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# **Cleaner Vehicles and Fuels: Opportunities, Barriers and Policy Measures**

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## Executive Summary

The challenge of Greenhouse Gas mitigation in the Transport sector is substantial.

However, specific opportunities exist for cleaner vehicles and fuels.

Policy measures are essential in overcoming barriers and realising these opportunities.

Due to the extent of mitigation required a wide range of measures are needed and must be explored; there is no “silver bullet”.

Opportunities for enhanced mitigation are identified in several areas, together with suggestions for policy measures:

- Increased availability of high efficiency vehicles
- Preferential purchase of high efficiency vehicles
- Accelerated attrition for low efficiency vehicles
- Increased availability of certified and manufacturer warranted alternative fuel systems
- Increased availability of cleaner fuels
- Avoidance of vehicle deterioration
- Enabling informed driver behaviour

Complementary approaches have been suggested to assist policy makers in decision making:

- Coordination of supply and demand side measures to ensure optimal outcomes
- Use of a vehicle Greenhouse Gas metric rather than fuel efficiency or economy
- Development of data to correlate of Real World and ADR Greenhouse Gas levels

*In particular, it is indicated that the use in isolation of an Emission Trading Scheme through CO<sub>2</sub>e permit pricing for fuels may not achieve the extent of mitigation necessary, and that complementary actions should be considered.*

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## Nomenclature

4WD	Four Wheel Drive
ADR	Australian Design Rule
AFCP	Alternative Fuels Conversion Program
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
CO <sub>2</sub> e	Carbon Dioxide Equivalent
DCC	Department of Climate Change
EF	Emission Factor
ETS	Emission Trading Scheme
FBT	Fringe Benefit Tax
GGE	Greenhouse Gas Emissions
GVM	Gross Vehicle Mass
GWP	Global Warming Potential
LPG	Liquefied Petroleum Gas
MON	Motor Octane Number
MVP	Motor Vehicle Producer
N <sub>2</sub> O	Nitrous Oxide
PULP	Premium Unleaded Petrol (98 RON)
RON	Research Octane Number
SUV	Sport Utility Vehicle
VKT	Vehicle Kilometres Travelled

# 1 Scope

This submission relates to the Garnaut Climate Change Review Issues Paper for Forum 5, "Transport, Planning and the Built Environment".

Specifically this submission focuses on

- Section 3, Transport and Planning
- Emissions from Passenger Transport (3.3) and Freight (3.4), rather than Aviation and Shipping
- Vehicle in-use GGE and not emissions arising from vehicle manufacture, disposal, servicing and maintenance
- Cleaner vehicles and fuels i.e. the characteristics of available transport modes rather than the factors influencing the selection and use of mode, such as urban form and infrastructure.

*Note that policy related suggestions have been indicated through the body of the submission with a gray highlight.*

## 2 Transport Sector Greenhouse Gas Emissions

In-use GGE arise from Passenger Transport and Freight as a product of fuel used and fuel emission factor<sup>1</sup> (Equation 2), which may be usefully expanded to include fuel consumption on a per-vehicle basis (Equation 3).

### Equation 1

$$GGE_{total} = \sum (\text{Fuel Used} \times \text{Volumetric Fuel Emission Factor})$$

Or:

### Equation 2

$$GGE_{total} = \sum (\text{litres} \times \text{gCO}_2\text{e/litre})$$

Or:

### Equation 3

$$GGE_{total} = \sum (\text{km} \times \text{litres/km} \times \text{gCO}_2\text{e/litre})$$

Or:

### Equation 4

$$GGE_{total} = \sum (\text{km} \times \text{litres/MJ} \times \text{MJ/km} \times \text{gCO}_2\text{e/litre})$$

Or:

### Equation 5

$$GGE_{total} = \sum (\text{km} \times \text{MJ/km} \times \text{gCO}_2\text{e/MJ})$$

Or:

### Equation 6

$$GGE_{total} = \sum (\text{Vehicle Kilometres Travelled} \times \text{Vehicle Energy Consumption} \times \text{Energetic Fuel Emission Factor})$$

The terms of Equation 6 may be readily used as a comprehensive top-down approach to identify and manage GGE mitigation opportunities, in that reduction in any of the three terms will yield a factorial reduction in Road Transport GGE.

As an illustration, the 2050 Kyoto commitment of 60% GGE reduction on 2000 levels<sup>2</sup> might be achieved through a 26% reduction in each of *Vehicle Kilometres Travelled*, *Vehicle Energy Consumption* and *Energetic Fuel Emission Factor* (0.6% per annum), or alternatively through a 37% reduction in each of *Vehicle Energy Consumption* and *Energetic Fuel Emission Factor* (0.9% per annum). The scale of the task is apparent, although the approaches are clear.

1. *Vehicle Kilometres Travelled* (VKT) for road vehicles (passengers and freight) has increased at an average annual rate of 1.7% over the period 2005 to 2010, and is projected to increase at an average annual rate of 1.8% over the period 2010 to 2020<sup>3</sup>. GGE mitigation may arise from
  - 1.1. constraint of VKT, and / or
  - 1.2. the transferral of VKT to transport modes with a lower GGE impact (Equation 10).These choices and the policies that may influence them are not included in the scope of this submission.

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<sup>1</sup> National Greenhouse Accounts (NGA) Factors, DCC, 2008

<sup>2</sup> <http://www.greenhouse.gov.au/international/kyoto/index.html>

<sup>3</sup> Transport Sector Greenhouse Gas Emissions Projections, DCC, 2007

2. *Vehicle Energy Consumption* is an effective metric of vehicle operating *Efficiency*<sup>4</sup> as it is normalised against fuel energy density<sup>5</sup>. It may be considered with regard to three factors.
- 2.1. *Vehicle Construction* – Vehicle hardware determines the efficiency that may be achieved from a vehicle for a given duty cycle, and may also determine the pattern of use; GGE mitigation may be achieved through the inclusion of more efficient vehicles in the fleet, and related policies are considered in a following section
- 2.2. *Vehicle Duty Cycle* – Varying patterns of driving style and use yield widely different efficiencies<sup>6</sup>, and may be influenced through driver choice and / or external conditions, for example
- Laden weight – efficiency improved by lower weight
  - Choice of gear – efficiency typically improved by use of higher gears
  - Rates of acceleration – efficiency typically improved by lower rates of acceleration
  - Average speed – efficiency typically improved by lower average speed
  - Use of ancillaries such as air conditioning – efficiency improved by lower use
  - Trip duration – efficiency typically improved for longer trips
  - Time spent at idle – efficiency improved by less time at idle
  - Ambient temperature – efficiency optimal at moderate temperatures

Whilst policy in this area may tend to be advisory rather than mandatory, and some aspects are beyond the reach of policy, opportunities exist in the areas of

- Constraint of driving style e.g. enforcement of maximum speed limits
- Driver information e.g. requirement for vehicle “change gear” or “a/c on” indications
- Control of driving environment to limit inefficient patterns e.g. reduce urban travel

In order to determine policy potential in this area, a quantitative assessment could be made of the impacts of vehicle duty cycle on operating efficiency.

- 2.3. *Vehicle Deterioration* – Vehicle hardware performs sub-optimally through improper maintenance or modification, and as this may only *reduce* efficiency it should be considered as a risk, for example:

- Tyres at wrong pressure or in poor condition
- Steering / suspension incorrectly aligned
- Engine fuelling system and controls incorrectly adjusted

Avoidance of deterioration may be achieved through the proper maintenance of vehicles, and related policies may include a mandated periodic roadworthiness inspection. In order to determine the requirement for policy in this area, a quantitative assessment could be made of the risk.

3. *Fuel Emission Factor* is determined by fuel type<sup>7</sup>, and may relate to

3.1. *Demand Side GGE* (also ‘direct’, or ‘Tank-to-Wheel’)

3.2. *Supply Side GGE* (also ‘indirect’, or ‘Well-to-Tank’)

3.3. *Life Cycle GGE* i.e. demand + supply sides (also ‘Well-to-Wheel’)

GGE mitigation may arise from reduction in fuel emission factors and / or the deployment of fuels with lower fuel emission factors; related policies are considered in a following section.

Of the approaches listed above, *Vehicle Construction* and *Fuel Emission Factor* are considered more fully in later sections of the submission.

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<sup>4</sup> Utilised by CSIRO & CONCAWE / EUCAR / JRC <http://ies.jrc.cec.eu.int/wtw.html> (Efficiency = 1/Consumption)

<sup>5</sup> For example, reduction in fuel consumption by the use of petrol in place of LPG does not ensure a positive GGE outcome.

<sup>6</sup> The measurement of efficiency is discussed under Section 3: Vehicle Construction for Higher Efficiency.

<sup>7</sup> National Greenhouse Accounts (NGA) Factors, DCC, 2008

These two approaches are closely inter-related:

- *Vehicle construction determines choice of fuel and hence fuel emission factor*, for example a diesel vehicle may not be operated on petrol.
- *Availability of fuel types determines which vehicle constructions may be operable in the market*, for example hydrogen infrastructure is presently limited, offering a constraint to the deployment of fuel cell vehicles<sup>8</sup>.
- *The characteristics of different fuels enable higher efficiencies to be achieved in vehicle construction, in particular for the engine*. For example, LPG demonstrates a higher octane rating than petrol<sup>9</sup>, potentially enabling higher engine compression ratio and efficiency.
- *Vehicles must be appropriately engineered to achieve the GGE potential offered by reduced fuel emission factors*, for example the use of natural gas in place of diesel may not ensure a positive GGE outcome where engine efficiency or emissions of methane are compromised<sup>10</sup>.

Cleaner vehicles and fuels must therefore be considered together, and by doing so it may be possible to realise optimal outcomes, such as combination of highest efficiency vehicles with cleanest fuels.

Similarly, a coordinated approach in policy with integrated supply and demand side measures will be required to ensure optimal outcomes. For example, an investment in alternatively fuelled vehicles will only be made if infrastructure is available, and investment in fuelling infrastructure will only occur if there is a market need for fuel: the free market may deliver a sub-optimal solution.

Vehicle related policies may be best focussed with consideration of a *Vehicle GGE Rating* (Equation 10) rather than vehicle fuel consumption (Equation 7):

**Equation 7 (cf. Equation 3)**

$$GGE_{total} = \sum (\text{Distance Travelled} \times \text{Fuel Consumption} \times \text{Volumetric Fuel Emission Factor})$$

Or:

**Equation 8**

$$GGE_{total} = \sum (\text{km} \times \text{litres/km} \times \text{gCO}_2\text{e/litre})$$

Or:

**Equation 9**

$$GGE_{total} = \sum (\text{km} \times \text{gCO}_2\text{e/km})$$

Or:

**Equation 10**

$$GGE_{total} = \sum (\text{Vehicle Kilometres Travelled} \times \text{Vehicle GGE Rating})$$

Regulation focussed on a gCO<sub>2</sub>e/km metric (Equation 9) encompasses the GGE performance of different fuels and allows a system optimal outcome. In particular, where CO<sub>2</sub>e relates to a fuel life cycle emission factor, a direct comparison is enabled between alternative fuels and all modes of transport, including electric vehicles powered from the grid.

The concept of a vehicle or engine GGE rating (gCO<sub>2</sub>/km or gCO<sub>2</sub>e/km) is used throughout the text of this submission.

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<sup>8</sup> "National Hydrogen Study"; A Report to the Department of Industry, Tourism and Resources; ACIL Tasman and Parsons Brinckerhoff, 2003.

<sup>9</sup> PULP MON = 88, LPG MON > 89; Bosch Automotive Handbook, 6th Edition, 2004.

<sup>10</sup> "Natural Gas as a Transportation Fuel: Best Practices for Achieving Optimal Emissions Reductions"; A Report to the International Council on Clean Transportation; M.J. Bradley & Associates, 2005.

## 3 Vehicle Construction for Higher Efficiency

### 3.1 Measurement of Efficiency

Fuel consumption and tailpipe CO<sub>2</sub> are measured as part of the respective ADR standards, and are therefore recorded under a standard set of conditions and over a standard test cycle for both Passenger car and Freight sectors<sup>11</sup>. This provides a ready basis on which to compare the fuel consumption and tailpipe CO<sub>2</sub> levels for different vehicles<sup>12</sup>. Vehicle efficiency may then be determined by application of respective data for fuel energy content<sup>13</sup>, and a vehicle GGE rating from fuel emission factors<sup>14</sup>.

In-use, vehicles are exposed to a very wide range of driving conditions, for example with regard to ambient temperature, average trip time, average speed or time spent at engine idle. Therefore real world vehicle use normally varies from the ADR test standard, the potential for which is indicated by differences in urban and extra-urban drive cycle data<sup>15</sup>. The differences between the ADR standard and real world use will result in differences of both fuel consumption and tailpipe CO<sub>2</sub>, and hence efficiency and GGE.

Whilst the ADR levels of tailpipe CO<sub>2</sub> give a ready basis on which to assess vehicles over a standard test cycle, it must be recognised that the actual vehicle levels of GGE will differ from the ADR standard. The GGE task for Transport is by necessity focused on reduction of actual GGE produced by the vehicle fleet. Therefore in any GGE mitigation proposals for Transport, a quantitative understanding must exist of the difference between ADR and real world data. Importantly, some technologies yield a significantly different outcome according to vehicle use<sup>16</sup>, and therefore an understanding of real world use should inform the selection of technologies.

Policy measures may address these issues through

1. recognition that a differential exists between ADR and real world vehicle efficiency,
2. information policies to clarify the differential between ADR and real world performance, and
3. the support of initiatives to develop data which quantify this differential.

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<sup>11</sup> Passenger and light duty vehicles are presently regulated under ADR79/01. Engines utilised in Freight transport are presently regulated under ADR80/02.

<sup>12</sup> <http://www.greenvehicleguide.gov.au>

<sup>13</sup> National Greenhouse Accounts (NGA) Factors, DCC, 2008

<sup>14</sup> National Greenhouse Accounts (NGA) Factors, DCC, 2008

<sup>15</sup> <http://www.vcacarfueldata.org.uk/downloads/may2007.asp>

<sup>16</sup> For example, hybrid powertrains in passenger vehicle yield significant advantage on urban cycles and comparatively less benefit on extra-urban cycles (<http://www.vcacarfueldata.org.uk/downloads/may2007.asp>).

### 3.2 Aggregated Efficiency

The change in aggregated efficiency of the vehicle fleet over time may be considered to arise from:

- New Stock i.e. new vehicles to be added to the fleet, in terms of
  - Efficiency of new vehicles added to the fleet, and
  - Rate at which new vehicles are added to the fleet
- Old Stock<sup>17</sup> i.e. old vehicles that have been removed from the fleet, in terms of
  - Efficiency of vehicles removed from the fleet, and
  - Rate at which vehicles are removed from the fleet
- Overall Rate of Fleet Growth, which constrains the rates of addition and removal.

### 3.3 Rates of Vehicle Turnover

Rates at which vehicles are added to and removed from the fleet present an opportunity to improve fleet efficiency through addition of highly efficient vehicles and removal of low efficiency vehicles. However, resultant overall growth in the fleet presents a significant risk for fleet GGE. For example, whilst passenger car VKT per vehicle is projected to decline over the period 2010 to 2020, total VKT increases at an average annual rate of 1.3% over the period 2010 to 2020 due to growth in the fleet<sup>18</sup>.

Policies that concern growth may be considered as follows:

- Overall growth – potentially problematic and do not accurately target a positive GGE outcome
- Rate at which new vehicles are added to the fleet – acquisition of new vehicles may be promoted by reduction in capital investment, for example through reduction in tax applied at purchase; this also does not directly ensure a positive GGE outcome
- Rate at which vehicles are removed from the fleet – the removal of old vehicles may be accelerated through an increased overhead in operating cost, for example through increased maintenance costs brought about by a periodic mandatory roadworthiness inspection; this also does not directly ensure a positive GGE outcome

In summary, policies that relate to growth may be considered imprecise. Policies that target the following may be considered more appropriate in achieving GGE mitigation:

- *removal of low efficiency vehicles, and*
- addition of high efficiency vehicles, with regard to
  - *selection of a high efficiency vehicle at time of purchase, and*
  - *range of high efficiency vehicles available.*

These are reviewed further.

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<sup>17</sup> The efficiency of vehicles remaining in the fleet may be adversely affected by deterioration. The potential to modify vehicles in the fleet to achieve higher efficiency is limited.

<sup>18</sup> Transport Sector Greenhouse Gas Emissions Projections, DCC, 2007

### 3.4 Removal of Low Efficiency Vehicles

Policies intended to target low efficiency or high GGE vehicles might target an increase of operating cost, or an increase of transfer cost. Where these constitute a relatively high proportion of vehicle operating or purchase costs for older vehicles there may be a significant incentive to consider a more cost effective i.e. more efficient, alternative:

1. Fuel Price – Whilst price of fuel may be noted to have an effect on fuel sales<sup>19</sup>, it has also been noted that the effect of fuel price may be limited in impact on driver behaviour<sup>20</sup>. A discussion of fuel pricing and its effects is beyond the scope of this submission, however it may be noted that other complementary measures should be considered<sup>21</sup>
2. Annual Fees – Registration fees are levied on all motor vehicles although at present are fixed; a sliding scale charge according to vehicle GGE rating<sup>22</sup> (gCO<sub>2</sub>/km or gCO<sub>2</sub>e/km) will:
  - 2.1. make drivers aware of the significance of vehicle GGE, and of a vehicle's GGE rating, and
  - 2.2. encourage drivers towards cleaner vehicles.
3. Transfer Costs – Taxes and duties are levied at time of sale; sliding scale charges applied on the basis of vehicle GGE rating will encourage drivers towards cleaner vehicles at time of purchase.

### 3.5 Selection of a High Efficiency Vehicle at Time of Purchase

The criteria determining the purchase decision for passenger car and freight vehicles are different, and therefore they are treated separately.

#### 3.5.1 Passenger Car

The selection of a passenger car may be made according to several requirements including performance, driveability and handling, image and style, refinement, purchase price, operating cost, safety, quality (reliability and durability), ease of service, vehicle range, features and functionality (interior space, off-road capability, towing capability, load carrying capability, etc.). Vehicle efficiency may be of significance to operating cost and range; however fuel cost is typically a small proportion of total cost, and a requirement for high range may often be accommodated through the addition of extra fuel carrying capability. It may be observed that efficiency of a passenger car is not a primary factor in its selection for purchase.

For a given range of vehicles available for purchase in the market, a consumer may elect to choose a vehicle of lesser efficiency with little consequence. Policy may be effective in encouraging consumers to choose more efficient vehicles, and by doing so may encourage motor manufacturers to produce more efficient vehicles.

A range of measures based on a vehicle GGE rating (gCO<sub>2</sub>/km or gCO<sub>2</sub>e/km) may be effective in highlighting the impact of vehicle choice on the environment, and guiding consumers towards cleaner vehicles.

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<sup>19</sup> Transport Sector Greenhouse Gas Emissions Projections, DCC, 2007

<sup>20</sup> "Modelling of the Transport Sector and its Response to an Emissions Trading Scheme"; A Report to the National Emissions Trading Taskforce; CSIRO, Rare Consulting, Orbital Australia, March 2008.

<sup>21</sup> "Modelling of the Transport Sector and its Response to an Emissions Trading Scheme"; A Report to the National Emissions Trading Taskforce; CSIRO, Rare Consulting, Orbital Australia, March 2008.

<sup>22</sup> Enacted in UK, 2001; revised 2008

([http://www.direct.gov.uk/en/Motoring/OwningAVehicle/HowToTaxYourVehicle/DG\\_10012524](http://www.direct.gov.uk/en/Motoring/OwningAVehicle/HowToTaxYourVehicle/DG_10012524))

1. Fuel Price – It has been noted that fuel price alone is not an effective mechanism in changing consumer behaviour, and this is particularly the case for new and inefficient vehicles where fuel cost constitutes a minor proportion of vehicle cost<sup>23</sup>. Note that the impact of an Emission Trading Scheme (ETS) on fuel price via CO<sub>2</sub>e permit price is proportionately small, and hence it is suggested that an ETS acting solely on fuel price may also not change consumer behaviour<sup>24</sup>. It is indicated that complementary measures should be considered.
2. Annual Fees – The application of a vehicle GGE based sliding scale to vehicle registration fees, as discussed above.
3. Purchase Costs – The application of a vehicle GGE based sliding scale to taxes and duties payable at time of purchase, as discussed above.
4. Fringe Benefit Tax (FBT) – At present a sliding scale applies to FBT which decreases as VKT increases. Whilst this does not discriminate against vehicles of higher efficiency, it may promote the otherwise un-required increase of VKT to reduce tax burden, and in consequence increase the total GGE contribution. A sliding scale for FBT based on vehicle GGE rating, such as that deployed in the UK<sup>25</sup>, can encourage the selection of cleaner vehicles and not promote an increase in VKT.
5. Indirect Measures – By leveraging some ownership in organisations that provide fleets, it may be possible to moderate vehicle efficiency through fleet purchasing decisions, for example by adopting a maximum permissible vehicle CO<sub>2</sub> rating. Mechanisms to further such policy may include an extension of the Greenhouse Challenge Plus scheme.
6. “Decide not to Buy” – Growth in the fleet has been identified as the primary driver for increase of passenger car GGE; policy makers may wish to consider how to attenuate the rate of fleet growth.

### 3.5.2 Freight

The purchase of a commercial vehicle intended to carry freight is based on suitability for purpose (GVM, etc.), purchase and operating cost, reliability and durability, and cost of service and maintenance. In particular, fuel cost constitutes a substantial overhead<sup>26</sup>, and the requirement to minimise this cost through selection of a more efficient vehicle is high. In consequence there is a strong market pull for vehicles of higher efficiency, and a clear business proposition for manufacturers to develop engines and vehicles with higher efficiency.

It is important to identify, however, that freight vehicles have historically operated with diesel fuelled engines. Recent innovations have enabled the use of other fuels, and in particular natural gas, for engines in this market. Whilst natural gas may offer a ready benefit in operating cost, engine efficiency may decrease<sup>27</sup> and emissions of methane may become significant<sup>28</sup>, thereby producing a negative GGE outcome.

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<sup>23</sup> Typical annual fuel cost may be typically in the range \$1500 to \$4000, or less than 10% of vehicle price.

<sup>24</sup> “Modelling of the Transport Sector and its Response to an Emissions Trading Scheme”; A Report to the National Emissions Trading Taskforce; CSIRO, Rare Consulting, Orbital Australia, March 2008.

<sup>25</sup> “Car benefits and car fuel benefits” (<http://www.hmrc.gov.uk/helpsheets/hs203.pdf>).

<sup>26</sup> Typical annual fuel cost may be typically in the range \$200,000 to \$400,000 for an articulated truck; personal communication, 2008.

<sup>27</sup> “An Efficiency Study of Alternative Heavy Duty Engine Technologies”; A Report to the Federal Australian Greenhouse Office; Orbital Australia, October 2007.

<sup>28</sup> “Natural Gas as a Transportation Fuel: Best Practices for Achieving Optimal Emissions Reductions”; A Report to the International Council on Clean Transportation; M.J. Bradley & Associates, 2005.

It is therefore suggested that policy considers the GGE impacts of technology choice to ensure that alternative fuels are selected appropriately, and that the technology applied can ensure a positive GGE outcome. It is understood that operating costs and credits are significant determinants in decisions of commercial enterprises, and two primary mechanisms may enable the preferential selection of cleaner vehicles.

1. Greenhouse Challenge Plus<sup>29</sup> – The monitoring, review and continued development of this scheme for adaption to latest market conditions.
2. Emissions Trading Scheme – The development and deployment of an ETS will enable financial value to be assigned to GGE through the use of CO<sub>2</sub>e permits.

### 3.6 The Range of High Efficiency Vehicles Available

Selection of highly efficient vehicles may only be made if they are available for purchase. This section addresses some of the opportunities and barriers surrounding the availability of more efficient vehicles.

#### 3.6.1 Passenger Car

Many of the world's most efficient passenger cars are presently represented in Australia<sup>30</sup> and it could therefore be suggested that Australia is not limited in choice. However, the current market offering and trends, including increased share of clean diesel, suggest that this choice may not be adequate<sup>31</sup> and opportunities should be explored to further improve efficiency. Importantly, the improvement of fleet efficiency through the free market take-up of smaller vehicles is limited<sup>32</sup>, and opportunities must be explored to improve efficiency within vehicle classes.

It is suggested that opportunities exist in two areas for accelerated improvement of passenger car efficiency: *Globally Engineered Vehicles* and *Australian Engineered Vehicles*<sup>33</sup>. These are reviewed below, together with barriers and some discussion of policy measures.

##### Globally Engineered Vehicles

Vehicle efficiency may be improved through actions on vehicle weight, aerodynamics, powertrain (i.e. engine & transmission) and driveline. It may be reasonably stated that numerous activities are in progress in all these areas, and by all manufacturers and many suppliers, with some more advanced than others. A detailed review of these opportunities is beyond the scope of this submission; however barriers may be identified in two areas.

1. Introduction of Existing Technologies to the Australian Market – Whilst many efficient vehicles are represented in Australia, there exist some that will be barred from entry by local market conditions. For example, fuel quality standards will impact:
  - 1.1. Availability of clean diesel<sup>34</sup> vehicles, which have been constrained by the availability of clean diesel fuel. With clean diesel available in the market, European and Japanese engineered vehicles and powertrains may become available.

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<sup>29</sup> <http://www.environment.gov.au/settlements/challenge/index.html>

<sup>30</sup> <http://www.greenvehicleguide.gov.au> vs <http://www.vcacarfueldata.org.uk/downloads/may2007.asp>

<sup>31</sup> Australian passenger fleet fuel consumption static over period 1995 to 2006; SMVU (ABS)

<sup>32</sup> Shift towards smaller vehicles in the period 1997 to 2007 has been offset by take-up of SUVs (VFACTS) contributing to static fuel consumption<sup>31</sup>

<sup>33</sup> Australian manufactured vehicles comprised 19% of Australian vehicle sales in 2007, or approximately 200k units; Review of Australia's Automotive Industry 2008, Background Paper

<sup>34</sup> Compliant with ADR79/01 or ADR79/02.

1.2. Availability of advanced petrol combustion engines which may utilise advanced exhaust gas aftertreatment systems, and which are sensitive to fuel sulphur content.

It is suggested that where ADRs are unified with other markets, the barriers to introduction of Global vehicles will be removed. Policy review may wish to consider which ADRs present barriers to introduction, and evaluate the associated potential for improvement.

2. Development of New Technologies – New technologies require extensive R&D in terms of investment and time-to-market, and are typically associated with an increase of vehicle production costs, requiring either a reduction in margins or increase in price to consumer.

However, as observed in 3.5.1, efficiency may not be a primary factor in purchase of passenger cars. With a weak market pull, the business case to invest in fuel efficient technologies is often not compelling, and it is problematic to justify a level of vehicle on-cost to achieve an improvement in fuel consumption. Moreover, the other factors that play a significant part in a decision to purchase a vehicle are typically achieved at the expense of efficiency.

- Performance is achieved through high output (larger capacity) engines and shorter gearing.
- Driveability and handling are achieved through, for example, chassis and suspension characteristics such as the use of wider and softer tyres.
- Image and style dictate a certain vehicle profile which is often not conducive to a low aerodynamic drag coefficient.
- Refinement, or quietness and smoothness of operation, is often achieved through the use of sound deadening materials which add vehicle weight.
- Safety is often achieved through construction of the vehicle body and addition of safety devices such as airbags, which tend to increase vehicle weight.
- Features, such as climate control, electric seats, satellite navigation and multi-media entertainment will add weight and also impact efficiency through “parasitic” losses to the engine.
- Functionality, for example vehicle size or 4WD capability, will tend to increase weight.

The barriers may therefore be identified as an historically low market pull for high efficiency (note time-to-market of 3 to 6 years), and the absence of a mechanism to price for efficiency improvements.

Policy makers may be well placed to address these barriers by promoting market pull for efficiency and providing mechanisms by which a market value can be assigned to efficiency improvements. Australian vehicle imports in 2007 were approximately 0.85m units<sup>35</sup>, and whilst Australia alone may not influence global auto-makers, it has a significant voice.

In addition to the measures referred to in 3.4 and 3.5.1, a national standard for vehicle GGE ratings may be contemplated. A standard may take one of two basic forms<sup>36</sup>:

2.1. Individual Vehicle Limits as implemented in China, and proposed in California and New Zealand, or

2.2. Manufacturer Fleet Average Limits as implemented in the US and Japan, and proposed for Europe.

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<sup>35</sup> Review of Australia’s Automotive Industry 2008, Background Paper

<sup>36</sup> [http://delphi.com/pdf/emissions/2008\\_Delphi\\_PC.pdf](http://delphi.com/pdf/emissions/2008_Delphi_PC.pdf)

In these examples the mechanism for enforcing standards varies as does the metric used to assess efficiency. It is strongly suggested that any proposals for such a standard should refer to a vehicle GGE rating metric, either in the form gCO<sub>2</sub>/km or gCO<sub>2</sub>e/km.

### Australian Engineered Vehicles

It has been noted that Australian MVPs are relatively small in scale with total manufacturing volumes in 2007 of 327,984 units<sup>37</sup> and domestic sales in the order of 200,000 units<sup>38</sup>, and are subsidiaries of overseas MVPs due in part to economies of scale<sup>38</sup>.

With reference to the preceding discussion it may also be noted that R&D investments to deliver fuel efficient technologies may typically be significant, and in consequence may only be recovered through application to global vehicle platforms. In this context, fundamental technologies are engineered by parent companies, and opportunity for local subsidiaries to undertake fundamental engineering is limited<sup>38</sup>.

However, there exist certain market conditions in Australia that indicate potential for product not supported by parent companies, or by other vehicle importers. In this case, there may exist opportunities for Australian MVPs to tailor base vehicles and powertrains to local market conditions. As an illustration:

1. *Optimised LPG Engine* – The use of LPG in place of gasoline *may* enable a reduction in demand side and life cycle CO<sub>2</sub>e in the order of 10%<sup>39</sup> due to carbon density, and potential exists to extend this advantage by optimisation of engine architecture to leverage the particular characteristics of LPG<sup>40</sup>. It may be suggested that this application could be considered for large but also smaller vehicles which possess greater market share, and where a competitive advantage may be gained. To realise this opportunity requires system engineering at the manufacturer level.
2. *Large Cars with “Down-Sized” Engine* – Australian MVPs have investment in production of large cars and have seen market share of this vehicle type decline significantly in the period 1997 to 2007<sup>41</sup>. Share has been taken by both light / small vehicles and also SUVs, the former attributed in part to a desire for improved fuel efficiency. One primary route for improvement of fuel efficiency adopted in Europe is the use of smaller capacity engines with higher output enabled by turbocharging<sup>42</sup>. Such an approach might be considered in Australia for large cars, by replacement of large capacity 6 cylinder engines with turbocharged 4 cylinder engines available from the parent company.

Market specific applications such as an *Optimised LPG Engine* or *Large Cars with “Down-Sized” Engine* would only be developed by Australian MVPs, but barriers are presented by investment costs and potentially unit cost.

Policies may be considered in the areas of:

- Targeting R&D Assistance at GGE Improvement, and provided through an existing R&D grant structure such as ACIS or Commercial Ready
- Individual Vehicle Schemes Targeted at GGE Improvement

<sup>37</sup> <http://www.fcai.com.au/volumes>

<sup>38</sup> Review of Australia’s Automotive Industry 2008, Background Paper

<sup>39</sup> National Greenhouse Accounts (NGA) Factors, DCC, 2008

<sup>40</sup> “Why Liquid Phase LPG Port Injection has Superior Power and Efficiency to Gas Phase Port Injection”, University of Melbourne, 2007

<sup>41</sup> VFACTS

<sup>42</sup> “GDI Turbo: The next Steps”, AVL List GmbH, 2007.

### 3.6.2 Freight

Australia has access to the global stock of heavy duty engines, and these are typically engineered to meet a market demand for high fuel efficiency, whilst satisfying prevailing toxic emission regulations. Heavy duty vehicles may be either bought in or constructed locally, in some instances local construction being predicated by the unique market requirements for high GVM. Whilst the fuel efficiency of the freight task in terms of new vehicle construction could be considered competitive, the challenge to efficiency in this area is high as commercial vehicles contribute 38% of road transport GGE, and the level is projected to grow 27% between 2010 and 2020<sup>43</sup>. Moreover, engines in this class are already engineered for high efficiency and only minor opportunities remain<sup>44</sup>.

In this context it is suggested that opportunities exist in two areas for improvement of freight efficiency: *Emerging Technologies* and *Locally Developed Solutions*. These are reviewed below, together with barriers and some discussion of policy measures.

#### Emerging Technologies

Whilst a substantial proportion of heavy duty engine R&D is focussed on achieving future emission standards, other activity is on-going in vehicle and engine systems to improve vehicle efficiency. Incremental improvements continue to be made in many areas and will not be detailed here; however significant potential exists in the field of hybridisation or energy recovery, and approaches take one of two forms:

1. *Recovery of Mechanical Energy* – A moving vehicle possesses kinetic energy, and by recovering and storing this energy for re-use the efficiency of a vehicle may be improved. In addition, and according to the degree of hybridisation, features such as *stop-start* and *launch assist* may offer further efficiency gains. This principle is that used in hybrid passenger vehicles, although the implementation in commercial vehicles may vary through the use of hydraulic in place of electrical systems. Whilst hybrid passenger vehicles may demonstrate efficiency gains in excess of 35% over certain cycles, it may be anticipated that the savings for heavy vehicles would be somewhat less, due to both the extent of hybridisation and the characteristics of drive cycle. A number of manufacturers have entered production with such systems, for example Eaton<sup>45</sup>, although as yet there is no widespread uptake in Australia.
2. *Recovery of Thermal Energy* – It is known that heavy duty engines may operate with efficiencies in the order of 40%<sup>46</sup>, in that 40% of the fuel energy used is converted to useful work. The remaining 60% of fuel energy content will leave the engine as waste heat, either through coolant and oil, or through the hot exhaust gas. Whilst the proportions vary, it may be generally stated the energy lost to exhaust is of the same order of magnitude as that recovered in useful work. A significant opportunity therefore exists to improve engine efficiency where exhaust thermal energy is recovered. Such a system may be referred to as a *heat hybrid*. At least one heavy duty engine manufacturer will enter production with such a system in 2008, and claims up to 5% improvement in efficiency<sup>47</sup>, whilst systems are under development by other suppliers.

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<sup>43</sup> Transport Sector Greenhouse Gas Emissions Projections, DCC, 2007

<sup>44</sup> "An Efficiency Study of Alternative Heavy Duty Engine Technologies"; A Report to the Federal Australian Greenhouse Office; Orbital Australia, October 2007.

<sup>45</sup> <http://www.eaton.com/EatonCom/ProductsServices/Hybrid/SystemsOverview/HydraulicHLA/index.htm>

<sup>46</sup> "An Efficiency Study of Alternative Heavy Duty Engine Technologies"; A Report to the Federal Australian Greenhouse Office; Orbital Australia, October 2007.

<sup>47</sup> <http://www.detroitdiesel.com/pdf/engines/2007-dd15-brochure.pdf>

Market forces may ultimately cause hybrid technology to become widespread in the commercial fleet; however the strong growth in Australia in this sector coupled with the potential for an interim 2020 Kyoto commitment suggests a role for policy makers in facilitating deployment of such technologies, for example through the sponsorship of demonstration programs.

### Locally Developed Solutions

The technology employed in Australia for heavy duty vehicles is predominantly imported, more so than for passenger cars, and heavy duty diesel engine development is undertaken extensively by manufacturers for the global engine market. Development is focussed on efficiency, performance and toxic emissions for diesel engines and it is acknowledged that requirements in this class are typically similar between markets.

However, there will exist market specific requirements that are not adequately addressed by a global product, and these requirements present an opportunity to further improve efficiency through a locally developed solution. An illustration is presented below by way of indicating policy that may facilitate such development.

It is the case that unique market conditions exist within Australia:

- Gross Vehicle Mass in excess of 100 tons, hence very high engine power
- Ambient temperature approaching 50°C
- Near term potential for *targeted* deployment of natural gas infrastructure i.e. vehicles should operate on natural gas and / or diesel.

There is no manufacturer supplied engine that can satisfy these market conditions, although the potential for a solution has been demonstrated through trials of “aftermarket” imported systems in association with the Alternative Fuels Conversion Program (AFCP)<sup>48</sup>. Based on these experiences, an opportunity exists to realise a significant GGE outcome through development of a technology tailored to the unique conditions of the Australian market.

Whilst the financial drivers for a natural gas technology exist in the commercial sector due to fuel cost differential, and unit costs are manageable, the R&D and other early stage investments required are substantial and block the path to market.

Policies may be considered in the areas of:

- Targeting R&D Assistance at GGE Improvement, and provided through an existing R&D grant structure such as ACIS or Commercial Ready

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<sup>48</sup> <http://www.environment.gov.au/settlements/transport/afcp/>

## 4 Fuel Emission Factor for Reduced GGE

The relationship between fuel emission factor and GGE may be restated as follows.

**Equation 11 (from Equation 6)**

$$GGE_{total} = \sum (\text{Vehicle Kilometres Travelled} \times \text{Vehicle Energy Consumption} \times \text{Energetic Fuel Emission Factor})$$

Or:

**Equation 12**

$$GGE_{total} = \sum (km \times MJ/km \times gCO_2e/MJ)$$

Or:

**Equation 13**

$$GGE_{total} = \sum (MJ \times gCO_2e/MJ)$$

Or:

**Equation 14**

$$GGE_{total} = \sum (\text{Energy} \times \text{Energetic Fuel Emission Factor})$$

The quantity of *Energy* consumed is determined by *VKT* and *Vehicle Energy Consumption*, for which mitigation opportunities have been reviewed. Further opportunities for GGE mitigation may be identified by reference to Emission Factors (EF) of selected fuels, which are presented in Table 1.

Fuel	Demand Side	Supply Side	Life Cycle
Petrol	67.0	5.3	72.3
Diesel	69.8	5.3	75.2
LPG	60.2	5.3	65.5
Ethanol (molasses)	0.4	54.8	54.8
Biodiesel (Canola)	0.4	62.1	62.5
Natural Gas (LDV)	57.0	11.4	68.4
Natural Gas (HDV)	53.6	11.4	65.0
Electricity (NSW & ACT)			295.0

**Table 1: Emission Factors of Selected Fuels (g CO<sub>2</sub>e / MJ)<sup>49</sup>**

Approaches to reduce GGE may be considered in two areas: *Reduction of EF for a Given Fuel*, and *Utilisation of Fuel with a Lower EF*.

### 4.1 Reduction of EF for a Given Fuel

On the demand side for fossil fuels, EF is set predominantly by CO<sub>2</sub> emitted by combustion and hence is determined by fuel energy content and fuel carbon content, which are typically fixed for a given fuel. Emissions of methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) occur at relatively low levels, although due to respective GWPs<sup>50</sup> may offer some contribution to CO<sub>2</sub>e. Potential for reduction of EF on the demand side is limited for fossil fuels.

<sup>49</sup> DCC 2007, Table 78. By convention, demand side CO<sub>2</sub> for bio-fuels is not reported.

<sup>50</sup> CH<sub>4</sub> = 21, N<sub>2</sub>O = 310; National Greenhouse Accounts (NGA) Factors, DCC, 2008

On the supply side for fossil fuels the contributions to life cycle CO<sub>2e</sub> are in the order of 7% for liquid fuels, and 17% for natural gas. There may be some opportunity in fuel extraction, processing, transportation and storage to reduce EF.

Bio-fuels and other renewables such as hydrogen may potentially offer a route to low EFs. Supply side contribution is of course highly dependent on methods of production (and also subject to differences in approach to calculation). A degree of uncertainty surrounds the outlook for bio-fuels and other renewables, but whilst they offer promise of medium term mitigation it may be considered that they will constitute part of a future energy scenario and would be deployed through a sustainable model.

## 4.2 Utilisation of Fuel with a Lower EF

Whilst diesel exhibits a higher EF than petrol it will produce a lower vehicle CO<sub>2e</sub>/km due to the higher efficiency of the combustion process, illustrating that EF must ultimately be considered in conjunction with combustion process. However, when assuming the same combustion process, a direct comparison may be made.

LPG may be seen to offer a 10% advantage in EF with respect to petrol, and 13% with respect to diesel, for both demand side and life cycle. Natural gas offers an advantage with respect to petrol of 15 – 20% on demand side and 5 – 10% for life cycle, and with respect to diesel of 18 – 23% on demand side and 9 – 13% for life cycle.

Hence LPG and natural gas offer a similar level of benefit, and according to practicality of fuelling infrastructure the following opportunities may be proposed:

1. Displace gasoline with LPG, and
2. Displace heavy duty diesel with natural gas (LPG less suited to large CI engines).

Barriers to these proposals relate to the availability of manufacturer integrated systems with capability to deliver the indicated level of benefit, and with ADR compliance.

By displacing the majority of petrol and diesel it may be anticipated that the GGE reduction would be in the order of 10% for life cycle GGE, and it has been previously suggested that a reduction in the order of 26 ~ 37% may be required to support Kyoto commitments. Therefore complementary measures are required, and for fuels the increased used of renewables is indicated<sup>51</sup>. Barriers to renewables relate to feasibility of large scale production and roll-out of infrastructure.

The potential to use grid electricity for “plug-in” vehicles may be regarded with some caution in light of the life cycle EF. The relative GGE outcome of such vehicles will be highly dependent on relative vehicle efficiencies, and the potential to reduce life cycle EF for grid electricity. Informed choices will require the development of further data.

In this area, policy makers may wish to consider:

- Periodic review of fuel Emission Factors,
- Fossil fuel supply side EF improvement potential,
- Roadmaps for renewable and bio-fuels,
- Scenarios for medium and long term energy supply, with projections for fuel Emission Factors.
- Scenarios for infrastructure deployment

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<sup>51</sup> Discussions surrounding energy strategy should refer also to Australia’s energy independence and balance of trade.