase steadily.
Policy		
▪ The slow introduction of hybrid vehicles into the broader market has burnt out much of the market's interest in ATFT, and little will exists for more ambitious ATFT policies.		

Table 8.1: Summary Description for Status Quo Scenario

8.1.2 Summary Scenario Outlook

8.1.2.1 PTFG Mix

The likely PTFG mix for the ‘Status Quo’ scenario:

- Remains similar to the current mix;
- Includes minor increases in uptake of hybrid petrol vehicles by;
  - Concerned individuals; and,
  - Organisations keen to portray a ‘sustainable’ image.

8.1.3 Policy Options

Within the ‘Status Quo’ policy environment the Victorian Government is still committed to reducing GHG and air pollutant emissions from the road transport sector. The policy development process may consider inclusion of the measures and initiatives outlined in Table 8.2 to assist other efforts to minimise the amount of GHG and air pollutant emissions from road transport by promoting certain PTFG and ATFT generally. The policy options are presented as a summary of initiatives and measures in place by 2014 which have extended in a complimentary fashion the policy measures and initiatives in place in 2004.

steEp Dimension	‘Status Quo’ Policy Options
Technical	▪ Research and development funding for ATFT development is offered to local industry. ▪ Establishment and training grants (and programs designed to provide experience with servicing hybrid technologies that are used in Government fleets) are offered to assist in expanding the hybrid maintenance network beyond the Government fleet and a small selection of vehicle retailer maintenance services. Initially the general public are able to service their hybrid PMV through fleet and retailer maintenance infrastructure through an advanced booking service.
Economic	▪ The Government fleet adopts a policy of steadily increasing its percentage of ‘green’ PTFG and places advanced orders for more petrol hybrid PMVs to encourage their availability. ▪ Local production of ATFT is championed to Federal Government. ▪ Victoria champions to the Federal Government for fuel taxation to gradually change to reflect the amount of GHG and air pollutant emissions contributed by each fuel type.
Environmental	▪ Use of hybrid petrol-electric vehicles in the Government fleet, and through consultation with other fleet operators, is promoted as taking action on minimising GHG emissions from road transport vehicles. ▪ Funding is provided for local automotive technology research and development initiatives aimed at technology development for existing PTFG. Focus is placed on retrofitting exhaust filtration technology to existing diesel vehicles in an attempt to make tighter emissions standards capable of being applied to existing vehicles. ▪ Supports federal actions to reduce importation tariffs and sales tax on hybrid petrol-electric vehicles. ▪ Reduced registration fees are offered for hybrid vehicles.
Political	▪ Champions steadily increasing fuel quality standards and vehicle emissions regulations at the Federal level. ▪ Government fleet uptake of hybrid vehicles continues to show leadership. ▪ Monitoring of inter-state and overseas ATFT developments. ▪ Fostering of State and National long term planning horizons (between 10-30 years) regarding ATFT due to long lead times on infrastructure and technology development and fleet changeovers.
Social	▪ Promotion of hybrid vehicles in the broader market is based on the results of hybrid use in Government fleets.

Table 8.2: Some Policy Options within Status Quo Scenario's Policy Environment to 2014

8.2 Scenario 2: Time for Action

8.2.1 Policy Environment Description

Little development in the viability of ATFT has occurred in the past decade. The PTFG available in Australia, and Victoria's road transport fleet, have remained very similar for the past decade. The key difference is in the mix of PTFG in the market. There is motivation within the community, within government and within the automotive industry to significantly reduce GHG and air pollutant emissions from road transport. Most people are keen to do their bit to help, and want to be recognised for this. Hybrid petrol-electric PMVs and to a lesser extent, LPG vehicles, became the rising stars in vehicle sales over the past decade. Around the world and throughout Australia, fleet operations are recognised for spearheading adoption of these vehicles, along with selected vehicle retailers committed to development of the supporting maintenance infrastructure and skill base. Continued development in the past decade has seen significant improvements in efficiency without compromising power output. Reductions in purchase price relative to conventional technology, mainly due to the increased scale of international production, have also occurred. Local manufacturers have the improved hybrid vehicles nearing market entry.

It is recognised however, that switching to hybrids alone is not enough. Significant efforts by Government at all levels, in close relationship with industry who are responding in a concerted manner to the shift in public demand, has resulted in the rapid evolution of LPG technology and cleaner diesel vehicles. Locally manufactured, dedicated LPG vehicles have found growing demand outside their previous niches. Imported diesel hybrid PMVs from Europe, having benefited from developments in tailpipe filtering, offer the lowest GHG emissions available, with emissions of key air pollutants in line with those from advanced petrol vehicles. Air pollutant emissions higher than petrol hybrids are cautiously regarded as an acceptable trade-off for the reduction in GHG emissions. Uptake of CNG and LPG by bus and LCV fleets operating from fixed locations has also seen enhanced development of these technologies, their maintenance networks and fuel supply infrastructure. Biofuels receive increased attention and support, but remain a relatively small component of the overall road transport fuel mix. In addition to the ATFT development, the advances in diesel tailpipe filtering technologies coupled with reduced sulfur level in diesel fuel has allowed for relatively cheap modifications to the existing diesel vehicles in all classes. Performance of tailpipe filtering is carefully monitored to ensure that its purported benefits (minimising negative health impacts) are in fact realised.

Demand	Supply	Environment
▪ There is the motivation within the community to significantly reduce GHG and air pollutant emissions. ▪ Most people (both individuals and fleet managers) are keen to do their bit to help.	▪ Hybrid petrol-electric vehicles are becoming more affordable, mainly due to the increased scale of international production. ▪ Local manufacturers also have hybrid vehicles nearing market entry.	▪ Growth in net GHG and air pollutant emissions has been minimised in Victoria ▪ Pollution monitoring programs indicating that air quality has stabilised or slightly improved.
Policy		
▪ There have been significant efforts by Government at all levels, in close relationship with industry, to further shift public demand toward low emission technologies.		

Table 8.3: Time for Action Scenario Summary Description

Overall, while the net road transport task has steadily increased with population, growth in net GHG and air pollutant emissions has been minimised in Victoria, with pollution monitoring programs indicating that air quality has stabilised or slightly improved.

8.2.2 Comparative Assessment

As shown in Table 8.4, a ‘Time for Action’ scenario brings a number of changes likely to impact on the triple-bottom-line viability of a number of technologies.

TBL		**steEp**		
'Bottom Line'	**Orienting Question**	**Dimension**	**Capability**	**Differences vs Status Quo**
Economic	*Is it possible?*	Technical	Viability	
		Economic	Feasibility	
Environment	*Does it help?*	Environmental	Sustainability	Relative differences in environmental impact become more critical, environmental concern drives development of air pollution reduction technology.
Social	*Is it wanted?*	Political	Compatibility	Fuel and emission standards become increasingly strict.
		Social	Acceptability	Vehicles with high emissions are no longer considered socially acceptable.

Table 8.4: Time for Action Scenario TBL/steEp Key Driver Changes

Increased concern for the environment is likely to mean, in particular, that vehicles with high GHG emissions are no longer considered socially acceptable. This would reduce the attractiveness of Advanced Diesel and Advanced Petrol technologies, removing them from the preferred PTFG mix. Hybrid diesel PMVs, despite advances in tailpipe filtering and exhaust catalyst technology, exhibit air pollutant emissions similar to advanced petrol. The compensation of lower relative GHG emissions however, allows these to be retained in the fleet mix, with health authorities and environmental monitors carefully watching the affect of increased uptake.

8.2.3 Summary Scenario Outlook

8.2.3.1 PTFG Mix

The likely PTFG mix for the ‘Time for Action’ scenario is:

- Hybrid technology becomes the focus for PMV;
  - Existing technology can be developed further;
- LPG may provide a transition path to hydrogen ATFT (via hybrid LPG technology);
  - Existing fuel infrastructure; and,
  - Conversion of petrol-driven vehicles is relatively affordable.
- A range of preferable options exist for heavy vehicles
  - Advanced diesel/hybrid diesel (with adequate tailpipe filtering)
  - CNG/hybrid CNG

- LPG/hybrid LPG

8.2.4 Policy Options

steEp Dimension	'Time for Action' Policy Options
Technical	▪ Research and development funding is also offered to local manufacturers and specialist businesses for the rapid evolution of conventional technologies to aid reductions in GHG and air pollutant emissions. The main emphasis is on diesel (heavy vehicle) and LPG related PTFG.
Economic	▪ The Government fleet adopts a program of rigorously trialling promising new ATFT, and highly publicises the study results. Fleet purchase policy is shaped in accordance with viability assessments resulting from these studies and potential for promoting broader market uptake. Along with hybrid petrol-electric, hybrid diesel-electric and dedicated LPG vehicles in all classes are purchased. ▪ The significant gains possible through the promotion of significant changes to the market PTFG mix is championed to Federal Government. ▪ Funding is provided to fleet operators to either retrofit particulate matter filtering equipment to their existing diesel vehicles or convert their petrol vehicles to LPG (for LCV in particular) and diesel vehicles to CNG (for heavy vehicles in particular). CNG infrastructure development is also heavily financially supported for fleets with a central depot and that operate within a limited distance of the depot. This could involve larger LCV as well as heavy vehicles. ▪ Additional financial incentives are provided to local manufacturers to increase their production and marketing of LPG and hybrid vehicles.
Environmental	▪ Use of hybrid petrol-electric vehicles and LPG vehicles in the Government fleet, and through consultation with other fleet operators, is promoted to the broader market as taking action on minimising GHG emissions from road transport vehicles. ▪ Supports Federal actions to reduce importation tariffs and sales tax on all ATFT and cleaner vehicles in general. ▪ Reduced registration fees are offered for cleaner vehicles, on a scale reflecting their lower environmental impacts.
Political	▪ Champions aggressive tightening of fuel quality standards and vehicle emissions regulations at the Federal level. ▪ Government fleet uptake of a diversified mix of PTFG continues and is extended to ATFT trials, showing continued leadership. ▪ Monitoring of inter-state and overseas ATFT developments. ▪ Fostering State and National long term planning horizons (between 10-30 years) regarding ATFT due to long lead times on infrastructure and technology development and fleet changeovers.
Social	▪ Awareness campaigns, coupled with reduced registration fees, fuel and purchase taxes aggressively promote the uptake of cleaner PTFG in the broader market.

Table 8.5: Some Policy Options within 'Time for Action' Scenario's Policy Environment to 2014

8.3 Scenario 3: Dry Well

8.3.1 Policy Environment Description

Economic concern over the increasingly volatile price of crude oil based fuels has begrudgingly driven attention towards LPG and CNG. Fleet operations have slowly become more interested in taking up the Federal Government's conversion grants and indicating a desire to use more CNG. Industry lagged in its response, but increasingly drew on the CNG infrastructure program and established CNG refuelling stations around depot-based LCV and bus fleets. Biofuels become more financially attractive as well, and a rapid increase in their production is achieved, although it contributes little to the overall national road transport fuel supply.

PMV conversions to LPG have also increased, stimulating the aftermarket LPG industry to develop or acquire improved technologies. Supply of ex-factory LPG variants of pre-existing models by local manufacturers is meeting with growing market support. Petrol hybrid vehicles are becoming increasingly available for broader market uptake. Diesel hybrids are also meeting with acceptance, although this is at the cost of increased PM and NOx emissions relative to their petrol equivalent. As this option gains more attention for its greater fuel economy, many people question the wisdom of a large-scale PMV fleet shift to technology that would potentially lead to a deterioration in air quality. While the net road transport task is reduced somewhat, and the uptake of LPG and CNG vehicles has increased, the growth in net road transport GHG and air pollutant emissions is only marginally affected.

Demand	Supply	Environment
▪ Economic concern over the increasingly volatile price of crude-oil based fuels has driven attention towards LPG and CNG.	▪ LPG technologies have been improved and industry has eventually started to establish CNG refuelling stations around depot-based truck and bus fleets.	▪ The growth in net road transport GHG and air pollutant emissions is only marginally affected.
Policy		
▪ Economic imperatives have forced the Government to assist those looking to switch to alternative technologies, and to support the development of alternative fuel infrastructure.		

Table 8.6: Dry Well Scenario Summary Description

8.3.2 Comparative Assessment

Table 8.7 highlights the key changes in the steEp drivers, and thus TBL guiding assessment questions for the ‘Dry Well’ scenario.

TBL		steEp		
'Bottom Line'	**Orienting Question**	**Dimension**	**Capability**	**Differences vs Status Quo**
Economic	*Is it possible?*	Technical	Viability	A number of technical barriers are lowered due to increased investment.
		Economic	Feasibility	Conventional vehicles using petroleum-based fuels are considered unaffordable by many operators.
Environment	*Does it help?*	Environmental	Sustainability	
Social	*Is it wanted?*	Political	Compatibility	Governments move to reduce their exposure to unpredictable oil prices.
		Social	Acceptability	

Table 8.7: Dry Well Scenario TBL/steEp Key Driver Changes

Under the ‘Dry Well’ scenario, the economic feasibility of petroleum-based fuels is severely compromised, making all conventional petrol and diesel PTFG unattractive. Hybrid vehicles continue to build a following, however with oil price volatility only set to increase, popularity is likely to be short-lived.

8.3.3 Summary Scenario Outlook

8.3.3.1 PTFG Mix

The likely PTFG mix for the ‘Dry Well’ scenario is:

- LPG technology becomes the focus;
  - Conversion of existing vehicles initially;
  - Eventually move to hybrid LPG (based on existing hybrid petrol technology);
- CNG may become popular for larger vehicle classes;
  - CNG tank size is less of a constraint vs passenger vehicles; and,
  - Eventually move to hybrid CNG technology.

8.3.4 Policy Options

Many of the policy options for the ‘Dry Well’ scenario are essentially the same as for ‘Status Quo’, as market demand slowly drives industry change. Options for accommodating the increasing economic pressures associated with high and more volatile crude oil based fuel costs are addressed in the ‘Paradigm Shift’ scenario.

8.4 Scenario 4: Paradigm Shift

8.4.1 Policy Environment Description

Public concern for the environmental impacts of road transport dramatically increased in lock step with more volatile oil price and resulting petrol and diesel fuel costs over the past decade. Internationally, efforts towards the fast track development of hydrogen PTFG technologies continue apace, yet there is the recognition that transition PTFG such as those using LPG and CNG can help to streamline this process. Australia adopts a broad policy vision promoted by Western Australia to also transition to a hydrogen based transport sector in the coming decades. Both the public and Government are inspired by the urgency of the transition and the potential of near-zero-emission vehicles. This translates into increased efforts by industry, both worldwide and locally, financially supported by Governments at all levels, to evolve ATFT.

The transition road map places significant emphasis on the use of LPG technologies, providing additional fuel security through exploitation of Australia's NG reserves and simultaneous expansions of LPG production capacity. Technologically advanced, dedicated LPG vehicles are rapidly introduced, first through widespread fleet uptakes by both Government and LCV operators. Local manufacture of ex-factory LPG variants of pre-existing models has also increased with the ex-factory hybrid LPG vehicles nearing market entry following on from many petrol-hybrid conversions to LPG. Conversion to CNG for heavy vehicles has become significantly attractive and the development of a limited but wide spread refuelling and maintenance infrastructure is also currently underway. The improved propulsion technologies for CNG and LPG, along with LPG and CNG fuel supply security and lower price, see significant numbers of PMV and LCV conversions to LPG and heavy vehicles to CNG.

Hybrid vehicles are also included in the waves of rapid ATFT uptake, and greatly assist in the development of hybrid maintenance skills that facilitate the LPG wave of ATFT uptake. The remaining diesel fleets increasingly shift to purchasing biodiesel where it is available and cheaper than petroleum diesel due to the crude oil based diesel fuel price volatility. Biofuels in general continue to be an important but small component of the overall road transport fuel mix.

A significant reduction in the total road transport contribution to net GHG and air pollutant emissions has been achieved, with increasing reductions projected as market penetration of ATFT vehicles continues and older, conventional petrol and diesel vehicles are rapidly phased out of service in the next decade.

Demand	Supply	Environment
▪ The public is inspired by the urgency of the transition to (and the potential of) near zero emission vehicles.	▪ This translates into increased efforts by industry (both globally and locally) to evolve to ATFT.	▪ A significant reduction in the total road transport contribution to net GHG and air pollutant emissions has been achieved. ▪ Further emission reductions are projected.
Policy		
▪ Australia adopts a broad policy vision to support and promote the adoption of ATFT, with an eventual transition to a hydrogen based transport sector in the coming decade.		

Table 8.8: Paradigm Shift Scenario Summary Description

8.4.2 Comparative Assessment

The following Table 8.9 highlights the key changes in the steEp drivers, and thus TBL guiding assessment questions for the 'Paradigm Shift' scenario.

TBL		steEp		
'Bottom Line'	**Orienting Question**	**Dimension**	**Capability**	**Differences vs Status Quo**
Economic	*Is it possible?*	Technical	Viability	A number of technical barriers are lowered due to increased investment.
		Economic	Feasibility	Petroleum-based fuels increasingly considered unaffordable by vehicle operators.
Environment	*Does it help?*	Environmental	Sustainability	Relative differences in environmental impact become more critical.
Social	*Is it wanted?*	Political	Compatibility	Governments reduce exposure to oil prices. Fuel emission standards become stricter.
		Social	Acceptability	Vehicles with high emissions are no longer considered socially acceptable.

Table 8.9: Paradigm Shift Scenario TBL/steEp Key Driver Changes

As with the 'Dry Well' scenario, under the 'Paradigm Shift' scenario the economic feasibility of petroleum-based fuels is severely compromised, making all petrol and diesel PTFG unattractive.

8.4.3 Summary Scenario Outlook

8.4.3.1 PTFG Mix

The likely PTFG mix for the 'Paradigm Shift' scenario is:

- LPG / CNG technology becomes the focus;
  - LPG for passenger vehicles, CNG for larger vehicles;
  - Eventually move to hybrid technology;
- Transition paths to hydrogen may need to be considered;
  - Possible path via hybrid LPG / CNG technology.

8.4.4 Policy Options

steEp Dimension	'Paradigm Shift' Policy Options
Technical	▪ Significant research and development funding is offered to related automotive industry companies to participate and/or take advantage of the rapid evolution of hydrogen technologies internationally. ▪ Comprehensive studies are conducted into the requirements for hydrogen fuel infrastructure. ▪ Local manufacturers are offered financial incentives for the introduction of advanced LPG technologies including dedicated hybrid LPG vehicles.
Economic	▪ Government fleets adopt an aggressive LPG purchase and conversion schedule, including pre-orders to stimulate the local manufacturing industry. ▪ Substantial funding is provided to support the development of LPG and CNG fuel production infrastructure. ▪ CNG refuelling infrastructure development and vehicle conversion is financially supported for fleet operations and heavy vehicles. ▪ Increased biofuels production is financially supported with managed consultations with freight industry operators to commit to purchasing the fuels.
Environmental	▪ Use of LPG and CNG vehicles in the Government fleet, and through consultation with other fleet operators, is promoted to the broader market as taking action on minimising GHG and air pollutant emissions from road transport. ▪ Encourages Federal actions to reduce importation tariffs and sales tax on all LPG and CNG ATFT. ▪ Reduced registration fees are offered for cleaner vehicles, on a scale reflecting their lower environmental impacts.
Political	▪ Champions aggressive increases in fuel quality standards and vehicle emissions regulations at the Federal level, to reflect the gains possible in LPG vehicles. ▪ Government fleet uptake of LPG and CNG vehicles continues to show leadership. ▪ Importation and local manufacturing are Federally legislated to contain increasing fixed percentages of LPG or cleaner vehicles in. General. ▪ Monitoring inter-state and overseas ATFT developments. ▪ Fostering State and National long term planning horizons (between 10-30 years) regarding ATFT due to long lead times on infrastructure and technology development and fleet changeovers.
Social	▪ Awareness campaigns, coupled with reduced registration fees, fuel and purchase taxes aggressively promote the uptake of cleaner PTFG in the broader market.

Table 8.10: Some Policy Options within Paradigm Shift Scenario's Policy Environment to 2014

9 Conclusion

9.1 Summary of Findings

After considering a wide range of social, technical, economic, environmental and political factors, three propulsion technology and fuel groupings (PTFG) appear to be preferable to the conventional petrol engine over the next ten years:

- Hybrid petrol;
- Advanced LPG; and,
- Hybrid LPG.

Advanced diesel and hybrid diesel offer significant reductions in GHG emissions for the passenger motor vehicle (PMV) class. This comes at the cost however, of PM emissions significantly higher than the incumbent petrol technology, and NOx emissions higher than their advanced and hybrid petrol equivalents. Emission performance for diesel vehicles may be improved by developments in tailpipe PM filtering and NOx catalyst systems. Provided such measures could be guaranteed to remain effective over vehicle life spans, diesel could play an important role in reducing GHG emissions from the PMV fleet. It would seem inappropriate for this to occur, however, at the cost of increased air pollutants and associated health risks. For heavy vehicles already using petroleum diesel, advanced engine technology and hybrid systems offer an attractive pathway to reduced GHG emissions. In addition, CNG and Hybrid CNG are preferable in heavy vehicles such as buses and trucks, where the comparatively large fuel tank size is less of an issue than for PMVs.

Biofuels will continue to be an important but small component of the overall road transport fuel mix. Biofuels are particularly attractive when derived from waste products of other processes, although the availability of such fuel is expected to remain very limited.

In the absence of any significant incentives or encouragement, uptake of these new technologies is expected to be minimal. Perhaps the only exception is the uptake of hybrid petrol vehicles by concerned individuals and organisations keen to portray a ‘sustainable’ image.

In order to encourage wider uptake of preferred ATFT, the Victorian Government might consider a range of measures such as:

- Modifying Government fleet policies to drive significant adoption of hybrid petrol-electric and LPG vehicles;
- Aligning registration fees with vehicle type (providing incentives for using lower emission vehicles); and,
- Lobbying the Australian Government to:
  - Continue tightening fuel quality / vehicle emission standards;
  - Align fuel taxation with emission levels; and,
  - Reduce importation tariffs and sales tax on hybrid petrol-electric vehicles.

9.2 Risk Management

In order to consider a range of other plausible futures, three additional scenarios were also developed. Table 9.1 describes each scenario, highlights the preferred PTFG, and provides examples of what role the Victorian Government might play to encourage their uptake.

Scenario Name	Time for Action	Dry Well	Paradigm Shift
Description	Society rallies together to address a number of increasingly serious environmental issues (accelerated global warming, extreme weather events, air pollution)	Global oil prices become significantly more volatile, causing widespread uncertainty around the future viability of fuels derived from crude oil	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')
Preferred PTFG – Passenger Motor Vehicles	• Hybrid Petrol • Advanced LPG • Hybrid LPG • Hybrid Diesel (if improved emissions reduction systems are effective) • Advanced Diesel (if improved emissions reduction systems are effective)	• Advanced LPG • Hybrid LPG	• Advanced LPG • Hybrid LPG
Preferred PTFG – Heavy Vehicles	• Hybrid Diesel (including improved emission reduction systems) • Advanced Diesel (including improved emissions reduction systems) • CNG / Hybrid CNG • LPG / Hybrid LPG	• CNG / Hybrid CNG • LPG / Hybrid LPG	• CNG / Hybrid CNG • LPG / Hybrid LPG
Role of Victorian Government (possible additional measures to be undertaken)	• Provide consumer rebates for LPG conversion (subject to emissions testing following conversion) • Provide industry incentives for local hybrid production	• Provide consumer rebates for LPG conversion (subject to emissions testing following conversion) • Invest in LPG / CNG infrastructure	• Provide consumer rebates for LPG conversion (subject to emissions testing following conversion) • Invest in LPG / CNG infrastructure • Monitor overseas developments to determine best hydrogen model

Table 9.1: Summary Scenario Descriptions

9.3 The National and Global Contexts

It is clear that Victoria cannot act alone to drive major technological advancement, or stimulate fledgling global industries such as the 'hydrogen economy.' It can however, work with the Federal Government and other State Governments to stimulate the local production of alternative fuels and vehicles, and the development of alternative fuel infrastructure. Opportunities do exist for some research and development within the field, but perhaps the most prudent strategy for a country of Australia's size is to continue to monitor overseas developments and adopt a fast-follower approach. Victoria needs to position itself in such a way that it can take advantage of new developments as soon as alternative fuels and technologies are proven to be viable in other countries or regions. In the meantime, Victoria must continue to lobby the Federal Government for ongoing improvements in vehicle emission and fuel standards.

While it may not be possible for Victoria, or even Australia, to become a 'technology pioneer' in this field, it can become a 'policy pioneer.' Apart from promoting wide scale, mainstream adoption of fuels and technologies proven elsewhere in smaller pilots, Victoria has the opportunity to lead the way on demand management though intelligent urban planning, encouraging reductions in vehicle sizes, and promoting practises such as car pooling and tele-commuting. Modal migration initiatives should also become a priority – both through investment in new mass public transit infrastructure, and through migration to existing under-utilised public transport systems and other modes such as walking and cycling. Apart from the fact that these initiatives have the potential to provide significant reductions in greenhouse gas emissions, many require little or no capital investment, and virtually no financial risk.

9.4 Time Horizons

While it is understood that boundaries need to be placed on a study of this nature to enable pragmatic policy options to be developed, the nature of this particular issue means that a timeframe beyond ten years is preferable. For example, some of the technical reference data considered a 15-20 year timeframe, in recognition of the significant lead times required to establish vehicle production capacity and fuel infrastructure, and for replacement of the existing road transport fleet.

From the perspective of fuel availability, a 20 to 30 year timeframe might be more appropriate considering that a growing consensus suggests global peak oil production will occur during this time. Should this be the case, the viability of petroleum-based fuels will quickly reach conditions similar to those described in the 'Dry Well' scenario.

Finally, from an environmental perspective, an appropriate timeframe might be more like 50 years since – if left unchecked – global warming is expected to become significant over this period.

9.5 Other Boundary Issues

Since the scope of the study also restricted greenhouse gas reduction measures to a 'substitution' of technologies for an unchanged road transport task, opportunities for emission reductions were limited significantly. To illustrate this issue, a basic model was developed using the following assumptions:

- New Vehicle Purchases: 5.7% of total stock per year (FCAI Data);
- Net Growth in Passenger Vehicles: 2.3% of total stock per year (ABS Data);
- Emissions of new 'conventional' vehicles: 90% of current average (plus efficiency improvements of 1.5% per year); and,
- Emissions of 'alternative' vehicles: 70% of current average (plus efficiency improvements of 2.5% per year).

A number of scenarios were then developed (which do not correspond in any way with the scenarios discussed in the findings of this report) assuming the following uptake of alternative vehicles, as a percentage of all new vehicles:

- Base Case: 0% (for all years);
- Scenario 1: 5% (2005); 10% (2006); 15% (2007);…100% (2024);
- Scenario 2: 10% (2005); 20% (2006); 30% (2007);…100% (from 2014); and,
- Scenario 3: 100% (for all years).

Overall road transport emissions (as a % of current emissions) are shown for each scenario in Figure 9.1. While the absolute values may be considered broadly indicative (provided the stated assumptions are seen to be appropriate), they are not presented as predictions. The value of this model is that it enables the relative differences between emissions levels for each scenario to be considered. The fact that these differences are small indicates the relatively low sensitivity of the system to even quite dramatic changes in ATFT uptake. Under the stated assumptions, even in the extremely unlikely event that only preferred ATFT are purchased from now on (Scenario 3), overall emissions still remain in line with current levels over the next 20 years.

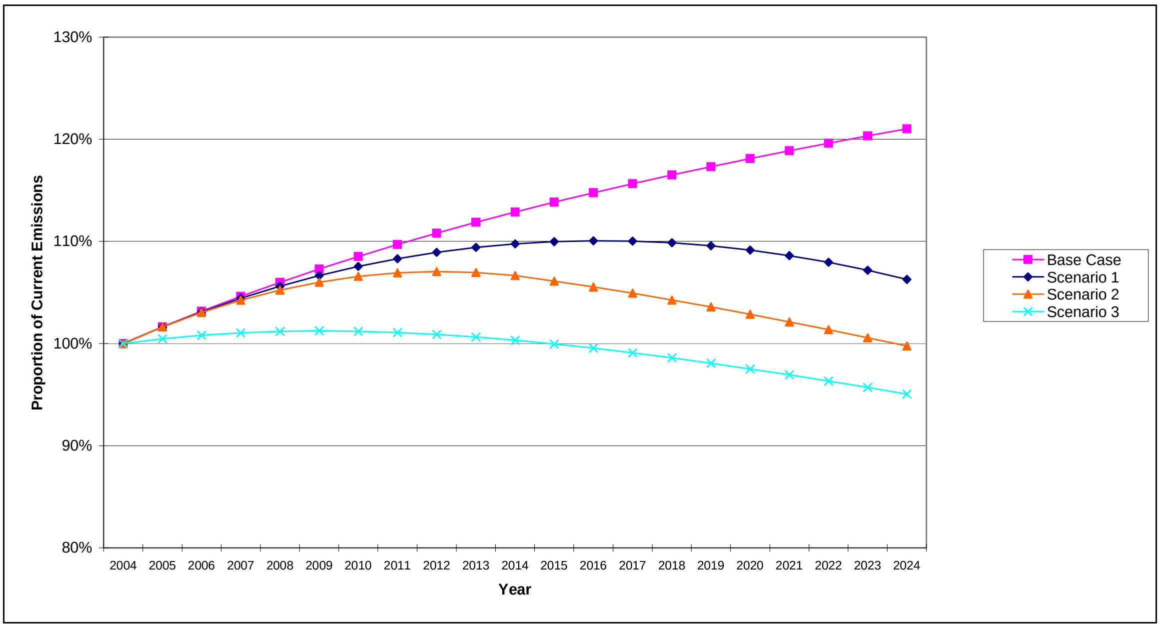

Figure 9.1: Possible Road Transport Emissions Scenarios

9.6 Conclusion

In summary, the promotion of alternative transport fuels and technologies (ATFT) in Victoria should be seen as necessary, but not sufficient, for reducing greenhouse gas emissions. Only in conjunction with a range of other measures – including demand management (for transportation and stationary energy) and migration to alternative forms of transport (including public transport, walking and cycling) – will the promotion of ATFT provide meaningful emission reductions. Acting alone, Victoria is not capable of achieving emission reductions of significance on a global scale. Since Victoria is a progressive state in one of the world's most advanced nations however, the Victorian Government has an essential leadership role to play on this vital issue. This leadership will not only promote greater awareness of environmental issues with consumers and local businesses, but also send an important message to local industry, other State Governments, the Federal Government, and other governments around the world.

9.7 Further Research

Numerous opportunities exist for further policy development studies that could significantly enhance Victoria's development of high quality ATFT policies for the next ten years. Directions for further work arising out of this study include:

- Detailed modelling of the road transport fleet PTFG mix to determine the potential impacts of ATFT uptake on:
    - Vehicle emissions (by type);
    - Demand for various fuel types (and hence fuel production requirements); and,
    - The Victorian economy.
- A more comprehensive and participative scenario development process that would engage more Government and non-government stakeholders in order to create a shared understanding about the most viable ATFT policy pathway for Victoria;
- Primary research into the triple-bottom-line feasibility of dual-fuel vehicles;
- Further research into the potential environmental risks associated with the production and distribution of each fuel type;
- Joint state and federal investigations that develop consensus on the preferred mix of policy measures aimed at reducing national road transport emissions through ATFT development and promotion;
- The creation of a watching brief or environmental scanning framework on international ATFT developments that inform local policy considerations in a timely manner; and,
- Dedicated studies into the development of new policy options that could significantly enhance the development and uptake of ATFT in Victoria in the next ten years.

10 Glossary of Terms

Advanced vehicle technology	Future propulsion technology for road transport vehicles benefiting from the incorporation of more revolutionary developments, such as infinitely variable valve timing and constant velocity transmissions.
Anhydrous ethanol	A fuel or fuel additive 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.
Biodiesel	A fuel produced by the estrification of vegetable oil, or by processing tallow. Biodiesel can be used in CI ICEs without modification.
Bus	Generally refers to heavy buses with GVM >5t.
Carbon Dioxide (CO_2)	Gas responsible for the majority of GHG emissions.
Carbon Dioxide Equivalent (CO_2-eq)	Some GHGs, while emitted in smaller amounts than CO2, have a greater greenhouse effect per unit mass. 'Carbon dioxide equivalent' is the mass of CO2 that would have a total greenhouse effect equivalent to the total greenhouse effect of all GHGs actually emitted by a particular process, taking into account the relative greenhouse effect of each gas.
Compression Ignition	Means of initiating combustion of the fuel and oxygen mixture in a diesel-cycle internal combustion engine. Increasing the pressure of the fuel-air mixture (by decreasing its volume) raises the mixture to its auto-ignition temperature.
Diesohol	A fuel comprising a blend of 84.5% petroleum diesel fuel, 15% hydrated ethanol and 0.5% emulsifier from Australian company APACE Research.
Embodied energy	The upstream processing and transport energy required to deliver a substance in a particular form and state to a particular location.
Euro (1, 2, 3 or 4)	European standards used as the basis for Australian emissions standards and incorporated into Australian Design Rules. Applicable to road transport vehicles using petrol, diesel, LPG and natural gas as their fuel source.
Evolved vehicle technology	Future propulsion technology for road transport vehicles benefiting from developments that would be considered as extrapolations of past and current trends, such as incremental improvements in SI ICE efficiency.
Exbodied emissions	The processing and transport emission produced in delivering a substance in a particular form and state to a particular location.
Fischer-Tropsch Diesel	Diesel fuel produced from natural gas via a gas-to-liquid process.
Fuel Cell	Energy conversion device that produces electric current from the electrochemical reaction of a fuel, commonly hydrogen, with oxygen from air.
Fuel Processor	A system that produces hydrogen from a secondary fuel source, commonly petrol, for reaction in a fuel cell.

Gas-to-liquid	Process for production of diesel fuel from natural gas.
Hybrid	Propulsion technology combining either an ICE or a FC with a battery system and electric motor to drive the vehicle’s wheels.
Hydrated ethanol	Hydrated ethanol is ethyl alcohol that contains around 5% water.
Light Commercial Vehicle	Goods vehicle with GVM <3.5t.
Particulate matter (PM)	Very fine solid material emitted during the fuel life cycle by combustion processes (in particular, tailpipe emissions resulting from combustion of fuel in vehicle engines). Particulate matter can aggravate respiratory and cardiovascular disease. Linked also to decrease in lung function, exacerbation of asthma and alteration of the body’s defense mechanisms and lung clearance mechanisms.
Passenger Motor Vehicle	Passenger car or passenger off-road vehicle with GVM <3.5t.
Petrohol	A blend of 10% anhydrous ethanol and 90% petrol, suitable for use in petrol SI ICEs without modification.
Spark Ignition	Combustion of the fuel and oxygen mixture in an otto-cycle internal combustion engine is initiated by means of an electrically produced spark.
Tank-to-wheels	Energy consumption and emissions associated with the use of a vehicle are generally described as ‘tank-to-wheels’.
Truck	Generally refers to medium and heavy goods vehicles with GVM >3.5t.
Well-to-tank	Energy consumption and emissions associated with fuel production, transport and delivery to the vehicle in which the fuel is used are generally described as ‘well-to-tank’. Note that this terminology is often used in relation to fuels for which the primary energy source is not extracted from a well as such (biofuels for example). While usage in these cases is not ideal, it is a widely used de-facto standard.
Well-to-wheels	Energy consumption and emissions associated with the full fuel life cycle, including fuel production and consumption, are generally described as ‘well-to-wheels’. Note that this terminology is often used in relation to fuels for which the primary energy source is not extracted from a well as such (biofuels for example). While usage in these cases is not ideal, it is a widely used de-facto standard.

Notes

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

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

[3] AGO (1998).

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

[5] Weiss, Heywood, Schafer, and Natarajan (2003), p11 and Green and Schafer (2003), p.13.

[6] Beer, Grant, Watson and Olaru (2004).

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

[8] Weiss, Heywood, Drake, Schafer and AuYeung (2000).

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

[10] General Motors Corporation, Argonne National Laboratory, BP, ExxonMobil and Shell (2001).

[11] EUCAR, CONCAWE and JRC (2004).

[12] Beer, Grant, Morgan, Lapszewicz, Anyon, Edwards, Nelson, Watson and Williams (2001).

[13] CSIRO, BTRE and ABARE (2003).