# Evolution Towards a Sustainable Transport Energy Source

**Background Paper for the Western Australian State Sustainability Strategy**

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**For**

**The Oil Vulnerability, Gas Transition, and Hydrogen Economy Workgroup**

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## *Conclusions and Recommendations*

*The world's developed nations are firmly committing to a path that will promote alternative energy sources. As oil supply becomes less certain and its use less environmentally acceptable, Europe and the USA are investing in alternative energy schemes on an unprecedented scale, introducing tough emissions standards, encouraging responsibility for pollution and greenhouse gases, and fostering sustainable industry upstream and downstream. The conditions are right for positive action in Australia to further address these same oil vulnerability and emissions issues head on, with strong public support, and a thriving national economy.*

*Western Australia is ideally placed to play a role in the nation's shift to alternative transport fuels, with abundant natural gas reserves, and solid public support for a cleaner environment. It is the responsibility of the State government to facilitate stakeholders in taking advantage of this opportunity, and address oil vulnerability and emissions issues through effective policy instruments.*

*Transport technology is rapidly progressing, and as such it is not possible to second-guess which technology combination will eventually provide the solution. Currently available information regarding transport fuel options shows little difference between the alternatives when error margins are incorporated, and is subject to rapid change as technology advances. Government must therefore facilitate the transition to lower emissions fuels and vehicle technology without picking winners, but by removing barriers to the rapid integration of new technology.*

*During research for this paper, a particular method has been exploited to identify fuel and technology combinations. Analysis has been split into the following eight areas for each Fuel/Technology combination: Energy Security, Lifecycle Greenhouse Emissions, Lifecycle Air Pollutants, Lifecycle Transport Energy Efficiency (i.e. resource efficiency), Infrastructure Considerations, ADR Compliance, Innovation Opportunities for WA, and potential for Assisting Transition to a Renewable, Clean Fuel. This method provides a model for future analysis of options, and should be subject to continuous improvement as new aspects of the issues are exposed.*

*This paper provides a brief review of issues related to alternative fuel choices, and is intended to generate debate on the subject. It should be used as a beginning point for future work, not an end in itself.*

## Recommendation 1: Transport Energy Taskforce

Creation of a Transport Energy Taskforce to further investigate, and act as facilitator, in the alternative transport industry, without attempting to second-guess the technology outcome. This taskforce should act and advise in the following areas:

- Create a State Transport Energy Strategy that will provide a vision of the future for stakeholders, and identify ways to pursue this vision, taking into account the rapid technology advancement being experienced and potential scenarios regarding oil vulnerability.
- Ensure Australian industry's full engagement, with particular focus on WA.
- Ensure all decisions and State regulatory arrangements take full account of environmental, health, and resource issues.
- Analyse and comment on technical standards for vehicles, fuels, and distribution infrastructure. Explore measures the federal government could take to ensure these standards can be hastily prepared and reviewed for future fuel options.
- Facilitate creation of new infrastructure as required.
- Encourage the State and Federal governments to devise the right fiscal regimes for vehicles and fuels to reflect their environmental benefits.
- Identify barriers to industry and consumer take-up of cleaner technology, and develop methods of removing them.
- Identify indicators and set aggressive targets for the next decade and beyond to help promote the State Transport Energy Strategy.
- Encourage consumers to take responsibility for their own energy use and emissions.

## Recommendation 2: Foster Fuel Diversity

In the short term, an effort should be made to foster the promising technology options that are currently available. Although this paper was not able to make any conclusions as to what the best fuel/technology options are, it is possible to say that Fischer-Tropsch Diesel (with carbon sequestration), Bio-Diesel, LPG, DME, and CNG are all candidates. Western Australia should ensure the fuel pool is diversified to incorporate all these options on a trial basis.

## Recommendation 3: Emissions Abatement Policy

Investigate the possibilities for emissions abatement policy in the State that ensures upstream and downstream transport sectors have unhindered access to mechanisms that will enable them to meet their emissions targets at least cost. Initial assessment could focus on developing negotiated emissions abatement agreements for “at-risk” industries combined with an emissions levy policy. This policy may be able to interface with systems being considered in the NSW emissions trading proposal for their State electricity sector, whilst allowing for future integration with national, and international emissions trading systems and flexibility mechanisms. Other related issues for consideration are the role of Western Australia in future climate change negotiation considering its economic structure, industry structure, and its environmental and social commitments.

Although this issue has only been touched on in this paper, it is apparent that it may be a shaping factor in the State’s upstream fuel industry in the near future. Stakeholder discussions held in assembling information for this paper have exposed a wide range of views on this topic, with most opinions being that more investigation is required.

## Recommendation 4: Research and Development

Promote R&D into alternative fuels, vehicles, and related issues. Further research is required into the full lifecycle of fuel alternatives in the Australian context, through creation of a model that is essentially “configurable” to account for rapid technology changes. Particular R&D emphasis should be include a fuel-technology combination that is amenable to the future introduction of fuel cells, which could be the transport technology of the future.

Full industry involvement in R&D activities is essential to ensure relevance of research, and that intellectual property generated is Australian-owned. Innovative activities in WA could be generated as a result of this involvement.

## Recommendation 5: The Government Fleet

Lead by example. The government fleet should make the fullest use of new vehicle and fuel technology, and encourage other public authorities to do so. The public transport fleet, and public service vehicles are clear winners for continuing trials and implementation of new technology.

## *Acknowledgements*

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## *Introduction*

The transport sector consumes a major share of the energy used in Australia, and is responsible for a substantial portion of greenhouse gas emissions and air pollutants. It is also a critical part of the national economy, underpinning a myriad of other industries, and reflecting directly upon the cost of everyday life in Australia. Almost all of the energy consumption in the transport sector is sourced from oil.

In recent years it has become apparent that Australia faces serious issues relating to oil vulnerability (Robinson, 2002). With oil supplies dwindling nationally, Australia will become increasingly reliant on oil imports to meet its energy needs, leading to a trade deficit on liquid hydrocarbons of $7.6 billion by 2009/10. Additionally, the economy will become increasingly vulnerable to oil price shocks and political instability in oil-producing regions. This vulnerability is particularly relevant in light of the fact that OPEC countries control 77% of the world's remaining oil reserves. Australia must diversify its transport energy sources in order to reduce its reliance on imported oil.

Environmental issues also represent a key factor when considering the sustainability of the country's transport energy use. At the time of publication, the transport sector accounted for 16% of all greenhouse gas emissions in Australia, and as this sector is expanding rapidly, this figure is likely to increase. Since 1990, GHG emissions in the transport sector in Australia have increased by 20%. The Kyoto protocol stipulates that Australia should aim for an 8% increase of GHG emissions on 1990 levels, to be achieved in the period 2008-2012. Clearly, reductions in emissions from the transport sector could contribute to meeting this target. Furthermore, the transport sector is largely responsible for urban air pollution such as benzene and aromatics, hydrocarbon precursors of smog and haze, and fine particles often associated with increasingly pertinent human health concerns. Targeted policies to encourage solutions to these oil vulnerability issues could therefore also improve air quality in Australian urban centres.

These problems need to be addressed through a comprehensive Transport Energy Strategy, that encompasses energy security, economic concerns, environmental impact, and the interests of key stakeholders. The eventual target of such a strategy should be the transition to a renewable, near-zero emission fuel. Currently, it appears that the most likely scenario for this transition is the use of hydrogen in fuel cell vehicles (Garrity, 2002).

This paper identifies a number of potential alternative fuel options and attempts to assess their suitability for use in Western Australia on the basis of energy use in the fuel lifecycle, emissions and pollutants in the fuel lifecycle, compatibility with existing infrastructure, ADR compliance, and potential for innovation in WA. Means by which the alternative fuels can assist in a transition to a renewable, near-zero emissions fuel will also be considered. This part of the study is essentially a literature review and desk analysis of existing research of transport fuel, primarily those of Beer et al. (2002) and Wang and Huang (1999).

Existing strategies that encourage movement towards sustainability in this sector are examined, and suggestions regarding the way forward are made. Finally, a number of recommendations are made based on the results of the analysis.

# *Transition Fuels - Analysis and Description*

## Key Sustainability Issues for Transition Fuels

### Oil Vulnerability

It is now generally recognised that oil reserves are about to reach the critical rollover point where half of the world's reserves have been consumed. This rollover is likely to occur within the next two decades, and possibly as early as 2003 as predicted by Campbell in1998 (Australian Energy News, December 2001). When specifically considering Australia's situation, Akehurst (2002) projects that the country faces a liquid hydrocarbon trade deficit of $7.6 billion by 2009/10, from a surplus of 1.2 billion in 2000/01. The government also faces a major taxation revenue loss as the trade balance shifts to imported oil.

Recent political instability in the Middle East reinforces the concept that it may not be wise to rely upon this region to supply such an important resource in the long term. The fundamental energy policy issue of security of supply is in danger of being compromised if Australia's energy needs are placed solely in the hands of OPEC suppliers.

Additionally, the Australian economy is subject to oil price shocks in the short term, which can have a serious detrimental effect on a number of industries.

### Environmental and Health Concerns

The reality of global warming is of increasing concern when considering the sustainability of human activities. The United Nations Framework Convention on Climate Change has identified six greenhouse gases that aid global warming in the Kyoto Protocol, and has identified and implemented a number of measures to reduce emissions of these gases.

In addition to greenhouse gas issues that have impact on a global scale, there are also serious air pollutant issues that are most relevant in the urban setting. Recently a number of studies have outlined the damage to human health caused by air pollution and the subsequent rise in the cost of public health care. Minute particles known as PM10s and PM2.5s, chemicals like benzene and its derivatives called aromatics, and other air pollutants can contribute towards cancer and respiratory diseases. Smog and haze are also important urban air quality issues caused primarily by emissions from the transport sector. Environment Australia estimates the health costs associated with air pollution are approximately $17.2 billion per year (http://www.ea.gov.au/soe/2001/fact-sheets/air.html).

There are also some potential costs associated with global warming, such as damages resulting from extreme weather events, potential loss of land to rising sea levels in low-lying areas, changes in rainfall patterns, crop growth potential, land degradation, pest and disease spread, forest growth potential, changes within ecosystems and in the boundaries of vegetation zones, species extinction, threats to hydrology and water resources, air quality, human health, human settlement, biomass (a principle source of energy in developing countries), transport and industry, coastal zones, low-lying islands and regions, barrier islands and reefs, estuaries and wetlands, seasonal snow cover, ice sheets and glaciers (IPCC, 1990).

**Transition Fuels Towards Sustainability**

The ideal fuel of the future would be completely renewable and create near-zero emissions in its lifecycle. At the moment, it appears that most likely fuel to meet this requirement is hydrogen, which can be burnt or otherwise converted into energy, with the only by-product being pure water. Unfortunately, the transition to hydrogen or another alternative will take time as R&D activities progress, and mechanisms through which infrastructure can be introduced are devised. Pathways towards the introduction of hydrogen are discussed further by Garrity (2002).

In the meantime, transition fuels must be identified to address oil vulnerability/price instability issues. These transition fuels should address environmental and health/air pollution concerns, should assist transition to hydrogen or other alternative fuel, and should not place unreasonable economic expectations on any stakeholders.

It should be noted that the transition fuel chosen is not likely to be sustainable in itself, but ideally will pave the way for a sustainable fuel future.

# *Literature Review: Fuel and Technology Analysis*

## Preliminary Fuel Identification

Fuel identification for this study was based on a number of assumptions. Only fuels that meet the key sustainability issues as identified above are considered, although conventional petrol and diesel are included to provide a comparison with alternative fuels in some instances. Factors that were considered in potential fuel identification were that the fuel must:

- Not be sourced solely from crude oil,
- Improve on existing fuels in terms of full life-cycle greenhouse gas emissions,
- Improve on existing fuels in terms of human health concerns, and air quality issues,
- Have favourable transport energy efficiency (full lifecycle),
- Use existing infrastructure, or it must be shown that overall benefit will be achieved from provision of infrastructure to support the fuel,
- Provide opportunities for sustainable industry in Western Australia, and
- Support the gradual introduction of a renewable, near-zero emission fuel.

Based on these requirements, LPG, Fischer-Tropsch Diesel (GTL Diesel), Bio-Diesel, CNG, ,LNG, and Dimethyl Ether (DME) have been identified as potential alternative fuels as set out in Table 1.

| Fuel/Factor | Not Oil Sourced | Abate Greenhouse Gases | Health & Air Quality | Transport Energy Efficiency[1] | Existing Infrastructure | Opportunities for WA | Leads to hydrogen economy |
|---|---|---|---|---|---|---|---|
| **LPG** | + | + | + | ++ | + | + | ? |
| **GTL Diesel** | ++ | +[2] | ++ | - | + | ++ | + |
| **Bio-Diesel** | ++ | ++ | ? | ? | + | ++ | ? |
| **CNG** | ++ | + | ++ | + | - | + | ++ |
| **LNG** | ++ | + | + | + | - | + | ++ |
| **DME** | ++ | + | ++ | + | - | + | ? |

Table 1: Alternative Transport fuels when compared with conventional gasoline/diesel[3]

[1] Transport Energy Efficiency is a qualitative indication of the energy consumed in full life-cycle of a fuel
[2] Carbon sequestration of $CO_2$ produced in the Fischer-Tropsch process is required for GTL Diesel to meet the requirement of abating greenhouse gases
[3] ++ clearly meets requirement, + meets requirement, ? unknown, - may not meet requirement

It is important that other potential fuels are not eliminated from the race, and as such it is noted that this part of the paper is a limited literature review of existing research on alternative fuels. Beer et al (2002) and Wang and Huang (1999) should be referenced for more comprehensive information, and further unbiased fuel studies should be completed. However, the analysis here will build on Table 1 to provide some of the comparative data used in the assessment.

## Alternative Fuel Background Information

### LPG Background

Liquid Petroleum Gas is already used extensively in Australia. Nationally, approximately 3 billion litres of "autogas" are consumed per annum, making LPG an important energy provider for transport. The Australian Liquid Petroleum Gas Association (ALPGA, http://www.alpga.asn.au/) has launched the Australian Autogas Challenge (http://www.autogaschallenge.com.au/), which aims to have the LPG industry providing at least 10% of the country's automotive fuel by 2005.

LPG is produced as a by-product of both the oil refining and natural gas extraction industries. According to the ALPGA, the majority of Australian LPG is sourced from naturally occurring deposits in oil and gas reserves.

Extensive consumer information regarding the benefits of switching to LPG as a fuel are presented by Kleenheat (http://www.kleenheat.com.au/auto/index.htm). It can be shown that in many circumstances, assuming the retention of zero fuel excise for LPG and the current $500 rebate for conversions of family vehicles, consumers are economically better off switching to LPG.

### Fischer-Tropsch Diesel Background

Gas-to-Liquids Diesel (GTL) is also known as Fischer-Tropsch Diesel, referring to the process by which it is manufactured. The feedstock to the process is natural gas, which is transformed to syngas (hydrogen and carbon monoxide) by a reforming process. The Fischer-Tropsch process then converts the syngas to middle distillates and naphtha, and finally the products can be upgraded to produce very high quality diesel fuel (Wang and Huang, 1999). As the process is highly exothermic, steam produced may be exported to nearby chemical plants, or used to produce electricity. Carbon dioxide is a by-product of the process, which implies there is potential for carbon sequestration of this gas as it can be captured and stored near the GTL plant.

There are currently no GTL plants in Australia, but Sasol Chevron, GTL Resources, Syntroleum, and Shell are employing FT processes elsewhere, and have expressed interest in Australian gas reserves, although these plants may not necessarily be used for diesel production. Sasol Chevron (http://www.sasolchevron.com/) has proposed the construction of a GTL diesel plant using gas from the Gorgon field in Western Australia, which is currently under consideration by the Federal and State governments. This plant would provide substantial economic benefits to the State, and to the nation. The project represents a total investment of A$8 billion, would create thousands of jobs during construction, and during full operation would produce enough fuel to cater for approximately 70% of the current domestic diesel market. Overall, it is predicted that GDP would be 0.5% above the level it would be in a world without the project, between 2015 and 2032.

**Bio-Diesel Background**

Biodeisel is a renewable fuel. It is primarily produced through the transesterification of vegetable oils, and from tallow. Biodiesel can be used in a diesel engine without any modifications, and is compatible with existing refuelling infrastructure. The fuel can also be mixed with conventional diesel to provide some of its benefits, whilst not requiring large-scale production, which may have an adverse impact on the environment. The most commonly quoted mixture consists of 20% biodiesel (B20), but other concentrations are also feasible.

Australian Renewable Fuels (http://www.ausrf.com.au/), a wholly owned subsidiary of Amadeus Energy Limited, are currently involved in a Biodiesel plant in WA that will produce 40 million litres of Biodiesel per year by early 2003. This represents approximately 3% of the State’s current diesel consumption. This plant is likely to use low-grade tallow, and waste cooking oil as primary feedstock.

Other Biodiesel plants exist in NSW, where Australian Biodiesel Consultancy and Collex are currently producing approximately 15 million litres per year.

Transperth may trial biofuel for use in Perth’s bus fleet in the near future.

**CNG Background**

Compressed natural gas is natural gas that has been compressed to approximately 20Mpa. Natural gas is currently distributed throughout the country in an extensive pipeline system. Part of this pipeline network is low pressure (7kpa, to deliver gas to consumers), and part is high-pressure long distance pipelines (up to 15Mpa).

The primary component of natural gas is methane ($CH_4$), which is also a greenhouse gas. A significant issue when considering emissions from the full lifecycle of CNG is the magnitude of the fugitive emissions from the pipeline network. Estimates of these emissions vary between 0.1% and 7.5%, a margin of error that substantially influences the viability of the fuel in terms of greenhouse gas emissions.

It is unlikely that CNG will be used in light vehicles due to excessive weight of the fuel tanks, and there are issues regarding its use in long distance transport due to the limited range of the vehicles, and lack of refuelling infrastructure.

Transperth is using CNG as part of a trial for Perth's bus fleet.

**LNG Background**

Liquid Natural Gas is natural gas that has been cooled to approximately minus 180 degrees Celsius. Issues facing the use of LNG in vehicles are similar to those of CNG, although it is possible that the necessity of creation of vacuum-insulated cryogenic tanks for storage will present additional cost and emissions hurdles.

Transperth may use LNG as part of a trial for Perth's bus fleet.

**Dimethyl Ether (DME)**

DME has similar properties to that of LPG, and has been tested as an alternative fuel to diesel in CI engines. Use of DME in diesel engines offers emission reductions benefits for $NO_x$ and PM (Wang and Huang, 1999).

DME is currently primarily used as an aerosol propellant, and is produced from methanol through a dehydration process. Previously production has involved a two-reactor process where methanol is synthesised from syngas (produced from Natural Gas), and then DME is produced through the dehydration of two methanol molecules to one DME molecule. Recently development of a new dual-function catalyst allows synthesis and dehydration to take place within a single reactor, significantly improving the economics of large-scale production (Wang and Huang, 1999).

In June 2001, a project for Western Australia to produce DME was announced. The venturers would be Mitsubishi Gas Chemicals, Itochu, JGC and Mitsubishi Heavy Industries. The plant is expected to produce 1.4 to 2.4 million tonnes of DME per year from a plant expected to cost US$600 million with production beginning 2006 if approval is granted (http://www.chemlink.com.au/wachem.htm).

## Full Fuel Life-Cycle Analysis

Full life cycle analysis (LCA) is the accepted methodology for analysis of fuel alternatives. The international standards series ISO 14040 provides a basic framework for carrying out this work. The benefits of LCA are that all stages of a fuel's life are considered, from when the raw materials are extracted or produced, until the fuel is finally converted to energy in a vehicle. An introduction to life cycle analysis may be found in Graedel and Allenby (1995).

Fuel life cycle emissions analysis in this report has been based on the work of Wang and Huang (1999) of the Argonne National Laboratories in the USA for the Department of Energy, and of Beer et al (2002) of the CSIRO in Australia for the Australian Greenhouse Office. Results in these reports are not comparable, as different assumptions have been made. Beer et al has specifically targeted the Australian situation, but has limited the results to apply to trucks and buses, whilst Wang and Huang focus on the American situation and light vehicles. Selected results from both analyses are presented here.

Wang and Huang (1999) break down life cycle components into feedstock (relating to extraction or production of raw material), fuel (relating to processing, transport, and distribution of fuel), and vehicle operations (relating to fuel conversion to energy and vehicle wear). Beer et al (2002) break down emissions from fuels into pre-combustion emissions, and combustion emissions.

Although LCA is the recognised method for analysis of fuel emissions and energy efficiency, there remain a number of contentious issues regarding its use. ISO 14040 stipulates that all products from a particular process be considered when attributing emissions etc to the actual product being considered. This makes the LCA an extremely complex task, the results of which are often only relevant to a particular fuel refinery, or feedstock extraction operation.

**Greenhouse Emissions LCA**

Greenhouse gas emissions are subject to a weighting system known as GWPs (Global Warming Potentials) that allow gases to be expressed in $CO_2$ equivalents. The GWP is used in national communications required by the UN Framework Convention on Climate Change. The Kyoto Protocol has adopted GWPs with a one hundred year time horizon as the basis for defining equivalence between emissions. GHGs presented here have been weighted with the appropriate GWPs.

Figure 1, below, provides quantitative information for greenhouse gas emissions per km for the fuel option analysed based on heavy vehicles, from the analysis of Beer et al (2002). Assumptions of note are 0.1% fugitive emissions loss for CNG production-distribution systems based on advice from the Australian gas industry, and Beer et al (2002) indicated that information regarding upstream FT Diesel production required further investigation when Sasol Chevron released relevant data.

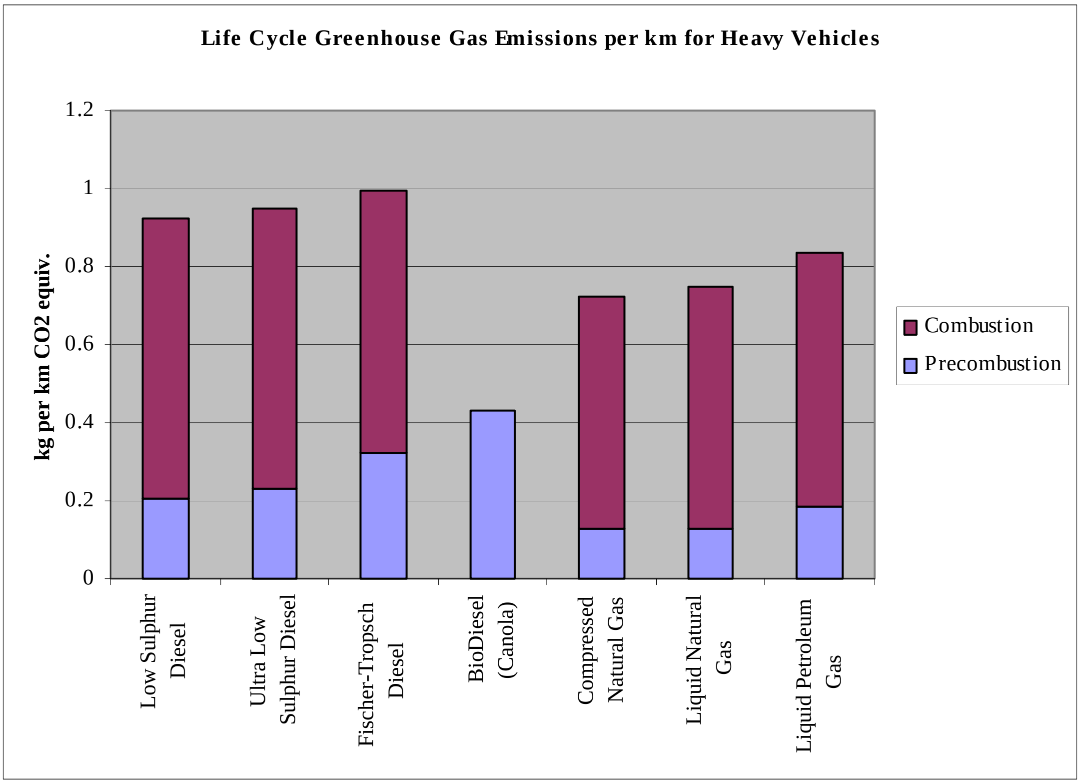


*Figure 1* Beer et al (2002) GHG emissions by fuel type per km for heavy vehicles[4]

Figure 1 clearly indicates the renewable nature of Bio-diesel in that all combustion emissions can be sequestered in the primary source of energy consumed (canola, tallow, etc). The figure

[4] Bio-diesel has no combustion GHG emissions as these are assumed to be sequestered in the canola crop (Beer et al, 2002)

also reflects the extra energy/emissions required to create ultra low sulphur diesel and Fischer-Tropsch diesel in the larger portion of pre-combustion emissions when compared with regular Low Sulphur Diesel.

At a glance, Figure 1 indicates that Compressed Natural Gas, Liquid Natural Gas, and Liquid Petroleum Gas create less GHG emissions in their life cycle than the diesel fuels for heavy vehicles. Data presented by Wang and Huang (1999) for light vehicles (Figure 2, below) reaches a slightly different conclusion. Re-formulated diesel (RFD) may actually produce lower emissions than CNG, LNG, or LPG for light vehicles. Fischer-Tropsch diesel has marginally higher lifecycle GHG emissions, primarily due to the $CO_2$ produced during the processing of the fuel. DME may have the lowest full lifecycle GHG emissions.

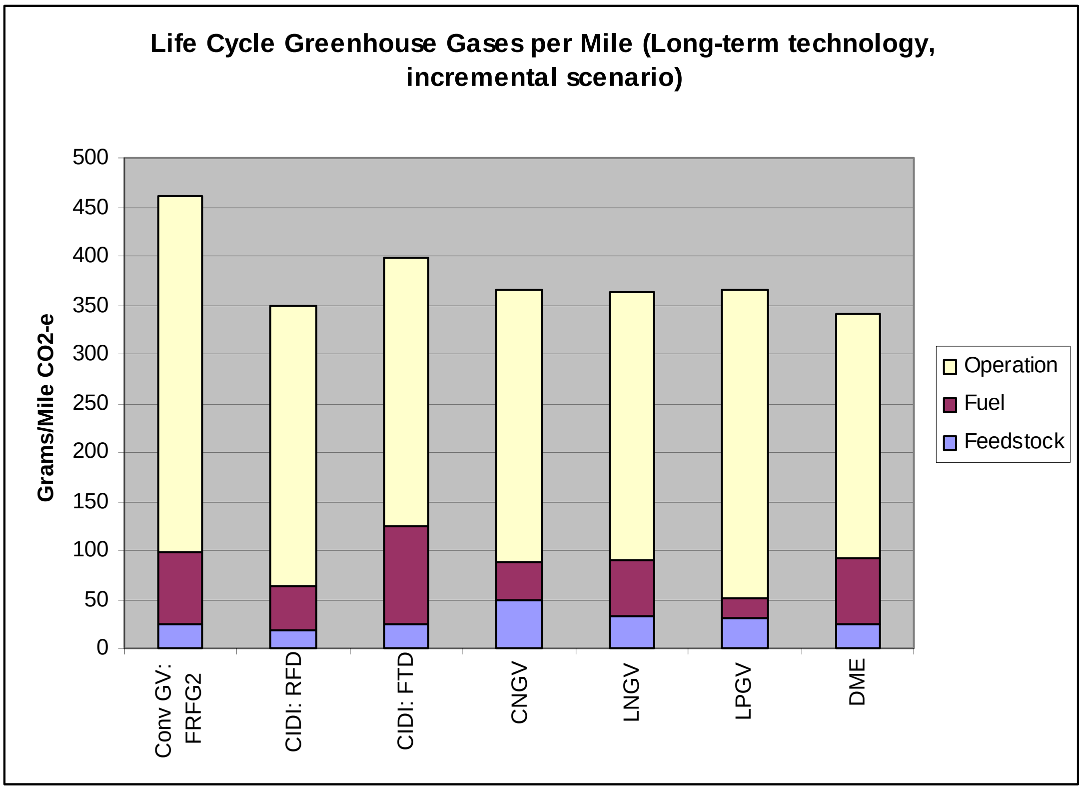


*Figure 2* Wang and Huang (1999) Life-cycle GHGs per mile for light vehicles[5]

Note that Figure 2 provides quantitative information in grams per mile GHG emissions for light vehicles, assuming long-term technologies[6] and incremental improvements in life cycle emissions efficiency.

[5] Bio-Diesel was not included in Wang and Huang (1999), but presumably has much lower emissions than other options. FRFG2 is Federal Phase 2 Reformulated Gasoline (USA), RFD is approximately equivalent to Ultra Low Sulphur Diesel, FTD is Fischer-Tropsch Diesel, CIDI is Compression Ignition Direct Injection, and CNGV in Compressed Natural Gas Vehicle, DME is Dimethyl Ether.
[6] Long-term technology is estimated to be available by 2010.

Generally, Figure 2 indicates little significant difference in GHG emissions between the six fuels compared, except to indicate that even very high standard gasoline is the least emissions efficient of fuels.

Sasol Chevron has indicated that it can reduce emissions from the "fuel" phase for FT Diesel through carbon sequestration. If 100% of carbon dioxide from the plant were sequestered, the entire "fuel" GHG emissions would disappear, making FT Diesel more emissions efficient than any other fuel for light vehicles. Sasol Chevron currently reference Wang and Huang (1999) as a relevant data source for their emissions efficiency. Note that similar sequestration arguments could apply to any of the fuels, but geological sequestration is probably only applicable for new plants (GTL diesel, and DME).

Wang and Huang (1999) have also included calculations of emissions where flared gas is used as a feedstock for FT Diesel, CNG, and LNG. Their assumption is that if this gas was going to be flared anyway, the use of this feedstock represents a saving of greenhouse gases and energy. Emissions obtained from calculations when this assumption is made are generally much lower than related emissions where the feedstock is regular natural gas.

**LCA Air Quality and Health Analysis**

Air pollutants released during the lifecycle of a fuel are of increasing importance when considering the viability of a fuel. They are particularly relevant in terms of human health implications, and smog and haze creation.

Fine particulate matter, often known as PM10s, has been associated with increases in mortality rates by the UK's Department of Health (2001). In another DOH study it is noted that, "There is clear evidence of associations between concentrations of particles similar to those encountered currently in the UK, and changes in a number of indicators of damage to health" (Department of Health, 2000). The Australian National Environment Protection Council has obtained similar results in its research (http://www.nepc.gov.au/). Odgen, Williams, and Larson (2001) cite the ExternE studies completed in Europe that showed that air pollution damage costs are dominated by adverse health impacts (mainly chronic mortality) associated with small particles in the air that are either emitted directly as a result of fossil fuel combustion or formed by reactions in the atmosphere from gaseous precursor emissions of $SO_2$, $NO_x$ and VOCs. Although the ExternE studies were completed for European conditions, the results may be adjusted for Australian population densities, and UV intensity.

VOCs (Volatile Organic Compounds), commonly associated with smog and haze, are organic compounds that participate in atmospheric photochemical reactions (National Pollutant Inventory, 2002).

Oxides of sulphur and Oxides of nitrogen are commonly associated with acid rain, smog and haze formation and their effects on human health. Oxides of Nitrogen and sulphur dioxide are ranked 1st and 3rd respectively of 208 pollutant rankings by the National Pollutant Inventory (http://www.npi.gov.au/), and are therefore considered damaging to the environment and damaging to health. Nitrous Oxide has a global warming potential (GWP) of 310 times that of $CO_2$ under a 100-year time frame as stipulated in the Kyoto Protocol.

The following table presents findings of Wang and Huang (1999) regarding air pollutants, as applied to long-term technologies, assuming incremental improvements in fuel-cycle emissions efficiency. These results apply to light vehicles, and are specific to the American energy situation.

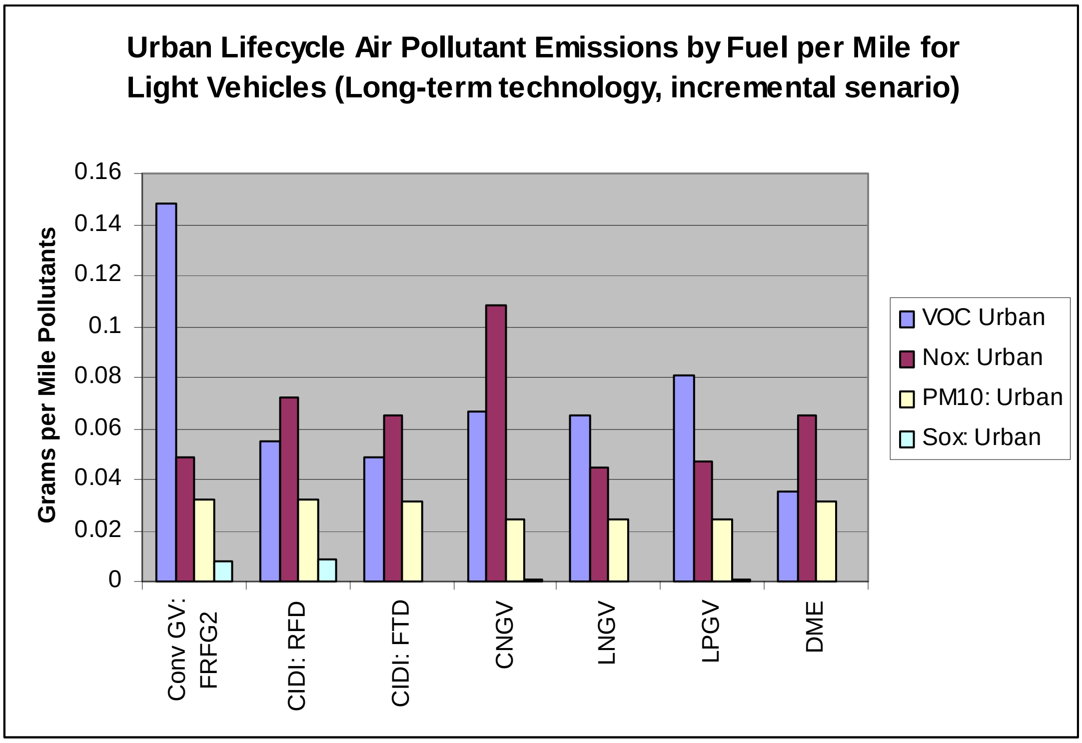


*Figure 3* Wang and Huang (1999) Urban component of life-cycle air pollutants

These results suggest that Fischer-Tropsch Diesel and DME produce the lowest air pollutant emissions of VOCs, and marginally higher amounts of PM10s and oxides of nitrogen than the lowest air polluters (CNG and Federal Phase 2 Reformulated Gasoline respectively). LNG, DME and Fischer-Tropsch Diesel emit effectively zero oxides of sulphur.

Biodiesel was not included in Wang and Huang (1999). Some studies have shown that biodiesel increases the emissions of $NO_x$ and hydrocarbons over conventional diesel, but decreases PM, oxides of sulphur, and carbon monoxide (Sheehan et al. 1998). Overall air pollutants for biodiesel appear to be dependent on the feedstock used in production (Graboski et al. 1999).

Notwithstanding the above results, it is noted that Beer et al (2002) concluded that CNG based heavy vehicle transport emitted substantially less oxides of nitrogen and PM10s than Fischer-Tropsch Diesel. It appears that the CNG vehicles used in these two studies varied greatly in their respective tailpipe emissions, and it is noted that Beer et al has based results on the latest OEM technology for CNG vehicles. The fact that Beer et al (2002) was based on heavy vehicles, and Wang and Huang (1999) was based on light vehicles could also account for these inconsistencies. A recent study by the Department of Transport in Western Australia on alternative fuels for the Transperth bus fleet concluded that CNG fuelled buses produced marginally more full cycle $CO_2$ emissions per kilometre than LPG and diesel, marginally more emission of air toxics than the other fuels, and a marginal reduction in the emissions of both PM10s and smog chemicals (Department of Transport, 1998). This is largely consistent with the findings of Wang and Huang (1999).

## Fuel Analysis Conclusions

Information regarding the lifecycle energy use and emissions from alternative fuels is subject to a large number of assumptions, and often-significant margins of error. Results from literature reviewed often gave conflicting outcomes. However, it is apparent that lifecycle analysis is the best method available for determining environmental and energy impact of the fuel/technology alternatives. Further analysis and research into the fuel options is necessary. This should follow a similar approach to that of Beer et al (2002), but should find more recent emissions data, and provide a software-based model that is configurable to allow for rapid technology changes and various assumptions in the fuel lifecycle.

Although no conclusion can be made regarding an alternative fuel of choice, the important factors to be considered have been identified. Lifecycle energy use and emissions (greenhouse and pollutant), availability of infrastructure, ADR compliance, opportunities for WA, and potential for transition to a clean-energy economy are all key issues that should be monitored whilst facilitating the transition to alternative fuels and transport technology. These will therefore be addressed briefly.

## Infrastructure Considerations

One of the requirements of potential alternative fuels is that existing infrastructure be able to support its full life cycle. If existing infrastructure does not support the full life cycle, it must be shown that provision of this infrastructure will not place an unreasonable burden on the environment, and consumer, industry, or government stakeholders.

The common argument is that provision of infrastructure to support a fuel has a substantial dollar value attached to it, and has potential to do non-trivial damage to the environment through emissions and energy expended during construction.

Fischer-Tropsch Diesel can be used in existing refuelling infrastructure, and in all newer compression ignition vehicles. Older compression ignition vehicles may require an overhaul to replace fuel seals that may shrink and cause leakage when FT Diesel or ULS Diesel is used, although this effect is yet to be proven. Note that this issue is relatively unimportant, as these vehicles will require this overhaul anyway when ULS Diesel becomes the mandatory standard in Australia in 2006, as Australia follows fuel specification changes implemented in the EU (http://www.ea.gov.au/atmosphere/transport/fuel/). Notwithstanding the above, the potential for FT Diesel to address air pollution and human health concerns is limited in that the majority of vehicles in Western Australian urban centres do not use diesel as a fuel. This fact may offset FT Diesel's advantage as one of the lowest emitters of "urban" pollutants. Based on information provided from the Department of Transport licensing database, almost 100% of heavy vehicles are diesel-powered, but only 13% of cars and wagons use the fuel, so market penetration of the fuel is likely to be slow in urban areas. However, it should be noted that as fuel specifications improve, more car manufacturers are likely to consider Australia as a viable market for their diesel-powered products, particularly considering the superior fuel efficiency and wearing characteristics when compared with their petrol-powered counterparts. There is also potential for the promising automotive development of hybrid electric-diesel vehicles that can run on FT Diesel. Additionally, if carbon dioxide at the well-head and produced during the FT process were sequestered, there may be a net GHG abatement, which multiplies in importance considering the volume of diesel fuels consumed in Australia as a whole, as opposed to urban-specific concerns.

There is currently very little infrastructure to support the introduction of Compressed Natural Gas in Western Australia. There are only 12 refuelling stations for CNG in Australia (http://www.greenhouse.gov.au/transport/cng.html). There are also concerns about the potential for the viability of conversion of light vehicles to CNG, due to excessive weight of the fuel tanks (http://www.iangv.org/html/sources/qa.html#size). Notwithstanding these concerns, there are some arguments that support the introduction of CNG to fuel Western Australia's heavy vehicle fleet. The federal government are currently pursuing an infrastructure creation program through the Australian Greenhouse Office, and arguments can be made that numerous jobs would be created and GHG and air pollutant emissions may be reduced. However, from a Western Australian point of view, the Australian Bus Industry Confederation has noted that conversion of buses to CNG will take time, but ULS Diesel introduction can have effect on emissions immediately (http://www.buscon.com.au/emissions.htm).

LNG faces similar infrastructure problems to CNG. In order to liquefy natural gas, it must be cooled to minus 180 degrees Celsius. Therefore it is necessary to build vacuum-insulated cryogenic tanks for storage, presenting more economic, energy use, and emissions problems.

Like Fischer-Tropsch diesel, Biodiesel can be used in existing infrastructure.

Liquid Petroleum Gas already has extensive infrastructure support, particularly in urban areas. There are currently over 3300 LPG refuelling stations in Australia (approximately 50% of all refuelling stations). Car manufacturers are already producing dedicated and dual fuel vehicles that use LPG, and conversions to LPG are possible under a government funded subsidy scheme for family vehicles. The average cost of a conversion is approximately $2200.[7] This cost is currently subsidised by $500 by the State government, and the subsidy also applies to the licensing of a new LPG vehicle (http://www.transport.wa.gov.au/licensing/lpg/index.html).

Dimethyl Ether (DME) transportation fuel production and infrastructure does not exist. Storage and transport costs are excessive, and as such fuel costs remain high. However, a number of proponents of DME in automotive applications exist including Volvo, Amoco, AVL Powertrain Engineering, Navistar, NKK and Halder Topsoe (California Energy Commision, 1999). DME is a gas at standard atmospheric pressure, but becomes a liquid under moderate pressure (DME is stored at around 100psi). Therefore, DME requires a pressurised vehicle fuel distribution system, similar to LPG.

## Australian Design Rules Compliance

It must be noted that all the fuel/technology combinations being considered in this paper conform to the *current* Australian Design Rules. No information regarding this compliance could be located for DME, but it is expected that this fuel would meet current standards. All fuel/technology combinations considered can be expected to meet *future* ADR design rules for all pollutants, with the possible exception of Biodiesel (Beer et al, 2002). Biodiesel may not meet the future ADR requirements for oxides of nitrogen for Euro3 and Euro4 standards and possibly the particulate matter standard for Euro3 (Arcoumanis, 2000). These data should be verified through further testing and trials, as some stakeholders have expressed disagreement with the findings (biodiesel particulates etc may be non-toxic).

## Transport Energy Efficiency

It is becoming more generally accepted that fossil fuel reserves will decrease below economic rates of supply, and progression to alternate technology is inevitable. How long the fossil fuel reserves will last is of upmost importance. The more time there is available for the switch to alternate fuels, the smoother the transition will be, and therefore lesser impact on the economy. The efficiency with which the fossil fuels are consumed will be directly proportional to the amount of time available for the transition.

For the purpose of this analysis, 'Transport Efficiency' will be considered, based on the findings of Wang and Huang (1999), on a BTU per mile basis. This approach gives a quantitative estimate of which fuels are efficiently using the available natural resources, by presenting the amount of extraction, processing, transport, distribution, and combustion energy required for 1 mile of travel in a light vehicle. Fuels that consume more energy (i.e. higher BTU/mile) have a lower transport efficiency, which implies that they are inefficiently utilising the available natural resources. The concept is only useful when comparing fuels sourced from the same base natural resource. For example, it is relevant for comparison of natural gas based fuels, but not for comparison between LPG and natural gas based fuels. For this reason, only natural gas based fuels are presented in the Figure 4 below.

[7] Stakeholder consultation with Kleenheat.

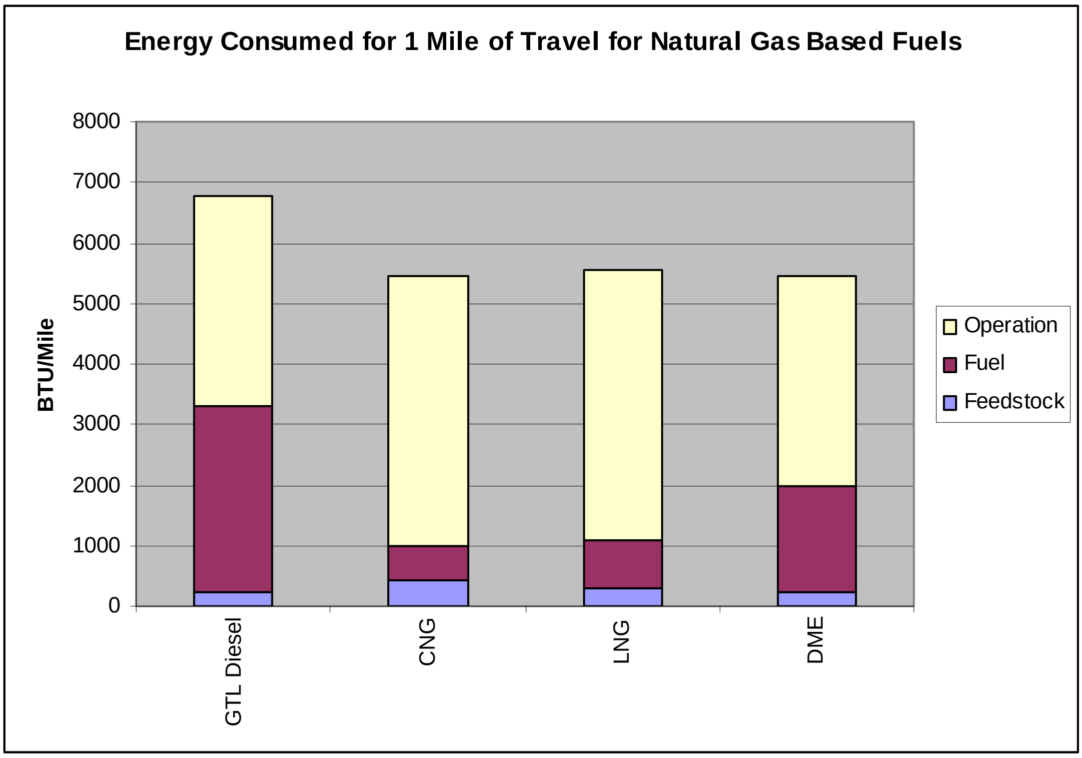


*Figure 4* Full lifecycle BTU per mile travelled by light vehicle (Wang and Huang, 1999)[8]

Figure 4 shows that there is significant difference between some fuels in terms of the total energy consumed in their lifecycles. Fischer-Tropsch Diesel consumes the most energy of the presented natural gas based fuels, which is most likely due to the large energy loss during the manufacturing process (Fischer-Tropsch reaction is exothermic).

This concept of 'Transport Efficiency' is loosely based on the concept of energy return on investment (or Energy Profit Ratio - net energy available in a fuel divided by the energy required to bring it to market from all sources) as presented by Hall et al (1986). It should be noted that in the light of a lack of reliable Australian data to calculate energy profit ratios for transport fuels, it is not currently possible to obtain more accurate figures. Values presented here should be used as an approximation only. A possibility for further study in this area is an analysis of the volume of each fossil fuel resource that is consumed for travelling one kilometre when considering the fuel's full lifecycle. Although this would be an extremely complex task, it would provide useful information regarding which fuel options are effectively utilising the available resources.

[8]Natural Gas based fuels only, as comparison with other fuels is not relevant in terms of "resource-use efficiency".

## Western Australian Opportunities for Alternative Fuel Innovation

Opportunities exist for WA to become a leader in emerging technology. Additional assistance for R&D, with a strong emphasis on industry involvement can aid Western Australian companies in taking advantage of future sustainable technology opportunities.

Western Australia has abundant natural gas reserves, some of which are being utilised by the energy sector to provide energy independence for the State, and providing a net emissions benefit. Proper incentives and regulation will make the utilisation of new reserves in WA a win-win situation. There is great interest in Gorgon reserves for GTL by a number of companies.

Companies such as Australian Renewable Fuels can manufacture bio-diesel in Western Australia. This fuel has very low net emissions, and may be as good as regular diesel in terms of performance. However, it is likely to remain in a niche market, as large-scale production is not feasible.

Many other opportunities exist for development in clean, renewable fuels and technology. Western Australian Government policy can facilitate enhancement of this industry.

## Potential for Transition to Cleaner Fuels

The potential for a fuel and technology combination to assist in a transition to a renewable, near-zero emissions fuel is important when considering the options because of the non-sustainable nature of natural-gas based, and other non-renewable fuels. A technology combination can aid this transition through provision of infrastructure. Production facilities, distribution networks, refuelling infrastructure, storage development, and manufacture of vehicles are all important infrastructure considerations.

Fischer-Tropsch fuels have the potential to be a bridge fuel between traditional fuels and cleaner fuels due to its low sulphur content and subsequent suitability for use in Fuel Cell Vehicles (Texaco, 2001). High sulphur fuels are well known for poisoning catalysts that are used in fuel cells, thus normally preventing their use in this application. Some research is currently underway at Argonne National Laboratories into the use of Fischer-Tropsch gasoline in fuel cells (Ahmed et al, 1999).

CNG and LNG can easily be converted to hydrogen, which represents a likely future fuel source. Both of these fuels have the potential for on-board reforming, or conversion to hydrogen at a fuel station for use in a vehicle.

Methanol is also a primary fuel for use in fuel cells. Western Australia has recently gained a potential methanol plant project on the Burrup peninsula, which will produce 1 million tonnes of Chemical Grade AA Methanol per year (http://www.gtlresources.com/projects-methanol-australian.htm). Methanol can usually be used in existing refuelling infrastructure with minor modifications (California Energy Commission, 1999). Although the prospect of using methanol in fuel cells should be supported, it must be noted that it generally cannot be used in existing engines, and most major car companies have stopped supporting methanol based spark ignition technology. This means that the fuel is not a suitable transition fuel, but should be considered when supplying future infrastructure (i.e. new refuelling tanks should be methanol compliant). Methanol produced for industrial purposes can be considered a transition fuel to methanol in fuel cells.

Fuel cell packages are being developed that can run on a variety of fuels, such as natural gas, gasoline, LPG, methanol, and ethanol (http://www.transportation.anl.gov/ttrdc/fuelcell/reformer.html). This suggests that it may be possible to assist the transition to cleaner renewable fuels, regardless of which fuels are available on the market, providing it is one of those listed above. This technology should be monitored to aid in decision making for future alternatives.

## *Existing Government Policy and Stakeholder Action*

Today there exists a climate of global action on emissions reduction, energy efficiency, and sustainable fuel development programs like never before seen. Two major energy consumers, Europe and the USA are implementing alternative energy programs across the board, providing incentives for energy-innovation to flourish, enforcing tough new fuel and emissions standards, and clearly demonstrating that significant positive change can be made whilst doing little damage to economies and often even improving performance. Relevant action can be broken down into Global and International, National, and State levels as follows.

## Global and International Action

### Kyoto Protocol and Flexibility Mechanisms

Global action is being taken in the form of the Kyoto Protocol. If sufficient countries ratify this protocol, it will bind them to cut their greenhouse gas emissions to specified levels relative to 1990 during the commitment period from 2008 to 2012. Australia has signed the protocol, but not ratified it. Should Australia ratify, it must achieve less than 8% increase of greenhouse gases before the commitment period relative to 1990. The European Union, and Japan are ratifying the protocol, and Russia is expected to follow suit before September 2002. It is therefore likely that it will enter into force 90 days after Russia and one or two other Annex I parties ratify.

Emissions Trading is a related global mechanism to encourage emissions cuts through fiscal incentives. Its allows the parties to meet emissions abatement targets at lower cost by purchasing emission reduction units from countries where abatement can be achieved more economically. Similar arguments apply to CDM (Clean Development Mechanism) and JI (Joint Implementation) projects, which allow developed countries to obtain credits through projects in developing and developed countries respectively. The recent Marrakech Accords conclusion for emissions trading are reasonably market friendly through provision of a key concept that the four emissions units generated under the Kyoto Protocol framework should be fungible (i.e. equivalent and interchangeable), which allows them to be traded in one market. This provision should allow for a more liquid market and lower transaction costs (http://www.aetf.net.au/ContentStore/pdf/ReviewDecJan2001.pdf). Parties compliant to the Kyoto Protocol provisions can trade the four emissions units between parties.

These developments in international climate change negotiation could be a shaping factor in the Australian upstream fuel/energy industry in the near future. The country's abundant natural gas reserves represent a potentially major increase in $CO_2$-e emissions as they are monetised, so if Australia ratifies the Kyoto Protocol, measures will need to be taken to reduce or offset these emissions. This could occur through carbon sequestration (geological and land use activities) and use of the Kyoto flexibility mechanisms mentioned above. If Australia continues to refuse to ratify the Kyoto Protocol, then it faces a potential international backlash where sanctions are imposed, possibly damaging the economy to a magnitude similar or greater than ratification itself.

**The European Union**

The EU has implemented a number of mechanisms to aid the development of cleaner transport systems including Policy Development, Initiatives, and Funded Programmes. Initiatives include:

- The European Commission and the International Union of Public Transport (UITP) fund ELTIS (European Local Transport Information Service) jointly. This is a guide to current transport measures, policies and practices implemented in cities and regions across Europe.
- Citizens' Network Benchmarking Initiative was carried out in 1998-99 and developed a set of indicators to compare one local passenger transport system with another. These indicators are available on ELTIS and the initiative is open to new participants through the 2000+ invitations.
- EPOMM (European Platform on Mobility Management) is an international partnership co-ordinated by the EC aiming to promote and develop Mobility Management in Europe and to fine-tune its implementation with the EU Member States and the other European countries.

European Union research activities are implemented for the most part under multi-annual research, technological development and demonstration (RTD) framework programmes. EU funding is available through calls for proposals or tenders. Examples of these and other funded programmes are:

- CIVITAS (City Vitality Sustainability) initiative that supports cleaner urban transport through 50 million Euros funding for promising urban transport projects around Europe.
- ENERGIE Programme. Energy along with Environment and Sustainable Development is a sub-theme of Theme 4 of the 5th Framework Programme. The priorities set by this programme are: to reduce by 2008-12 the amount of CO2 released in the atmosphere

by 8% compared to 1990 levels; to double (from 6 to 12%) the share of energy demand met by Renewables; and to increase energy efficiency by 18% by 2010, compared to 1995 levels. The priorities set in the transport sector are: to optimise combustion technologies using cleaner hydrocarbon fuels and other alternative fuels, such as hydrogen; to develop and demonstrate hybrid and electric propulsion systems, such as batteries, fuel cells, fuel processors and other energy storage and conversion devices and hybrid systems; to demonstrate innovative public and private transport systems by making comparative assessments of the energy efficiency, emissions, feasibility, reliability, safety, operability and economics of alternative vehicles; promoting the advanced transport technologies made in the EU.

- GROWTH – Sustainable Mobility and Intermodality. Projects need to contribute to safe, intelligent, efficient and interoperable rail, road, air and waterborne transport systems for passengers and freight. The objective is also to generate efficient links between one mode and another. A budget of 371 million € has been attributed to this key action. This represents a significant increase from its predecessor.

Individual European Union countries also support their own transport energy policies that work with EU instruments, and independently.

**UK Carbon-Reduction Strategy in Transport**

The UK government has drafted a government strategy entitled *Powering Future Vehicles* (UK Department of Transport, 2001). This strategy works on the country's current foundations for the support of clean vehicles through the DTLR (Department of Transport, Local Government, and Regions) *Powershift* and *Cleanup* Programmes. The DTI (Department of Trade and Industry) *New and Renewable Energy, Advanced Fuel Cells* and *Foresight* Vehicle programmes are helping to develop the science and knowledge base for these new vehicle technologies.

*PowerShift* is an Energy Saving Trust programme to help establish a sustainable market for alternative, clean fuel vehicles in the UK. It aims to create the conditions for clean fuel vehicles to be practically and economically viable. All applicants seeking grant funding for clean fuel vehicles (CFVs) must choose vehicles that appear on the PowerShift Register. This register is a buyer's guide to clean fuel vehicles. It allows purchasers to make informed choices about the merits of the different clean fuel vehicles on offer and provides the basis on which PowerShift grants are offered. The grants obtained from Powershift can cover up to 75% of the additional cost of purchasing a clean fuel vehicle (http://www.est-powershift.org.uk/).

The *CleanUp* campaign aims to improve air quality in the UK by encouraging the fitting of emissions reduction equipment to the most polluting diesel vehicles. The campaign has recently received a further cash injection from the Road Haulage Modernisation Fund, with an additional £30m allocated over a two-year period (2001-3) specifically to help clean up road haulage. Through its CleanUp programme, TransportAction offers grants to operators of both commercial and public sector vehicles worth up to 75 per cent of the capital cost of fitting pollution-reducing equipment (http://www.cleanup.org.uk/).

**California Energy Commission**

The Californian Energy Commission has created a number of schemes to foster an alternative fuels and technology industry. Highlights are as follows:

1. Clean Diesel Program: Diesel Emissions Reduction Fund. AB 1107 (Moore, Chapter 940 Statutes of 1989) mandates the California Energy Commission to provide technical assistance and support for the development of clean diesel fuel and cleaner diesel engine exhaust. AB 1107 specifies candidate technologies as those that are as clean as alternative fuels, provide energy savings and promote the use of state-of-the-art energy technologies. (http://www.energy.ca.gov/afvs/clean_diesel.html)
2. Alternative Fuels Infrastructure Program. The California Energy Commission is making available from $200,000 to $1 million through its Alternative Fuels Infrastructure Program to support non-petroleum alternative fuel infrastructure projects throughout California. This grant funding is made available to public agencies and qualified private entities that partner with and assist public agencies in establishing alternative fuel dispensing facilities (http://www.energy.ca.gov/afvs/clean_fuel.html).
3. Efficient Vehicle Incentive Program. With funding of $5 million from Governor Gray Davis's 2000-2001 Budget, the Energy Commission is implementing a new Efficient Vehicle Incentive Program. This new market transformation initiative is designed to effect consumer purchase decisions to help reduce our dependency on petroleum and increase the use of environmentally friendly vehicles. This program provides incentives for vehicles that offer public benefits such as improving transport energy efficiency, reducing petroleum reliance, increasing energy diversity, and mitigating adverse environmental impacts from transport fuels (http://www.energy.ca.gov/afvs/program_fact_sheets/efficient_vehicle_program.html).

### US Department of Energy

US Department of Energy runs a Clean Cities Program. This program supports public-private partnerships that deploy alternative fuel vehicles (AFVs) and build supporting infrastructure. By encouraging AFV use, the Clean Cities Program helps enhance energy security and environmental quality at both the national and local levels (http://www.ccities.doe.gov/what_is.shtml).

## National Action

### Australian Federal Government: Australian Greenhouse Office

The Australian Greenhouse Office (AGO) is the world's first government agency dedicated to cutting greenhouse gas emissions. It was established in 1998 as a separate agency within the environment portfolio to provide a whole of government approach to greenhouse matters. It also delivers the Commonwealth Government's $180 million climate change package, Safeguarding the Future: Australia's Response to Climate Change and the $796 million greenhouse component of Measures for a Better Environment announced as part of Australia' s new tax system in 1999.

The AGO has a number of Alternative Fuels Programs. These are:

1. CNG Infrastructure Program. The development of alternative refuelling infrastructure through the CNGIP is a key component of the Commonwealth alternative fuels programs. The CNGIP is a $7.6 million program designed to facilitate the establishment of a national network of CNG refuelling stations. No CNG refuelling stations are currently supported in Western Australian by this program (http://www.greenhouse.gov.au/transport/cng.html).
2. Alternative Fuels Conversion Program. The AFCP commenced in January 2002. It is a four year $75 million program designed to provide assistance to the operators of heavy commercial vehicles and buses, weighing 3.5 tonnes gross vehicle mass or more, to convert their vehicles to operate on either CNG or LPG, or to purchase new vehicles running on these fuels. The AFCP provides funds of up to 50 per cent of either:
   - The difference between the purchase price of new CNG or LPG fuelled vehicles over their conventionally fuelled equivalents;
   - The cost of converting conventionally fuelled vehicles to operate on CNG or LPG; or

- The cost of upgrading the fuel systems of vehicles already operating on CNG or LPG where improvements in greenhouse and other emissions can be demonstrated. (http://www.greenhouse.gov.au/transport/afcp.html)

3. Diesel and Alternative Fuels Grants Scheme. The DAFGS commenced in July 2000 and will maintain existing price relativities between diesel and a range of alternative fuels by allowing transport operators that are eligible for the diesel fuel grant to also be eligible for alternative fuel grants. The retention of the existing price differential between diesel and alternative fuels will encourage wider use of alternative fuels and reduce greenhouse gas emissions and improve air quality. The Government has adopted a percentage price relativity methodology for the Scheme based on maintaining the percentage price relativities existing before the reduction in the diesel excise. (http://www.greenhouse.gov.au/transport/dafgs.html).

In addition to these programs, the AGO has implemented the *Environmental Strategy for the Motor Vehicle Industry* including a fuel consumption guide and label for new cars. The fuel consumption label is mandatory for all new vehicles, and is intended to make consumers consider fuel efficiency when purchasing a vehicle (http://www.greenhouse.gov.au/fuellabel/index.html).

### Transport Energy Industry Regulation

Transport energy industry regulation can be split into two general categories – upstream and downstream. Upstream regulation applies to all stages of fuel supply until the fuel is put into a vehicle, and downstream refers to any aspect related to operation or manufacture of the vehicle and fuel system. The Environmental Protection and Biodiversity Conservation Act 1999 (EPBC), the Environmental Protection Act 1986 (WA only), the Commonwealth Petroleum (Submerged Lands) (Management of Environment) Regulations 1999, and numerous Australian and ISO standards dictate major project approvals and specifications for provision of re-fuelling and vehicle infrastructure. As such, these instruments are powerful tools for regulating towards a sustainable transport industry.

### Federal Fuel Excise

The cost of fuel to the motorist is the single most important factor that will determine consumer choice of vehicle and fuel in the marketplace. The Federal Fuel Excise currently stands at around 38 cents per litre for diesel and petrol, and zero for LPG. This policy gives LPG a significant advantage, effectively allowing it to be sold at half the price of unleaded petrol, thus propping up the LPG retail and conversion industry.

Taxation of fuel, particularly petroleum products, is widely considered an efficient means of raising government revenue because fuel is widely used by the community. Compared with many other goods, its level of consumption is not generally affected by changes in price. This makes it a relatively stable and reliable source of revenue to fund the range of services provided by governments (Fuel Taxation Inquiry Issues Paper, 2001). Stakeholders have expressed a wide range of views as to the purpose and possible future developments in fuel taxation. For example, it could be argued that fuel taxation should partially reflect the environmental benefits of various fuels and that some of the revenue could be directed at programs that improve environmental performance in the transport sector. A view has also been expressed that differentiation between fuels in fuel taxation should not be used as a tool to prop up particular fuel industries in the long term. These and other issues are under consideration by the Federal Treasury's Fuel Taxation Inquiry, which includes extensive stakeholder consultation (http://fueltaxinquiry.treasury.gov.au/content/welcome.asp).

**Greenfleet**

Effort is being made by the community to encourage consumers to take responsibility for carbon emissions. Greenfleet, a project founded in 1997 by the Foster Foundation and now a not-for-profit organisation in its own right, sequesters carbon dioxide on the behalf of its supporters (http://www.greenfleet.com.au/). Consumers pay Greenfleet a $30 (or larger) donation, which they subsequently use to plant trees that will remove the carbon dioxide emitted by an average vehicle over one year from the atmosphere. Greenfleet has calculated the number of trees in a steady-state native Australian forest necessary to capture the required $CO_2$. Greenfleet plants create 'Forests of Diversity' where the original native vegetation is restored to provide a permanent habitat for flora and fauna, whilst also tackling salinity and erosion. The trees will remain in the ground over their natural life. The donation is purely on a voluntary basis.

## State Action

**Department of Planning and Infrastructure**

The aim of Transport (part of DPI) is to provide the best transport system for West Australians, through policy development, planning, resourcing, co-ordinating, educating and regulating, and funding transport programs in the State (http://www.transport.wa.gov.au/about/purpose.html). The fundamental approach undertaken by Transport in developing strategies, policies and plans is contained in the Metropolitan Transport Strategy (MTS) and The Way Ahead.

At the State level, the issue of transition fuels and technology at the regulation and facilitation level is strongly influenced by Transport.

The Department for Planning and Infrastructure is supporting a number of trials for the Transperth bus fleet through Transport. Results from these trials will be used to determine direction for providing modern, clean, reliable, and economic public transport to the community. It will also provide useful information on the relative viability of each fuel/technology combination. Alternative fuel trials currently underway or planned are Hydrogen, CNG, Bio-fuels, and LNG.

The LPG Conversion Rebate implemented by Transport provides an incentive to consumers to convert their personal vehicles to LPG. This incentive is in the form of a $500 rebate on the conversion price, or $500 rebate on the purchase of an LPG family vehicle. There is currently very little demand for LPG conversion, and as such the rebate scheme is not being effectively utilised, although WA does have the highest proportion of LPG vehicles in Australia.

Transport also has a number of programs that encourage the use of alternative means of transport, particularly public transport, cycling, and walking. More information regarding these activities is available through the TravelSmart program (http://www.travelsmart.transport.wa.gov.au/).

**Fleet Strategies**

Government and industry regularly support the use of alternative fuel/technology combinations in their fleet vehicles. Almost the entire Perth taxi fleet runs off LPG, as it can be shown that this is more economically efficient. Likewise the government has previously attempted to convert up to 20% of their fleet to LPG, but with limited success, as it contracted out its fleet management until recently.

The inclusion of new fuel/technology combinations in fleet strategies can be beneficial to the industry selling the new product, providing a foothold for expansion into the general consumer market through the high turnover experienced in fleets. The economics of the new technologies can be more favourable than existing technology when the higher capital cost is offset by superior fuel efficiency and lower maintenance costs. However, there remains a degree of uncertainty when purchasing new technology, often preventing its uptake, as industry and government are unwilling to risk large sums of money on unproven equipment.

## *Where to from here?*

### Transport Energy Taskforce

Creation of a government taskforce to tackle transport energy issues is imperative to ensure the full exploitation of opportunities for innovation in Western Australia. Issues identified in this paper enable the compilation of topics for consideration for such a taskforce. These are (based on the UK's Draft Transport Strategy):

- Create a State Transport Energy Strategy that will provide a vision of the future for stakeholders, and identify ways to pursue this vision, taking into account the rapid technology advancement being experienced and potential scenarios regarding oil vulnerability.
- Ensure Australian industry's full engagement, with particular focus on WA.
- Ensure all decisions and State regulatory arrangements take full account of environmental, health, and resource issues.
- Analyse and comment on technical standards for vehicles, fuels, and distribution infrastructure. Explore measures the federal government could take to ensure these standards can be hastily prepared and reviewed for future fuel options.
- Facilitate creation of new infrastructure as required.
- Encourage the State and Federal governments to devise the right fiscal regimes for vehicles and fuels to reflect their environmental benefits.
- Identify barriers to industry and consumer take-up of cleaner technology, and develop methods of removing them.
- Identify indicators and set aggressive targets for the next decade and beyond to help promote the State Transport Energy Strategy.
- Encourage consumers to take responsibility for their own energy use and emissions

### Carbon Sequestration and Emissions Trading

Carbon Sequestration activities should be more seriously considered as a short-term solution to rising emissions in Western Australia, particularly due to rapid expansion of natural gas refining activities on Burrup Peninsula that could increase WA's emissions by up to 30%. Carbon sequestration can be achieved through planting vegetation (such as Oil Mallee), or through geological sequestration where $CO_2$ is pumped into underground geological features that are likely to contain it indefinitely.

An Emissions Trading system could provide the incentive necessary to foster carbon sequestration activities in the State. A discussion of issues and activities relating to an emissions trading system can be found at the Australian Emissions Trading Forum (http://www.aetf.net.au/).

## Fuel Diversification

Fuel diversification is important in the short term to guarantee the State's energy security. This diversification should represent a move away from fuels that are based solely on oil as feedstock, preferably towards those that are renewable, or based on natural gas, thus addressing security of supply issues. Essentially all of the fuels/technology combinations considered in this paper, with the exception of LNG, meet this requirement as infrastructure exists to support them, or federal government programs are underway to create that infrastructure.

## Research and Development

R&D activities are required to further our understanding of the fuel and technology options available, and enable opportunities for innovation. It is essential that industry is included in these R&D activities to ensure Australian industry ownership of intellectual property.

A number of areas can be identified where R&D would be extremely beneficial to policy makers and industry. Primarily, and directly relating to this study, a dynamic model of issues relating to appropriate decision making regarding fuel/technology combinations is required. This model must take into account the fact that technology in this area is progressing rapidly, and must therefore be easily configurable. Such a model already exists in the USA called GREET, but this is specific to the American energy-transport situation. An Australian-specific model is required.

## The Government Fleet

The government fleet is an obvious choice for trials and testing of alternative fuel/technology combinations. There is considerable scope for transition to cleaner, and possibly cheaper fuel alternatives, such as LPG and clean Diesel in the light vehicle fleet, and clean Diesel or CNG in the heavier fleet. The government fleet should make the fullest use of new vehicle and fuel technology, and encourage other public authorities to do so too. The high turnover of these fleets would enable effective distribution of technology into the private vehicle market.

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