2. Modelling Emission Standards and Driving Conditions

2.1 Modelling the Influence of Future Emission Standards

2.1.1 Introduction

The terms of reference require an examination of the fuels to determine whether each fuel is likely to meet future Australian Design Rules for vehicular emissions. This point has been examined for each fuel in Parts 1 and 2 but is explored in more technical detail in this chapter.

An approximate method for including the effect of future emission standards was developed for the technical study on fuels technology related to the Auto Oil 2 Program. The final report by Arcoumanis (2000) was released in December 2000 by the EC's Directorate-General for Energy. This was a survey of best available information on emissions and energy efficiency for a more limited range of fuels than are considered here. It introduced the concept of emission factors related to a base of Euro2, the same base that has been followed in this work where possible. The emission factors are developed from consideration of a range of influences of alternative fuels on combustion and other engine characteristics.

2.1.2 Methods

In this project an attempt is made to estimate future emission factors by considering the changes that may occur in the near future that could influence engine and vehicle technology, and the interaction of this with the fuel. For each regulated pollutant, CO, HC, NOx, PM and for CO_2 factors have been estimated, and then these are multiplied by the ratio of the new emission standard to Euro2 for each of the regulated pollutants. For CO_2, since there are no regulated emissions standards in place at this time, the Euro3/Euro2 and Euro4/Euro2 factors were considered as unity.

No allowance has been made for the different implementation times of the Euro standards in Australia to Europe. The time lags have been regarded as technology transfer times. However, experience with emission control equipment has indicated that the lags often allow the Australian implementation of more mature technology which might be expected to improve the emission factors. Here these benefits are assumed to be the same for the low sulfur diesel reference fuel and the alternative fuel technology.

The implication in the methodology is that in the absence of any special problems or benefits the reduction in alternative fuel performance will be similar to the reduction for a given pollutant as expected from the change in the emission standards.

Engine parameters that have an effect on exhaust emissions have been divided into the following groups (Arcoumanis, 2000):

1. Engine breathing - this determines the amount of mixture/air entering the cylinders and participating in combustion which controls the mass of exhaust pollutants.
2. Mixture preparation - which influences the local fuel air ratio in the engine and has influence on pollutant formation and emissions exiting from the exhaust.
3. Combustion - this influences the formation of pollutants in the cylinder as a function of the local thermodynamic conditions.
4. Exhaust after treatment - this determines the percentage of formed pollutants escaping in the atmosphere.
5. Engine/fuel compatibility - which determines the degree of positive or negative interaction of the given of alternative fuel with components of the fuel injection system.

6. Engine deterioration in use - this depends on the maintenance standards and the state of the engines exhaust emissions and any variation with time that may vary from the standard low sulfur diesel fuel.

It is important to note that the multiplying parameter n_{total} is a product of parameters just described. Thus for a fuel where the n_{total} coefficient is 0.8, this value would express that this particular alternative fuel has some advantage compared with the low sulfur diesel reference fuel. Conversely, a coefficient of 1.5 would indicate a major difficulty with respect to the pollutants being considered. The parameter EF given the following tables thus represents the final merit of an alternative fuel including the expected reduction factor of the changed emission standards. In order to make this clear the first table presented shows the Euro factors being the ratio of Euro4 to Euro2.

In summary the following equation forms the basis for the model

$$\mathbf{EF_{Euro3/4} = EF_{Euro2} \bullet n_{total} (R_{Euro3/4} / R_{Euro2})} \qquad (1)$$

where

$n_{total} = n_{br.}\, n_{mp.}\, n_{cmb.}\, n_{ea.}\, n_{fc}$

and

n_{br} = engine breathing coefficient

n_{mp} = mixture preparation coefficient

n_{cmb} = combustion coefficient

n_{ea} = exhaust after-treatment coefficient

n_{fc} = fuel/engine compatibility coefficient

$R_{Euro\ 3/4}$= regulated emission limit for a particular pollutant for Euro3/4 (in Europe in 2000/5 and Australia in 2005/8)

R_{Euro2} = regulated emission limit for a particular pollutant in 2002 (Euro2)

2.1.3 Emission factors for Euro3 and Euro4

Most of the coefficients in Equation 2.1, for the fuels given in Tables 2.1 –2.7, have values taken from the Auto-Oil II program (Arcoumanis, 2000). Where necessary, errors or inconsistencies in that work have been rectified. For some tables new factors have been generated based on the team’s knowledge and this review of the literature.

The tables which follow are restricted to Factors for Heavy Duty Vehicles and Buses. Only the last table refers to PULP plus E10 for passenger cars and Light Duty Vehicles.

2.1.4 Concluding remarks

This section has evaluated, through the process used in the Auto Oil II program, the prospects and difficulties that alternative fuels may suffer as a consequence of tightening emissions standards through Euro3 and Euro4 from a base of Euro2. These results have been tabulated and presented in each Chapter of Part 2 under the heading “Expected Future Emissions”.

Most fuels (including BD30) continue their relative advantages during the period of these tighter emission standards. The apparent exceptions are 100% biodiesel (PM > Euro3, NOx > Euro3 and Euro4), ethanol (THC > Euro3 and Euro4) and possibly diesohol.

Table 2.1
Future emission factors for heavy duty vehicles and buses for CNG/LNG

Technology		CO		THC		NOx		PM		Vehicle CO_2	
Euro 2 EF		**0.3**		**0.9**		**0.2**		**0.1**		**1.0**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	0.9	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	0.9	0.60	1.1	0.71	0.9	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.2	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	0.972	1.0	1.1	1.0	0.9	1.0	1
Euro 3 EF			**0.16**		**0.52**		**0.16**		**0.06**		**1.00**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.1	0.50	1.0	0.13	1.1	1
	n_{ea}	1.1	n_{total}	1.1	n_{total}	0.9	n_{total}	0.9	n_{total}	1.0	n_{total}
	n_{fc}	1.1	1.21	1.1	1.21	1.0	0.99	0.9	0.81	0.9	0.99
Euro 4 EF			**0.14**		**0.46**		**0.10**		**0.01**		**0.99**

Source: Arcoumanis(2000)

Table 2.2
Future emission factors for heavy duty vehicles and buses for LPG

Technology		**CO**		**THC**		**NOx**		**PM**		**Vehicle CO_2**	
Euro 2 EF		**0.4**		**0.5**		**0.3**		**0.3**		**1.1**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	0.9	0.71	1.0	0.67	0.9	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.1	1.1	1.0	0.9	1.0	1	1.0	0.9
Euro 3 EF			**0.21**		**0.33**		**0.19**		**0.20**		**0.99**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.0	0.50	1.0	0.13	0.9	1
	n_{ea}	1.0	n_{total}	0.9	n_{total}	1.1	n_{total}	0.9	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	0.90	1.0	1.10	0.9	0.81	1.0	0.9
Euro 4 EF			**0.15**		**0.19**		**0.17**		**0.03**		**0.99**

Table 2.3
Future emission factors for heavy duty vehicles and buses for 100% biodiesel

Technology		**CO**		**THC**		**NOx**		**PM**		**Vehicle CO_2**	
Euro 2 EF		**0.8**		**0.7**		**1.0**		**1.0**		**1.0**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	1.1	0.71	0.9	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.1	1.1	1.1	1.21	1.1	0.99	1.0	1
Euro 3 EF			**0.42**		**0.46**		**0.86**		**0.66**		**1.00**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.1	0.50	0.9	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1.1	1.0	0.9	1.0	1
Euro 4 EF			**0.30**		**0.29**		**0.55**		**0.12**		**1.00**

Table 2.4
Future emission factors for heavy duty vehicles and buses for diesohol

Technology		CO		THC		NOx		PM		Vehicle CO_2	
Euro 2 EF		**1.1**		**1.1**		**0.8**		**0.6**		**0.4**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	1.0	0.71	1.0	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 3 EF			**0.58**		**0.66**		**0.57**		**0.40**		**0.40**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.0	0.50	1.0	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 4 EF			**0.41**		**0.46**		**0.40**		**0.08**		**0.40**

Table 2.5
Future emission factors for heavy duty vehicles and buses for E85

Technology		**CO**		**THC**		**NOx**		**PM**		**Vehicle CO_2**	
Euro 2 EF		**1.1**		**1.1**		**0.8**		**0.6**		**0.4**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	1.0	0.71	1.0	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 3 EF			**0.58**		**0.66**		**0.57**		**0.40**		**0.40**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.0	0.50	1.0	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 4 EF			**0.41**		**0.46**		**0.40**		**0.08**		**0.40**

Table 2.6
Future emission factors for heavy duty vehicles and buses for hydrogen (Combustion Engine)*

Technology		CO		THC		NOx		PM		Vehicle CO_2	
Euro 2 EF		**0.05**		**0.02**		**0.2**		**0.01**		**0.01**	
Euro 3	n_{br}	0.9		0.9		0.9		0.9		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	0.9	0.53	0.9	0.60	1.1	0.71	0.2	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	0.765	1.0	0.765	1.0	0.935	1.0	0.17	1.0	1
Euro 3 EF			**0.02**		**0.01**		**0.13**		**0.00**		**0.01**
Euro 4	n_{br}	0.9		0.9		0.9		0.9		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.1	0.50	0.2	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	0.85	1.0	0.85	1.0	0.935	1.0	0.17	1.0	1
Euro 4 EF			**0.02**		**0.01**		**0.09**		**0.00**		**0.01**

* Fuel Cell vehicles assumed to emit only water vapour.

Table 2.7
Future emission factors for passenger cars and light duty vehicles for PULP

Technology		CO		THC		NOx		PM		Vehicle CO_2	
Euro 2 EF		**0.4**		**0.4**		**0.4**		**0.4**		**0.4**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	1.0	0.71	1.0	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 3 EF			**0.21**		**0.24**		**0.29**		**0.27**		**0.40**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.0	0.50	1.0	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1
Euro 4 EF			**0.15**		**0.17**		**0.20**		**0.05**		**0.40**

Table 2.8
Future emission factors for passenger cars and light duty vehicles for E10PULP

Technology		CO		THC		NOx		PM		Vehicle CO_2	
Euro 2 EF		**1.1**		**1.1**		**0.8**		**0.5**		**1.0**	
Euro 3	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.1	R_3/R_2	1.1	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2	1.0	R_3/R_2
	n_{cmb}	1.0	0.53	1.0	0.60	1.0	0.71	1.0	0.67	1.0	1
	n_{ea}	1.0	n_{total}	1.1	n_{total}	1.1	n_{total}	1.0	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1.1	1.0	1.21	1.0	1.1	1.0	1	1.0	1
Euro 3 EF			**0.64**		**0.80**		**0.63**		**0.33**		**1.00**
Euro 4	n_{br}	1.0		1.0		1.0		1.0		1.0	
	n_{mp}	1.1	R_4/R_2	1.1	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2	1.0	R_4/R_2
	n_{cmb}	1.0	0.38	1.0	0.42	1.0	0.50	1.0	0.13	1.0	1
	n_{ea}	1.0	n_{total}	1.1	n_{total}	1.1	n_{total}	0.9	n_{total}	1.0	n_{total}
	n_{fc}	1.0	1.1	1.0	1.21	1.0	1.1	1.0	0.9	1.0	1
Euro 4 EF			**0.45**		**0.56**		**0.44**		**0.06**		**1.00**

2.2 Modelling the Influence of Driving Conditions.

2.2.1 Introduction

The terms of reference require an examination of the fuels to determine approaches that would enable the downstream emissions from fuel and technology combinations to be approximated without conducting a large scale tailpipe emissions testing program.

This section of the chapter provides an initial appreciation of the effect of a range of urban and rural driving conditions on the greenhouse gas emissions of selected fuels. All of the results in the comparison of emissions with the base line diesel fuel have been made using data from the Euro 2 test schedule for vehicles or engines. The weighting applied to the 13 modes of this engine test schedule is somewhat arbitrary, reflecting a simplistic allocation of engine load and speed. The reference vehicles are a conventional diesel engined, standard 59 seat bus and a 45 tonne articulated truck..

2.2.2 Modelling methodology

The model used for the analysis is a deterministic one, of the engine mapping type. The computer program, MEEDAM (Model for Emissions and Energy Dissipation for Analysis of Missions) is a derivative of the main-frame models first used in late 1980's (Khatib and Watson, 1986) and developed for the SAE-A, as a commercial package, to allow operators when purchasing new trucks to be informed on the relative fuel efficiency of variants available from the manufacturer.

Central to the model are measured maps of engine performance, which describe an engine's emission or fuel rate use over the usable range of torque (positive and negative) and engine speed. The engine maps comprise emission rates of hydrocarbons, oxides of nitrogen, carbon monoxide or particulates and fuel rate for energy consumption simulation. Here, only steady state maps are employed, although when available maps in speed and torque time-derivative domains may be included. In comparative (sensitivity) analyses this limitation is not as important as in the calculation of absolute values of fuel consumption and CO_2 emissions. In any event, at the end of a period of ten or more minutes driving, the net contribution of the transient fuel supply is quite small, perhaps 3% of the total (Trayford and Watson, 1999).

An outline of the model is presented in Figure 2.1. At a given vehicle speed and acceleration the first step is the calculation of the instantaneous wheel torque and the selected gear ratio. The wheel torque is calculated from the rolling resistance, aerodynamic drag, inertial forces (linear and rotating). The transmission losses and engine auxiliaries' torque are added to the wheel derived torque to define the instantaneous engine speed and torque and thus the fuel rate is calculated from the map

Gear selection to simulate a manual transmission is made by an algorithm that uses shift points as a function of vehicle speed and acceleration.

For an automatic transmission the gear ratio selected is a function of engine speed and torque ratio to allow for torque converter slip, the coefficients for which came from an analysis of bus four speed automatic performance.

The final drive efficiency is a function of rotational speed and torque transmitted. More details of example applications are to be found in references Watson and Alimoradian (1989) and Watson (1995).

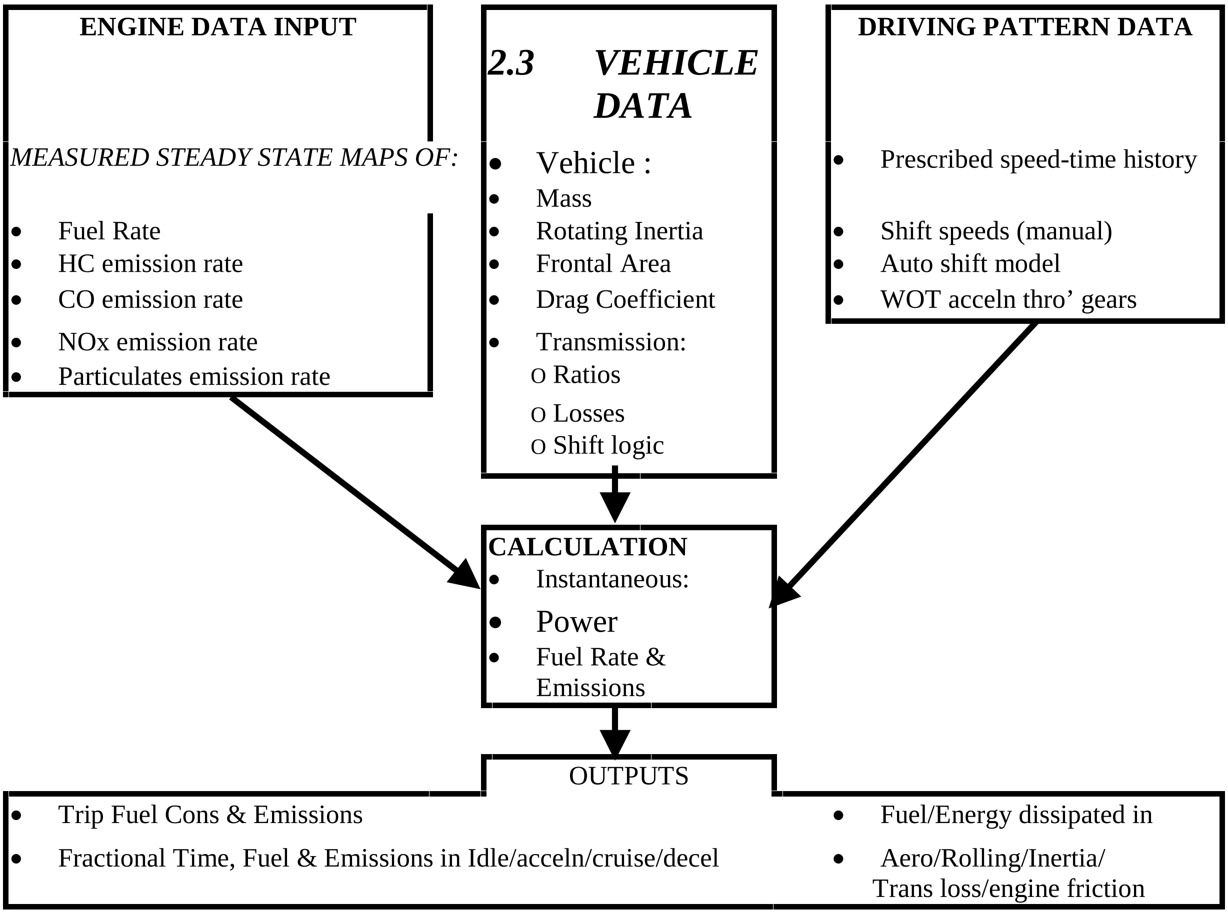


Figure 2.1
Model inputs and outputs

The model includes allowance for road gradient and wind speed and direction. Both of these effects have considerably more effect on trucks and buses than is found in passenger cars, because of their relatively poor power in proportion to size and weight.

Two examples follow to illustrate the effect of the change in liquid fuel composition and the change of fuelling system (liquid to gas).

2.2.3 Results of changed fuel - diesohol example

The test results in this section refer to earlier diesohol trials and are used for illustrative purposes only. Current emissions data for diesohol is provided in Parts 1 and 2.

The data for this comparison were obtained from the NSW EPA for the diesohol bus trial, which was conducted in 1993/4. The buses used in the test and simulated in the model were Renault/Mack buses operated by Action Buses in Canberra. The thirteen mode Euro 2 test was modified slightly by the EPA to produce the database, which nonetheless allowed the development of the relevant engine maps for modelling.

Figure 2.2 shows the CO_2 emissions rate for the bus No. 977 operated on diesohol fuel compared with diesel for a range of established test cycles. The average speed of these cycles forms the base of the graph. The cycles include the fuel consumption cycle AS2877 City and AS2877 Highway normally used for car and light commercial vehicles testing. However, experience has shown that buses can also perform satisfactory on these cycles. Also included are an urban truck and a highway truck cycle based on measurements made in Sydney and Melbourne and the interstate highways between Brisbane, Sydney and Melbourne in the period 1986/7. (Khatib 1987).

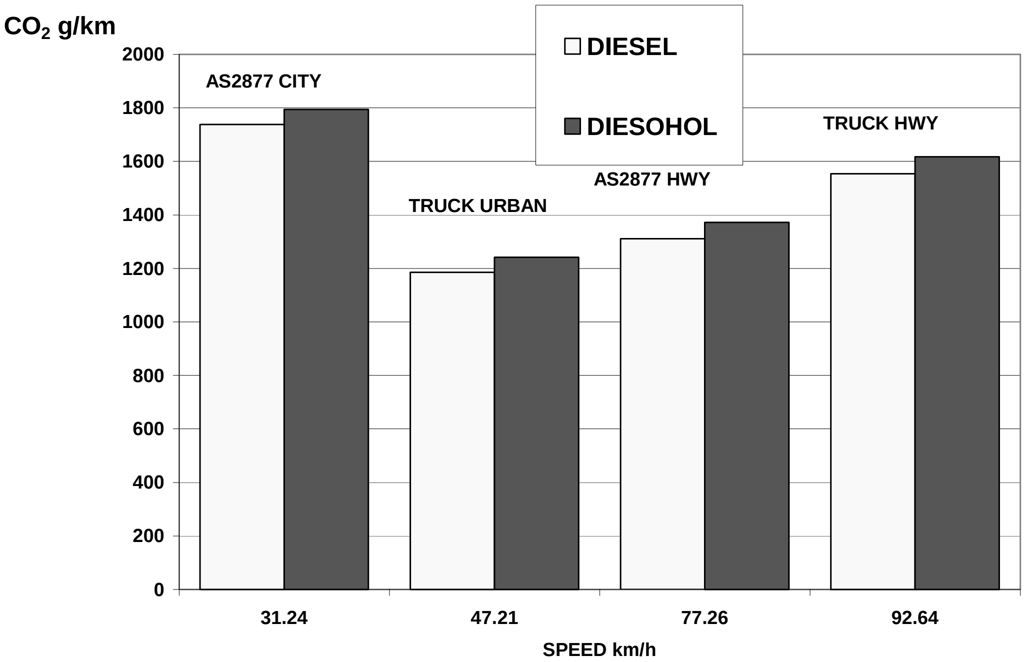


Figure 2.2
Variation in CO_2 emissions for the simulated bus over AS2877 and truck cycles for diesohol and reference diesel fuel

In Figure 2.3 a similar set of values are presented on the basis of driving as measured recently as part of the Diesel NEPM developed two years ago NEPC (1997). These cycles are disaggregated into congested, residential, arterial and highway driving. All were based on driving in Sydney.

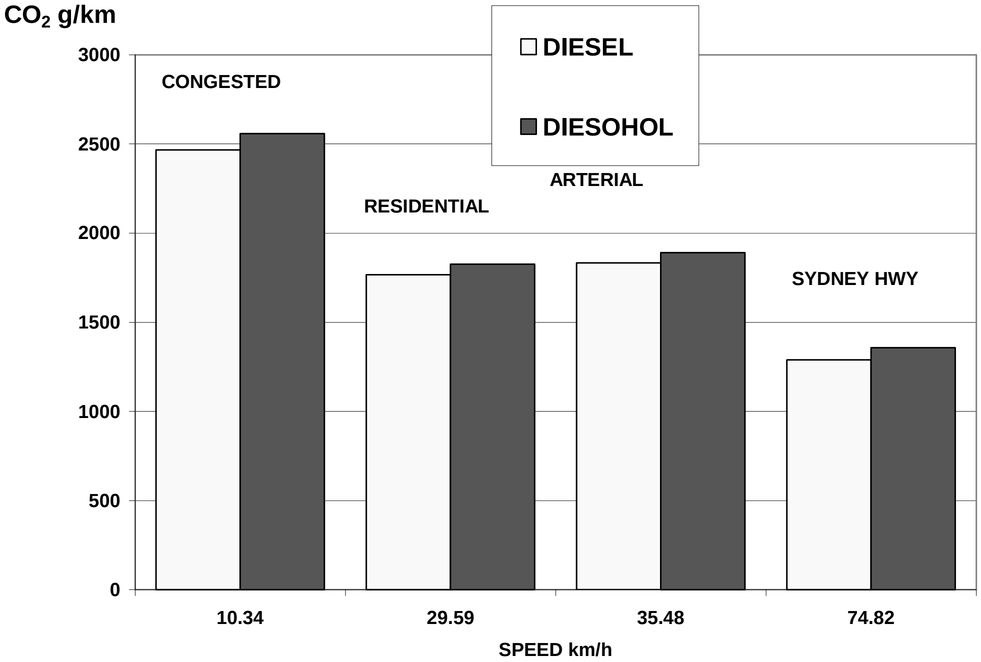


Figure 2.3
Variation in CO_2 emissions for the simulated bus over CUEDC developed as part of the diesel NEPM

It can be seen in each of the figures under all conditions that the diesohol bus has slightly higher CO_2 emissions than the diesel reference bus.

These sample results are now expressed as a ratio in Figure 2.4 - the ratio of the CO_2 emissions in the diesohol mode is compared with the CO_2 emissions in the diesel mode. It can be observed that the ratio varies between 1.031 to 1.053 with an average value of 1.038. The average value for the weighted Euro 2 cycle was 1.034.

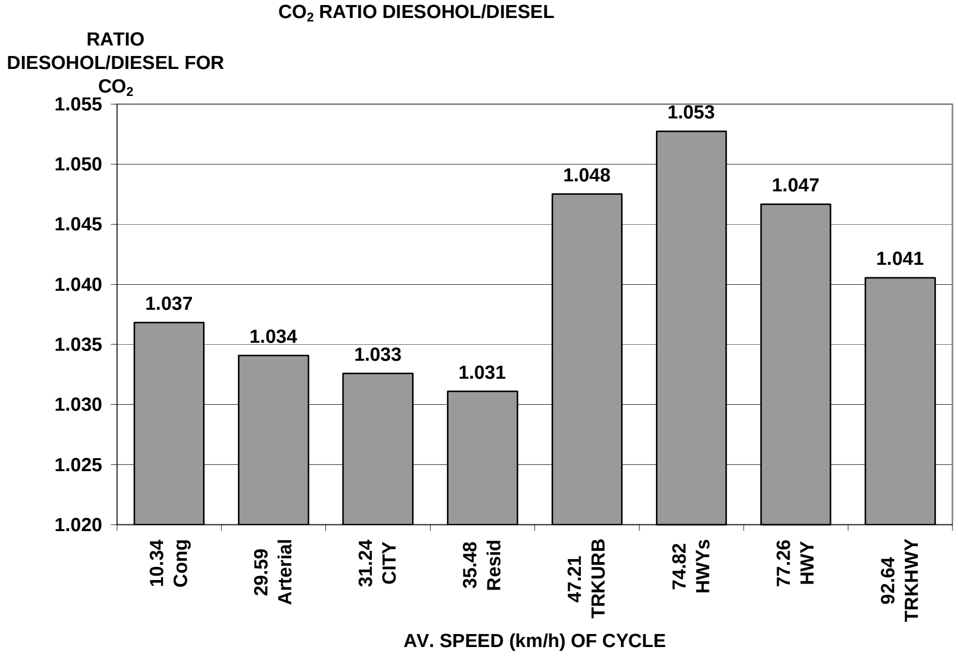


Figure 2.4
Ratios in CO_2 emissions for diesohol compared with diesel fuel the simulated bus over the eight cycles

It may be thought that the variation in CO_2 emissions with driving is very small. However, it should be recalled that diesohol comprises only 15% which replaces only about 9% of diesel fuel energy. Thus, with a 9% replacement in energy a 2% variation in CO_2 emissions is nearly 25% variation in the replaced CO_2.

Similar ratios are plotted for NOx and smoke emissions in figures 2.5 and 2.6 respectively. There is a general trend for these to be lower in the urban conditions and higher in highway driving. Overall there is a slight increase in NOx and a small reduction in exhaust smoke and therefore particulates.

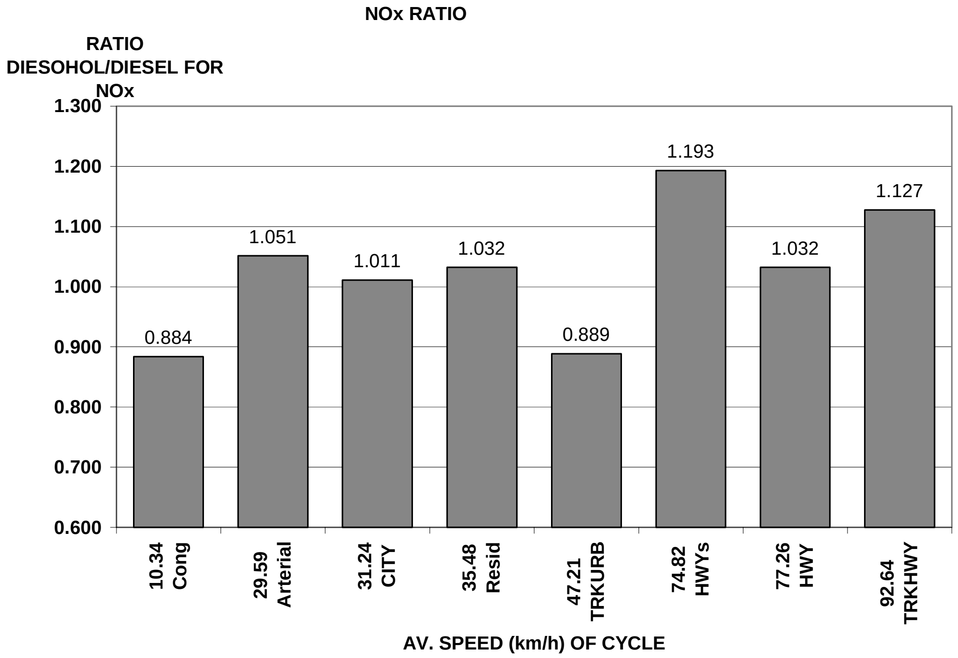


Figure 2.5
Ratios in NOx emissions for diesohol compared with diesel fuel the simulated bus over the eight cycles

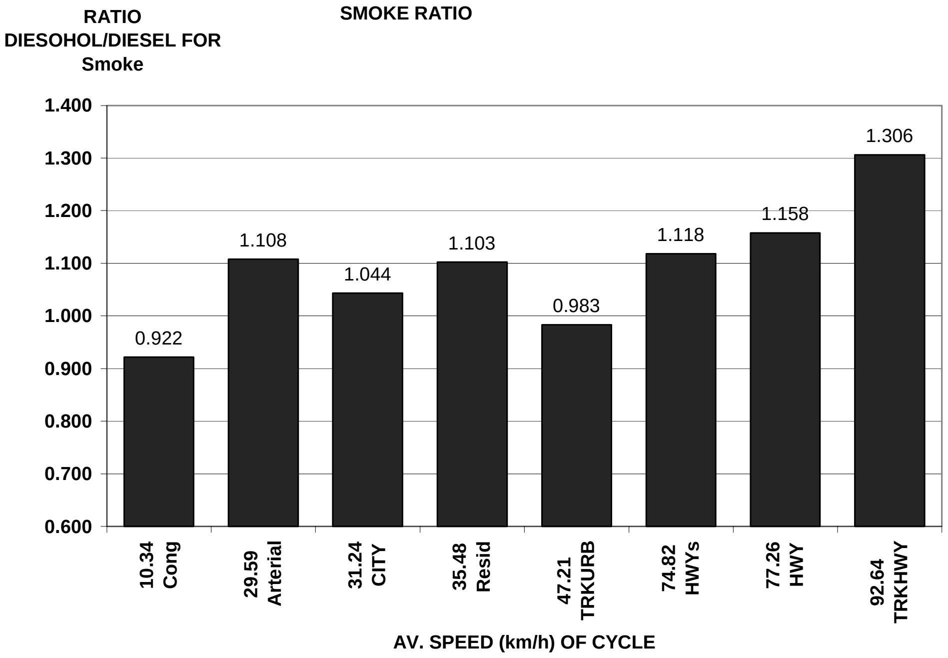


Figure 2.6
Ratios in Smoke emissions for diesohol compared with diesel fuel the simulated bus over the eight cycles

2.2.4 *Results for changed fuel supply system, example - dual fuel CNG*

This simulation is for an articulated truck with a minimum GVM of 15 tonnes and a maximum of 45 tonnes. It is powered by a 450HP engine sourced from the US and drives through a 12 speed transmission and dual axle drive.

As no Euro 13 mode data was available in the open literature for a spark ignited CNG vs diesel comparison, the simulation was performed for a dual fuel engine with 65% CNG substitution of gas for diesel over the 13 mode test schedule with the standard's weighting factors.

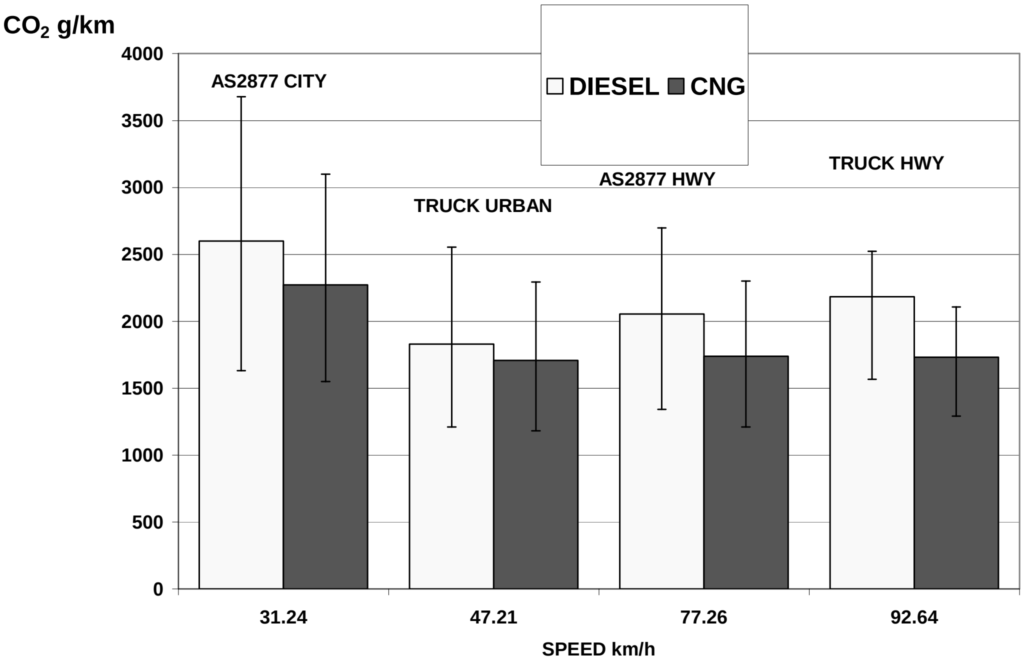


Figure 2.7
Variation in CO_2 emissions for the simulated truck over AS2877 and truck cycles for dual fuel CNG and reference diesel fuel

The bars are for 30 tonnes half-laden condition. The error bars show the 45 tonne and 15 tonne conditions.

The results in Figure 2.7 show CO_2 emissions for the simulated truck over AS2877 and truck cycles for the dual fuel CNG and LSD diesel fuel. The major bars are for 30 tonnes half laden condition, whilst the error bars show the 45 tonne fully laden and 15 tonne unladen conditions. It is noticeable that there is a significant variation of emission with load condition and relatively small variation with speed except for the aggressive-for-a-truck car city cycle. Indeed in the unladen condition the reduction in CO_2 is 7% compared with 18% under full load. This trend is expected as the CNG substitution tends to increase in proportion to the power output.

Similar conclusions may be drawn for the CUEDC cycles in Figure 2.8

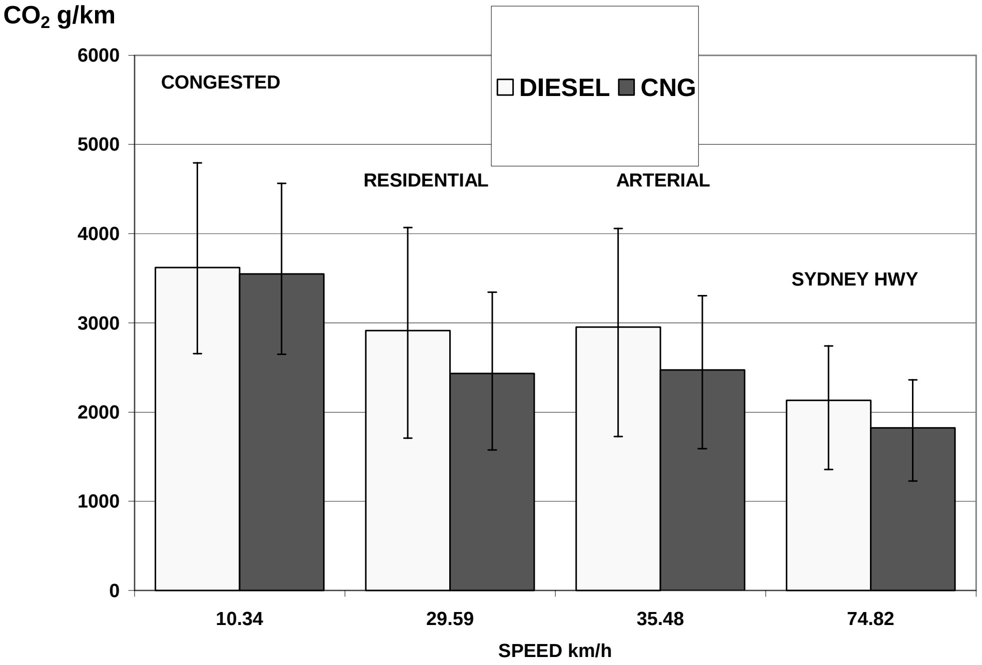


Figure 2.8
Variation in CO2 emissions for the simulated truck over CUEDC developed as part of the diesel NEPM. for dual fuel CNG and reference diesel fuel

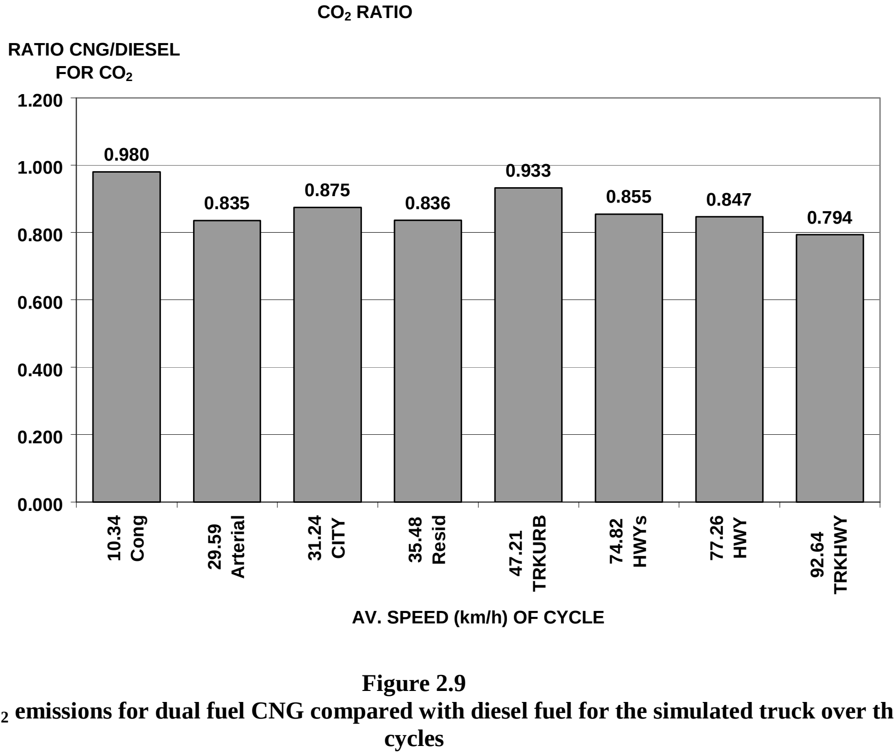
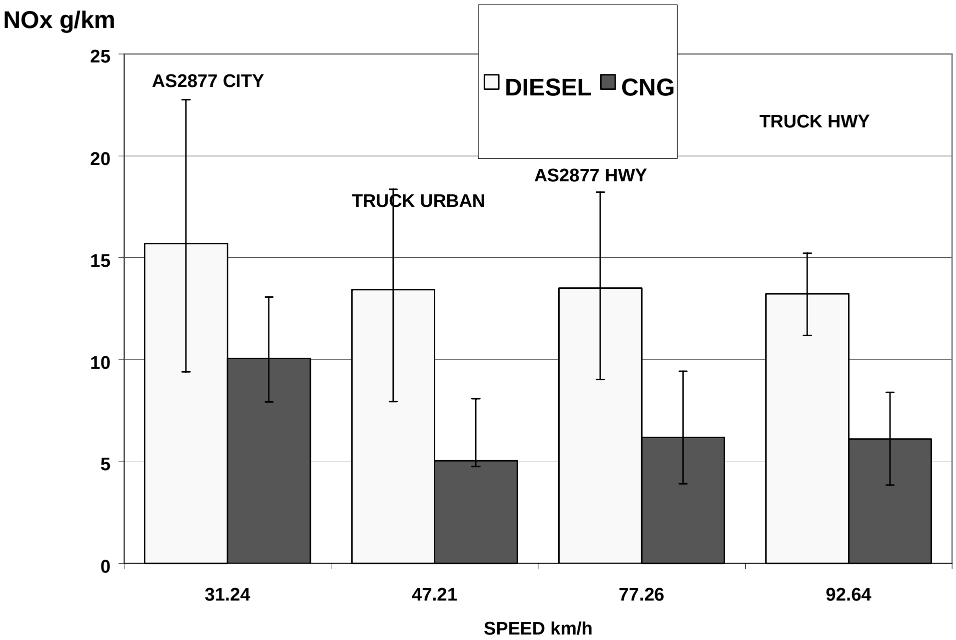


Figure 2.9
Ratios in CO_2 emissions for dual fuel CNG compared with diesel fuel for the simulated truck over the eight cycles

The bars are for 30 tonnes half laden condition. The error bars show the 45 tonne and 15 tonne conditions.

Figure 2.9 shows ratios in CO_2 emissions for dual fuel CNG/diesel fuel for the simulated truck over the eight cycles for a vehicle mass of 30 tonnes. The reduction in combustion CO_2 is about 16% on average.

Figure 2.10



Variation in NOx emissions for the simulated truck over AS2877 and truck cycles for dual fuel CNG and reference diesel fuel

The bars are for 30 tonnes half laden condition. The error bars show the 45 tonne and 15 tonne conditions.

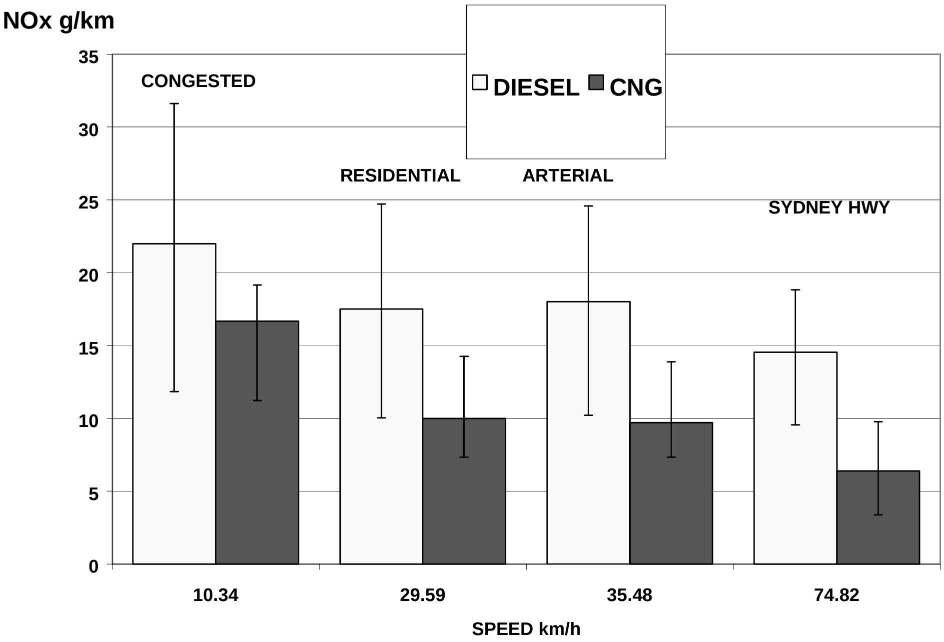


Figure 2.11
Variation in CO_2 emissions for the simulated truck over CUEDC developed as part of the diesel NEPM. for dual fuel CNG and reference diesel fuel.

The bars are for 30 tonnes half laden condition. The error bars show the 45 tonne and 15 tonne conditions.

The NOx emissions in Figures 2.10 and 2.11 demonstrate more pronounced reductions in NOx emissions with increased vehicle mass with reductions in excess of 40% under the fully laden condition. The ratios of CNG dual fuel to diesel at the 30 tonne mass condition are shown in Figure 2.12 where the trend for reducing NOx with increasing speed is evident. This of course means that the NOx emission benefit is not so great where it matters most in urban areas.

Unfortunately the data on CNG dual fuel did not cover particulate emissions.

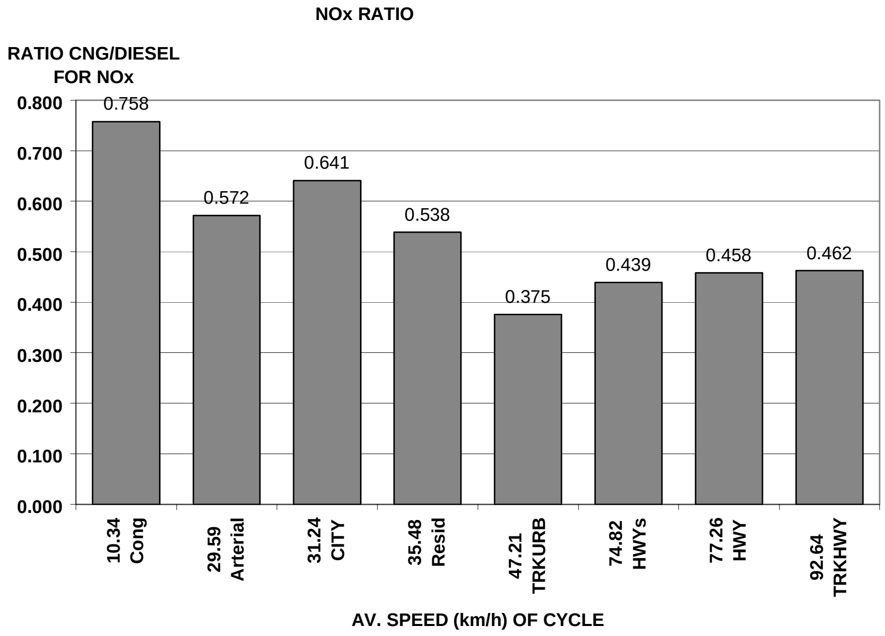


Figure 2.12
Ratios in NOx emissions for dual fuel CNG compared with diesel fuel for the simulated truck over the eight cycles

2.2.5 Conclusions

In this section we have examined two examples of alternative fuels application to heavy-duty vehicles, a bus and a truck. In the first example the impact of a change fuel composition (to dieshol) which showed that the CO_2 emissions might increase somewhat more in real world driving from the expected increase in the Euro 2 steady state test. However the increase is small, and other tests have shown an opposite trend,

In contrast the example of a changed fuel application of CNG to a large truck the real world CO_2 emissions were somewhat better than expected from the Euro 2 base.

Whilst this has only been a limited illustration of the available methodology for modelling these changes, the method does provide a workable basis for the estimation of emissions from alternative fuel vehicles in a range of driving circumstances which include interstate highway and urban situations including congested and free driving conditions. This information should be useful for those involved in undertaking analysis of transport emission sources or CO_2 emissions inventories.

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