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6. VEHICLE AIR EMISSIONS

This chapter presents a motor vehicle air emissions inventory for each state/territory capital for the scenario years 2000, 2005, 2010 and 2020. The assumption of '*business as usual*'' (BAU) trends in VKT growth and transport policy forms the basis of the assessment.

Vehicle emissions estimates for each of the six project scenarios were derived from a consideration of current/future emission standards, fleet composition and fuel quality effects.

The structure of this chapter is as follows:

Section 6.1 presents the general approach to emissions estimation and nominates the pollutants inventoried. Section 6.2 discusses the characteristics of the Australian motor vehicle fleet including the distribution of vehicle categories (passenger vehicles, light commercial vehicles, rigid trucks etc), vehicle usage, the age structure of the fleet, fuel usage profiles (petrol, diesel, LPG and CNG) and fuel consumption performance. Section 6.3 sets out the influence of fuel composition on emissions. Section 6.4 discusses the effect of petrol volatility on evaporative and tail pipe emissions. Section 6.5 describes the treatment of air toxics including benzene. Sections 6.6 to 6.11 present an assessment of emissions for each of the six scenarios modelled. Section 6.12 summarises the results of emissions projections and presents plots of the projected emissions for Australian capital cities combined to illustrate the changes associated with the various scenarios over time.

6.1 General Methodology

Exhaust and evaporative emissions from motor vehicles are documented to vary according to a wide range of factors. These include vehicle type, vehicle age, fuel type, traffic flow conditions, temperature and fuel composition.

Emission factors for motor vehicle fleets in each capital city were estimated using a vehicle kilometres travelled (VKT) based methodology developed as part of previous inventory studies for urban airsheds in Australia (Carnovale et al, 1996; Coffey, 1995). Diesel vehicle emission factors have been based on emission information compiled by the Environment Protection Authority of NSW (EPANSW), Dr John Cox and the Apelbaum Consulting Group (ACG) as part of the recently published study of the Australian diesel fleet, undertaken on behalf of the National Environment Protection Council (NEPC; Cox and ACG, 1999).

The suite of pollutants inventoried consisted of common air pollutants and a number of air toxics as follows:

- Total Hydrocarbons (HC);
- Carbon monoxide (CO);
- Oxides of nitrogen (NO_x);

- Sulfur dioxide (SO_2);
- Particulate matter, smaller than 10 micron and 2.5 micron respectively (PM_{10} and $PM_{2.5}$);
- Lead;
- Acetaldehyde;
- Benzene;
- 1,3-Butadiene;
- Formaldehyde;
- Polyaromatic hydrocarbons (PAH).

The general methodology adopted for calculating annual emissions involves multiplying an activity related parameter by an emission factor for each substance of concern. The methodology can be expressed as follows:

$$E\ (kg/yr)_p = (VKT \times EF_p)/1000$$

where $E\ (kg/yr)_p$ is the annual emission of substance *p* in kilograms;

VKT is the annual Vehicle Kilometres Travelled by the vehicle fleet in the study area;

EF_p is the annual fleet emission rate for substance *p* in grams/km.

Emission rates for heavy duty diesel vehicles (rigid/non-freight carrying trucks, articulated trucks and buses) have been considered explicitly in this study. Previous inventory studies in Australia have aggregated these vehicle categories into a single category for emissions estimation.

6.1.1 Greenhouse Emissions

National emissions of greenhouse gases were assessed for vehicles. In addition, the changes to greenhouse emissions from refineries were assessed with respect to the base case (Scenario 1).

Vehicle greenhouse emissions of carbon dioxide (CO_2) were obtained from projections of fuel usage using the methodologies set out in the *Workbook for Transport (Mobile Sources) - Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks* – (National Greenhouse Gas Inventory Committee, 1996). In addition to CO_2, Australian greenhouse gas inventories for transport sources include estimates of emissions of methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane hydrocarbons (NMVOC) and sulfur dioxide (SO_2). With the exception of CH_4 and N_2O, these emissions were assessed for each scenario. Methane emissions were taken as a proportion (5%) of NMVOC emissions and N_2O emissions were taken as a proportion (3%) of NO_x emissions, based on the ratios that have been obtained in the Australian greenhouse gas inventories for the years 1990 to 1997.

AQIRP studies (see Table 3-3 in Section 3.3.1) report that changes in fuel economy for petrol vehicles are affected by changes in concentrations of aromatics, oxygenates and olefins. Based on these sensitivities improvements in fuel economy of 1 to 2% would accompany a change in petrol quality from the existing average Australian petrol composition to that called for in the Euro-3 and Euro-4 fuel specifications. The influence of the aromatic content of petrol on fuel consumption identified by EPFEE (1995) was attributed to changes in carbon content of the fuel.

Greenhouse emissions from refineries were assessed based on the additional energy consumption that would be required by the refineries for the production of fuel for the proposed fuel quality scenarios. The increase in energy demand was compared with the base case (Scenario 1). The refineries provided estimates of the additional energy consumption (fuel and electricity) required to deliver Euro-3 and Euro-4 petrol and diesel and these estimates were used to obtain increase in carbon dioxide emissions for each scenario compared with Scenario 1. Refining companies have advised that fugitive emissions would not increase materially due to implementation of fuel quality changes so that the greenhouse impacts at the refineries would be limited to those associated with energy consumption and hydrogen production.

The greenhouse emissions for transport and petroleum refining for the period 1990 to 1997 reported by the National Greenhouse Gas Inventory Committee are summarised below:

TABLE 6-1: TRANSPORT AND REFINERY GREENHOUSE EMISSIONS 1990 to 1997

	Australian Greenhouse Gas Emission (Gg)						
Year	CO	CO_2	N_2O	NO_x	CO	NMVOC	SO_2
	Transport Emissions						
1990	52766	25.2	5.0	371.3	4901.6	620.1	
1991	51749	23.7	5.7	350.2	4342.9	567.7	
1992	52615	21.9	6.9	328.4	3840.0	523.4	
1993	43805	21.5	7.8	329.8	3667.9	506.2	
1994	55168	20.7	8.7	316.3	3241.2	477.6	
1995	56907	20.5	9.6	316.4	3103.4	464.6	
1996	58500	19.6	10.3	304.9	2822.2	435.0	36.8
1997	59886	20.7	11.1	363.2	2471.7	417.9	38.6
	Petroleum Refining Emissions						
1990	5769	0.1	0.1	33.6	4.5	0.1	
1991	5991	0.1	0.1	34.5	4.7	0.1	
1992	5980	0.1	0.1	34.1	4.6	0.1	
1993	6318	0.1	0.1	36.1	4.9	0.1	
1994	6291	0.1	0.1	35.4	4.8	0.1	
1995	6825	0.1	0.1	37.5	5.2	0.1	
1996	7107	0.12	0.06	37.8	5.1	0.09	27.8
1997	6392	0.10	0.05	41.8	5.5	0.08	27.8

6.2 Fleet Characteristics

The Australian motor vehicle fleet has been characterised in terms of vehicle activity levels, expressed as Vehicle Kilometres Travelled (VKT). This approach is adopted to account for differences in usage between vehicle categories and vehicle vintages.

The fleet composition forms part of the input for subsequent emissions inventory development for the base case emissions scenario and the scenarios describing the agreed fuel formulation options. As the emissions inventories are developed for each state capital, the fleet profiles presented in this report relate to metropolitan travel within each state. National VKT estimates which are used to assess greenhouse gas emissions and national fuel demand estimation, involved factoring of the state level fleet profiles to estimate national fleet activity.

6.2.1 Vehicle Stock

The motor vehicle fleet has been assessed in terms of the following vehicle categories:

- passenger vehicles;
- light commercial vehicles;
- rigid trucks;
- articulated trucks;
- buses;
- motor cycles.

Current registration data is available from State and Territory transport departments and ABS (Motor Vehicle Census). Projected registration information is not available from these authorities, however, projections of total vehicle stock estimates are available from a number of sources.

For example, recent modelling work undertaken by Bureau of Transport Economics (BTE, 1995) assumed that the size of the passenger vehicle fleet would grow by 1.6% between 1995 and 2000. Urban bus fleet activity was assumed to grow in line with the population. Road freight transport varies with economic activity, although increases in carrying capacity of freight vehicle means that the road freight task is growing ahead of the number of freight-carrying vehicles.

6.2.2 Vehicle Kilometres Travelled

A survey of state transport departments was undertaken to investigate the availability of projected VKT data for metropolitan centres:

VIC – the Department of Infrastructure (DOI) has recently produced VKT estimates for use in the Melbourne air emissions inventory update on behalf of EPA Victoria. Projected VKT data are not available;

NSW - VKT modelling has been undertaken by the Transport Data Centre (TDC) for an area equivalent to the Metropolitan Air Quality Study (MAQS) region. Projections have been made to 2021 and VKT indices are published in “Action for Transport 2010” (Department of Transport, 1996) and “Action for Air – The NSW Government’s 25 year AQMP” (EPANSW, 1998). Detailed VKT data were not available for this study;

QLD - VKT modelling was recently completed as part of the South East Queensland Regional Air Quality Scheme (SEQRAQS) by Adam Pekol Consulting and Sinclair Knight Merz (1998). Projections of VKT were made to 2020;

WA – VKT estimates were prepared by Main Roads WA as part of the Perth Photochemical Smog Study (PPSS, 1995) and include projections to 2021;

NT – VKT estimates are not available from local transport departments;

SA – VKT estimates are not available from local transport departments;

TAS – VKT data are not available from local transport departments;

ACT - VKT data are not available from local transport departments;

The Apelbaum Consulting Group (ACG) has undertaken work on VKT on behalf of the Department of Industry, Science and Resources (DISR, 1995). The publication contains estimates of VKT on a national basis with some disaggregation.

The recent work undertaken by Dr John Cox and ACG (Cox and ACG, 1999) on behalf of the (NEPC) has been adopted for this study. The report by Cox and ACG (1999) details VKT per vehicle category (excluding motorcycles) on a state basis for all years up to 2015. Motorcycle VKT has been estimated from earlier work by Jakeman et al. (1987). VKT estimates for 2020 were derived by linear extrapolation.

It should be noted that Victoria, NSW, QLD and WA are considering VKT reduction targets as part of Air Quality Management Plans for metropolitan areas. These VKT targets have not been finalised for all jurisdictions and are not considered in this study.

Estimates of total VKT according to vehicle type for each state/territory capital for the scenario years are presented in Tables 6-2 to 6-5.

TABLE 6-2: CAPITAL CITY VKT BY VEHICLE CATEGORY, 2000 (MILLION VKT)

	Vehicle Type						
City	Passenger	Light	Rigid/Other	Articulated	Buses	Motorcycle	Total
Sydney	27,350	3,829	1,219	371	216	749	33,734
Melbourne	25,000	4,100	1,000	470	176	344	31,090
Brisbane	11,850	2,702	559	189	87	405	15,792
Perth	10,680	2,121	388	122	93	192	13,596
Adelaide	8,180	1,201	236	46	70	138	9,871
Hobart	1,350	322	61	25	19	21	1,798
Canberra	2,300	333	61	6	23	101	2,824
Darwin	550	215	31	9	11	52	868

TABLE 6-3: CAPITAL CITY VKT BY VEHICLE CATEGORY, 2005 (MILLION VKT)

City	Vehicle Type Passenger	Light	Rigid/Other	Articulated	Buses	Motorcycle	Total
Sydney	29,130	4,608	1,259	437	216	993	36,643
Melbourne	25,820	4,785	1,049	628	176	471	32,929
Brisbane	13,110	3,432	624	235	87	542	18,030
Perth	11,690	2,695	407	152	93	224	15,261
Adelaide	8,500	1,401	229	46	70	162	10,408
Hobart	1,400	376	64	31	19	27	1,917
Canberra	2,530	388	64	8	23	141	3,154
Darwin	590	273	33	11	11	59	977

TABLE 6-4: CAPITAL CITY VKT BY VEHICLE CATEGORY, 2010 (MILLION VKT)

City	Vehicle Type Passenger	Light	Rigid/Other	Articulated	Buses	Motorcycle	Total
Sydney	30,660	5,377	1,297	515	216	1,236	39,301
Melbourne	26,860	5,583	1,097	839	176	597	35,152
Brisbane	14,260	4,360	691	292	87	678	20,368
Perth	12,630	3,424	426	189	93	256	17,018
Adelaide	8,730	1,635	220	46	70	186	10,887
Hobart	1,430	439	67	39	19	32	2,026
Canberra	2,740	453	67	10	23	181	3,474
Darwin	610	346	35	14	11	66	1,082

TABLE 6-5: CAPITAL CITY VKT BY VEHICLE CATEGORY, 2020 (MILLION VKT)

2020 City	Vehicle Type Passenger	Light	Rigid/Other	Articulated	Buses	Motorcycle	Total
Sydney	33,617	7,089	1,371	680	216	1,723	44,696
Melbourne	28,747	7,320	1,192	1,325	176	850	39,609
Brisbane	16,543	6,485	830	420	87	951	25,315
Perth	14,493	5,092	463	271	93	320	20,732
Adelaide	9,167	2,144	200	46	70	234	11,860
Hobart	1,483	575	73	56	19	43	2,249
Canberra	3,100	593	73	14	23	261	4,064
Darwin	670	515	38	20	11	80	1,333

It is well established that motor vehicle emissions vary substantially according to traffic flow parameters such as average speed of travel and degree of congestion. In this study, total VKT for each capital city was allocated to arterial travel, which is defined as travel on major roads with moderate average speeds and moderate congestion levels. The effect of increasing levels of congestion on emissions in future years has not been modelled.

6.2.3 VKT Per Vehicle Category and Vehicle Age Group

Data on vehicle numbers, average VKT per vehicle category and vehicle age are compiled by the Australian Bureau of Statistics (ABS) in the Survey of Motor Vehicle Use (SMVU). State level data from the current Survey (ABS, 1995) was used to generate profiles of motor vehicle use according to vehicle type and age. The Survey data supplied by ABS were not smoothed for use in this study. Previous studies by BTE and other authorities, however, have tended to employ some form of smoothing to reduce the potential for statistical anomalies.

In line with previous inventory practice, these profiles were used to determine relative VKT according to vehicle vintage and vehicle category for each state for each of the scenario years. It is recognised, however, that there may be significant changes in relative levels of use between different vehicle types and vintages in future years.

Profiles of motor vehicle use according to vehicle type and age are presented in Appendix 6-A.

6.2.4 Fuel Use Profiles According to Relative VKT.

VKT must be apportioned according to the fuel used (petrol, diesel, LPG, CNG). The split by fuel type according to relative VKT is an area for which there is little information.

Estimates of national level motor vehicle fuel fleet splits provided by BTE for 2000 and 2010 as part of earlier studies (BTE, 1996) were adopted for this study. Comparison of these fuel splits with current SMVU data (ABS, 1995) and fuel consumption data (DISR, 1999) suggest that the proportion of VKT accounted for by diesel vehicles may differ significantly between states for the passenger vehicle and light commercial vehicle categories. The fuel splits for these categories were adjusted using the more current VKT work of Cox and ACG (1999) on the assumption that projected diesel usage by these vehicles would substitute for petrol fuelled vehicle activity.

The fuel split profiles adopted are shown in Appendix 6-G. The national level estimates (BTE, 1996) for trucks and buses are assumed to apply to all states for all scenarios. VKT estimates for 2020 were derived by linear extrapolation.

As discussed, the effects of accelerated LPG/CNG conversion of buses and light commercial vehicles will be considered as part of emissions inventory development and fuel demand estimation. Based on data contained in the current Motor Vehicle Census (ABS, 1997), these changes are expected to have a small effect on the overall fleet profile, resulting in fuel substitution of approximately 5% for buses and 1% for light commercial vehicles over the period June 2000 to June 2004.

6.2.5 Fuel Consumption

Fuel consumption estimates were derived from a consideration of fleet composition, fleet activity, fuel intensity and projected fuel usage scenarios. The results were used by the refining industry in the assessment of refinery plant configuration and for greenhouse gas emission calculation.

6.2.5.1 Fuel Intensity

Passenger Vehicles

Average passenger vehicle fuel intensities according to year of manufacture were sourced from the Bureau of Transport Economics (BTE, 1996a). These rates, which represent “on-road” performance, were projected forward using these factors:

Technology – 1% per year improvement in fuel efficiency between 2000 and 2010 as specified for Scenario 1 and 2. Additional 1.5% per year improvement in fuel efficiency between 2000 and 2010 as specified for Scenarios 3 to 6;

Deterioration – average fuel intensity of a vintage from the value when new to be 20% higher after 10 years, decreasing to 10% above new value after 20 years. This aging factor was adopted from BTE (1996a);

Congestion – 30% increase in congestion leads to 10% increase in fuel intensity from 1995 to 2015 (BTE, 1996a). This factor was applied linearly for 2000, 2005 and 2010.

Fuel type – a 1.5% improvement in fuel efficiency was adopted for Scenarios 5 and 6 for vehicles using 98 RON petrol. During the industry consultation process, vehicle industry representatives indicated that the introduction of high octane (98 RON) fuel would assist in meeting fuel efficiency targets. The refining industry indicated that fuel efficiency improvements of the order of 0.5% would be obtained for each unit increase in research octane number, so a 1.5% improvement was adopted for use of 98 RON rather than 95 RON petrol for elements of the vehicle fleet under Scenarios 5 and 6.

Fleet average fuel intensity was calculated by weighting separate vintage fuel intensities according to relative VKT by year of manufacture. The fleet average derived is assumed to represent all fuel types.

Other Vehicle Categories

Average fuel intensities according to year of manufacture were sourced from the Bureau of Transport Economics (BTE, 1996b) for light commercial vehicles, rigid trucks and articulated trucks. Bus fuel intensity was assumed to be similar to that of rigid trucks. These fuel intensities were projected forward using a deterioration factor recommended by BTE (1996b).

Motorcycle fuel intensity was sourced from the current Survey of Motor Vehicle Use (ABS, 1995) and is assumed to apply for all years and all scenarios.

Fleet average fuel intensity for each vehicle category was calculated by weighting separate vintage fuel intensities according to relative VKT by year of manufacture.

6.2.6 Petrol Fuel Splits

Apportioning of petrol consumption into 91 RON unleaded petrol (ULP), 95 RON unleaded petrol (PULP) and 98 RON unleaded petrol (SPULP) was based on a vintage analysis as described in Table 6-6. Consumption of leaded petrol/lead replacement petrol (LP/LRP) was based on energy demand forecasts for states and territories level data supplied by the Department of Industry, Science and Resources (DISR, 1999) and national data from ABS (1995).

TABLE 6-6: APPORTIONING OF PETROL CONSUMPTION

VEHICLE CATEGORY	BASIS FOR PETROL SPLIT
Passenger vehicles and Light Commercial Vehicles	<u>Scenario 1 (BAU)</u> All models: LP/ULP/PULP split based on extrapolation of current splits from state/territory level consumption data. <u>Scenarios 2 to 6</u> 1986 – 2002 models: LP / ULP / PULP split based on current splits from state/territory level consumption data. 2002 – 2005 models : LP / ULP / PULP split based on current ratio of local and imported engines in fleet. 2005+ : all new vehicles use PULP. 2008+ : all new vehicles use SPULP (Scenarios 5 and 6 only).
Rigid Trucks, Buses and Motorcycles	<u>Year 2000 (all scenarios)</u> LP/ULP split based on extrapolation of current splits from state/territory level consumption data. <u>Years 2005 to 2020 (all scenarios)</u> 100% ULP consumption.

6.2.7 Fuel Consumption

Total fuel consumption (all fuel types) was calculated by multiplying VKT by the average fleet intensity for each vehicle category. Consumption of particular fuel types was calculated from the total consumption, adjusted according to relative fuel intensities per fuel type taken from the ABS (1995). Fuel efficiency is recognised as increasing with fuel octane. To account for this factor, a reduction of 1.5% in fuel intensity was adopted for vehicles fuelled with SPULP (98 RON) petrol for scenarios 5 and 6, as compared with Scenarios 2, 3 and 4.

Estimates of fuel consumption between 2000 and 2020 are presented in Appendix 6-B. Estimates of national consumption for year 2000 are in good agreement (less than 2% difference) with linear extrapolations derived from national fuel consumption data provided from DISR (1999). Results on a state and territory basis are more variable, particularly for the Northern Territory, where fuel consumption appears to be underestimated.

6.3 Fuel Quality Effects

Specific properties of fuels are known to have an effect on vehicle emissions. The fuel properties considered as part of this review are:

Petrol	**Diesel**
Sulfur content	Sulfur content
Vapour pressure	Polyaromatic content
Benzene/Aromatic content	Distillation point
Mid-range and tail-end volatility	Cetane number
Olefin content	Density
Oxygenates	
Lead content	

As Australian data relating to these effects are limited, a review of international work on the subject was undertaken. The findings of the review were discussed in Section 3.3 and are summarised in the following sections.

6.3.1 Criteria Pollutants - Combined Fuel Property Effects

A recent project on future road vehicle emissions (Samaras et al., 1998) reviewed and summarised the European and American programs (EPEFE and AQIRP), which investigated the effect of improved petrol and diesel fuels on emissions from existing vehicles. Relationships between fuel properties and emissions are presented for petrol and diesel fuelled vehicles. These relationships allow the assessment of combined effects of changes in multiple fuel variables.

The fuel composition and emission relationships of Samaras et al. (1998) were adopted for use in this study. Emission rate scaling factors were developed for each Scenario according to the expected fuel changes and vehicle technologies. These factors are presented in later sections dealing with each scenario.

As future vehicle emission rates are associated with specific fuel compositions, the scaling factors for each vehicle vintage are based on the differences between available fuel quality and the specified fuel for that vintage. This means, for example, that no emission rate adjustment is applied for Euro 3 vehicles for Scenario years in which Euro 3 petrol (mandated) is available.

6.3.2 Non-Catalyst Light Duty Petrol Vehicles

A summary of fuel effects on exhaust and evaporative emissions from non-catalyst petrol vehicles is presented in Table 6-7. It should be noted that the effects of fuel quality changes on criteria pollutant emissions from these vehicles have not been modelled as part of this study. We are not aware of data that describe the combined effects of changes in multiple fuel parameters on emissions from vehicles of this vintage.

TABLE 6-7: EFFECT OF IMPROVED PETROL ON THE EMISSIONS OF NON-CATALYST LIGHT DUTY VEHICLES (reproduced from Samaras et al 1998)

Property	Change	Pb	CO	VOC (exh)	VOC (evap)	NO_x
Pb	0.15 to 0.08g/L	-50%	0	0	0	0
Oxygenate	0 to 2.7% O_2	0	-20 to -40%	-2 to -10%	0 – 10%	-2 to 2%
Aromatics	40 to 25%	0	0	-2 to -10%	0	-2 to -10%
Benzene	3 to 2%	0	0	0	0	0
Olefins	10 to 5%	0	-2 to 2%	2 to 5%	-2 to 0%	-2 to -10%
Sulfur	300 to 100ppm	0	0	0	0	0
RVP	70 to 60 kPa	0	0	-2 to 2%	-20%	0
E 100	50 to 60%	0	0 – 2%	-2 to -10%	-2 to 2%	0
E 150	85 to 90%	0	0	-10 to -20%	0	2 to 10%

Pb: Lead
CO: Carbon monoxide
VOC: Volatile Organic Compounds
NO_x: Oxides of nitrogen
RVP: Reid Vapour Pressure
E100/E150: Percentage of petrol distilled at 100^0C/150^0C

6.3.3 Catalyst Light Duty Petrol Vehicles

Relationships describing fuel parameter effects on emissions from catalyst petrol vehicles are presented in Table 6-8.

TABLE 6-8: RELATIONS BETWEEN EMISSIONS AND FUEL PROPERTIES FOR CATALYST LIGHT DUTY VEHICLES (reproduced from Samaras et al 1998)

Emission Rate (g/km)	Equation
CO	$[2.459 - 0.05513 \,.\, (E100) + 0.0005343 \,.\, (E100)^2 + 0.009226 \,.\, (ARO) - 0.0003101 \,.\, (97-S)] \,.\, [1-0.037 \,.\, (O_2 - 1.75)] \,.\, [1-0.008 \,.\, (E150 - 90.2)]$
VOC	$[0.1347 + 0.0005489 \,.\, (ARO) + 25.7 \,.\, (ARO) \,.\, e^{(-0.2642 \,.\, (E100))} - 0.0000406 \,.\, (97-S)] \,.\, [1-0.004 \,.\, (OLEFIN - 4.97)] \,.\, [1-0.022 \,.\, (O_2 - 1.75)] \,.\, [1-0.01 \,.\, (E150 - 90.2)]$
NO_x	$[0.1884 - 0.001438 \,.\, (ARO) + 0.00001959 \,.\, (ARO) \,.\, (E100) - 0.00005302 \,.\, (97 - S)] \,.\, [1+0.004 \,.\, (OLEFIN - 4.97)] \,.\, [1+0.001 \,.\, (O_2 - 1.75)] \,.\, [1+0.008 \,.\, (E150 - 90.2)]$

NOTE: All parameters in the equations are in % with the exception of sulfur, which is in ppm.

6.3.4 Light Duty Diesel Vehicles

Relationships describing fuel parameter effects on emissions from light duty diesel vehicles are presented in Table 6-9.

TABLE 6-9: RELATIONS BETWEEN EMISSIONS AND FUEL PROPERTIES FOR LIGHT DUTY DIESEL VEHICLES (reproduced from Samaras et al 1998)

Emission Rate (g/km)	Equation
CO	-1.3250726 + 0.003037 . DEN - 0.0025643 . POLY - 0.015856 . CN + 0.0001706 . T95
VOC	-0.293192 + 0.0006759 . DEN - 0.0007306 . POLY - 0.0032733 . CN - 0.000038 . T95
NO_x	1.0039726 - 0.0003113 . DEN + 0.0027263 . POLY - 0.0000883 . CN - 0.0005805 . T95
PM	[-0.3879873 + 0.0004677 . DEN + 0.0004488 . POLY + 0.0004098 . CN + 0.0000788 . T95] . [1- 0.015 . (450 - SULFUR)/100]

PM: Particulate matter

6.3.5 Heavy Duty Diesel Vehicles

Relationships describing fuel parameter effects on emissions from heavy duty diesel vehicles are presented in Table 6-10.

TABLE 6-10: RELATIONS BETWEEN EMISSIONS AND FUEL PROPERTIES FOR HEAVY DUTY DIESEL VEHICLES (reproduced from Samaras et al 1998)

Emission Rate (g/kWh)	Equation
CO	2.24407 - 0.0011 . DEN + 0.00007 . POLY - 0.00768 . CN - 0.00087 . T95
VOC	1.61466 - 0.00123 . DEN + 0.00133 . POLY - 0.00181 . CN - 0.00068 . T95
NO_x	-1.75444 + 0.00906 . DEN + 0.0163 . POLY - 0.00493 . CN + 0.00266 . T95
PM	[0.06959 + 0.00006 . DEN + 0.00065 . POLY - 0.00001 . CN] . [1-0.0086 . (450 - SULFUR)/100]

NOTE: All parameters in the equations are in % with the exception of sulfur, which is in ppm.

Diesel vehicle emission factors adopted from Cox and Apelbaum (1999) are for an Australian average diesel fuel sulphur content of 1500 ppm. This sulfur level has been assumed for all states and territories when using the equations in Tables 6.8 and 6.9 to estimate PM emissions for the base case.

6.4 FUEL VOLATILITY EFFECTS

RVP effects on evaporative and exhaust emissions from petrol fuelled vehicles have been considered in this Study.

Evaporative emissions may be generated whilst vehicles are at rest (engine off) or in motion. There are basically four different categories of evaporative emissions:

Diurnal Loss of vapour from parked vehicles as fuel is heated by rising ambient temperatures;

Hot Soak Loss of vapour after vehicle operation resulting from the heating of the tank vapour space and or carburettor. The sum of diurnal and hot soak emissions constitute regulatory SHED emission limits for motor vehicles;

Running Loss of vapour during vehicle operation. These emissions are not monitored during SHED testing; and

Resting Loss of vapour from the fuel system or the evaporative control system as a result of vapour permeation through various fuel system components (eg hosing). These emissions are not monitored during SHED testing.

Evaporative emissions are significantly affected by fuel RVP. There is sufficient literature (Stebar et al., 1985; Halberstadt, 1989; USEPA, 1994) and Australian data (FORS 1997) to conclude that the reduction of petrol volatility will lead to an immediate and significant reduction of evaporative emissions from vehicles.

The impact of RVP changes on petrol evaporative emissions for each scenario modelled has been conducted using the Reddy (1989) Equation. The Reddy Equation enables the calculation of vapour generation as a function of fuel RVP, ambient temperatures and height above sea level.

Results from the Reddy Equation have reportedly been formally tested against experimental SHED results and found to be in excellent agreement.

In this Study, the Reddy Equation has been used to estimate diurnal and hot soak evaporative emissions in preference to the use of SHED test results for the following reasons:

- The effect of emission changes resulting from city to city variation in ambient temperatures and RVP can be modelled directly. SHED results are only applicable to temperatures and RVP employed under test conditions. Moreover, Reddy predictions can be shown to be comparable with SHED results when identical temperatures and RVP are used.
- Whilst Australian data for SHED evaporative emissions are available (FORS, 1996) for approximately 250 vehicles fuelled by commercially representative RVP fuel, data on the effect of RVP on evaporative (and exhaust) emissions are only available for 2 non-catalyst and 2 catalyst vehicles (FORS, 1997). Whilst these data provide indicative trends, the small sample size limits their use for fleet-representative modelling purposes. Moreover, a sub-report on fuel RVP reductions and canister replacement inventory modelling presented as Appendix IX in FORS (1997), also adopted the Reddy Equation for modelling purposes rather than using SHED results of the Study, for technical reasons noted therein.
- SHED testing data as reported by FORS (1996) tend to be as the sum of diurnal and hot soak, for comparison with the relevant regulatory evaporative emissions limit. For real-world modelling purposes however, diurnal and hot soak emissions data are required to be reported separately (because daily hot soak and diurnal emissions are equal to the product of number of trips by hot soak plus diurnal).

- Previous inventory estimates for motor vehicle emission rates (combined exhaust and evaporative) of which the evaporative component has been estimated using the Reddy Equation, have been shown to be in good agreement with real-world inventory validation work in Perth (DEP, 1996) and Melbourne (EPAV, 1999).

Fuel RVP effects have also been reported for exhaust emissions from petrol-fuelled vehicles. The Mobile 5 vehicle emissions model of USEPA (1994) for example, predicts that decreasing RVP results in a relatively small decrease in HC and CO emissions from light duty petrol-fuelled vehicles. NO_x emissions are reportedly unchanged. However, testing conducted on a small set of catalyst and non-catalyst vehicles (total of 4 vehicles) using commercially representative Australian fuel (FORS, 1997) found that exhaust emissions of HC, NO_x and CO remained unchanged across a range of petrol RVP (63 – 74 kPa).

Given the finding of the FORS (1997) Study on exhaust emissions as a function of RVP, and the relatively small effects noted from overseas data, exhaust emissions have been assumed to be invariant with the petrol RVP changes in the Scenarios modelled. Evaporative emission rates, however, which are significantly reduced by reductions in petrol RVP, have been modelled for each scenario.

6.5 AIR TOXICS

6.5.1 Benzene

Petrol engine exhaust is responsible for the bulk of benzene emissions, with relatively small contributions from petrol evaporative losses and diesel engine exhaust. Incomplete combustion of fuel benzene and other aromatics result in exhaust emissions of benzene. The introduction of catalyst technology has lead to large reductions in benzene emissions (Concawe, 1999).

A study of emissions of air toxics from motor vehicles (USEPA, 1993) presented relationships between exhaust benzene levels and the aromatic content (benzene and total) of petrol for catalyst and non-catalyst light duty vehicles. These relationships were used to estimate the benzene content of petrol engine exhaust and are shown below:

Catalyst vehicles:

% Benzene of Exhaust HC =
1.077+0.7732x%Benzene(vol)+0.0987x{%Aromatics(vol)-%Benzene(vol)}

Non-Catalyst vehicles:

% Benzene of Exhaust HC = 0.8551x%Benzene(vol)+0.12198x%Aromatics(vol)-1.1626

Exhaust benzene emissions from medium duty diesel trucks have been reported by Schauer et al. (1999) to be equivalent to 2.5% of total exhaust HC. This value has been adopted for all diesel vehicles considered in this study and is assumed to stay constant under all scenarios. Benzene emissions from LPG/CNG fuelled vehicles are assumed to be negligible.

To a good approximation, the benzene content of petrol vapour (for evaporation processes) can be scaled according to vapour/liquid partitioning determined experimentally for a 'typical' petrol formulation (Nelson and Quigley, 1984) as follows:

% Benzene (Vap, New Formulation) = % Benzene (Liq, New Formulation) x 0.9/2.6

6.5.2 Other Air Toxics

The other air toxic compounds considered are:

- Acetaldehyde;
- Fomaldehyde;
- 1,3 – butadiene;
- PAH.

Only limited testing of the emissions response of these unregulated compounds to changes in fuel quality and vehicle technology has been undertaken. Statistically significant data relating to these effects are not currently available (CONCAWE, 1999).

The effects of fuel quality changes on the emissions of these substances have not been modelled in this study. Values sourced from Australian and international literature have been adopted for all scenarios as follows:

- Petrol fuelled vehicles - Acetaldehyde and formaldehyde as reported in Carnovale et al. (1991). 1,3-butadiene as reported by Nelson et al. (1998). PAH emissions from these vehicles are assumed to be negligible;

- Diesel vehicles - emissions of toxic species as reported by Schauer et al. (1999).

A summary of these data is presented in Table 6-11.

TABLE 6-11: EXHAUST VOC SPECIES PROFILES

Substance	% Weight of Calculated HC				
	Petrol	Petrol	Diesel[e]	LPG[f]	LPG[f]
	Pre '86 P&LCV/Non-Cat Vehicles	Post '85 P&LCV/3W-Cat Vehicles	All	Non-Cat PV	Cat PV
Acetaldehyde[a]	0.4	0.3	37.5	1.0	0.2
Benzene[b]	4.5	5.1	2.5	0	0
1,3-Butadiene[c]	1.1	0.6	0.3	0	0
Formaldehyde[a]	2.2	0.7	20.0	2.9	0.6
PAH (Semi-Volatile) [d,e]	0.01	0.01	3.0	0	0
PAH (% wt of PM10) [d,e]	Neg.	Neg.	0.9	0	0

a. Carnovale et al., 1991.
b. For Australian pool average benzene content (Associated Octel, 1996). Adjustments made for each State and Territory according to USEPA (1993).
c. Nelson et al., 1998.
d. Westerholm et al., 1996.
e. Schauer et al., 1999.
f. EMEP/Corinair, 1996.

6.6 Fleet Emissions - Scenario 1

Scenario 1 represents the continuation of current policy settings with a number of additional assumptions. Scenario assumptions affecting emission rates are:

- Continuation of ADR 37/01 and ADR 70/00;
- Leaded petrol phased out in 1/1/2002 (earlier in some States);
- Diesel sulfur content of 500 ppm in urban WA from 1/1/2000;
- Diesel sulfur content of 500 ppm in Brisbane from 1/7/2000;
- Reductions in volatility that are planned in a number of states;
- Other changes proposed by individual refineries.

It is assumed that the alternate Euro2/3 amendment to ADR 37/01 does not significantly affect adoption of the standard.

6.6.1 Relative and Accumulated VKT

The relative VKT and average accumulated VKT estimates for each vehicle category and fuel type according to the vehicle vintages applicable to this scenario have been estimated based on data from the current Survey of Motor Vehicle Use (SMVU, 1995) published by the Australian Bureau of Statistics (ABS). Relative and accumulated VKT for other fuel types (LPG/CNG) are grouped together for the purposes of this study.

Melbourne fleet data are presented in Tables 6-12 to 6-15 as an example, with similar data for other States and Territories included in Appendix 6-C. In the absence of other data, it is assumed that the fleet profiles from the current survey are applicable to all years of the study. Fleet profiles for passenger vehicles and light commercial vehicles were estimated using state level data. The fleet profiles presented for heavy duty vehicles and motorbikes are based on national level data and are the same for each capital city.

TABLE 6-12: MELBOURNE FLEET PROFILE, PETROL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 1, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT % 2000	2005	2010	2020
Passenger	Post 96	26.5	46.9	77.6	100.0
	86 - 96	55.0	47.7	22.4	0.0
	76 - 85	18.5	5.5	0.0	0.0
Light Commercial	Post 96	20.8	45.3	66.6	100.0
	86 - 96	50.5	44.2	33.4	0.0
	76 - 85	28.7	10.5	0.0	0.0
		Accumulated VKT ('000 km) 2000	2005	2010	2020
Passenger	Post 96	58.7	74.4	118.9	141.2
	86 - 96	142.3	192.7	191.7	0.0
	76 - 85	150.0	150.0	0.0	0.0
Light Commercial	Post 96	66.0	114.8	152.4	193.8
	86 - 96	179.5	236.6	245.5	0.0
	76 - 85	150.0	150.0	0.0	0.0

VKT = Vehicle Kilometres Travelled

TABLE 6-13: MELBOURNE FLEET PROFILE, DIESEL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 1, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT (%) all years	Accumulated VKT ('000 km) all years
Passenger	all	100	141
Light Commercial	all	100	194

VKT = Vehicle Kilometres Travelled

TABLE 6-14: NATIONAL FLEET PROFILE, DIESEL FUELLED MEDIUM/HEAVY DUTY VEHICLES, SCENARIO 1, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT % 2000	2005	2010	2020
Rigid trucks	Post '94	26.4	61.2	84.7	100.0
	Pre '95	73.6	38.8	15.3	0.0
Non-freight trucks	Post '94	28.3	54.5	82.5	100.0
	Pre '95	71.7	45.5	17.5	0.0
Articulated trucks	Post '94	38.0	70.5	85.7	100.0
	Pre '95	62.0	29.5	14.3	0.0
Buses	Post '94	40.8	70.7	86.2	100.0
	Pre '95	59.2	29.3	13.8	0.0
		Accumulated VKT ('000 km) 2000	2005	2010	2020
Rigid trucks	Post '94	121.3	204.7	239.7	207.3
	Pre '95	225.7	209.1	154.4	0.0
Non-freight trucks	Post '94	77.3	111.0	168.7	171.2
	Pre '95	200.9	231.2	176.9	0.0
Articulated trucks	Post '94	327.2	515.4	589.5	603.4
	Pre '95	703.0	709.0	638.6	0.0
Buses	Post '94	116.2	192.1	235.2	274.9
	Pre '95	376.9	433.3	455.5	0.0

TABLE 6-15: NATIONAL FLEET PROFILE, PETROL FUELLED MEDIUM/ HEAVY DUTY VEHICLES AND MOTORCYCLES, SCENARIO 1, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT (%) all years	Accumulated VKT ('000 km) all years
Rigid trucks	all	100.0	207.3
Non-freight trucks	all	100.0	171.2
Articulated trucks	all	100.0	603.4
Buses	all	100.0	274.9
Motorcycles	all	100.0	53.6

6.6.2 Fuel Properties

Specific changes to current fuel properties considered in this scenario are:

- Diesel sulfur content – reductions in sulfur content in diesel fuel as agreed by individual companies. BP Oil has undertaken to supply 500 ppm diesel to Perth and Brisbane from January 2000. A pool average of 1000 ppm will apply for other refiners supplying to urban areas from January 2000;

- Petrol vapour pressure – reductions in summer RVP are planned in a number of States. BP is reducing RVP to 70 kPa from 1999/2000, with a further reduction to 67 kPa from 2000/2001. Refineries in NSW will reduce summer RVP to 67 kPa from 2000;

- Leaded petrol – BP Oil has agreed to phase out leaded petrol in WA from January 2000. Shell has announced plans to phase out leaded petrol in Victoria by late 2000. For other refineries, leaded petrol will be phased out before 2005;

- Petrol benzene content – BP oil has agreed to reduce benzene content to 2% in petrol supplied to the WA market from January 2000.

'Business as usual' fuel composition for other refineries and/or States are based on recent data on average pool qualities of petrol and diesel. A summary of the fuel parameters considered for Scenario 1 emissions estimation is presented in Tables 6-16 to 6-19. It is assumed that ACT fuel is supplied by NSW refineries, Tasmanian fuel is supplied by Victorian refineries and Darwin fuel is supplied by the Western Australian refinery.

TABLE 6-16: SCENARIO 1 - DIESEL SULFUR CONTENT, 2000-2020

	Diesel Sulfur Content (% w/w)			
City	2000	2005	2010	2020
Sydney	0.178	0.100	0.100	0.100
Melbourne	0.134	0.100	0.100	0.100
Brisbane	0.074	0.050	0.050	0.050
Perth	0.050	0.050	0.050	0.050
Adelaide	0.090	0.090	0.090	0.090
Hobart	0.134	0.100	0.100	0.100
Canberra	0.178	0.100	0.100	0.100
Darwin	0.074	0.050	0.050	0.050

TABLE 6-17: SCENARIO 1 - PETROL VAPOUR PRESSURE, 2000-2020

	Petrol Vapour Pressure (kPa)			
City	2000	2005	2010	2020
Sydney	67	67	67	67
Melbourne	72	72	72	72
Brisbane	75	75	75	75
Perth	70	67	67	67
Adelaide	67	67	67	67
Hobart	72	72	72	72
Canberra	67	67	67	67
Darwin	75	75	75	75

TABLE 6-18: SCENARIO 1 - LEADED PETROL AVAILABILITY, 2000-2020

	Leaded Petrol Available (Y/N)			
City	2000	2005	2010	2020
Sydney	Y	N	N	N
Melbourne	Y	N	N	N
Brisbane	Y	N	N	N
Perth	N	N	N	N
Adelaide	Y	N	N	N
Hobart	Y	N	N	N
Canberra	Y	N	N	N
Darwin	Y	N	N	N

TABLE 6-19: SCENARIO 1 - PETROL BENZENE CONTENT, 2000-2020

	Benzene Content (% vol)			
City	2000	2005	2010	2020
Sydney	2.5	2.5	2.5	2.5
Melbourne	3.6	3.6	3.6	3.6
Brisbane	2.6	2.6	2.6	2.6
Perth	2.0	2.0	2.0	2.0
Adelaide	3.4	3.4	3.4	3.4
Hobart	3.6	3.6	3.6	3.6
Canberra	2.5	2.5	2.5	2.5
Darwin	2.6	2.6	2.6	2.6

6.6.3 HC, NO_x and CO Exhaust Emission Rates

The methodology and assumptions used in the estimation of HC, NO_x and CO exhaust emission factors for each vehicle category is presented in Table 6-20.

TABLE 6-20: METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING HC, NOX AND CO EXHAUST EMISSION FACTORS, SCENARIO 1

Vehicle Category	**Fuel**	**Methodology/Assumptions**
Passenger	Petrol	Reference exhaust emission rates and deterioration rates established using vehicle testing data from EPANSW (1995) and the Federal Office of Road Safety (FORS, 1996). For post catalyst vehicles, deterioration according to vehicle travel capped at pre catalyst vehicle emissions (150,000 km travel).
	Diesel	Exhaust emission rates adopted from Cox and Apelbaum (1999), Scenario 1.
	LPG/CNG	Petrol emission factors scaled according to FORS data as reported by Parsons (1998): Pre catalyst – scale petrol emission factors by 0.5 HC, 0.7 NO_x, 1.0 CO Post catalyst - scale petrol emission factors by 1.2 HC, 1.1 NO_x, 1.9 CO
Light Commercial	Petrol	As for passenger vehicles for HC and CO, NOx scaled by 1.15 (EPANSW, 1995)
	Diesel	Exhaust emission rates adopted from Cox and Apelbaum (1999), Scenario 1.
	LPG/CNG	As for passenger vehicles
Rigid and Non-Freight Trucks	Petrol	Assume equal to USEPA Heavy Duty Vehicles, 1985 vintage.
	Diesel	Exhaust emission rates adopted from Cox and Apelbaum (1999), Scenario 1.
	LPG/CNG	As for buses (shown below)
Articulated Trucks	Diesel	Exhaust emission rates adopted from Cox and Apelbaum (1999), Scenario 1.
Buses	Petrol	As for rigid/non-freight trucks scaled by 0.7. Factor based on ratio of petrol fuel consumption of buses to that of rigid/non-freight trucks from current SMVU.
	Diesel	Exhaust emission rates adopted from Cox and Apelbaum (1999), Scenario 1.
	LPG/CNG	As for petrol fuelled buses, scaled by 0.4 HC, 1.7 NO_x, 0.2 CO. Factors scaled according to data for 1990 vintage vehicles as reported by Parsons (1998).
Motor Cycles	Petrol	Assume equal to USEPA motor cycles, HC 1988+, NO_x 1980+ and CO 1982+.

6.6.4 Particulate Matter

There are limited data available on particulate emissions from Australian vehicles. Particulate emission rates for the Australian diesel fleet as reported by Cox and Apelbaum (1999) were adopted for this study. A review of recent Australian and overseas work was undertaken to estimate particulate emission rates for the Australian petrol and LPG fuelled vehicle fleet. A summary of the methodology is presented in Table 6-21.

TABLE 6-21: SCENARIO 1 - METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING PARTICULATE EMISSION FACTORS

Vehicle Category	Fuel	Methodology/Assumptions
Passenger	Petrol	Emission rates assumed equal to that of US 1986-90 catalyst equipped vehicles (Maricq et al., 1999) and US 1970-74 non-catalyst vehicles (USEPA, 1995).
	Diesel	Emission rates adopted from Cox and Apelbaum (1999), Scenario 1. Reference rates adjusted for sulphur content.
	LPG/CNG	Emission rate assumed equal to that of recent model catalyst equipped European vehicle (Rijkeboer et al., 1994).
Light Commercial	Petrol	As for passenger vehicles
	Diesel	Emission rates adopted from Cox and Apelbaum (1999), Scenario 1. Reference rates adjusted for sulphur content.
	LPG/CNG	As for passenger vehicles
Rigid and Non-Freight Trucks	Petrol	Assume equal to USEPA emission rates for heavy duty vehicles, pre 1987 vintage, no catalyst.
	Diesel	Emission rates adopted from Cox and Apelbaum (1999), Scenario 1. Reference rates adjusted for sulphur content.
	LPG/CNG	As for passenger vehicles
Articulated Trucks	Diesel	As for Rigid and Non-Freight trucks
Buses	Petrol	As for Rigid and Non-Freight trucks
	Diesel	Emission rates adopted from Cox and Apelbaum (1999), Scenario 1. Reference rates adjusted for sulphur content.
	LPG/CNG	As for Rigid and Non-Freight trucks
Motor Cycles	Petrol	Assume equal to emission rates for early model US motor cycles, weighted for 80% 4-stroke and 20% 2-stroke engines

It is assumed for the purposes of this study that all particulate matter from motor vehicles is smaller than 10µm and that 90% of this is smaller than 2.5µm. Cadle et al., (1999) reported that 91% of particulate mass from petrol vehicles was smaller than 2.5µm, this proportion being 97% and 98% respectively for smoking and diesel vehicles.

Reductions in diesel sulphur content proposed for this scenario are expected to result in reductions in particulate emissions from light and heavy duty diesel vehicles. The magnitude of these reductions was estimated using the relationships reported by Samaras et al. (1998) as discussed in Section 6.3.

6.6.5 Evaporative HC Emissions

Evaporative emissions from petrol fuelled passenger vehicles have been estimated using methodologies developed as part of previous inventory studies undertaken in Australia. Details of the methodology employed are contained in Carnovale et al. (1996). Passenger vehicle evaporative emission rates are assumed to be representative of fleet evaporative rates in accordance with previous studies. A summary of the methodology adopted is presented in Table 6-22. Evaporative emission rate estimates for this Scenario are shown in Section 6.6.6.

TABLE 6-22: METHODOLOGY USED TO ESTIMATE EVAPORATIVE EMISSIONS FROM PETROL FUELLED PASSENGER VEHICLES

Evaporative Component	Estimation Method
Diurnal	Calculation of uncontrolled fuel tank vapour generation using equation developed by Reddy (1989). Reduce uncontrolled vapour generation estimates according to evaporative control systems in later passenger vehicle models (ADR 27 and ADR 37/01)
Hot soak	Based on relative magnitudes of diurnal and hot soak losses for different vehicle vintages as reported in the international literature
Running	Given lack of data on these losses for Australian vehicles, running loss assumed to be 0.5 g/km for summer, 0.25 g/km for winter (Coffey, 1995)
Resting	Given lack of data on these losses for Australian vehicles, resting loss assumed to be 0.5 g/km for summer, 0.25 g/km for winter (Coffey, 1995)

6.6.6 Fleet HC, NOx, CO and PM_{10} Emission Rates

From a consideration of vehicle vintage, VKT travel according to year of manufacture and emission rates according to vehicle vintage, composite emission factors for HC, NO_x, CO and PM_{10} have been estimated for metropolitan passenger vehicle fleets for the study years. A summary of results is presented in Table 6-23.

TABLE 6-23: SCENARIO 1 - FLEET HC, NO_x, CO AND PM_{10} ANNUAL EMISSION RATES FOR CAPITAL CITIES, 2000 - 2020

	Emission Factor (g/km)					
City/year	HC (exh)	HC (evap)	HC (total)	NO_x	CO	PM10
2000						
Sydney	1.17	0.94	2.11	1.69	14.94	0.08
Melbourne	1.28	0.96	2.24	1.83	17.49	0.09
Brisbane	1.22	1.08	2.30	1.87	16.28	0.09
Perth	1.30	1.10	2.40	1.80	17.87	0.07
Adelaide	1.31	0.97	2.28	1.76	18.76	0.07
Canberra	1.33	0.96	2.30	1.70	19.64	0.07
Hobart	1.35	0.93	2.27	1.97	19.24	0.09
Darwin	0.93	1.21	2.14	1.65	10.46	0.09
Average	1.24	1.02	2.25	1.78	16.84	0.08
2005						
Sydney	0.93	0.92	1.85	1.40	11.30	0.07
Melbourne	1.11	0.93	2.04	1.68	15.42	0.08
Brisbane	1.03	1.04	2.07	1.64	13.35	0.08
Perth	1.08	1.02	2.10	1.64	15.13	0.07
Adelaide	1.06	0.93	2.00	1.56	15.48	0.07
Canberra	1.04	0.95	1.99	1.37	14.52	0.06
Hobart	1.04	0.90	1.94	1.69	14.70	0.09
Darwin	0.75	1.16	1.91	1.40	7.67	0.08
Average	1.01	0.98	1.99	1.55	13.44	0.08
2010						
Sydney	0.79	0.90	1.70	1.24	9.25	0.06
Melbourne	0.77	0.92	1.68	1.35	9.34	0.07
Brisbane	0.79	1.00	1.79	1.40	9.33	0.08
Perth	0.88	0.99	1.87	1.45	11.94	0.07
Adelaide	0.76	0.92	1.68	1.25	10.18	0.07
Canberra	0.80	0.92	1.73	1.15	10.24	0.06
Hobart	0.76	0.88	1.65	1.45	9.85	0.09
Darwin	0.61	1.14	1.75	1.22	5.23	0.08
Average	0.77	0.96	1.73	1.31	9.42	0.07
2020						
Sydney	0.56	0.90	1.46	0.95	4.18	0.06
Melbourne	0.53	0.92	1.45	1.12	4.21	0.06
Brisbane	0.56	1.00	1.57	1.13	4.28	0.09
Perth	0.49	0.99	1.47	1.07	4.10	0.07
Adelaide	0.48	0.92	1.40	0.94	4.19	0.07
Canberra	0.65	0.92	1.57	0.93	5.62	0.07
Hobart	0.56	0.88	1.44	1.23	4.90	0.10
Darwin	0.55	1.14	1.69	1.08	3.27	0.09
Average	0.55	0.96	1.51	1.06	4.34	0.08

PM10 = Particulates < 10 µm
HC (exh) = Hydrocarbons from exhaust
HC (evap) = Hydrocarbons from evaporatives
NO_x = Oxides of nitrogen
CO = Carbon monoxide

6.6.7 SO_2 And Lead

Fleet emissions of SO_2 and lead were estimated from a consideration of fuel consumption projections and sulfur/lead contents of Australian fuels. All sulfur contained in fuel is assumed to be oxidised to SO_2. For lead, it is assumed that 75% of the alkyl lead additive in petrol is emitted in exhaust as inorganic lead salts with an additional 2% of the alkyl lead being emitted unchanged due to fuel evaporation (Carnovale et al., 1991).

Sulfur contents under this scenario are shown in Section 6.4.2. Leaded and unleaded petrol is assumed to contain 200 mg/L and 2.5 mg/L of lead respectively.

A summary of results is presented in Section 6.6.9. It should be noted that leaded petrol is to be phased out as part of this Scenario and lead emissions from motor vehicles will fall to low levels after 2002/3.

6.6.8 Air Toxics

Weighted volatile organic compound (VOC) species profiles are based on fleet characteristics for this scenario and the reference information presented in Section 6.5. A summary of the exhaust and evaporative profiles for this Scenario for Melbourne is presented in Table 6-24, with similar information for other cities presented in Appendix 6-E.

TABLE 6-24 FLEET AVERAGE AIR TOXIC PROFILES, MELBOURNE, SCENARIO 1, 2000-2020

	2000	2005	2010	2020
Substance	% w/w Hydrocarbons			
Acetaldehyde	4.4%	5.1%	5.9%	7.6%
Benzene	5.1%	4.1%	4.1%	4.3%
1,3-Butadiene	0.6%	0.6%	0.5%	0.5%
Formaldehyde	3.1%	3.3%	3.6%	4.5%
PAH (Semi-Volatile)	0.3%	0.4%	0.5%	0.6%
PAH as % wt of PM10	0.1%	0.1%	0.1%	0.2%
Toluene	8.0%	7.5%	7.1%	7.0%
Xylenes (o,m,p)	7.1%	6.7%	6.5%	6.4%

PAH = Poly-Aromatic Hydrocarbons

6.6.9 Greenhouse Emissions

Greenhouse emissions for the national fleet were predicted based upon the fuel usage projections presented in Appendix 6-B. We have adopted CO_2 emission factors and liquid fuel densities reported in the greenhouse workbook for transport (NGGIC, 1996) as shown in Table 6-25.

TABLE 6-25: CO_2 EMISSION FACTORS AND LIQUID ENERGY DENSITIES BY FUEL TYPE

Fuel Type	Proportion of Fuel Oxidised	CO_2 Emission Factor (g/MJ)	Energy Density (MJ/L)
Automotive Petrol	0.99	66.0	34.2
Automotive Diesel Oil	0.99	69.7	38.6
Liquified Petroleum Gas	0.99	59.4	25.7

Table 6-26 presents the predicted greenhouse emissions for road transport under Scenario 1.

TABLE 6-26: SCENARIO 1 – AUSTRALIAN GREENHOUSE EMISSIONS FROM ROAD TRANSPORT

Year	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
2000	63600	21.9	10.8	360.5	3349.5	438.7	13.3
2005	68900	20.9	10.2	341.4	2950.6	418.3	14.2
2010	73900	19.5	9.4	312.9	2255.9	390.0	15.8
2020	81100	18.9	8.6	286.0	1164.0	378.5	18.2

6.6.10 Fleet Emissions

A summary of vehicle fleet emissions for Scenario 1 is presented in Tables 6-27 to 6-30.

TABLE 6-27: SCENARIO 1 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	37100	33200	22900	6610	4180	1910	247000
NO_x	57100	56900	28700	24200	17200	4800	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2250	1940	1950	580	245	153	116	42.4	7280
Pb	95.8	95.8	50.2	58.2	35.7	8.3	7	1.89	353
Acetaldehyde	1270	1760	979	733	430	110	110	49.1	5450
Benzene	2280	2410	1080	1040	855	221	149	52.2	8090
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	995	1250	681	553	341	90.3	79.5	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.55	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1980	1850	1280	371	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1730	1610	1110	323	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-28: SCENARIO 1 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	67800	67100	37800	32400	21100	6370	3780	1900	238000
NO_x	51400	55300	28100	24200	15900	4270	3150	1320	184000
CO	414000	508000	237000	228000	160000	45500	27600	7330	1630000
PM_{10}	2560	2560	1350	1040	656	196	153	73.9	8580
SO_2	2480	2250	1950	612	278	166	133	45.9	7920
Pb	5.81	5.81	3.1	2.74	1.92	0.58	0.34	0.16	20.5
Acetaldehyde	1250	1870	1060	782	424	110	105	50.5	5660
Benzene	2090	2260	984	802	754	205	126	36.7	7250
1,3-Butadiene	203	207	110	98.5	65.6	20.6	11.9	4.32	721
Formaldehyde	892	1210	688	524	295	82.3	69.1	31.5	3790
PAH (Semi-Volatile)	97.9	148	84.1	61.5	33.2	8.53	8.32	4.01	445
PAH as %wt of PM_{10}	2.18	3.1	1.79	1.13	0.57	0.15	0.19	0.12	9.22
Total PAH	100	151	85.9	62.6	33.7	8.68	8.5	4.13	454
Toluene	3220	3250	1820	1600	1040	321	183	82.4	11500
Xylenes (o,m,p)	2800	2850	1600	1410	910	280	159	73.6	10100
$PM_{2.5}$	2300	2300	1210	932	590	177	137	66.5	7720

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-29: SCENARIO 1 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	66600	59200	36700	32000	18500	6080	3370	1910	224000
NO_x	48800	47300	26100	23400	13100	3860	2750	1220	167000
CO	364000	328000	183000	199000	109000	35000	19000	5410	1240000
PM_{10}	2410	2440	1330	1020	618	194	143	73.1	8230
SO_2	2770	2610	2190	705	313	178	152	53	8970
Pb	5.95	5.95	3.35	2.96	1.95	0.61	0.35	0.17	21.3
Acetaldehyde	1300	1580	1040	814	367	106	94.9	52.8	5360
Benzene	2010	1800	908	734	607	186	104	32.5	6380
1,3-Butadiene	173	144	87.1	81.7	46.4	16.4	8.4	3.61	561
Formaldehyde	862	979	639	511	240	73.4	58.4	31.8	3400
PAH (Semi-Volatile)	102	126	82.7	64.5	28.9	8.32	7.53	4.21	424
PAH as %wt of PM_{10}	2.35	3.43	2.05	1.31	0.63	0.17	0.21	0.14	10.3
Total PAH	104	129	84.8	65.8	29.5	8.49	7.74	4.35	434
Toluene	2890	2470	1550	1410	792	271	141	75.1	9600
Xylenes (o,m,p)	2510	2140	1370	1250	693	236	122	66.9	8390
$PM_{2.5}$	2170	2200	1200	922	556	175	129	65.8	7410

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-30 SCENARIO 1 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	65100	57400	39300	30300	16600	6420	3220	2230	221000
NO_x	42500	44300	24600	19700	10300	3510	2450	1230	149000
CO	186000	167000	97500	78000	47700	22100	9490	3950	612000
PM_{10}	2540	2490	1520	1130	617	224	144	84.1	8750
SO_2	3190	3180	2620	854	348	189	178	66	10600
Pb	6.06	6.06	3.77	3.29	1.94	0.66	0.35	0.19	22.3
Acetaldehyde	1360	1600	1190	694	325	135	98.7	78.6	5490
Benzene	1900	1610	875	512	485	206	91.2	36.6	5720
1,3-Butadiene	141	111	74.3	51.7	30.9	16	6.4	3.89	435
Formaldehyde	868	960	705	419	203	88.6	58.6	45.7	3350
PAH (Semi-Volatile)	108	128	94.8	55.2	25.7	10.6	7.88	6.29	436
PAH as %wt of PM_{10}	3.33	4.56	3.17	1.91	0.84	0.27	0.28	0.23	14.6
Total PAH	111	132	98	57.2	26.6	10.9	8.16	6.52	451
Toluene	2520	2090	1480	1080	599	275	117	85.2	8240
Xylenes (o,m,p)	2160	1780	1280	932	511	237	98.5	75.6	7070
$PM_{2.5}$	2290	2240	1370	1010	555	201	129	75.7	7880

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

6.7 Fleet Emissions - Scenario 2

Vehicle assumptions affecting emission rates are presented in Table 6-31.

TABLE 6-31: VEHICLE ASSUMPTIONS FOR SCENARIO 2

Component	Scenario Assumptions
Additional 10% NAFC 2000 to 2010	✔
Further 15% NAFC 2000 to 2010	✔
Business as usual VKT growth	✔
Euro 2 petrol vehicles <3.5 t	From 2003/4
Euro 3 petrol vehicles <3.5 t	From 2005/6
Euro 2 diesel vehicles <3.5 t	From 2002/3
Euro 3 diesel vehicles >3.5 t	From 2002/3
Euro 4 all diesel vehicles	From 2006/7
Accelerated CNG/LPG conversions vehicles >3.5 t	✔

It is assumed that the alternate Euro compliance to ADR 37/01 from year 2000 does not significantly impact on emissions.

6.7.1 Relative and Accumulated VKT

The relative VKT and average accumulated VKT estimates for each vehicle category according to the vehicle vintages applicable to this scenario have been estimated based on data from the current Survey of Motor Vehicle Use (SMVU, 1995). Melbourne fleet data are presented in Tables 6-32 to 6-35 as an example, with similar data for other States and Territories included in Appendix 6-C.

In the absence of other data, it is assumed that the fleet profiles from the current survey are applicable to all years of the study. Fleet profiles for passenger vehicles and light commercial vehicles were estimated using state level data. The fleet profiles presented for heavy duty vehicles and motorbikes are based on national level data and are the same for each capital city.

TABLE 6-32: MELBOURNE FLEET PROFILE, PETROL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 2, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT %			
		2000	2005	2010	2020
Passenger	Post 07	0.0	0.0	0.0	0.0
	2005 - 2007	0.0	3.6	35.9	83.6
	2003 - 2004	0.0	15.5	7.6	3.9
	97 - 02	26.5	27.7	34.1	12.5
	86 - 96	55.0	47.7	22.4	0.0
	76 - 85	18.5	5.5	0.0	0.0
Light Commercial	Post 07	0.0	0.0	0.0	0.0
	2005 - 2007	0.0	1.7	30.9	76.5
	2003 - 2004	0.0	14.7	10.8	6.2
	97 - 02	20.8	28.9	24.8	17.3
	86 - 96	50.5	44.2	33.4	0.0
	76 - 85	28.7	10.5	0.0	0.0
		Accumulated VKT ('000 km)			
		2000	2005	2010	2020
Passenger	Post 07	0.0	0.0	0.0	0.0
	2005 - 2007	0.0	12.0	66.6	123.7
	2003 - 2004	0.0	74.2	90.2	153.1
	97 - 02	58.7	83.9	168.4	218.8
	86 - 96	142.3	192.7	191.7	0.0
	76 - 85	150.0	150.0	0.0	0.0
Light Commercial	Post 07	0.0	0.0	0.0	0.0
	2005 - 2007	0.0	14.1	90.4	165.4
	2003 - 2004	0.0	66.2	149.6	216.8
	97 - 02	66.0	144.6	208.5	267.2
	86 - 96	179.5	236.6	245.5	0.0
	76 - 85	150.0	150.0	0.0	0.0

TABLE 6-33: MELBOURNE FLEET PROFILE, DIESEL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 2, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT %			
		2000	2005	2010	2020
Passenger	2006-	0.0	0.0	30.9	81.5
	2002-05	0.0	26.5	16.0	10.9
	pre 2002	100.0	73.5	53.1	7.6
Light Commercial	2006-	0.0	0.0	25.6	71.3
	2002-05	0.0	20.8	19.7	16.0
	pre 2002	100.0	79.2	54.7	12.7
		Accumulated VKT ('000 km)			
		2000	2005	2010	2020
Passenger	2006-	0.0	0.0	63.0	122.3
	2002-05	0.0	58.7	87.4	219.6
	pre 2002	141.2	159.1	186.9	173.0
Light Commercial	2006-	0.0	0.0	76.8	153.4
	2002-05	0.0	66.0	157.1	281.5
	pre 2002	193.8	215.6	235.1	246.9

TABLE 6-34: MELBOURNE FLEET PROFILE, DIESEL FUELLED MEDIUM/HEAVY DUTY VEHICLES, SCENARIO 2, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT % 2000	2005	2010	2020
Rigid trucks	2006+	0.0	0.0	19.2	80.0
	2002-05	0.0	15.6	27.2	12.8
	1995-01	26.4	45.7	38.2	7.2
	Pre '95	73.6	38.8	15.3	0.0
Non-freight trucks	2006+	0.0	0.0	22.2	75.2
	2002-05	0.0	16.0	22.3	16.8
	1995-01	28.3	38.5	38.1	8.0
	Pre '95	71.7	45.5	17.5	0.0
Articulated trucks	2006+	0.0	0.0	31.7	82.2
	2002-05	0.0	27.8	25.0	11.9
	1995-01	38.0	42.7	28.9	5.8
	Pre '95	62.0	29.5	14.3	0.0
Buses	2006+	0.0	0.0	34.8	82.4
	2002-05	0.0	28.3	26.3	11.2
	1995-01	40.8	42.4	25.0	6.4
	Pre '95	59.2	29.3	13.8	0.0
		Accumulated VKT % 2000	2005	2010	2020
Rigid trucks	2006+	0.0	0.0	121.3	239.7
	2002-05	0.0	88.7	246.2	270.2
	1995-01	121.3	244.0	302.5	108.9
	Pre '95	225.7	209.1	154.4	0.0
Non-freight	2006+	0.0	0.0	77.3	168.7
	2002-05	0.0	59.1	136.4	269.1
	1995-01	77.3	130.0	254.5	131.6
	Pre '95	200.9	231.2	176.9	0.0
Articulated trucks	2006+	0.0	0.0	327.2	589.5
	2002-05	0.0	253.1	606.6	799.4
	1995-01	327.2	658.3	818.7	509.4
	Pre '95	703.0	709.0	638.6	0.0
Buses	2006+	0.0	0.0	116.2	235.2
	2002-05	0.0	90.5	281.7	505.2
	1995-01	116.2	262.2	387.0	415.3
	Pre '95	376.9	433.3	455.5	0.0

TABLE 6-35: MELBOURNE FLEET PROFILE, PETROL FUELLED MEDIUM/ HEAVY DUTY VEHICLES AND MOTORCYCLES, SCENARIO 2, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT % 2000	2005	2010	2020
Rigid trucks	2008+	0.0	0.0	19.2	80.0
	2003-07	0.0	15.6	27.2	12.8
	Pre 2003	26.4	45.7	38.2	7.2
Non-freight trucks	2008+	0.0	0.0	22.2	75.2
	2003-07	0.0	16.0	22.3	16.8
	Pre 2003	28.3	38.5	38.1	8.0
Buses	2008+	0.0	0.0	34.8	82.4
	2003-07	0.0	28.3	26.3	11.2
	Pre 2003	40.8	42.4	25.0	6.4
Motorcycles	all	100.0	100.0	100.0	100.0
		Accumulated VKT ('000 km)			
		2000	2005	2010	2020
Rigid trucks	2008+	0.0	0.0	121.3	239.7
	2003-07	0.0	88.7	246.2	270.2
	Pre 2003	121.3	244.0	302.5	108.9
Non-freight trucks	2008+	0.0	0.0	77.3	168.7
	2003-07	0.0	59.1	136.4	269.1
	Pre 2003	77.3	130.0	254.5	131.6
Buses	2008+	0.0	0.0	116.2	235.2
	2003-07	0.0	90.5	281.7	505.2
	Pre 2003	116.2	262.2	387.0	415.3
Motorcycles	all	53.6	53.6	53.6	53.6

6.7.2 Fuel Properties

Fuel properties for this scenario are as for Scenario 1 with the following additions:

- Euro 2 sulfur levels in petrol (500 ppm) introduced in 2002;
- Euro 3 sulfur levels in petrol (150 ppm) introduced in 2005;
- Euro 2 sulfur levels in diesel (500 ppm) introduced in 2003;
- Euro 4 sulfur levels in diesel (50 ppm) introduced in 2006.

6.7.2.1 Emission Rate Scaling Factors

Emission rate adjustment factors were developed for this Scenario according to the expected fuel changes and vehicle technologies, using the relationships reported by Samaras et al. (1998). As future vehicle emission rate limits for regulated gases are associated with specific fuel compositions, the scaling factors for each vehicle vintage are based on differences between available fuel quality and the specified fuel for that vintage. For existing vehicle vintages, the scaling factors are based on differences between proposed new fuel specifications and the existing (average) Australian fuel properties.

6.7.3 HC, NO_X and CO Exhaust Emission Rates

A summary of the methodology and assumptions used in the estimation of HC, NO_x and CO exhaust emission factors for each vehicle category is presented in Table 6-36.

TABLE 6-36: METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING HC, NO_X AND CO EXHAUST EMISSION FACTORS, SCENARIO 2

Vehicle Category	Fuel	Methodology/Assumptions
Passenger	Petrol	Reference exhaust emission rates and deterioration rates for ADR 37 and ADR 27 vehicles established using vehicle testing data from EPANSW (1995) and FORS (1996). For post catalyst vehicles, deterioration according to vehicle travel capped at pre catalyst vehicle emissions (150,000 km travel).
		Euro 2 and 3 emission limits adopted as reference rates for these vehicles. Deterioration rates based on Euro specification of 20% deterioration from 0 to 80 000 km.
		Reference emission rates modified to account for fuel specifications proposed for this Scenario as described in Section 6.2.1.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	Petrol emission factors scaled according to FORS data as reported by Parsons (1998):
		Pre catalyst – scale petrol emission factors by 0.5 HC, 0.7 NO_x, 1.0 CO
		Post catalyst - scale petrol emission factors by 1.2 HC, 1.1 NO_x, 1.9 CO
Light Commercial	Petrol	As for passenger vehicles for HC and CO, NO_x scaled by 1.15 (EPANSW, 1995)
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for passenger vehicles

TABLE 6-36: METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING HC, NO_X AND CO EXHAUST EMISSION FACTORS (CONTINUED)

Rigid and Non-Freight Trucks	Petrol	Pre 2003 and post 2003 emission rates equal to USEPA Heavy Duty Vehicles, 1985 and 1996 vintage respectively. Deterioration as for USEPA heavy duty vehicles, 1985 vintage.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3 Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for buses (shown below)
Articulated Trucks	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
Buses	Petrol	Pre 2003 : emission rates as for rigid/non-freight trucks scaled by 0.7. Factor based on ratio of petrol fuel consumption of buses to that of rigid/non-freight trucks from current SMVU. Post 2003 : as for rigid/non-freight trucks.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3 Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for petrol fuelled buses, scaled by 0.4 HC, 1.7 NO_x, 0.2 CO. Factors scaled according to data for 1990 vintage vehicles as reported by Parsons (1998).
Motor Cycles	Petrol	Assume equal to USEPA motor cycles, HC 1988+, NO_x 1980+ and CO 1982+.

6.7.4 Particulate Matter

There are limited data available on particulate emissions from Australian diesel vehicles. A review of recent Australian and overseas work was undertaken to estimate particulate emission rates for the current Australian motor vehicle fleet, as discussed in Section 6.6.4. A summary of the methodology is presented in Table 6-37.

TABLE 6-37: METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING PARTICULATE EMISSION FACTORS, SCENARIO 2

Vehicle Category	Fuel	Methodology/Assumptions
Passenger	Petrol	Emission rates assumed equal to that of US 1986-90 catalyst equipped vehicles (Maricq et al., 1999) and US 1970-74 non-catalyst vehicles (USEPA, 1995).
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	Emission rate assumed equal to that of recent model catalyst equipped European vehicle (Rijkeboer et al., 1994).
Light Commercial	Petrol	As for passenger vehicles
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for passenger vehicles
Rigid and Non-Freight Trucks	Petrol	Assume equal to USEPA emission rates for heavy duty vehicles, pre 1987 vintage, no catalyst.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for passenger vehicles
Articulated Trucks	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
Buses	Petrol	As for Rigid and Non-Freight trucks
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for Rigid and Non-Freight trucks
Motor Cycles	Petrol	Assume equal to emission rates for early model US motor cycles, weighted for 80% 4-stroke and 20% 2-stroke engines

As for Scenario 1, it is assumed for the purposes of this study that all particulate matter from motor vehicles is smaller than 10 micron and that 90% of this is smaller than 2.5 micron.

6.7.5 Evaporative HC Emissions

Euro emission limits do not specify tighter restrictions on evaporative emissions from petrol fuelled passenger vehicles, however, the evaporative testing procedures for future vehicles will become more stringent. This implies that improved evaporative emission control will be a feature of future motor vehicle fleets. For the purposes of this study, we have conservatively estimated evaporative emission rates using the Scenario 1 methodology described in Section 5.5, taking account of fuel volatility reductions. A summary of the emission rate estimates is presented in Tables 6-38.

6.7.6 Fleet HC, NO_x, CO and PM_{10} Emission Rates

From a consideration of vehicle vintage, VKT travel according to year of manufacture and emission rates according to vehicle vintage, composite emission factors for HC, NO_x, CO and PM_{10} have been estimated for metropolitan passenger vehicle fleets for the study years. A summary of results is presented in Table 6-38 with detailed results presented in Appendix 6-D.

TABLE 6-38: SCENARIO 2 - FLEET HC, NO_x, CO AND PM_{10} ANNUAL EMISSION RATES FOR CAPITAL CITIES, 2000

	Emission Factor (g/km)					
City/year	HC (exh)	HC (evap)	HC (total)	NO_x	CO	PM_{10}
2000						
Sydney	1.17	0.94	2.11	1.69	14.94	0.08
Melbourne	1.28	0.96	2.24	1.83	17.50	0.09
Brisbane	1.22	1.06	2.28	1.87	16.29	0.09
Perth	1.30	1.10	2.39	1.81	17.88	0.07
Adelaide	1.31	0.97	2.28	1.76	18.77	0.07
Canberra	1.33	0.99	2.32	1.70	19.65	0.07
Hobart	1.35	0.93	2.27	1.97	19.25	0.09
Darwin	0.93	1.21	2.14	1.65	10.46	0.09
Average	1.24	1.02	2.25	1.78	16.84	0.08
2005						
Sydney	0.89	0.92	1.81	1.30	10.77	0.07
Melbourne	1.06	0.93	1.99	1.58	14.56	0.07
Brisbane	0.99	1.04	2.03	1.54	12.79	0.08
Perth	1.04	1.02	2.05	1.54	14.38	0.06
Adelaide	1.02	0.93	1.95	1.48	14.64	0.06
Canberra	0.99	0.95	1.93	1.30	13.55	0.06
Hobart	0.98	0.90	1.88	1.59	13.72	0.08
Darwin	0.73	1.16	1.89	1.29	7.66	0.08
Average	0.96	0.98	1.94	1.45	12.76	0.07
2010						
Sydney	0.70	0.90	1.60	0.94	8.64	0.05
Melbourne	0.67	0.92	1.59	1.08	8.53	0.06
Brisbane	0.70	1.00	1.70	1.10	8.67	0.06
Perth	0.79	0.99	1.77	1.17	10.95	0.05
Adelaide	0.68	0.92	1.60	1.01	9.29	0.05
Canberra	0.71	0.92	1.63	0.89	9.17	0.05
Hobart	0.65	0.88	1.54	1.14	8.68	0.06
Darwin	0.55	1.14	1.68	0.90	5.29	0.06
Average	0.68	0.96	1.64	1.03	8.65	0.06
2020						
Sydney	0.40	0.90	1.30	0.41	4.23	0.04
Melbourne	0.37	0.92	1.29	0.51	4.14	0.04
Brisbane	0.38	1.00	1.38	0.51	4.06	0.04
Perth	0.34	0.99	1.33	0.46	3.97	0.04
Adelaide	0.35	0.92	1.27	0.39	4.18	0.04
Canberra	0.47	0.92	1.39	0.40	5.35	0.04
Hobart	0.36	0.88	1.25	0.54	4.33	0.04
Darwin	0.35	1.14	1.49	0.46	3.34	0.04
Average	0.38	0.96	1.34	0.46	4.20	0.04

PM_{10} = Particulates < 10 μm
HC (exh) = Hydrocarbons from exhaust
HC (evap) = Hydrocarbons from evaporatives
NO_x = Oxides of nitrogen
CO = Carbon monoxide

6.7.7 SO_2 And Lead

Fleet emissions of SO_2 and lead were estimated from a consideration of fuel consumption projections and sulfur/lead contents of Australian fuels. All sulfur contained in fuel is assumed to be oxidised to SO_2. For lead, it is assumed that 75% of the alkyl lead additive in petrol is emitted in exhaust as inorganic lead salts with an additional 2% of the alkyl lead being emitted unchanged due to fuel evaporation (Carnovale et al., 1991).

Sulfur contents under this scenario are discussed in Section 6.7.2. Leaded and unleaded petrol is assumed to contain 200 mg/L and 2.5 mg/L of lead respectively.

A summary of results is presented in Section 6.7.9. It should be noted that leaded petrol is to be phased out as part of this scenario and lead emissions from motor vehicles will fall to low levels after 2002/3.

6.7.8 Air Toxics

Weighted VOC species profiles are based on fleet characteristics for this Scenario and the reference information presented in Section 6.5. A summary of the exhaust and evaporative profiles for this Scenario for Melbourne is presented in Table 6-39, with similar information for other cities presented in Appendix 6-E.

TABLE 6-39: FLEET AVERAGE AIR TOXIC PROFILES, MELBOURNE, SCENARIO 2, 2000-2020

Substance	2000	2005	2010	2020
	% w/w Hydrocarbons			
	Melbourne			
Acetaldehyde	4.4%	5.1%	5.9%	7.6%
Benzene	5.2%	5.3%	5.9%	6.5%
1,3-Butadiene	0.6%	0.6%	0.5%	0.5%
Formaldehyde	3.1%	3.3%	3.6%	4.5%
PAH (Semi-Volatile)	0.3%	0.4%	0.5%	0.6%
PAH as % wt of PM_{10}	0.1%	0.1%	0.1%	0.2%
Toluene	8.0%	7.5%	7.1%	7.0%
Xylenes (o,m,p)	7.1%	6.7%	6.5%	6.4%

6.7.9 Greenhouse Emissions

Greenhouse emissions for the national fleet were predicted based upon the fuel usage projections presented in Appendix 6-B. We have adopted CO_2 emission factors and liquid fuel densities reported in the greenhouse workbook for transport (NGGIC, 1996) as shown in Table 6-25 (Section 6.6.9).

Table 6-40 presents the predicted greenhouse emissions for road transport under Scenario 2.

TABLE 6-40 SCENARIO 2– AUSTRALIAN GREENHOUSE EMISSIONS FROM ROAD TRANSPORT

Year	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
2000	63600	21.9	10.8	360.7	3350.3	438.1	13.3
2005	68900	20.4	9.6	318.5	2793.2	408.4	8.3
2010	73900	18.4	7.3	243.3	2054.1	367.8	4.5
2020	81100	16.7	3.8	125.4	1083.9	334.0	4.5

6.7.9 Fleet Emissions

A summary of vehicle fleet emissions for Scenario 2 is presented in Tables 6-41 to 6-44.

TABLE 6-41: SCENARIO 2 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	36800	33200	22900	6680	4180	1910	247000
NO_x	57100	57000	28700	24200	17200	4810	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2220	1940	1950	580	245	155	116	42.4	7250
Pb	102	95.8	50.2	58.2	35.7	8.32	7	1.89	359
Acetaldehyde	1270	1760	980	734	430	110	110	49.2	5450
Benzene	2280	2410	1080	1040	855	222	149	52.2	8090
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	996	1250	681	553	341	90.3	79.6	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.56	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1960	1850	1280	375	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1710	1610	1110	326	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-42 SCENARIO 2 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	66400	65400	37100	31800	20600	6200	3670	1880	233000
NO_x	47600	52100	26600	22900	15100	4040	2980	1220	173000
CO	395000	479000	228000	218000	152000	42500	25900	7370	1550000
PM_{10}	2440	2420	1320	1020	629	188	144	72.3	8220
SO_2	1420	1460	796	608	156	106	86.2	45.6	4680
Pb	6.42	5.75	3.07	2.72	1.9	0.57	0.34	0.16	20.9
Acetaldehyde	1200	1780	1030	751	406	104	100	49.4	5420
Benzene	2180	2250	1010	774	761	212	125	36	7350
1,3-Butadiene	194	197	107	94.6	62.8	19.6	11.2	4.22	690
Formaldehyde	854	1160	665	504	283	78.1	65.5	30.8	3640
PAH (Semi-Volatile)	93.8	141	81.2	59.1	31.8	8.1	7.89	3.92	427
PAH as %wt of PM_{10}	2.07	2.93	1.75	1.11	0.55	0.14	0.18	0.11	8.84
Total PAH	95.8	144	82.9	60.2	32.3	8.24	8.06	4.04	435
Toluene	3110	3130	1770	1550	999	307	175	81.2	11100
Xylenes (o,m,p)	2700	2740	1560	1370	877	268	152	72.6	9730
$PM_{2.5}$	2190	2170	1190	914	566	169	130	65	7400

HC = Hydrocarbons

VOC = Volitile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-43: SCENARIO 2 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	62900	55800	35000	30400	17600	5720	3150	1840	212000
NO_x	36900	38000	20900	19100	10600	2990	2210	914	131000
CO	340000	300000	173000	184000	100000	31600	17100	5580	1150000
PM_{10}	2070	2050	1150	900	541	172	120	62.6	7070
SO_2	825	760	429	368	20.8	73.2	44.5	22.1	2540
Pb	6.45	5.73	3.23	2.87	1.89	0.59	0.34	0.16	21.3
Acetaldehyde	1140	1380	932	730	326	93.1	81.7	47.8	4730
Benzene	2110	1800	921	685	609	194	102	30.6	6440
1,3-Butadiene	152	126	78	73.2	41.2	14.3	7.24	3.26	495
Formaldehyde	758	855	572	458	213	64.3	50.3	28.7	3000
PAH (Semi-Volatile)	89.8	110	74	57.8	25.7	7.28	6.49	3.81	375
PAH as %wt of PM_{10}	2.02	2.88	1.77	1.15	0.55	0.15	0.17	0.12	8.81
Total PAH	91.8	113	75.8	59	26.2	7.43	6.66	3.93	383
Toluene	2610	2220	1430	1300	722	244	125	70.5	8720
Xylenes (o,m,p)	2250	1920	1260	1150	629	212	107	62.8	7590
$PM_{2.5}$	1860	1840	1040	810	487	154	108	56.3	6360

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-44: SCENARIO 2 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	58000	51000	35300	27600	15100	5680	2830	2010	198000
NO_x	18500	20200	11000	8380	4030	1440	1090	517	65200
CO	189000	164000	98300	79300	48200	21300	9250	4240	613000
PM_{10}	1750	1600	1010	807	454	161	92.5	54.1	5930
SO_2	833	756	469	395	22.6	74.7	43.5	24.2	2620
Pb	6.4	5.46	3.42	3	1.74	0.6	0.31	0.17	21.1
Acetaldehyde	974	1120	843	507	236	97.5	67.2	54.6	3900
Benzene	1690	1380	751	406	430	182	75.9	27.7	4940
1,3-Butadiene	100	77.7	52.7	37.8	22.5	11.6	4.36	2.71	310
Formaldehyde	619	671	500	306	148	64	39.9	31.8	2380
PAH (Semi-Volatile)	77	89.3	67.2	40.4	18.7	7.68	5.36	4.37	310
PAH as %wt of PM_{10}	2.29	2.94	2.1	1.37	0.62	0.19	0.18	0.15	9.83
Total PAH	79.3	92.2	69.3	41.7	19.3	7.87	5.54	4.52	320
Toluene	1990	1640	1190	889	486	216	89.1	69.6	6560
Xylenes (o,m,p)	1670	1370	1020	762	408	184	73.6	61.7	5550
$PM_{2.5}$	1580	1440	907	726	409	145	83.3	48.7	5340

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

6.8 Fleet Emissions - Scenario 3

Vehicle assumptions affecting emission rates for Scenario 3 are presented in Table 6-45.

TABLE 6-45: VEHICLE ASSUMPTIONS FOR SCENARIO 3

Component	Scenario Assumptions
Additional 10% NAFC 2000 to 2010	✔
Further 15% NAFC 2000 to 2010	✔
Business as usual VKT growth	✔
Euro 2 petrol vehicles <3.5 t	From 2003/4
Euro 3 petrol vehicles <3.5 t	From 2005/6
Euro 4 petrol vehicles	From 2008/9
Euro 2 diesel vehicles <3.5 t	From 2002/3
Euro 3 diesel vehicles >3.5 t	From 2002/3
Euro 4 all diesel vehicles	From 2006/7
Accelerated CNG/LPG conversions vehicles >3.5 t	✔

It is assumed that the alternate Euro compliance to ADR 37/01 from year 2000 does not significantly impact on emissions.

6.8.1 Relative and Accumulated VKT

The relative VKT and average accumulated VKT estimates for each vehicle category according to the vehicle vintages applicable to this scenario have been estimated based on data from the current Survey of Motor Vehicle Use (SMVU, 1995). Melbourne fleet data are presented in Tables 6-46 and 6-47 as an example, with similar data for other States and Territories included in Appendix 6-E.

In the absence of other data, it is assumed that the fleet profiles from the current survey are applicable to all years of the study. Fleet profiles for passenger vehicles and light commercial vehicles were estimated using state level data. The fleet profiles presented for heavy duty vehicles and motorbikes are based on national level data and are the same for each capital city.

TABLE 6-46: MELBOURNE FLEET PROFILE, PETROL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 3, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT %			
		2000	2005	2010	2020
Passenger	Post 07	0.0	0.0	19.1	71.2
	2005 - 2007	0.0	3.6	16.8	12.4
	2003 - 2004	0.0	15.5	7.6	3.9
	97 - 02	26.5	27.7	34.1	12.5
	86 - 96	55.0	47.7	22.4	0.0
	76 - 85	18.5	5.5	0.0	0.0
Light Commercial	Post 07	0.0	0.0	16.5	62.3
	2005 - 2007	0.0	1.7	14.5	14.3
	2003 - 2004	0.0	14.7	10.8	6.2
	97 - 02	20.8	28.9	24.8	17.3
	86 - 96	50.5	44.2	33.4	0.0
	76 - 85	28.7	10.5	0.0	0.0
		Accumulated VKT ('000 km)			
		2000	2005	2010	2020
Passenger	Post 07	0.0	0.0	51.9	110.0
	2005 - 2007	0.0	12.0	78.4	185.8
	2003 - 2004	0.0	74.2	90.2	153.1
	97 - 02	58.7	83.9	168.4	218.8
	86 - 96	142.3	192.7	191.7	0.0
	76 - 85	150.0	150.0	0.0	0.0
Light Commercial	Post 07	0.0	0.0	56.4	146.2
	2005 - 2007	0.0	14.1	129.7	222.0
	2003 - 2004	0.0	66.2	149.6	216.8
	97 - 02	66.0	144.6	208.5	267.2
	86 - 96	179.5	236.6	245.5	0.0
	76 - 85	150.0	150.0	0.0	0.0

TABLE 6-47: MELBOURNE FLEET PROFILE, DIESEL FUELLED PASSENGER AND LIGHT COMMERCIAL VEHICLES, SCENARIO 3, 2000-2020

Vehicle Type	Vintage (year)	Relative VKT % 2000	2005	2010	2020
Passenger	2006-	0.0	0.0	30.9	81.5
	2002-05	0.0	26.5	16.0	10.9
	pre 2002	100.0	73.5	53.1	7.6
Light Commercial	2006-	0.0	0.0	25.6	71.3
	2002-05	0.0	20.8	19.7	16.0
	pre 2002	100.0	79.2	54.7	12.7
		Accumulated VKT ('000 km) 2000	2005	2010	2020
Passenger	2006-	0.0	0.0	63.0	122.3
	2002-05	0.0	58.7	87.4	219.6
	pre 2002	141.2	159.1	186.9	173.0
Light Commercial	2006-	0.0	0.0	76.8	153.4
	2002-05	0.0	66.0	157.1	281.5
	pre 2002	193.8	215.6	235.1	246.9

6.8.2 Fuel Properties

Fuel properties for this scenario are as for Scenario 2 with the following additions:

- Euro 3 petrol introduced in 2005, with parameters other than sulfur concentration and RON set on a refinery ‘best endeavours’ basis;
- Euro 4 petrol introduced in 2008, with parameters other than sulfur concentration and RON set on a refinery best endeavours basis;
- Euro 4 diesel introduced in 2006, with parameters other than sulfur concentration and RON set on a refinery best endeavours basis.

It should be noted that Euro 4 fuel specifications for a number of fuel components are not yet available. Assumptions regarding specifications for these components have been provided by Australian Institute of Petroleum (AIP) members. Agreed fuel quality specifications for this Scenario are presented in Tables 6-48 and 6-49. In cases where Euro 3 specifications are ‘open’, the value adopted is the less stringent of the ‘best endeavours’ Euro 4 or current refinery specification for that component.

TABLE 6-48 'BEST ENDEAVOURS' EURO 3 / EURO 4 PETROL SPECIFICATIONS

Fuel Parameter	Euro 3 Best Endeavours	Euro 4 Best Endeavours
RON min	95	95
Distillation		
Evaporated at 100°C %v/v min	Open	46
Evaporated at 150°C %v/v min	Open	75
Hydrocarbon analysis		
Olefins	Open	18
Aromatics	48	42
Oxygen content (% m/m max)	2.7	2.7
Sulfur content (mg/kg) max	150	50
Lead content (g/L) max	0.005	

TABLE 6-49: 'BEST ENDEAVOURS' EURO 4 DIESEL SPECIFICATIONS

Fuel Parameter	Euro 4 Best Endeavours
Cetane No min	51
Cetane Index min	46
Density at 15°C kg/m^3 max	845
95% point °C max	360
Polycyclic aromatics %m/m max	11
Sulfur mg/kg	50

6.8.2.1 Emission Rate Scaling Factors

The relationships between fuel properties and emissions presented by Samaras et al. (1998) as reported in Section 6.3 were used to model the combined effects of changes in multiple fuel variables on regulated gases. For benzene, the relationships reported by USEPA (1993) were used to estimate benzene emissions from light duty catalyst and non-catalyst petrol vehicles.

Emission rate adjustment factors were developed for this scenario according to the expected fuel changes and vehicle technologies. As future vehicle emission rate limits for regulated gases are associated with specific fuel compositions, the scaling factors for each vehicle vintage are based on differences between available fuel quality and the specified fuel for that vintage. For existing vehicle vintages and unregulated gases (i.e. benzene), the scaling factors are based on differences between proposed new fuel specifications and the existing (average) Australian fuel properties.

6.8.3 HC, NO_x and CO Exhaust Emission Rates

A summary of the methodology and assumptions used in the estimation of HC, NO_x and CO exhaust emission factors for each vehicle category is presented in Table 6-50.

TABLE 6-50: METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING HC, NO_X AND CO EXHAUST EMISSION FACTORS

Vehicle Category	Fuel	Methodology/Assumptions
Passenger	Petrol	Reference exhaust emission rates and deterioration rates for ADR 37 and ADR 27 vehicles established using vehicle testing data from EPANSW (1995) and FORS (1996). For post catalyst vehicles, deterioration according to vehicle travel capped at pre catalyst vehicle emissions (150,000 km travel).
		Euro 2, 3 and 4 emission limits adopted as reference rates for these vehicles. Deterioration rates based on Euro specification of 20% deterioration from 0 to 80 000 km.
		Reference emission rates modified to account for fuel specifications proposed for this Scenario as described in Section 7.2.1.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	Petrol emission factors scaled according to FORS data as reported by Parsons (1998):
		Pre catalyst – scale petrol emission factors by 0.5 HC, 0.7 NO_x, 1.0 CO
		Post catalyst - scale petrol emission factors by 1.2 HC, 1.1 $NO_{x,}$ 1.9 CO
Light Commercial	Petrol	As for passenger vehicles for HC and CO, NO_x scaled by 1.15 (EPANSW, 1995)
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3
		Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for passenger vehicles

TABLE 6-50 METHODOLOGY AND ASSUMPTIONS FOR ESTIMATING HC, NO_X AND CO EXHAUST EMISSION FACTORS (CONTINUED)

Rigid and Non-Freight Trucks	Petrol	Pre 2003 and 2003-2007 emission rates equal to USEPA Heavy Duty Vehicles, 1985 and 1996 vintage respectively. Post 2007 emission rates equal to Euro 4 limits. Deterioration as for USEPA heavy duty vehicles, 1985 vintage.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3 Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for buses (shown below)
Articulated Trucks	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3 Reference emission rates adjusted according to fuel quality changes for this Scenario.
Buses	Petrol	Pre Euro : emission rates as for rigid/non-freight trucks scaled by 0.7. Factor based on ratio of petrol fuel consumption of buses to that of rigid/non-freight trucks from current SMVU. Post Euro : as for rigid/non-freight trucks.
	Diesel	Adopted from Cox and Apelbaum (1999), Scenario 3 Reference emission rates adjusted according to fuel quality changes for this Scenario.
	LPG/CNG	As for petrol fuelled buses, scaled by 0.4 HC, 1.7 NO_x, 0.2 CO. Factors scaled according to data for 1990 vintage vehicles as reported by Parsons (1998).
Motor Cycles	Petrol	Assume equal to USEPA motor cycles, HC 1988+, NO_x 1980+ and CO 1982+.

6.8.4 Particulate Matter

The methodology adopted to estimate particulate emissions from Australian diesel vehicles for this Scenario is the same as that for Scenario 2 (Section 6.7.4, Table 6-37).

6.8.5 Evaporative HC Emissions

Euro emission limits do not specify tighter restrictions on evaporative emissions from petrol fuelled passenger vehicles, however, the evaporative testing procedures for future vehicles will become more stringent. This implies that improved evaporative emission control will be a feature of future motor vehicle fleets. For the purposes of this study, we have conservatively estimated evaporative emission rates using the Scenario 1 methodology described in Section 6.6.5, taking account of fuel volatility reductions. A summary of the emission rate estimates is presented in Tables 6-51.

6.8.6 Fleet HC, NO_x, CO and PM_{10} Emission Rates

From a consideration of vehicle vintage, VKT travel according to year of manufacture and emission rates according to vehicle vintage, composite emission factors for HC, NOx, CO and PM_{10} have been estimated for metropolitan passenger vehicle fleets for the study years. A summary of results is presented in Table 6-51 with detailed results presented in Appendix 6-D.

TABLE 6-51: SCENARIO 3 - FLEET HC, NO_x, CO AND PM_{10} ANNUAL EMISSION RATES FOR CAPITAL CITIES, 2000 - 2020

	Emission Factor (g/km)					
City/year	HC (exh)	HC (evap)	HC (total)	NO_x	CO	PM_{10}
2000						
Sydney	1.17	0.94	2.11	1.69	14.94	0.08
Melbourne	1.28	0.96	2.24	1.83	17.50	0.09
Brisbane	1.22	1.08	2.30	1.87	16.29	0.09
Perth	1.30	1.10	2.39	1.81	17.88	0.07
Adelaide	1.31	0.97	2.28	1.76	18.77	0.07
Canberra	1.33	0.96	2.30	1.70	19.65	0.07
Hobart	1.35	0.93	2.27	1.97	19.25	0.09
Darwin	0.93	1.21	2.14	1.65	10.46	0.09
Average	1.24	1.02	2.25	1.78	16.84	0.08
2005						
Sydney	0.87	0.91	1.78	1.30	10.29	0.07
Melbourne	1.01	0.90	1.92	1.58	13.94	0.07
Brisbane	0.97	0.99	1.96	1.54	12.30	0.08
Perth	1.01	1.00	2.02	1.54	13.83	0.06
Adelaide	0.99	0.93	1.92	1.48	13.99	0.06
Canberra	0.97	0.94	1.90	1.30	12.98	0.06
Hobart	0.96	0.88	1.84	1.59	13.12	0.08
Darwin	0.71	1.11	1.82	1.29	7.32	0.08
Average	0.94	0.96	1.89	1.45	12.22	0.07
2010						
Sydney	0.65	0.88	1.53	0.92	7.73	0.05
Melbourne	0.62	0.88	1.50	1.07	7.66	0.06
Brisbane	0.65	0.95	1.60	1.09	7.92	0.06
Perth	0.74	0.95	1.69	1.15	10.08	0.06
Adelaide	0.63	0.90	1.53	0.99	8.45	0.05
Canberra	0.66	0.90	1.56	0.88	8.34	0.05
Hobart	0.61	0.86	1.46	1.13	7.80	0.07
Darwin	0.51	1.07	1.58	0.89	4.69	0.06
Average	0.63	0.92	1.56	1.01	7.83	0.06
2020						
Sydney	0.30	0.88	1.19	0.37	2.77	0.04
Melbourne	0.29	0.88	1.17	0.47	2.67	0.04
Brisbane	0.29	0.95	1.24	0.47	2.74	0.04
Perth	0.25	0.95	1.21	0.42	2.61	0.04
Adelaide	0.26	0.90	1.16	0.35	2.71	0.04
Canberra	0.36	0.90	1.26	0.35	3.68	0.04
Hobart	0.27	0.86	1.13	0.51	2.82	0.04
Darwin	0.28	1.07	1.35	0.43	2.31	0.04
Average	0.29	0.92	1.21	0.42	2.79	0.04

PM_{10} = Particulates < 10 μm
HC (exh) = Hydrocarbons from exhaust
HC (evap) = Hydrocarbons from evaporatives
NO_x = Oxides of nitrogen
CO = Carbon monoxide

6.8.7 SO_2 And Lead

Fleet emissions of SO_2 and lead were estimated from a consideration of fuel consumption projections and sulfur/lead contents of Australian fuels. All sulfur contained in fuel is assumed to be oxidised to SO_2. For lead, it is assumed that 75% of the alkyl lead additive in petrol is emitted in exhaust as inorganic lead salts with an additional 2% of the alkyl lead being emitted unchanged due to fuel evaporation (Carnovale et al., 1991).

Sulfur contents under this scenario are discussed in Section 6.8.2. Leaded and unleaded petrol is assumed to contain 200 mg/L and 2.5 mg/L of lead respectively.

A summary of results is presented in Section 6.8.10. It should be noted that leaded petrol is to be phased out as part of this Scenario and lead emissions from motor vehicles will fall to low levels after 1 January, 2002.

6.8.8 Air Toxics

Weighted VOC species profiles are based on fleet characteristics for this Scenario and the reference information presented in Section 4.3. A summary of the exhaust and evaporative profiles for this Scenario for Melbourne is presented in Table 6-52, with similar information for other cities presented in Appendix 6-E.

TABLE 6-52: FLEET AVERAGE AIR TOXIC PROFILES, MELBOURNE, SCENARIO 3, 2000-2020

	2000	2005	2010	2020
Substance	% w/w Hydrocarbons			
Acetaldehyde	4.4%	5.1%	5.9%	7.6%
Benzene	5.1%	5.1%	5.2%	5.5%
1,3-Butadiene	0.6%	0.6%	0.5%	0.5%
Formaldehyde	3.1%	3.3%	3.6%	4.5%
PAH (Semi-Volatile)	0.3%	0.4%	0.5%	0.6%
PAH as % wt of PM10	0.1%	0.1%	0.1%	0.2%
Toluene	8.0%	7.5%	7.1%	7.0%
Xylenes (o,m,p)	7.1%	6.7%	6.5%	6.4%

6.8.9 Greenhouse Emissions

Greenhouse emissions for the national fleet were predicted based upon the fuel usage projections presented in Appendix 6-B. We have adopted CO_2 emission factors and liquid fuel densities reported in the greenhouse workbook for transport (NGGIC, 1996) as shown in Table 6-25 (Section 6.6.9).

Table 6-53 presents the predicted greenhouse emissions for road transport under Scenario 3.

TABLE 6-53 SCENARIO 3– AUSTRALIAN GREENHOUSE EMISSIONS FROM ROAD TRANSPORT

Year	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
2000	63600	21.9	10.8	360.7	3350.3	438.5	13.3
2005	68900	20.0	9.6	319.0	2676.6	399.4	7.6
2010	73900	17.5	7.2	240.1	1859.4	349.6	1.9
2020	81100	15.1	3.5	115.8	720.4	302.4	1.9

6.8.10 Fleet Emissions

A summary of vehicle fleet emissions for Scenario 3 is presented in Tables 6-54 to 6-57.

TABLE 6-54: SCENARIO 3 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	37100	33200	22900	6610	4180	1910	247000
NO_x	57100	57000	28700	24200	17200	4810	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2200	1940	1950	583	245	153	115	42.5	7230
Pb	102	95.8	50.2	58.2	35.7	8.32	7	1.89	359
Acetaldehyde	1270	1760	980	734	430	110	110	49.2	5450
Benzene	2280	2330	1090	1090	855	221	145	55	8060
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	996	1250	681	553	341	90.3	79.6	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.56	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1980	1850	1280	371	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1730	1610	1110	323	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-55: SCENARIO 3 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	65400	63800	35900	31200	20200	6090	3590	1820	228000
NO_x	47700	52100	26600	22900	15100	4040	2980	1220	173000
CO	377000	459000	219000	209000	145000	40700	24700	7040	1480000
PM_{10}	2440	2420	1320	1020	629	188	144	72.3	8220
SO_2	1030	1350	796	608	156	71.3	79.8	45.6	4140
Pb	6.42	5.75	3.07	2.72	1.9	0.57	0.34	0.16	20.9
Acetaldehyde	1170	1740	1010	735	396	102	97.6	48.3	5300
Benzene	1990	2040	935	757	688	194	114	35.1	6750
1,3-Butadiene	189	193	104	92.6	61.2	19.1	11	4.13	675
Formaldehyde	834	1130	651	493	275	76.3	63.9	30.1	3550
PAH (Semi-Volatile)	91.5	138	79.5	57.8	31	7.91	7.7	3.84	417
PAH as %wt of PM_{10}	2.07	2.93	1.75	1.11	0.55	0.14	0.18	0.11	8.84
Total PAH	93.6	140	81.3	58.9	31.5	8.05	7.87	3.95	426
Toluene	3040	3030	1700	1510	974	300	170	77.7	10800
Xylenes (o,m,p)	2630	2640	1490	1330	854	261	147	68.9	9420
$PM_{2.5}$	2190	2170	1190	914	566	169	130	65	7400

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-56: SCENARIO 3 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	60100	52800	32900	29000	16900	5480	3000	1720	202000
NO_x	36200	37500	20700	18800	10400	2930	2180	902	130000
CO	304000	269000	158000	169000	91600	28700	15300	4930	1040000
PM_{10}	2100	2100	1210	932	545	174	123	65.1	7250
SO_2	331	322	182	149	20.8	27.9	18.8	9.73	1060
Pb	6.45	5.73	3.23	2.87	1.89	0.59	0.34	0.16	21.3
Acetaldehyde	1060	1290	870	684	308	87.1	76.1	44.2	4410
Benzene	1650	1370	765	643	478	153	78.1	28.2	5160
1,3-Butadiene	141	117	72.8	68.6	38.9	13.4	6.74	3.01	461
Formaldehyde	702	795	534	429	201	60.1	46.9	26.6	2800
PAH (Semi-Volatile)	83.2	102	69.1	54.2	24.3	6.82	6.04	3.52	349
PAH as %wt of PM_{10}	2.05	2.94	1.86	1.19	0.56	0.15	0.18	0.12	9.06
Total PAH	85.2	105	71	55.4	24.8	6.96	6.22	3.64	358
Toluene	2420	2040	1310	1210	680	228	116	63.9	8070
Xylenes (o,m,p)	2080	1750	1130	1060	588	196	98.3	56.1	6960
$PM_{2.5}$	1890	1890	1090	839	490	156	111	58.6	6530

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-57: SCENARIO 3 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	53000	45900	31500	25100	13800	5160	2560	1820	179000
NO_x	16600	18700	10100	7600	3540	1260	1000	472	59300
CO	124000	106000	65000	51200	31200	14600	5860	2880	400000
PM_{10}	1760	1630	1050	828	457	162	93.9	55.9	6030
SO_2	343	339	208	165	22.6	29.1	19.4	11.2	1140
Pb	6.4	5.46	3.42	3	1.74	0.6	0.31	0.17	21.1
Acetaldehyde	743	843	650	377	179	76.2	50.4	43.5	2960
Benzene	1080	854	513	315	269	118	47.2	22.6	3220
1,3-Butadiene	76.6	58.5	40.6	28.1	17	9.05	3.27	2.15	235
Formaldehyde	473	505	386	227	112	50	29.9	25.3	1810
PAH (Semi-Volatile)	58.8	67.2	51.9	30	14.1	6.01	4.02	3.48	236
PAH as %wt of PM_{10}	2.31	2.98	2.18	1.41	0.62	0.19	0.18	0.15	10
Total PAH	61.1	70.2	54.1	31.4	14.8	6.2	4.2	3.63	246
Toluene	1630	1320	961	727	399	178	71.7	58.2	5340
Xylenes (o,m,p)	1340	1060	803	608	326	149	57.2	50.5	4400
$PM_{2.5}$	1590	1460	944	745	411	146	84.5	50.3	5430

HC = Hydrocarbons
VOC = Volatile organic compounds
NO_x = Oxides of nitrogen
CO = Carbon monoxide
PAH = Poly-aromatic hydrocarbons
Pb = Lead
SO_2 = Sulfur dioxide
PM_{10} = Particulates < 10 µm
$PM_{2.5}$ = Particulates < 2.5 µm

6.9 Fleet Emissions - Scenario 4

Scenario 4 is the same as Scenario 3 (Section 7) with the requirement that Euro fuel specifications are mandatory rather than 'best endeavours'.

6.9.1 Relative and Accumulated VKT

The relative VKT and average accumulated VKT estimates for this Scenario are identical to Scenario 3 (Section 6.7).

6.9.2 Fuel Properties

Fuel properties for this scenario are as for Scenario 3 with the following additions:

- Euro 3 petrol introduced in 2005, with all fuel parameters required to meet the Euro 3 petrol specification;
- Euro 4 petrol introduced in 2008, with all fuel parameters required to meet the Euro 4 petrol specification;
- Euro 4 diesel introduced in 2006, with all fuel parameters required to meet the Euro 4 diesel specification, including specific requirements for 50 ppm sulfur.

It should be noted that Euro 4 fuel specifications for a number of fuel components are not yet available. Assumptions regarding specifications for these components have been provided by AIP members. Agreed fuel quality specifications for this Scenario are presented in Tables 6-58 and 6-59. Specifications assumed for Euro 4 fuels are displayed in brackets.

TABLE 6-58: MANDATORY EURO 3 / EURO 4 PETROL SPECIFICATIONS - SCENARIO 4

Fuel Parameter	Euro 3 Specification	Euro 4 Adopted
RON min	95	95
RVP (summer) kPa max	60	55
Distillation		
Evaporated at 100°C %v/v min	46	46
Evaporated at 150°C %v/v min	75	75
FBP °C max	210	205
Hydrocarbon analysis		
Olefins	18	14
Aromatics	42	(35)
Benzene	1	1
Oxygen content (% m/m max)	2.7	2.7
Sulfur content (mg/kg) max	150	(50)
Lead content (g/L) max	0.005	

TABLE 6-59: MANDATORY EURO 4 DIESEL SPECIFICATIONS – SCENARIO 4

Fuel Parameter	Euro 4 Adopted
Cetane No min	55
Cetane Index min	52
Density at 15°C kg/m^3 max	845
95% point °C max	350
Polycyclic aromatics %m/m max	4
Sulfur mg/kg	(50)

6.9.2.1 Emission Rate Scaling Factors

As for previous scenarios, the relationships between fuel properties and emissions reported by Samaras et al. (1998) as discussed in Section 6.3.1 were adopted to model the combined effects of changes in multiple fuel variables on regulated gases. For benzene, the relationship reported by USEPA (1993) was used to estimate benzene emissions from light duty catalyst and non-catalyst petrol vehicles.

Emission rate adjustment factors were developed for this scenario according to the expected fuel changes and vehicle technologies. As future vehicle emission rates (regulated gases) are associated with specific fuel compositions, the scaling factors for each vehicle vintage are based on differences between available fuel quality and the specified fuel for that vintage. For existing vehicle vintages and unregulated gases (i.e. benzene), the scaling factors are based on differences between proposed new fuel specifications and the existing (average) Australian fuel properties.

6.9.3 HC, NO_x and CO Exhaust Emission Rates

The methodology and assumptions used in the estimation of HC, NO_x and CO exhaust emission factors for this scenario are the same as for Scenario 3 (Section 6.8.3), the only difference being the magnitude of the emission rate adjustment factors (due to mandatory rather than 'best endeavours' fuel specifications).

6.9.4 Particulate Matter

The methodology and assumptions used in the estimation of particulate matter exhaust emission factors for this scenario are the same as for Scenario 3 (Section 6.8.4), the only difference being the magnitude of the emission rate adjustment factors (due to mandatory rather than 'best endeavours' fuel specifications).

6.9.5 Evaporative HC Emissions

The methodology used in the estimation of evaporative emission factors for this scenario are the same as for Scenario 3 (Section 6.8.5), the only difference being the fuel volatility assumptions (due to mandatory rather than 'best endeavours' fuel specifications).

6.9.6 Fleet HC, NO_x, CO and PM_{10} Emission Rates

From a consideration of vehicle vintage, VKT travel according to year of manufacture and emission rates according to vehicle vintage, composite emission factors for HC, NO_x, CO and PM_{10} have been estimated for metropolitan passenger vehicle fleets for the study years. A summary of results is presented in Table 6-60 with detailed results presented in Appendix 6-D.

TABLE 6-60: SCENARIO 4 – FLEET HC, NO_x, CO AND PM_{10} ANNUAL EMISSION RATES FOR CAPITAL CITIES, 2000 - 2020

	Emission Factor (g/km)					
City/year	HC (exh)	HC (evap)	HC (total)	NO_x	CO	PM_{10}
2000						
Sydney	1.17	0.94	2.11	1.69	14.94	0.08
Melbourne	1.28	0.96	2.24	1.83	17.50	0.09
Brisbane	1.22	1.08	2.30	1.87	16.29	0.09
Perth	1.30	1.10	2.39	1.81	17.88	0.07
Adelaide	1.31	0.97	2.28	1.76	18.77	0.07
Canberra	1.33	0.96	2.30	1.70	19.65	0.07
Hobart	1.35	0.93	2.27	1.97	19.25	0.09
Darwin	0.93	1.21	2.14	1.65	10.46	0.09
Average	1.24	1.02	2.25	1.78	16.84	0.08
2005						
Sydney	0.87	0.90	1.77	1.31	10.27	0.07
Melbourne	1.03	0.89	1.92	1.59	13.92	0.07
Brisbane	0.97	0.97	1.94	1.55	12.29	0.07
Perth	1.01	0.98	1.99	1.55	13.82	0.06
Adelaide	0.99	0.91	1.90	1.48	13.97	0.06
Canberra	0.96	0.92	1.88	1.30	12.96	0.06
Hobart	0.96	0.87	1.83	1.59	13.10	0.08
Darwin	0.71	1.09	1.80	1.29	7.30	0.07
Average	0.94	0.94	1.88	1.46	12.20	0.07
2010						
Sydney	0.63	0.87	1.51	0.92	7.62	0.05
Melbourne	0.61	0.87	1.48	1.06	7.54	0.06
Brisbane	0.64	0.93	1.58	1.08	7.81	0.06
Perth	0.73	0.93	1.66	1.15	9.97	0.05
Adelaide	0.62	0.88	1.51	0.99	8.34	0.04
Canberra	0.65	0.88	1.54	0.88	8.21	0.04
Hobart	0.60	0.85	1.44	1.12	7.68	0.06
Darwin	0.50	1.05	1.55	0.89	4.60	0.05
Average	0.62	0.91	1.53	1.01	7.72	0.05
2020						
Sydney	0.29	0.87	1.17	0.38	2.64	0.04
Melbourne	0.27	0.87	1.14	0.47	2.53	0.04
Brisbane	0.28	0.93	1.21	0.47	2.61	0.03
Perth	0.24	0.93	1.18	0.43	2.47	0.03
Adelaide	0.24	0.88	1.13	0.35	2.56	0.02
Canberra	0.35	0.88	1.24	0.36	3.53	0.02
Hobart	0.26	0.85	1.11	0.51	2.67	0.03
Darwin	0.27	1.05	1.32	0.43	2.22	0.03
Average	0.28	0.91	1.19	0.42	2.65	0.03

PM_{10} = Particulates < 10 μm
HC (exh) = Hydrocarbons from exhaust
HC (evap) = Hydrocarbons from evaporatives
NO_x = Oxides of nitrogen
CO = Carbon monoxide

6.9.7 SO_2 and Lead

Fleet emissions of SO_2 and lead were estimated from a consideration of fuel consumption projections and sulfur/lead contents of Australian fuels. All sulfur contained in fuel is assumed to be oxidised to SO_2. For lead, it is assumed that 75% of the alkyl lead additive in petrol is emitted in exhaust as inorganic lead salts with an additional 2% of the alkyl lead being emitted unchanged due to fuel evaporation (Carnovale et al., 1991).

Sulfur contents under this scenario are discussed in Section 8.2. Leaded and unleaded petrol is assumed to contain 200 mg/L and 2.5 mg/L of lead respectively.

A summary of results is presented in Section 6.9.10.

6.9.8 Air Toxics

Weighted VOC species profiles are based on fleet characteristics for this Scenario and the reference information presented in Section 6.5. A summary of the exhaust and evaporative profiles for this Scenario for Melbourne is presented in Table 6-61, with similar information for other cities presented in Appendix 6-E.

TABLE 6-61: FLEET AVERAGE AIR TOXIC PROFILES, MELBOURNE, SCENARIO 4, 2000-2020

	2000	2005	2010	2020
Substance	% w/w Hydrocarbons			
Acetaldehyde	4.4%	5.1%	5.9%	7.6%
Benzene	5.1%	4.1%	4.1%	4.3%
1,3-Butadiene	0.6%	0.6%	0.5%	0.5%
Formaldehyde	3.1%	3.3%	3.6%	4.5%
PAH (Semi-Volatile)	0.3%	0.4%	0.5%	0.6%
PAH as % wt of PM_{10}	0.1%	0.1%	0.1%	0.2%
Toluene	8.0%	7.5%	7.1%	7.0%
Xylenes (o,m,p)	7.1%	6.7%	6.5%	6.4%

6.9.9 Greenhouse Emissions

Greenhouse emissions for the national fleet were predicted based upon the fuel usage projections presented in Appendix 6-B. We have adopted CO_2 emission factors and liquid fuel densities reported in the greenhouse workbook for transport (NGGIC, 1996) as shown in Table 6-25 (Section 6.6.9).

Table 6-62 presents the predicted greenhouse emissions for road transport under Scenario 4.

TABLE 6-62: SCENARIO 4– AUSTRALIAN GREENHOUSE EMISSIONS FROM ROAD TRANSPORT

Year	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
2000	63600	21.9	10.8	360.7	3350.3	438.5	13.3
2005	68900	19.8	9.6	319.7	2673.4	395.6	8.3
2010	73900	17.2	7.2	239.3	1835.9	344.7	1.9
2020	81100	14.8	3.5	115.7	688.3	296.7	1.9

6.9.10 Fleet Emissions

A summary of vehicle fleet emissions for Scenario 4 is presented in Tables 6-63 to 6-66.

TABLE 6-63: SCENARIO 4 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	37100	33200	22900	6610	4180	1910	247000
NO_x	57100	57000	28700	24200	17200	4810	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2210	1940	1950	583	245	154	116	42.5	7240
Pb	102	95.8	50.2	58.2	35.7	8.32	7	1.89	359
Acetaldehyde	1270	1760	980	734	430	110	110	49.2	5450
Benzene	2280	2340	1090	1090	855	221	145	55	8070
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	996	1250	681	553	341	90.3	79.6	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.56	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1980	1850	1280	371	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1730	1610	1110	323	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-64: SCENARIO 4 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	64800	63300	35600	30800	20000	6030	3570	1790	226000
NO_x	47900	52300	26700	23000	15200	4060	2990	1230	173000
CO	376000	459000	219000	209000	145000	40700	24700	7020	1480000
PM_{10}	2440	2420	1320	1020	629	188	144	72.3	8220
SO_2	1420	1460	796	608	156	106	86.2	45.6	4680
Pb	6.42	5.75	3.07	2.72	1.9	0.57	0.34	0.16	20.9
Acetaldehyde	1170	1740	1000	734	395	102	97.4	48.2	5290
Benzene	1520	1490	781	754	509	150	83.7	34.9	5320
1,3-Butadiene	189	192	104	92.5	61.1	19.1	11	4.12	673
Formaldehyde	832	1130	650	492	275	76.2	63.8	30.1	3550
PAH (Semi-Volatile)	91.3	137	79.4	57.7	30.9	7.89	7.69	3.83	416
PAH as %wt of PM_{10}	2.07	2.93	1.75	1.11	0.55	0.14	0.18	0.11	8.84
Total PAH	93.4	140	81.2	58.8	31.5	8.03	7.86	3.94	425
Toluene	3010	3000	1680	1490	964	297	169	76.6	10700
Xylenes (o,m,p)	2600	2610	1470	1310	843	257	145	67.7	9300
$PM_{2.5}$	2190	2170	1190	914	566	169	130	65	7400

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-65: SCENARIO 4 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	59300	52000	32400	28500	16700	5390	2960	1690	199000
NO_x	36100	37400	20700	18800	10400	2940	2170	899	129000
CO	299000	265000	156000	167000	90400	28200	15100	4830	1030000
PM_{10}	2060	2050	1190	913	548	171	120	63.6	7110
SO_2	331	322	182	149	20.8	27.9	18.8	9.73	1060
Pb	6.45	5.73	3.23	2.87	1.89	0.59	0.34	0.16	21.3
Acetaldehyde	1040	1260	854	674	304	85.6	74.5	43.1	4330
Benzene	1200	977	609	600	340	112	56.1	26.3	3920
1,3-Butadiene	138	115	71.4	67.6	38.4	13.2	6.6	2.94	453
Formaldehyde	690	779	524	423	199	59.1	45.9	25.9	2750
PAH (Semi-Volatile)	81.7	100	67.8	53.4	23.9	6.7	5.92	3.44	343
PAH as %wt of PM_{10}	2.02	2.88	1.82	1.16	0.56	0.15	0.17	0.12	8.88
Total PAH	83.7	103	69.7	54.5	24.5	6.85	6.09	3.56	352
Toluene	2370	1990	1280	1180	666	223	113	62.1	7890
Xylenes (o,m,p)	2030	1700	1100	1030	573	191	95.7	54.3	6770
$PM_{2.5}$	1860	1840	1070	822	493	154	108	57.3	6400

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-66: SCENARIO 4 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	52000	45000	30900	24500	13500	5050	2510	1790	175000
NO_x	16800	18700	10200	7670	3630	1280	1010	471	59700
CO	118000	100000	62000	48300	29500	14000	5530	2770	380000
PM_{10}	1750	1600	1030	817	459	160	92.5	55	5970
SO_2	343	339	208	165	22.6	29.1	19.4	11.2	1140
Pb	6.4	5.46	3.42	3	1.74	0.6	0.31	0.17	21.1
Acetaldehyde	714	805	623	358	170	73.7	47.9	41.9	2830
Benzene	708	551	374	276	164	80	30.6	20.2	2200
1,3-Butadiene	73.6	55.8	39	26.7	16.2	8.75	3.11	2.08	225
Formaldehyde	454	482	370	216	106	48.4	28.5	24.4	1730
PAH (Semi-Volatile)	56.5	64.1	49.8	28.5	13.5	5.81	3.82	3.36	225
PAH as %wt of PM_{10}	2.28	2.94	2.15	1.39	0.62	0.19	0.18	0.15	9.9
Total PAH	58.8	67.1	51.9	29.9	14.1	6	4	3.5	235
Toluene	1570	1260	923	691	381	171	68.7	56.1	5120
Xylenes (o,m,p)	1280	1010	765	571	308	142	54.3	48.5	4180
$PM_{2.5}$	1570	1440	931	736	413	144	83.3	49.5	5370

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

6.10 Fleet Emissions - Scenario 5

Scenario 5 is the same as Scenario 4 (Section 6.9) with the requirement that mandatory Euro 4 fuel specifications for petrol and diesel are both introduced in 2006.

The methodology adopted to estimate emissions for this Scenario is essentially the same as that for Scenario 4. A summary of vehicle fleet emissions is presented in Tables 6-67 to 6-70. Emissions of greenhouse gases for this Scenario are discussed in Section 6.12.

TABLE 6-67: SCENARIO 5 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	37100	33200	22900	6610	4180	1910	247000
NO_x	57100	57000	28700	24200	17200	4810	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2210	1940	1950	583	245	154	116	42.5	7240
Pb	102	95.8	50.2	58.2	35.7	8.32	7	1.89	359
Acetaldehyde	1270	1760	980	734	430	110	110	49.2	5450
Benzene	2280	2340	1090	1090	855	221	145	55	8070
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	996	1250	681	553	341	90.3	79.6	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.56	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1980	1850	1280	371	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1730	1610	1110	323	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-68: SCENARIO 5 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	64800	63300	35600	30800	20000	6030	3570	1790	226000
NO_x	47900	52300	26700	23000	15200	4060	2990	1230	173000
CO	376000	459000	219000	209000	145000	40700	24700	7020	1480000
PM_{10}	2440	2420	1320	1020	629	188	144	72.3	8220
SO_2	1420	1460	796	608	156	106	86.2	45.6	4680
Pb	6.42	5.75	3.07	2.72	1.9	0.57	0.34	0.16	20.9
Acetaldehyde	1170	1740	1000	734	395	102	97.4	48.2	5290
Benzene	1520	1490	781	754	509	150	83.7	34.9	5320
1,3-Butadiene	189	192	104	92.5	61.1	19.1	11	4.12	673
Formaldehyde	832	1130	650	492	275	76.2	63.8	30.1	3550
PAH (Semi-Volatile)	91.3	137	79.4	57.7	30.9	7.89	7.69	3.83	416
PAH as %wt of PM_{10}	2.07	2.93	1.75	1.11	0.55	0.14	0.18	0.11	8.84
Total PAH	93.4	140	81.2	58.8	31.5	8.03	7.86	3.94	425
Toluene	3010	3000	1680	1490	964	297	169	76.6	10700
Xylenes (o,m,p)	2600	2610	1470	1310	843	257	145	67.7	9300
$PM_{2.5}$	2190	2170	1190	914	566	169	130	65	7400

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-69: SCENARIO 5 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	59300	52000	32300	28500	16600	5380	2960	1690	199000
NO_x	36100	37400	20700	18800	10400	2950	2170	899	129000
CO	299000	265000	156000	167000	90300	28200	15100	4830	1030000
PM_{10}	2060	2050	1190	913	548	171	120	63.6	7110
SO_2	331	322	182	149	20.8	27.9	18.8	9.73	1060
Pb	6.45	5.73	3.23	2.87	1.89	0.59	0.34	0.16	21.3
Acetaldehyde	1040	1260	853	674	304	85.6	74.5	43.1	4330
Benzene	1200	970	607	599	339	112	55.8	26.3	3910
1,3-Butadiene	138	115	71.4	67.6	38.4	13.2	6.6	2.94	453
Formaldehyde	690	779	524	423	198	59.1	45.9	25.9	2740
PAH (Semi-Volatile)	81.6	99.9	67.8	53.4	23.9	6.69	5.91	3.43	343
PAH as %wt of PM_{10}	2.02	2.88	1.82	1.16	0.56	0.15	0.17	0.12	8.88
Total PAH	83.6	103	69.6	54.5	24.5	6.84	6.09	3.55	352
Toluene	2370	1990	1280	1180	666	222	113	62.1	7880
Xylenes (o,m,p)	2030	1690	1100	1030	573	191	95.7	54.3	6770
$PM_{2.5}$	1860	1840	1070	822	493	154	108	57.3	6400

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-70: SCENARIO 5 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	52000	44900	30900	24400	13500	5050	2510	1790	175000
NO_x	16800	18700	10200	7690	3630	1280	1010	472	59800
CO	118000	100000	61800	48200	29400	13900	5510	2760	379000
PM_{10}	1750	1600	1030	817	459	160	92.5	55	5970
SO_2	343	339	208	165	22.6	29.1	19.4	11.2	1140
Pb	6.4	5.46	3.42	3	1.74	0.6	0.31	0.17	21.1
Acetaldehyde	713	804	623	358	170	73.6	47.9	41.9	2830
Benzene	705	548	372	275	164	79.8	30.4	20.2	2190
1,3-Butadiene	73.5	55.7	38.9	26.7	16.2	8.74	3.1	2.08	225
Formaldehyde	453	481	370	216	106	48.3	28.4	24.4	1730
PAH (Semi-Volatile)	56.4	64	49.7	28.5	13.4	5.8	3.82	3.35	225
PAH as %wt of PM_{10}	2.28	2.94	2.15	1.39	0.62	0.19	0.18	0.15	9.9
Total PAH	58.7	67	51.8	29.9	14.1	5.99	4	3.5	235
Toluene	1570	1260	922	690	380	171	68.6	56.1	5120
Xylenes (o,m,p)	1280	1010	764	571	308	142	54.2	48.5	4170
$PM_{2.5}$	1570	1440	931	736	413	144	83.3	49.5	5370

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

6.11 Fleet Emissions - Scenario 6

Scenario 6 is the same as Scenario 4 (Section 6.9) with the requirement that mandatory Euro 4 fuel specifications for petrol and diesel are both introduced in 2005. In addition, fuels with ultra-low sulfur content (30 ppm), are modelled as being required from 2008.

The methodology adopted to estimate emissions for this Scenario is essentially the same as that for Scenario 4. A summary of vehicle fleet emissions is presented in Tables 6-71 to 6-74. Emissions of greenhouse gases for this Scenario are discussed in Section 6.12.

TABLE 6-71: SCENARIO 6 – SUMMARY OF FLEET EMISSIONS, 2000 (t/yr)

2000 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	71600	69500	37100	33200	22900	6610	4180	1910	247000
NO_x	57100	57000	28700	24200	17200	4810	3500	1420	194000
CO	506000	544000	255000	242000	185000	55300	34300	8990	1830000
PM_{10}	2710	2720	1390	1060	710	196	164	76.4	9030
SO_2	2210	1940	1950	583	245	154	116	42.5	7240
Pb	102	95.8	50.2	58.2	35.7	8.32	7	1.89	359
Acetaldehyde	1270	1760	980	734	430	110	110	49.2	5450
Benzene	2280	2340	1090	1090	855	221	145	55	8070
1,3-Butadiene	255	249	127	121	86.7	25.2	16.3	5.23	886
Formaldehyde	996	1250	681	553	341	90.3	79.6	32.4	4020
PAH (Semi-Volatile)	98.2	138	76.9	57	33.2	8.47	8.56	3.88	424
PAH as %wt of PM_{10}	1.98	2.82	1.59	0.99	0.52	0.13	0.17	0.1	8.29
Total PAH	100	141	78.5	58	33.7	8.59	8.72	3.99	432
Toluene	3820	3720	1980	1850	1280	371	234	92.3	13300
Xylenes (o,m,p)	3300	3230	1730	1610	1110	323	201	82.2	11600
$PM_{2.5}$	2440	2450	1250	958	639	177	148	68.8	8130

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-72: SCENARIO 6 – SUMMARY OF FLEET EMISSIONS, 2005 (t/yr)

2005 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	63800	62300	34900	30200	19800	5930	3520	1760	222000
NO_x	47100	51500	26400	22700	15000	3990	2940	1210	171000
CO	370000	451000	215000	206000	143000	40000	24300	6870	1460000
PM_{10}	2360	2330	1310	995	618	182	139	70.7	8000
SO_2	320	306	165	136	18.8	26.5	18	9.02	1000
Pb	6.42	5.75	3.07	2.72	1.9	0.57	0.34	0.16	20.9
Acetaldehyde	1150	1710	981	720	393	100	95.9	46.8	5200
Benzene	1470	1440	754	730	499	144	81.1	33.6	5150
1,3-Butadiene	186	189	102	90.7	60.7	18.8	10.8	4	662
Formaldehyde	818	1110	635	483	273	74.9	62.8	29.2	3480
PAH (Semi-Volatile)	89.7	135	77.6	56.6	30.7	7.77	7.56	3.72	409
PAH as %wt of PM_{10}	2.01	2.82	1.74	1.08	0.54	0.14	0.17	0.11	8.61
Total PAH	91.7	138	79.3	57.7	31.3	7.9	7.73	3.83	417
Toluene	2950	2940	1640	1450	952	290	166	74.3	10500
Xylenes (o,m,p)	2540	2550	1430	1270	831	251	142	65.5	9080
$PM_{2.5}$	2120	2100	1180	896	556	164	125	63.6	7200

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-73: SCENARIO 6 – SUMMARY OF FLEET EMISSIONS, 2010 (t/yr)

2010 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	59300	52000	32300	28500	16600	5380	2960	1690	199000
NO_x	36100	37400	20700	18800	10400	2950	2170	899	129000
CO	299000	265000	156000	167000	90300	28200	15100	4830	1030000
PM_{10}	2060	2050	1180	912	547	171	120	63.5	7100
SO_2	331	322	182	149	20.8	27.9	18.8	9.73	1060
Pb	6.45	5.73	3.23	2.87	1.89	0.59	0.34	0.16	21.3
Acetaldehyde	1040	1260	853	674	304	85.6	74.5	43.1	4330
Benzene	1200	970	607	599	339	112	55.8	26.3	3910
1,3-Butadiene	138	115	71.4	67.6	38.4	13.2	6.6	2.94	453
Formaldehyde	690	779	524	423	198	59.1	45.9	25.9	2740
PAH (Semi-Volatile)	81.6	99.9	67.8	53.4	23.9	6.69	5.91	3.43	343
PAH as %wt of PM_{10}	2.01	2.87	1.82	1.16	0.56	0.15	0.17	0.12	8.86
Total PAH	83.6	103	69.6	54.5	24.5	6.84	6.09	3.55	352
Toluene	2370	1990	1280	1180	666	222	113	62.1	7880
Xylenes (o,m,p)	2030	1690	1100	1030	573	191	95.7	54.3	6770
$PM_{2.5}$	1850	1840	1070	821	492	153	108	57.2	6390

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm

TABLE 6-74: SCENARIO 6 – SUMMARY OF FLEET EMISSIONS, 2020 (t/yr)

2020 Parameter (t/yr)	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra	Hobart	Darwin	Total
HC	52000	44900	30900	24400	13500	5050	2510	1790	175000
NO_x	16800	18700	10200	7690	3630	1280	1010	472	59800
CO	118000	100000	61800	48200	29400	13900	5510	2760	379000
PM_{10}	1750	1600	1030	816	458	160	92.4	54.9	5960
SO_2	308	290	179	147	15.1	26.9	16.6	9.42	992
Pb	6.4	5.46	3.42	3	1.74	0.6	0.31	0.17	21.1
Acetaldehyde	713	804	623	358	170	73.6	47.9	41.9	2830
Benzene	705	548	372	275	164	79.8	30.4	20.2	2190
1,3-Butadiene	73.5	55.7	38.9	26.7	16.2	8.74	3.1	2.08	225
Formaldehyde	453	481	370	216	106	48.3	28.4	24.4	1730
PAH (Semi-Volatile)	56.4	64	49.7	28.5	13.4	5.8	3.82	3.35	225
PAH as %wt of PM_{10}	2.28	2.94	2.15	1.39	0.62	0.19	0.18	0.15	9.89
Total PAH	58.7	67	51.8	29.9	14.1	5.99	4	3.5	235
Toluene	1570	1260	922	690	380	171	68.6	56.1	5120
Xylenes (o,m,p)	1280	1010	764	571	308	142	54.2	48.5	4170
$PM_{2.5}$	1570	1440	930	735	412	144	83.2	49.4	5370

HC = Hydrocarbons

VOC = Volatile organic compounds

NO_x = Oxides of nitrogen

CO = Carbon monoxide

PAH = Poly-aromatic hydrocarbons

Pb = Lead

SO_2 = Sulfur dioxide

PM_{10} = Particulates < 10 µm

$PM_{2.5}$ = Particulates < 2.5 µm