Technical Report No. 7

Air Emissions Inventory for the Greater Metropolitan Region in New South Wales

2008 Calendar Year

On-Road Mobile Emissions: Results

NSW EPA

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

An air emissions inventory project for on-road mobile sources has taken over 2 years to complete. The base year of the on-road mobile inventory represents activities that took place during the 2008 calendar year and is accompanied by emission projections from 2011 through to the 2036 calendar year, in five yearly increments. The area included in the inventory covers the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The inventory region defined as the GMR measures 210 km (east–west) by 273 km (north–south). The inventory region is defined in Table ES-1 and shown in Figure ES-1.

Table ES-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA[1] coordinates		North-east corner MGA[1] coordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

[1]Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2006).

The on-road mobile emissions inventory includes the following sources:

- Exhaust emissions from petrol passenger vehicles;
- Exhaust emissions from light-duty diesel vehicles;
- Exhaust emissions from petrol light commercial vehicles;
- Exhaust emissions from heavy-duty diesel vehicles;
- Exhaust emissions from other vehicles;
- Evaporative emissions from all petrol vehicles; and
- Non-exhaust particulate matter (NEPM) emissions from all vehicles.

The pollutants inventoried include criteria pollutants specified in the Ambient Air Quality NEPM (NEPC, 2003), air toxics associated with the National Pollutant Inventory NEPM (NEPC, 2008) and the Air Toxics NEPM (NEPC, 2004) and any other pollutants associated with state-specific programs, i.e. Load Based Licensing (Protection of the Environment Operations (General) Regulation 2009 (PCO, 2010) and the Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011).

Figure ES-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Table ES-2 presents total estimated annual emissions (for selected substances) from all on-road mobile sources in the GMR and the Sydney, Newcastle and Wollongong regions. Total estimated annual emissions are also presented for the region defined as Non Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. The selected substances were chosen because they:

- Are the most common air pollutants found in airsheds according to the National Pollutant Inventory NEPM (NEPC, 2008);
- Are referred to in National Environment Protection Measures (NEPMs) for Ambient Air Quality (NEPC, 2003) and Air Toxics (NEPC, 2004); and
- Have been classified as priority air pollutants (NEPC, 2006).

Table ES-2: Total estimated annual emissions from on-road mobile sources in each region

Substance	Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	142	9.65	5.22	18.3	175
ACETALDEHYDE	101	7.30	3.79	16.1	128
BENZENE	624	42.7	23.0	82.3	772
CARBON MONOXIDE	123,712	8,369	4,786	16,944	153,812
FORMALDEHYDE	266	19.3	10.0	42.4	338
ISOMERS OF XYLENE	979	67.1	36.0	129	1,210
LEAD AND COMPOUNDS	2.82	0.227	0.112	0.495	3.65
OXIDES OF NITROGEN	45,392	3,902	2,184	9,453	60,932
PARTICULATE MATTER ≤ 10 µm	2,110	176	90.3	417	2,793
PARTICULATE MATTER ≤ 2.5 µm	1,553	131	68.2	319	2,071
POLYCYCLIC AROMATIC HYDROCARBONS	89.8	6.98	3.84	16.0	117
SULFUR DIOXIDE	210	15.1	8.13	35.0	269
TOLUENE	1,315	90.9	48.6	177	1,632
TOTAL SUSPENDED PARTICULATE	2,737	226	115	525	3,603
TOTAL VOLATILE ORGANIC COMPOUNDS	23,512	1,678	879	3,435	29,504

Figure ES-2 shows the proportions of total estimated GMR annual emissions (for selected substances) from on-road mobile sources in the Sydney, Newcastle, Wollongong and Non Urban regions.

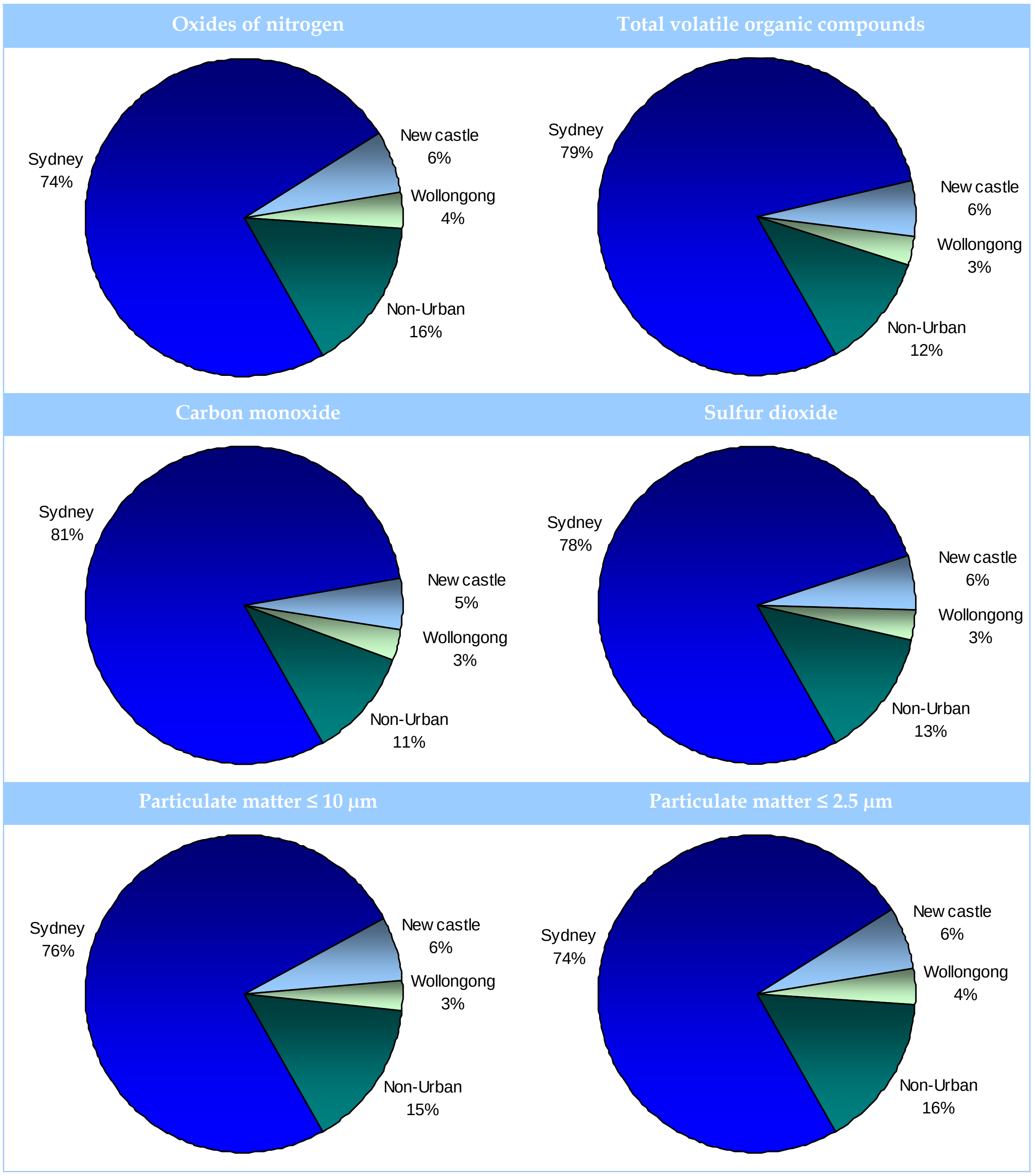

Figure ES-2: Proportions of total estimated GMR annual emissions from on-road mobile sources in each region

Table ES-3, Table ES-4, Table ES-5, Table ES-6, and Table ES-7 present total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR and in the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Figure ES-3, Figure ES-4, Figure ES-5, Figure ES-6 and Figure ES-7 show the proportions of total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR and in the Sydney, Newcastle, Wollongong and Non Urban regions, respectively.

Table ES-3: Total estimated annual emissions by on-road mobile source type in the GMR

Substance	Emissions (tonne/year)							
	Petrol passenger vehicles - exhaust	Light-duty diesel vehicles - exhaust	Petrol light commercial vehicles - exhaust	Heavy-duty diesel vehicles - exhaust	Other vehicles - exhaust	All vehicles - evaporative	All vehicles - non-exhaust particulate matter	On-road mobile total
1,3 BUTADIENE	121	0.819	41.9	4.72	6.55	0	0	175
ACETALDEHYDE	54.2	7.75	18.7	44.7	2.46	0	0	128
BENZENE	474	2.17	164	12.5	25.6	94.3	0	772
CARBON MONOXIDE	93,437	1,176	48,731	5,705	4,762	0	0	153,812
FORMALDEHYDE	145	20.0	50.0	116	7.58	0	0	338
ISOMERS OF XYLENE	729	0.780	252	4.50	39.3	185	0	1,210
LEAD & COMPOUNDS	0.043	0.055	0.023	0.150	0.0033	0	3.38	3.65
OXIDES OF NITROGEN	27,515	3,060	8,679	21,419	259	0	0	60,932
PARTICULATE MATTER ≤ 10 µm	121	308	63.7	841	9.39	0	1,450	2,793
PARTICULATE MATTER ≤ 2.5 µm	115	299	60.7	816	8.95	0	771	2,071
POLYCYCLIC AROMATIC HYDROCARBONS	49.5	10.1	21.2	32.6	3.20	0	0	117
SULFUR DIOXIDE	181	9.01	41.2	36.2	1.49	0	0	269
TOLUENE	881	0.954	304	5.50	47.5	392	0	1,632
TOTAL SUSPENDED PARTICULATE	121	311	63.7	850	9.39	0	2,249	3,603
TOTAL VOLATILE ORGANIC COMPOUNDS	9,647	203	3,331	1,173	518	14,632	0	29,504

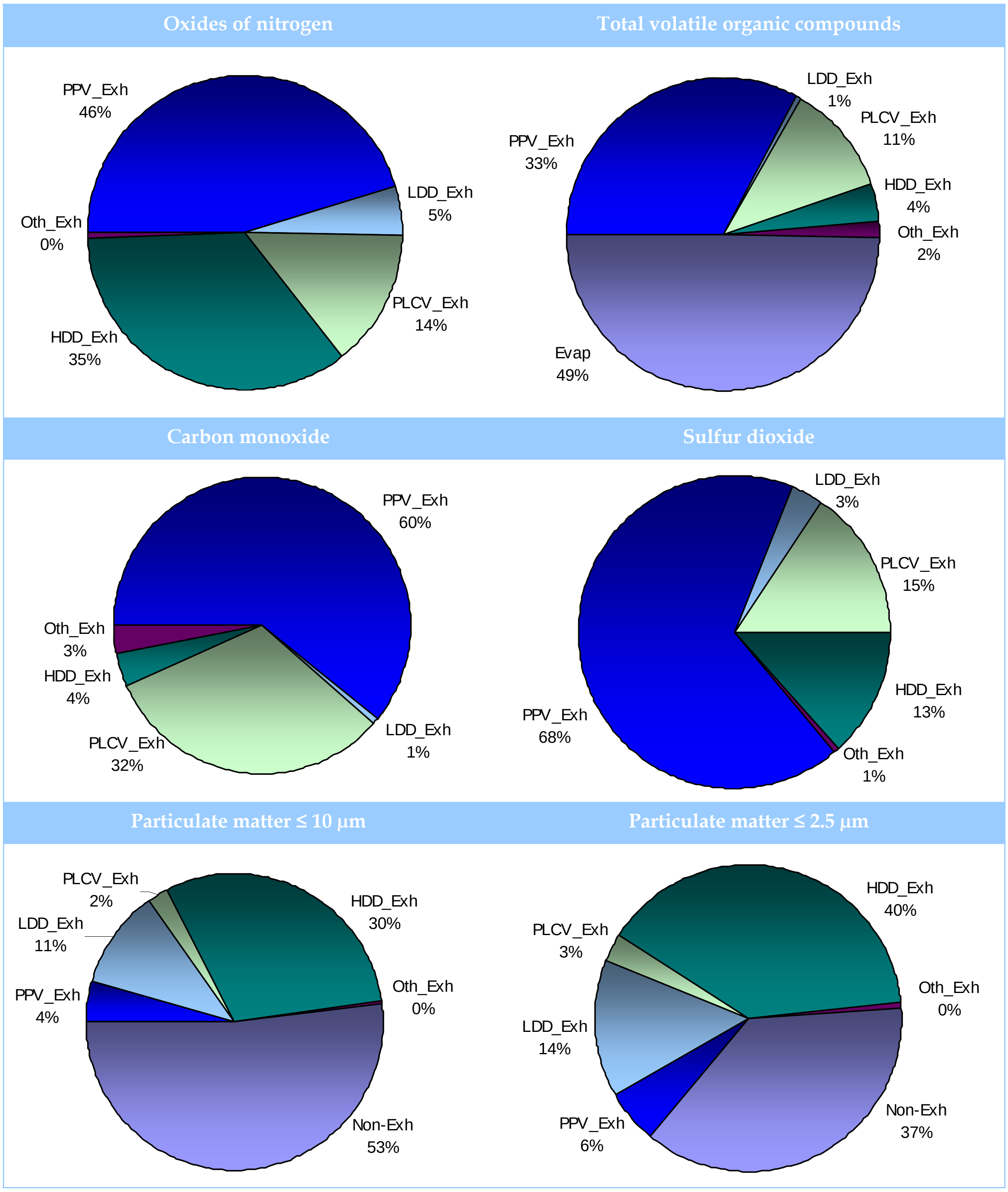

Figure ES-3: Proportions of total estimated annual emissions by on-road mobile source type* in the GMR

* PPV_Exh = Petrol passenger vehicle – exhaust, LDD_Exh = Light-duty diesel – exhaust, PLCV_Exh = Petrol light commercial vehicle – exhaust, HDD_Exh = Heavy-duty diesel – exhaust, Oth_Exh = Other vehicles – exhaust, Evap = Evaporative emissions all petrol vehicles, Non-Exh = Non-exhaust particulate matter – all vehicles

Table ES-4: Total estimated annual emissions by on-road mobile source type in the Sydney region

Substance	Emissions (tonne/year)							
	Petrol passenger vehicles - exhaust	Light-duty diesel vehicles - exhaust	Petrol light commercial vehicles - exhaust	Heavy-duty diesel vehicles - exhaust	Other vehicles - exhaust	All vehicles - evaporative	All vehicles - non-exhaust particulate matter	On-road mobile total
1,3 BUTADIENE	98.0	0.677	34.8	3.49	5.18	0	0	142
ACETALDEHYDE	43.8	6.41	15.6	33.0	1.95	0	0	101
BENZENE	382	1.79	136	9.23	20.3	74.2	0	624
CARBON MONOXIDE	75,067	951	39,923	4,081	3,691	0	0	123,712
FORMALDEHYDE	117	16.6	41.6	85.3	5.99	0	0	266
ISOMERS OF XYLENE	589	0.645	209	3.32	31.1	146	0	979
LEAD & COMPOUNDS	0.033	0.044	0.018	0.106	0.0025	0	2.62	2.82
OXIDES OF NITROGEN	21,575	2,417	6,799	14,423	178	0	0	45,392
PARTICULATE MATTER ≤ 10 µm	92.3	247	49.5	592	6.99	0	1,123	2,110
PARTICULATE MATTER ≤ 2.5 µm	87.9	239	47.2	574	6.67	0	597	1,553
POLYCYCLIC AROMATIC HYDROCARBONS	39.0	8.12	17.0	23.3	2.45	0	0	89.8
SULFUR DIOXIDE	144	7.25	33.3	24.6	1.13	0	0	210
TOLUENE	712	0.788	253	4.06	37.6	308	0	1,315
TOTAL SUSPENDED PARTICULATE	92.3	249	49.5	598	6.99	0	1,742	2,737
TOTAL VOLATILE ORGANIC COMPOUNDS	7,789	168	2,768	866	409	11,512	0	23,512

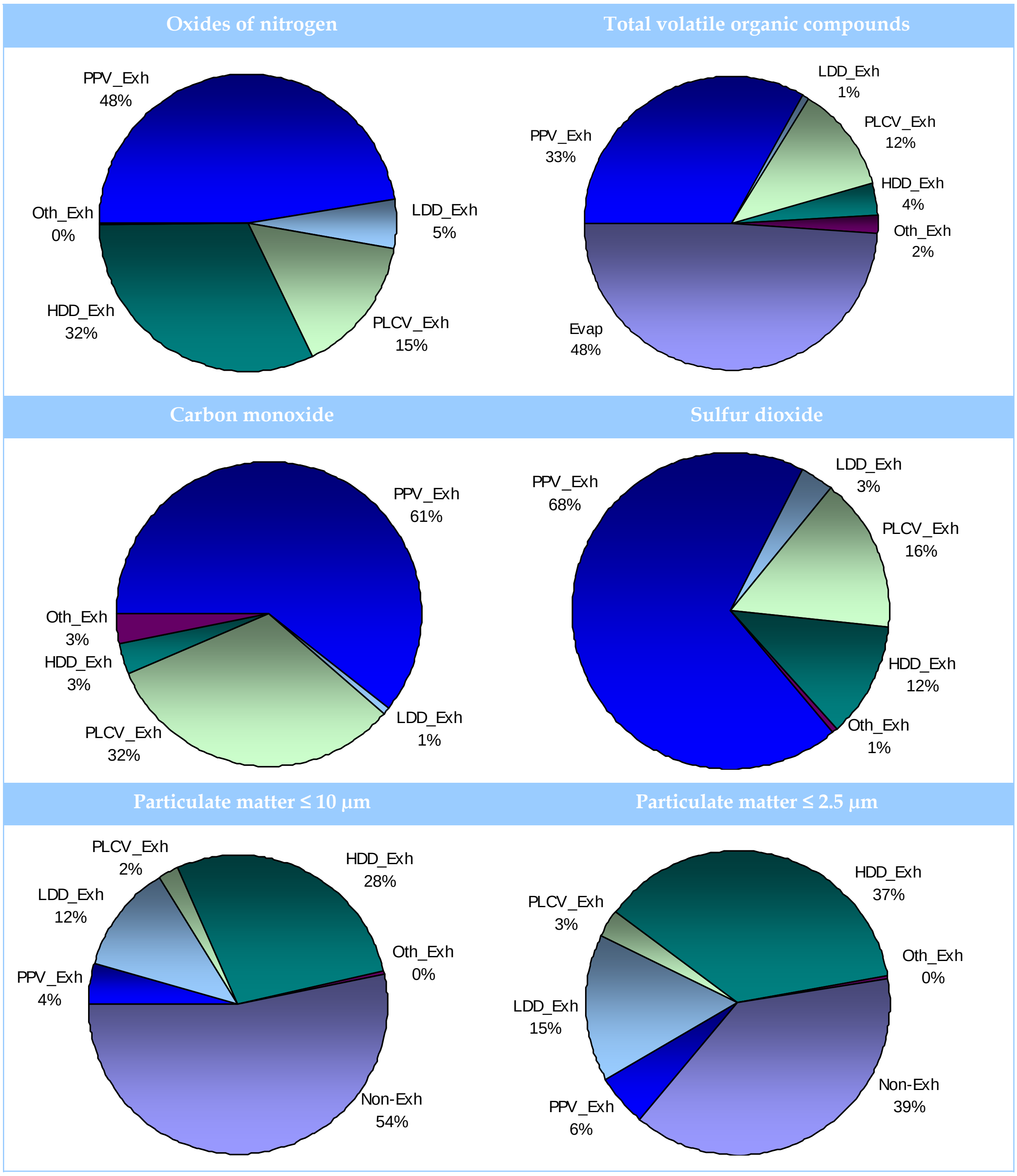

Figure ES-4: Proportions of total estimated annual emissions by on-road mobile source type in the Sydney region

Table ES-5: Total estimated annual emissions by on-road mobile source type in the Newcastle region

Substance	Emissions (tonne/year)							
	Petrol passenger vehicles - exhaust	Light-duty diesel vehicles - exhaust	Petrol light commercial vehicles - exhaust	Heavy-duty diesel vehicles - exhaust	Other vehicles - exhaust	All vehicles - evaporative	All vehicles - non-exhaust particulate matter	On-road mobile total
1,3 BUTADIENE	6.75	0.042	2.18	0.293	0.377	0	0	9.65
ACETALDEHYDE	3.02	0.400	0.976	2.77	0.142	0	0	7.30
BENZENE	26.3	0.112	8.52	0.775	1.47	5.51	0	42.7
CARBON MONOXIDE	4,997	66.1	2,650	375	280	0	0	8,369
FORMALDEHYDE	8.06	1.03	2.61	7.16	0.436	0	0	19.3
ISOMERS OF XYLENE	40.5	0.040	13.1	0.279	2.26	10.8	0	67.1
LEAD & COMPOUNDS	0.0026	0.0031	0.0014	0.010	0.0002	0	0.209	0.227
OXIDES OF NITROGEN	1,666	177	530	1,511	18.2	0	0	3,902
PARTICULATE MATTER ≤ 10 µm	7.27	17.3	3.91	57.2	0.592	0	89.8	176
PARTICULATE MATTER ≤ 2.5 µm	6.93	16.8	3.72	55.5	0.564	0	47.7	131
POLYCYCLIC AROMATIC HYDROCARBONS	2.86	0.558	1.21	2.16	0.193	0	0	6.98
SULFUR DIOXIDE	9.73	0.505	2.27	2.53	0.091	0	0	15.1
TOLUENE	49.0	0.049	15.9	0.341	2.73	22.9	0	90.9
TOTAL SUSPENDED PARTICULATE	7.27	17.5	3.91	57.8	0.592	0	139	226
TOTAL VOLATILE ORGANIC COMPOUNDS	537	10.5	174	72.7	29.8	855	0	1,678

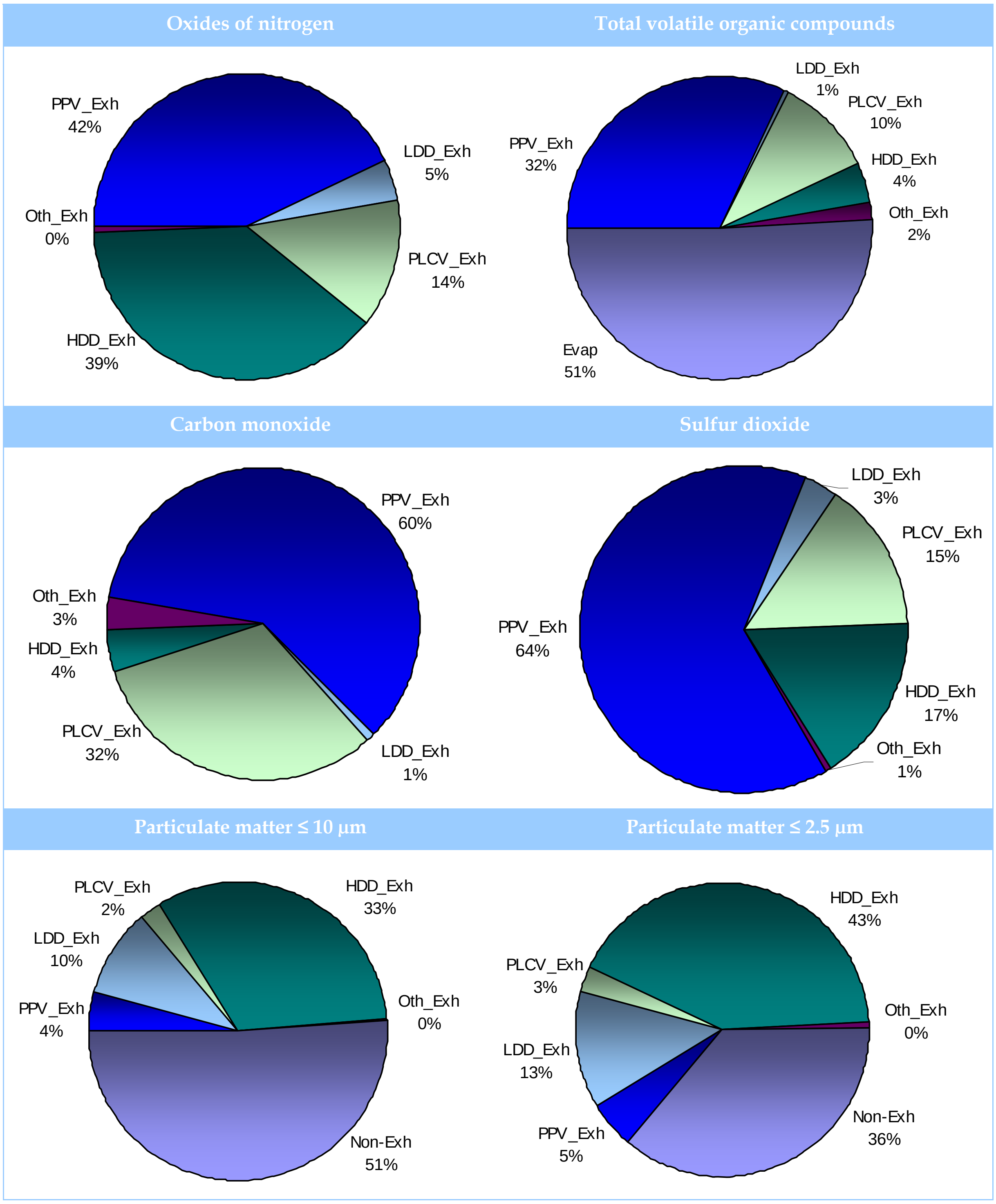

Figure ES-5: Proportions of total estimated annual emissions by on-road mobile source type in the Newcastle region

Table ES-6: Total estimated annual emissions by on-road mobile source type in the Wollongong region

Substance	Emissions (tonne/year)							
	Petrol passenger vehicles - exhaust	Light-duty diesel vehicles - exhaust	Petrol light commercial vehicles - exhaust	Heavy-duty diesel vehicles - exhaust	Other vehicles - exhaust	All vehicles - evaporative	All vehicles - non-exhaust particulate matter	On-road mobile total
1,3 BUTADIENE	3.69	0.022	1.19	0.141	0.178	0	0	5.22
ACETALDEHYDE	1.65	0.210	0.531	1.33	0.067	0	0	3.79
BENZENE	14.4	0.059	4.63	0.373	0.696	2.81	0	23.0
CARBON MONOXIDE	2,861	38.2	1,564	184	140	0	0	4,786
FORMALDEHYDE	4.40	0.542	1.42	3.45	0.206	0	0	10.0
ISOMERS OF XYLENE	22.2	0.021	7.13	0.134	1.07	5.52	0	36.0
LEAD & COMPOUNDS	0.0015	0.0019	0.0009	0.0052	0.0001	0	0.102	0.112
OXIDES OF NITROGEN	938	107	346	783	9.92	0	0	2,184
PARTICULATE MATTER ≤ 10 µm	4.14	10.4	2.58	29.0	0.314	0	43.9	90.3
PARTICULATE MATTER ≤ 2.5 µm	3.95	10.1	2.46	28.1	0.300	0	23.3	68.2
POLYCYCLIC AROMATIC HYDROCARBONS	1.59	0.329	0.744	1.08	0.098	0	0	3.84
SULFUR DIOXIDE	5.15	0.281	1.36	1.30	0.046	0	0	8.13
TOLUENE	26.8	0.026	8.62	0.164	1.29	11.7	0	48.6
TOTAL SUSPENDED PARTICULATE	4.14	10.5	2.58	29.3	0.314	0	68.0	115
TOTAL VOLATILE ORGANIC COMPOUNDS	293	5.50	94.4	35.0	14.1	436	0	879

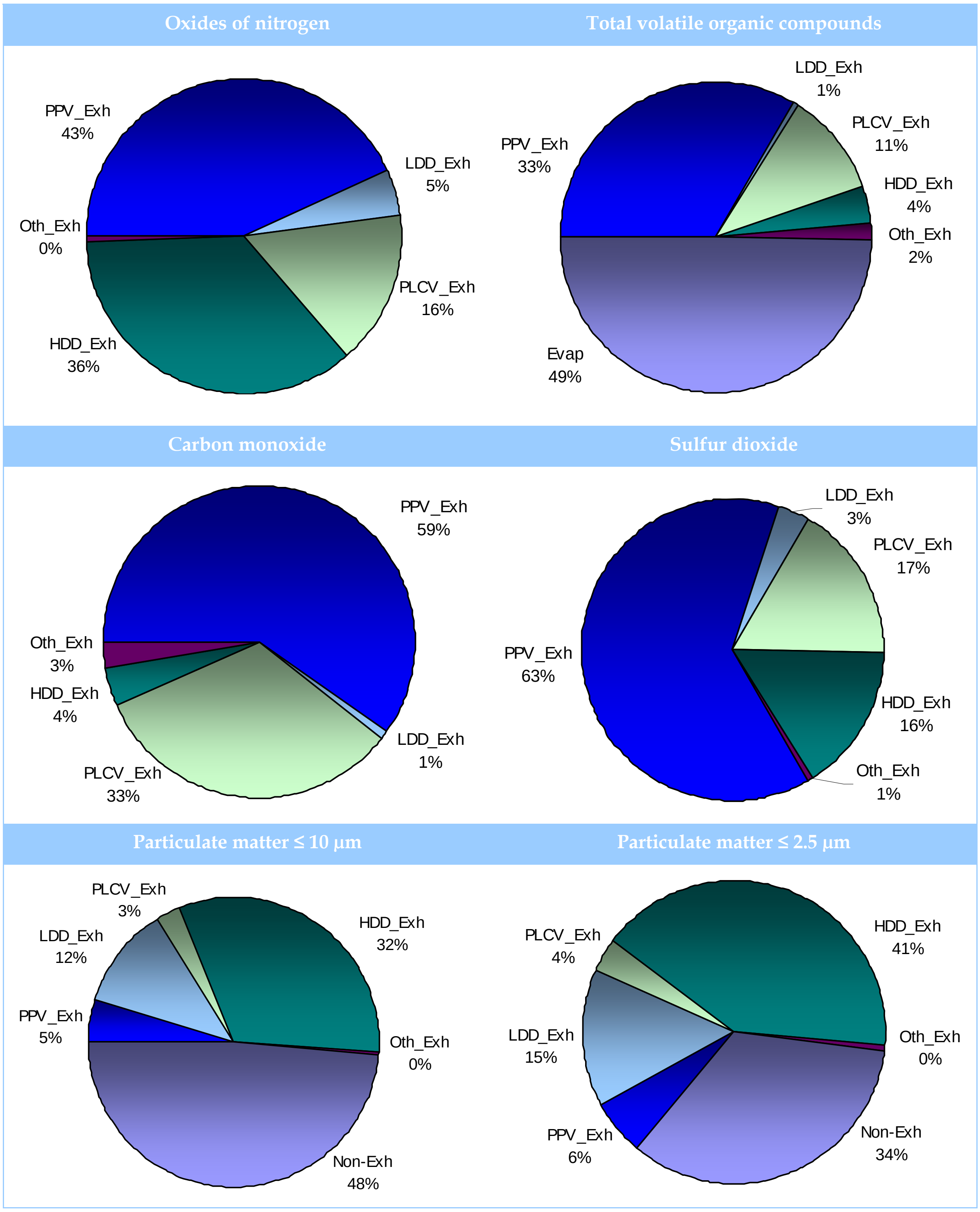

Figure ES-6: Proportions of total estimated annual emissions by on-road mobile source type in the Wollongong region

Table ES-7: Total estimated annual emissions by on-road mobile source type in the Non Urban region

Substance	Emissions (tonne/year)							
	Petrol passenger vehicles - exhaust	Light-duty diesel vehicles - exhaust	Petrol light commercial vehicles - exhaust	Heavy-duty diesel vehicles - exhaust	Other vehicles - exhaust	All vehicles - evaporative	All vehicles - non-exhaust particulate matter	On-road mobile total
1,3 BUTADIENE	12.9	0.077	3.71	0.805	0.815	0	0	18.3
ACETALDEHYDE	5.78	0.733	1.66	7.62	0.307	0	0	16.1
BENZENE	50.5	0.205	14.5	2.13	3.19	11.8	0	82.3
CARBON MONOXIDE	10,512	121	4,595	1,065	651	0	0	16,944
FORMALDEHYDE	15.4	1.90	4.42	19.7	0.944	0	0	42.4
ISOMERS OF XYLENE	77.7	0.074	22.3	0.766	4.90	23.1	0	129
LEAD & COMPOUNDS	0.0061	0.0060	0.0027	0.029	0.0005	0	0.451	0.495
OXIDES OF NITROGEN	3,336	359	1,004	4,702	52.0	0	0	9,453
PARTICULATE MATTER ≤ 10 µm	17.2	33.5	7.73	163	1.49	0	193	417
PARTICULATE MATTER ≤ 2.5 µm	16.4	32.5	7.37	159	1.42	0	103	319
POLYCYCLIC AROMATIC HYDROCARBONS	6.08	1.07	2.26	6.11	0.459	0	0	16.0
SULFUR DIOXIDE	21.8	0.973	4.24	7.77	0.224	0	0	35.0
TOLUENE	94.0	0.090	26.9	0.937	5.92	49.0	0	177
TOTAL SUSPENDED PARTICULATE	17.2	33.9	7.73	165	1.49	0	300	525
TOTAL VOLATILE ORGANIC COMPOUNDS	1,029	19.2	295	200	64.5	1,828	0	3,435

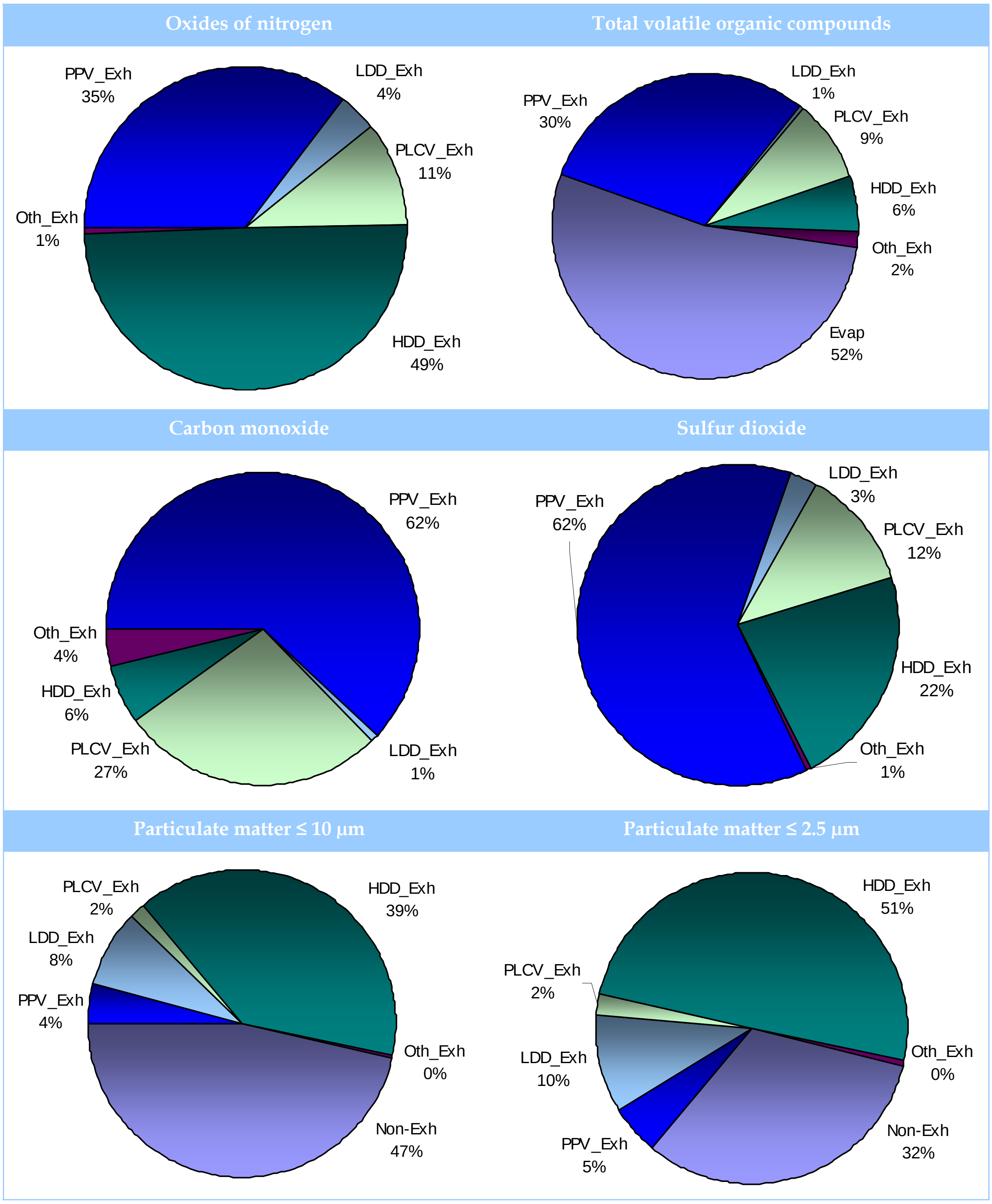

Figure ES-7: Proportions of total estimated annual emissions by on-road mobile source type in the Non Urban region

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GLOSSARY/ABBREVIATIONS

Acronym	Definition
°C	Degrees Celsius
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
Ambient Air Quality NEPM	National Environment Protection (Ambient Air Quality) Measure
ADR	Australian Design Rule
am	ante meridiem (indicating the time period from midnight to midday)
ANZSIC	Australian and New Zealand Standard Industrial Classification, 1993
ARB	Air Resources Board
ARTEMIS	Assessment of Reliability of Transport Emission Models and Inventory Systems. European inventory project and resulting inventory model
BTS	Bureau of Transport Statistics, NSW Department of Transport (Formerly TDC)
CARB	California Air Resources Board
CO	Carbon monoxide
CO_2	Carbon dioxide
Combustion products	CO, NO_x, TSP, PM_{10}, $PM_{2.5}$, particulate matter, VOC, SO_2, SO_3, H_2SO_4, speciated metals, speciated organics, greenhouse gases, ammonia
COPERT 4	COmputer Program to calculate Emissions from Road Transport - Widely used European Inventory Model
CORINAIR	CO-oRdinated INformation on the Environment in the European Community - AIR.
CRC	United States Coordinating Research Council
CSEE	Cold Start Extra Emission
CSPF	Cold Start Parking Factor
CSTC	Cold Start Temperature Correction
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CUEDC	(Australian) Combined Urban Emission Drive Cycle
CVES	Comparative Vehicle Emissions Study
DCC	Australian Commonwealth Department of Climate Change
DCCEE	Australian Commonwealth Department of Climate Change and Energy Efficiency
DEC	Department of Environment and Conservation (NSW)
Dec	December
DECC	Department of Environment and Climate Change (NSW)
DECCW	Department of Environment, Climate Change and Water (NSW)
DEH	Australian Commonwealth Department of Environment and Heritage
DEW	Australian Commonwealth Department of Environment and Water
DEWHA	Australian Commonwealth Department of Environment, Water, Heritage and the Arts
DLCV	Diesel Light Commercial Vehicles
DPV	Diesel Passenger Vehicles
DRET	Australian Commonwealth Department of Resources, Energy and Tourism
DSEWPC	Australian Commonwealth Department of Sustainability, Environment, Water, Population and Communities
E10	Unleaded petrol with up to 10% ethanol
EA	Environment Australia
EEA	European Environment Agency
EI	Emissions inventory
EIIP	Emission Inventory Improvement Program
EMEP	Automotive Testing Laboratories
EPA	Environment Protection Authority

Acronym	Definition
FMM	Freight Movement Model produced by TDC
GJ	Gigajoule (1 x 10^9 joule)
GMR	Greater Metropolitan Region
GSP	Gross state product
GVM	Gross vehicle mass
HC	Hydrocarbons
I.C.	Internal combustion
HBEFA	German/Austrian/Swiss Handbook on Emission Factors
HDCP	Heavy Duty Commercial Vehicles
HDD	Heavy Duty Diesel Vehicles – an inventory source type grouping
HTS	Household Travel Survey
kg	kilogram (1,000 gram)
kL	kilolitre (1,000 litre)
km	kilometre (1,000 metre)
kPa	kilopascal
kW	kilowatt (1,000 watt)
L	Litre
LCV	Light Commercial Vehicles (≤ 3500 kg) – utility vehicles and vans
LDD	Light Duty Diesel Vehicles (≤ 3500 kg) – an inventory source type grouping of DPV & DLCV
LGA	Local government area
LPG	Liquefied Petroleum Gas
m	metre
m/s	metre per second
m^2	Square metre
m^3	Cubic metre
mg	milligram (i.e. 1 thousandth of a gram, 1 millionth of a kilogram)
MA	ADR class Passenger Car (≤ 9 seats, GVM ≤ 3,500 kg)
MB	ADR Class Forward Control Vehicle (≤ 9 seats, GVM ≤ 3,500 kg)
MB1	ADR Class Forward Control Vehicle, GVM ≤ 2,700 kg
MB2	ADR Class Forward Control Vehicle, GVM > 2,700 kg
MC	ADR Class Off-Road Passenger Vehicle, GVM ≤ 3,500 kg
MC1	ADR Class Off-Road Passenger Vehicle, GVM ≤ 2,700 kg
MC2	ADR Class Off-Road Passenger Vehicle, GVM > 2,700 kg
MD	ADR Class Light Omnibus, GVM ≤ 5.0 tonne
ME	ADR Class Heavy Omnibus, GVM > 5.0 tonne
MGA	Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94)
Misc	Miscellaneous
MJ	Megajoule (1,000,000 joule)
ML	Megalitre (1,000,000 litre)
mm	millimetre (1,000th of a metre or 1x10^{-3} metre)
Mt	Megatonne (1,000,000 tonne)
N_2O	Nitrous oxide
N/A	Not applicable
NA	ADR class Light Goods Vehicle, GVM ≤ 3,500 kg
NA1	ADR class Light Goods Vehicle, GVM ≤ 2,700 kg
NA2	ADR class Light Goods Vehicle, GVM > 2,700 kg
NB	ADR class Medium Goods Vehicle, 3,500 < GVM ≤ 12,000 kg
NB1	ADR class Medium Goods Vehicle, 3,500 < GVM ≤ 4,500 kg
NB2	ADR class Medium Goods Vehicle, 4,500 < GVM ≤ 12,000 kg
NC	ADR class Heavy Goods Vehicle, GVM > 12,000 kg

Acronym	Definition
ND	No data
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NISE1	First National In-Service Emissions Study
NISE2	Second National In-Service Emissions Study
NO	Nitric oxide
No.	Number
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen (sum of nitric oxide and nitrogen dioxide expressed as nitrogen dioxide equivalent)
NPI	National Pollutant Inventory
NPI NEPM	National Environment Protection (National Pollutant Inventory) Measure
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW)
OEM	Original equipment manufacturers
P	Power
PAE	Pacific Air & Environment
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDD/F	Polychlorinated dibenzo-p-dioxins & polychlorinated dibenzo-p-furans (polychlorinated dioxins and furans)
PCDD/PCDF	Polychlorinated dibenzo-p-dioxins & polychlorinated dibenzo-p-furans (polychlorinated dioxins and furans)
PCDF	Polychlorinated dibenzo-p-furans
PLCV	Petrol Light Commercial Vehicles – an inventory source type
PM	Particulate matter (included in the air emissions inventory as TSP, PM_{10} and $PM_{2.5}$)
pm	post meridiem (indicating the time period from midday to midnight)
PM_{10}	Particulate matter with an aerodynamic diameter of less than or equal to 10 micrometres
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than or equal to 2.5 micrometres
POP	Persistent Organic Pollutants
pp	pages
ppm	Parts per million (in mass) (e.g. gram/tonne)
PPV	Petrol Passenger Vehicles – an inventory source type grouping
PULP	Premium unleaded petrol (95 RON)
RTA	Road and Traffic Authority
RON	Research Octane Number – the octane rating displayed at petrol stations
RVP	Reid Vapour Pressure
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
SPULP	Super premium unleaded petrol (98 RON)
STM	Strategic Travel Model produced by TDC
t	tonne (1,000 kilogram)
TAPM	The Air Pollution Model
TDC	Transport Data Centre (Bureau of Transport Statistics from July 2011)
TSP	Total suspended particulate matter
ULP	Unleaded petrol (91 RON)
USA	United States of America
USEPA	United States Environmental Protection Agency
VOC	Total volatile organic compounds

1 INTRODUCTION

An air emissions inventory project for on-road mobile sources has taken over 2 years to complete. The base year of the on-road mobile inventory represents activities that took place during the 2008 calendar year and is accompanied by emission projections in five yearly increments from 2011 up to the 2036 calendar year. The area included in the inventory covers greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The purpose of this document is to present the emission estimation methodologies and results of the on-road mobile air emissions inventory. The information is structured as follows:

- A description of the commercial air emissions inventory specification (Section 2) including:
    - The inventory year (Section 2.1);
    - A description of the inventory region (Section 2.2);
    - A description of the grid coordinate system (Section 2.3);
    - A description of emission sources considered (Section 2.4); and
    - A description of the pollutants evaluated (Section 2.5).
- The emission estimation methodology (Section 3).
- An emissions summary for selected substances presented by on-road mobile source type for the GMR, Sydney, Newcastle, Wollongong and Non Urban regions (Section 4).
- An emissions summary for selected substances presented for all on-road mobile sources for the GMR, Sydney, Newcastle, Wollongong and Non Urban regions (Section 5).
- A complete list of references (Section 6).
- Total on-road mobile source emissions of all substances emitted in the GMR (APPENDIX A).
- Emission projections from 2011 to 2036 (APPENDIX B).
- Detailed cold start parameters (APPENDIX C).
- Full speciation tables (APPENDIX D).

2 INVENTORY SPECIFICATIONS

2.1 The Inventory Year

The on-road mobile air emissions inventory results presented in this report are based on activities that took place in the 2008 calendar year.

2.2 The Inventory Region

The inventory region defined as the GMR measures 210 km (east-west) by 273 km (north-south). The inventory region is defined in Table 2-1 and shown in Figure 2-2.

Table 2-1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

Region	South-west corner MGA# co-ordinates		North-east corner MGA# co-ordinates	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

#MGA = Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2006).

2.3 Grid Coordinate System

The grid coordinate system used for the on-road mobile air emissions inventory uses 1 km by 1 km grid cells. The grid coordinates start from the bottom left corner having index number with Easting (km) in the horizontal and Northing (km) in the vertical direction. The grid coordinate system is illustrated in Figure 2-1.

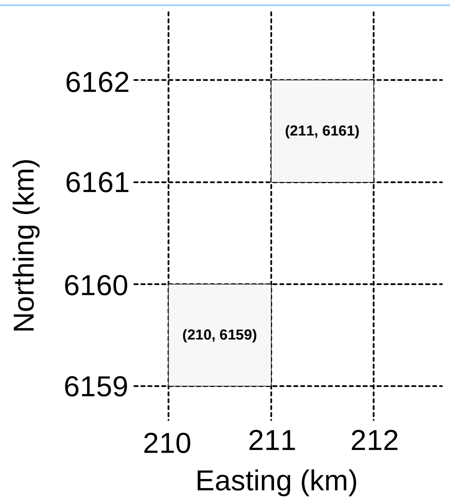

Figure 2-1: Grid coordinate system

Figure 2-2: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

2.4 Emission Sources Considered

The on-road mobile sources included in the on-road mobile emissions inventory are outlined in Table 2-2.

Table 2-2: On-road mobile emission sources

Source	Description
Exhaust Emissions from Petrol Passenger Vehicles	Exhaust emissions from all petrol vehicles used primarily for the purpose of passenger transport. This source group includes cars, people movers, and sports utility vehicles (SUV) or four wheel drives (4WD)
Exhaust Emissions from Light Duty Diesels	Exhaust emissions from all light duty diesel vehicles (≤ 3500 kg GVM), including both passenger vehicles (cars and SUV/4WD) and light commercial vehicles (vans and utilities).
Exhaust Emissions from Petrol Light Commercial Vehicles	Exhaust emissions from all petrol light commercial vehicles (≤ 3500 kg GVM), vans and utilities.
Exhaust Emissions from Heavy Duty Diesel Vehicles	Exhaust emissions from all heavy duty diesel vehicles (> 3500 kg GVM), including rigid trucks, articulated and heavy truck-trailer combinations, and heavy diesel buses (> 5000 kg GVM)
Exhaust Emissions from Other Vehicles	Exhaust emissions from heavy duty commercial petrol vehicles (> 3500 kg GVM) and motorcycles.
Evaporative Emissions from all Petrol Vehicles	Total evaporative emissions from all evaporative loss mechanisms, from all petrol vehicles
Non-exhaust Particulate Matter Emissions from all vehicles	Particulate matter emissions from all vehicles, from brake, tyre and road surface wear mechanisms

2.5 Pollutants Evaluated

The following pollutants have been considered:

- Substances included in the National Environment Protection (National Pollutant Inventory) Measure (NEPC, 2008);
- Pollutants included in the National Environment Protection (Ambient Air Quality) Measure (NEPC, 2003);
- Pollutants included in the National Environment Protection (Air Toxics) Measure (NEPC, 2004);
- Pollutants associated with the Protection of the Environment Operations (Clean Air) Regulation 2010 (PCO, 2011);
- Air pollutants associated with the Protection of the Environment Operations (General) Regulation 2009 (PCO, 2010);
- Speciation of oxides of nitrogen (i.e. NO and NO_2) for photochemical modelling;
- Speciated organic compounds for photochemical modelling sourced from Carter (2010);
- Speciated particulate emissions (i.e. TSP (total suspended particulate), PM_{10} (particulate matter with an aerodynamic diameter ≤ 10 µm) and $PM_{2.5}$ (particulate matter with an aerodynamic diameter ≤ 2.5 µm));
- Environment Protection Authority of Victoria air toxic pollutants sourced from Hazardous Air Pollutants - A Review of Studies Performed in Australia and New Zealand (EPAV, 1999);
- Commonwealth Government Air Toxics Program Technical Advisory Group (13 March 2000) priority air pollutants (EA, 2001);
- U.S. Environmental Protection Agency list of 189 Hazardous Air Pollutants (USEPA, 2010);
- Air pollutants included in the Office of Environmental Human Health Assessment (OEHHA)/Air Resources Board (ARB) 'hot spots' list (CARB, 2011);

- EPA regulated pollutants with design ground level concentrations (DEC, 2005);
- USEPA 16 priority polycyclic aromatic hydrocarbons (PAH) (Keith et. al., 1979);
- WHO97 polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF) and polychlorinated biphenyls (PCB) (Van den Berg et. al., 1998); and
- Greenhouse gases (i.e. carbon dioxide, methane and nitrous oxide) included in the National Greenhouse Accounts (NGA) Factors (DCCEE, 2010).

3 METHODOLOGY

This section details the methodology used to develop the on-road mobile air emissions inventory. Specific details and data are provided in Section 4.

3.1 Inventory Model Structure

The fundamental structure of the on-road mobile emissions model combines estimates of vehicle activity, as vehicle kilometres travelled (VKT), with estimates of the amount of pollutant per kilometre travelled (g/km), known as an emission factor.

The total emission in the region of interest is given by the general calculation shown in Equation 3-1.

$$E_i = \sum_{Road=j}^{n} \sum_{Veh=k}^{p} \frac{\left(EF_{i,j,k} \times VKT_{j,k}\right)}{1000} \qquad \text{Equation 3-1}$$

Where:

E_i	=	Total annual emissions of substance *i* from all vehicles	(kg/year)
$EF_{i,j,k}$	=	Fleet composite emission factor for pollutant *i* on road type *j*, from source type *k* (vehicle type)	(g/km)
$VKT_{j,k}$	=	Vehicle kilometres travelled on road type *j* for source type *k*	(km/year)

Emission factors are estimated for:

- 9 vehicle types incorporating petrol and diesel fuels (aggregated to 7 source type groupings);
- Vehicle age classes defined generally by emission regulation;
- Season and time of day;
- 5 road types;
- 8 primary exhaust pollutants including 2 greenhouse gases;
- Non-exhaust particulate matter and evaporative VOC emissions; and
- 382 speciated organic and inorganic pollutants in both gas and particle phase.

In addition to base exhaust emission factors described above, estimates are made for cold start emissions, and also for evaporative VOC emissions comprising diurnal, hot soak, resting losses and running losses.

VKT is estimated for each of the 1 x 1 km grid cells in the inventory regions for each of the 9 base vehicle types and 5 road types, by hour of the day for the average week day. Weekend day to week day factors by hour of the day are applied to estimate weekend day VKT.

The key components of the model are shown in Figure 3-1. A fleet model defines the age profile of each vehicle type and applies vehicle type specific attrition functions, combined with vehicle fleet growth algorithms to project the fleet profile into the future. The age profile feeds into the emission factor model which produces fleet composite hot running emission factors for each of the nine vehicle source types, for each road type defined in the model. Fleet composite cold running factors are also calculated as are speed correction curves. These are then combined with the VKT of each vehicle source type on each road type within the 1 x 1 km grid cell to determine the total annual emissions. A speciation model is applied to determine the emission mass of the individual compounds.

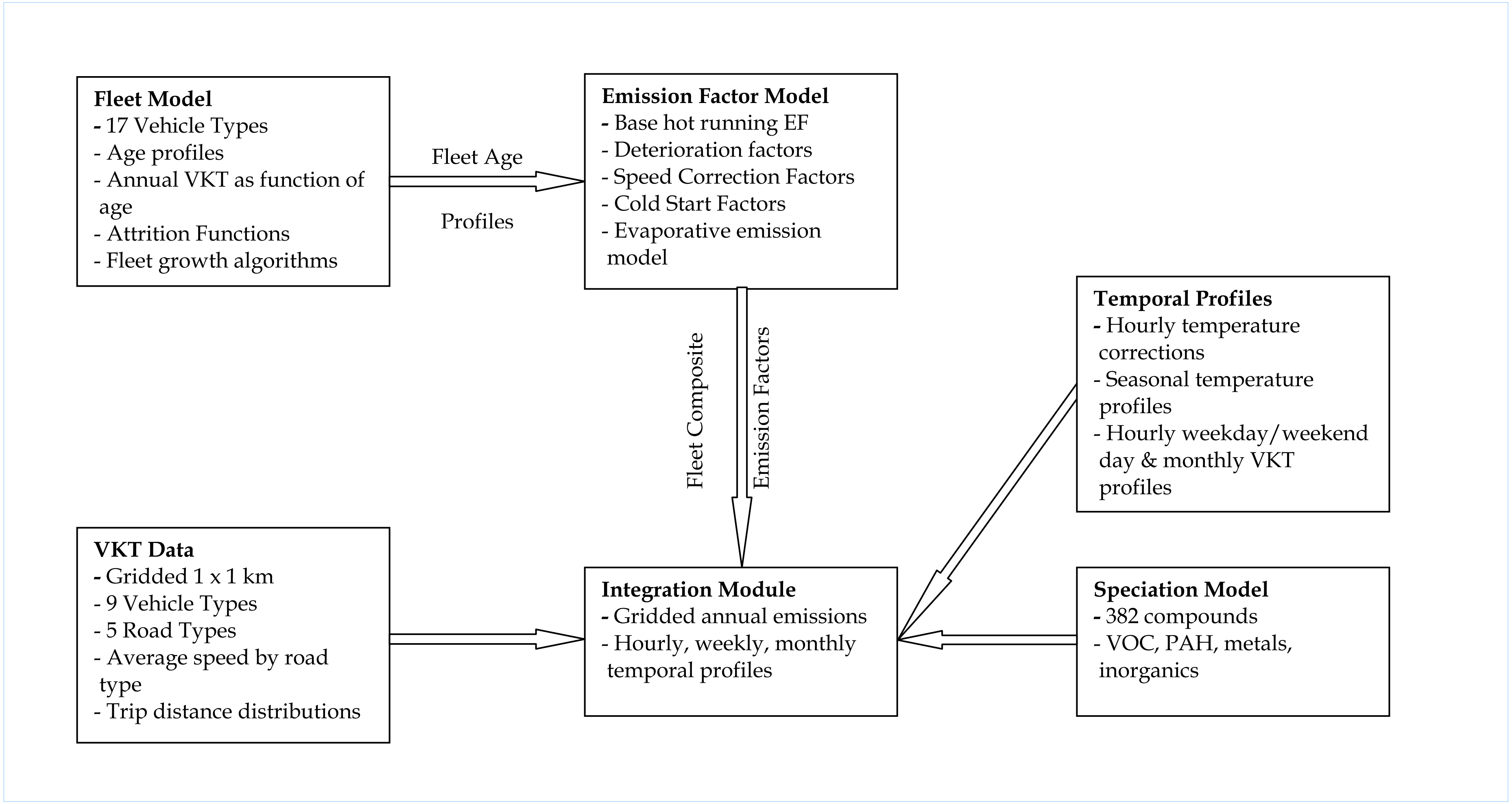

Figure 3-1: Schematic of on-road mobile inventory model structure

3.2 On-Road Mobile Source Type Classification

Seven emission source types are defined:

1. Exhaust emissions from petrol passenger vehicles;
2. Exhaust emissions from light duty diesel vehicles;
3. Exhaust emissions from petrol light commercial vehicles;
4. Exhaust emissions from heavy duty diesel vehicles;
5. Exhaust emissions from other vehicles;
6. Evaporative emissions from all petrol vehicles; and
7. Non-exhaust particulate matter emissions from all vehicles.

These source types are distinct from *Vehicle Types.* Nine vehicle types are defined and modelled in the inventory. The individual vehicle types are described below within the source type to which they are aggregated.

3.2.1 Petrol Passenger Vehicles Source Type

The petrol passenger vehicle source type includes all petrol vehicles with gross vehicle mass (GVM) of less than 3500 kg whose primary usage is for movement of passengers. As such it includes cars (ADR MA class), sports utility vehicles (SUV) or four wheel drives (4WD) (ADR MC class), and people movers (ADR MB class), and together these comprise the inventory source type *Petrol Passenger Vehicles* (PPV). LPG fuelled vehicles are included as petrol passenger vehicles and assigned the same emissions characteristics, as limited emissions data exists for LPG vehicles, and the existing data indicates relatively small differences in emissions between comparable petrol and LPG vehicles (NSW EPA, 1997).

Petrol passenger vehicles accounted for 73% of the vehicle kilometres travelled (VKT) in the NSW GMR during 2008. The activity of passenger vehicles in the GMR has been extensively studied through a long term Household Travel Survey (HTS) conducted by the Bureau of Transport Statistics (BTS, formerly Transport Data Centre, TDC), (e.g. TDC, 2010). The VKT of PPV is modelled by the BTS' Strategic Travel Model (STM), (BTS 2011).

The emissions performance of the Australian petrol vehicle fleet has also been extensively studied, including the National In-Service Emissions Study (NISE1), (FORS, 1996), the Comparative Vehicle Emissions Study (DOTARS, 2001), the second National In-Service Emissions Study (NISE2), (DEWHA, 2009), and earlier major measurement programs by the NSW and Victoria EPAs.

The emissions regulations for PPV have been progressively tightened under the Commonwealth government's program of Australian Design Rules (ADRs). The first emission control was introduced as ADR27 in 1974, with regular revision through ADR37 and recently the Euro based ADR79/xx series of regulations. ADR79/00 and subsequent revisions have occurred since the last NSW inventory for base year 2003. The recent NISE2 project, which tested 400 petrol vehicles, demonstrated a significant improvement in the emissions performance of petrol light vehicles with the introduction of this new series of regulations.

The emissions regulations applicable to petrol passenger vehicles are shown in Table 3-1. Note that test methods vary and hence the emission limits cannot be directly compared. Notwithstanding the varying test procedures the regulations show a significant tightening of the limits. MB2 and MC2 class vehicles (GVM > 2700 kg) were able to be certified under the more lenient ADR36/00 standard from 1/7/88 up until the introduction of ADR79/00 in 2003. This standard required an engine test as opposed to a chassis dynamometer test, and vehicles did not generally require a catalyst or closed loop air-fuel ratio control in order to meet the limits. Hence vehicles certified under ADR36/00 typically had significantly higher emissions than those certified under ADR37/00/01 (DEWHA, 2009).

Table 3-1: ADR emission limits applicable to petrol passenger vehicles

ADR	Date of Introduction[1]	Vehicle Classes[2]	Test Cycle	CO (g/km)	HC (g/km)	NOx (g/km)	HC+NOx (g/km)	Evap (g)
ADR27	1/1/74	MA	ECE15	24.7 - 54.5[3]	1.99 - 3.17[3]	N/A	N/A	N/A
ADR27A	1/7/76	MA	LA72	24.2	2.1	1.9	N/A	2.0[4]
ADR27B	1/1/82	MA	LA72	24.2	2.1	1.9	N/A	6.0[5]
ADR27C	1/1/83	MA	LA72	24.2	2.1	1.9	N/A	6.0[5]
ADR36/00[6]	1/7/88	MB2, MC2, NA2	9 mode engine cycle	1.0%	180 ppm C6	N/A	N/A	N/A
ADR37/00	1/7/88	MA, (MB1, MC1)	FTP75	8.45 (11.3)	0.85 (1.13)	1.75 (1.75)	N/A	1.9[5]
ADR37/01	1/1/97 - 1/1/99	MA, (MB1, MC1)	FTP75	1.91 (5.64)	0.24 (0.45)	0.57 (1.27)	N/A	1.9[5]
ADR79/00	1/1/03 - 1/1/04	MA, MB, MC	ECE15 + EUDC	2.2 - 5.0[7]	N/A	N/A	0.5-0.7[7]	2.0[5]
ADR79/01	1/1/05 - 1/1/06	MA, MB, MC (GVM > 2500 kg)	NEDC[8]	2.3 (5.22)	0.20 (0.29)	0.15 (0.21)	N/A	2.0[9]
ADR79/02	1/7/08 - 1/7/10	MA, MB, MC (GVM > 2500 kg)	NEDC	1.0 (2.27)	0.10 (0.16)	0.08 (0.11)	N/A	2.0[9]
ADR79/03/04	1/11/13 - 1/11/16	MA, MB, MC (GVM > 2500 kg)	NEDC	1.0 (2.27)	0.10 (0.16)	0.06 (0.082)	N/A	2.0[9]

[1] – Where two dates are shown, the first applies to all new model vehicles, the second to all vehicles

[2] – MA = Passenger car, GVM ≤ 3500 kg, MB = forward control passenger vehicle GVM ≤ 3500 kg, MC = four wheel drive GVM ≤ 3500 kg, MB1 = forward control passenger vehicle ≤ 2700 kg, MB2 > 2700 kg MC1 = four wheel drive GVM ≤ 2700 kg, MC2 > 2700 kg

[3] – Limits vary according to mass of vehicle. Range given for < 750 kg to > 2150 kg vehicles

[4] – Not a SHED test, includes running losses

[5] – SHED Test, diurnal + hot soak

[6] – ADR36/00 sets limits for petrol vehicles 2700 kg < GVM ≤ 3500 kg as weighted average raw exhaust gas concentrations of CO and HC only

[7] – Limits vary according to mass. Range given for ≤ 1250 kg to >1700 kg

[8] – NEDC is same as ECE15+EUDC but includes sampling of cold start emissions, whereas in ECE15+EUDC the vehicle is idled for 40 sec prior to commencing sampling

[9] – The diurnal test changed from 1 hour to 24 hour

3.2.2 *Light Duty Diesel Vehicles Source Type*

Source type Light Duty Diesel comprises:

- Diesel passenger vehicles (DPV). Diesel passenger vehicles includes passenger cars (ADR MA class), people movers (ADR MB class) and SUV or 4WD (ADR MC class) vehicles and
- Diesel light commercial vehicles (DLCV). Diesel LCV include utilities and vans (ADR NA class) used for commercial purposes.

These two vehicle type groupings are combined together in the inventory to comprise the *light duty diesel vehicles* (LDD) source type. The on-road mobile inventory model calculates separately the emissions from the two vehicle types prior to combining into the LDD source type.

Historically DPV have represented only a very small proportion of the total passenger vehicle fleet, with diesel cars being 0.1-0.2% of total new car registrations, whilst diesel 4WD vehicles sales have comprised a greater proportion of the 4WD fleet at 10-30%. The greatly improved performance and refinement of the new generation of light duty diesel vehicles over the last 10 years together with the superior fuel economy has boosted sales and the market share of LDD is increasing rapidly. In 2008 diesel cars comprised 6.3% of the new passenger car registrations, up from 0.8% in 2005, whilst diesel 4WD comprised 25% of new 4WD registrations (RTA, 2008).

DLCV have historically comprised 15-30% of total LCV sales. As for DPV, sales of DLCV have risen rapidly over the last 3 years, rising from 26% in 2005 to 45% of total LCV sales in 2008.

The VKT of LDD is modelled by the Strategic Travel Model for the DPV and by TDC's Freight Movement Model (FMM) (TDC, 2010a) for the DLCV. These predict VKT of 2.1% and 4.3% of the total 2008 GMR VKT for DPV and DLCV respectively, giving a total of 6.4% for the LDD source type.

Australian emission data for LDD is relatively sparse. A limited number of ADR MC and NA vehicles (13) were tested in the Diesel National Environment Protection Measure (DNEPM) project 2.2 (NEPC, 2000). A further 110 diesel light vehicles were tested in the South Australian Test and Repair Program Zito & Markov, 2008), although this data was measured under DNEPM test protocols which stipulate less stringent measurement techniques, especially for particulate matter. As such, the data for LDD is significantly more limited than for PPV, and is supplemented by emission factor data from European models such as COPERT 4 (Nztiachristos & Samaras, 2009) and ARTEMIS (INRETS, 2007).

The emissions regulations applicable to LDD vehicles are shown in Table 3-2. Note that test methods vary and hence the emission limits cannot be directly compared. Notwithstanding the varying test procedures the regulations show a significant tightening of the limits.

Table 3-2: ADR emission limits applicable to light duty diesel vehicles

ADR	Date of Introduction[1]	Vehicle Classes	Test Cycle	CO (g/km)	NOx (g/km)	HC+NOx (g/km)	PM (g/km)
ADR30	1/7/88	MA, MB, MC, NA	Smoke test only				
ADR70[2]	1/1/95 - 1/1/96 1/7/95 - 1/7/96	MA, MB, MC NA	ECE15 + EUDC	2.72	NA	0.97	0.14
ADR79/00	1/1/02 - 1/1/03	MA, MB, MC[3], NA[4]	ECE15 + EUDC	1.0 1.5	NA	0.7 1.2	0.08 0.17
ADR79/01	1/1/06 - 1/1/07	MA, MB, MC[3], NA[4]	NEDC	0.50 0.74	0.25 0.39	0.30 0.46	0.025 0.06
ADR79/02	1/1/08 - 1/1/10	MA, MB, MC[3], NA[4]	NEDC	0.50 0.74	0.25 0.39	0.30 0.46	0.025 0.06
ADR79/03/04	1/11/13 - 1/11/16	MA, MB, MC[3], NA[4]	NEDC	0.50 0.74	0.18 0.28	0.23 0.35	0.005[5] 0.005

[1] – Where two dates are shown, the first applies to all new model vehicles, the second to all vehicles

[2] – ADR70 applied Euro 1 as minimum requirement. Euro 1 limits shown

[3] – Limits in first row apply to M class vehicles of GVM ≤ 2500 kg. Vehicles > 2500 kg are subject to NA limits

[4] – NA limits are mass dependent; limits shown are for reference mass > 1700 kg

[5] – ADR79/03/04 adopts Euro 5, but does not require the particle number certification specified by Euro 5

3.2.3 Petrol Light Commercial Vehicles Source Type

Petrol light commercial vehicles (PLCV) comprise vans and utility vehicles used for commercial purposes. These are classified as NA class in the ADR regulations.

The VKT of PLCV is predicted by a combination of the STM and the FMM. From the Household Travel Survey it is known that some LCV are used for passenger transport in addition to commercial activities, and this VKT component is predicted by the STM. The commercial activity is predicted by the FMM (TDC, 2010a). The VKT of PLCV contributes 12.8% to the total 2008 GMR motor vehicle fleet VKT.

The emissions regulations applicable to PLCV are shown in Table 3-3. Note that test methods vary and hence the emission limits cannot be directly compared. Notwithstanding the varying test procedures the regulations show a significant tightening of the limits. MB2, MC2 and NA2 class vehicles (> 2700 kg) were also able to be certified under the more lenient ADR36/00 standard from 1/7/88 up until the introduction of ADR79/00 in 2003. This standard required an engine test as opposed to a chassis dynamometer test, and vehicles did not generally require a catalyst or closed loop air-fuel ratio control in order to meet the limits. Hence vehicles certified under ADR36 typically had significantly higher emissions than those certified under ADR37/xx (DEWHA, 2009). Most PLCV have GVM > 2700 kg and hence were able to be certified to ADR36/00 until 2003.

The emissions of PLCV were not studied until the NISE2 project, where 22 1990-1998 vehicles (ADR36/00, ADR 37/00), 15 1999-2003 vehicles (ADR 36/00, ADR 37/01), 13 ADR79/00 and 12 ADR79/01 vehicles were tested. The pre-ADR79/00 PLCV were found to be significantly higher emitters than cars of the same age class. Twelve of the 37 pre-ADR79/00 PLCV were identified to be certified to the more lenient ADR36/00 rather than the ADR37/00/01 standards.

Table 3-3: ADR emission limits applicable to petrol light commercial vehicles

ADR	Date of Introduction[1]	Vehicle Classes[2]	Test Cycle	CO (g/km)	HC (g/km)	NOx (g/km)	HC+NOx (g/km)	Evap (g)
ADR36/00[3]	1/7/88	NA2	9 mode engine cycle	1.0%	180 ppm C6	N/A	N/A	N/A
ADR37/00	1/7/88	NA1	FTP75	11.3	1.13	1.75	N/A	1.9[4]
ADR37/01	1/7/98 - 1/1/99	NA1	FTP75	5.64	0.45	1.27	N/A	1.9[4]
ADR79/00	1/1/03 - 1/1/04	NA	ECE15 + EUDC	2.2 - 5.0[5]	N/A	N/A	0.5 - 0.7[5]	2.0
ADR79/01	1/1/05 - 1/1/06	NA	NEDC[6]	2.3 - 5.22[7]	0.20 - 0.29[7]	0.15 - 0.21[7]	N/A	2.0[8]
ADR79/02	1/7/08 - 1/7/10	NA	NEDC	1.0 - 2.27[7]	0.10 - 0.16[7]	0.08 - 0.11[7]	N/A	2.0
ADR79/03/04	1/11/13 - 1/11/16	NA	NEDC	1.0 - 2.27[7]	0.10 - 0.16[7]	0.06 - 0.082[7]	N/A	2.0

1 – Where two dates are shown, the first applies to all new model vehicles, the second to all vehicles

2 – NA = light commercial vehicles ≤ 3500 kg, NA1 ≤ 2700 kg, NA2 2700 kg < GVM ≤ 3500 kg

3 – ADR36/00 sets limits for weighted average raw exhaust gas concentrations of CO and HC only

4 – SHED Test, diurnal + hot soak

5 – Limits vary according to mass. Range given for ≤ 1250 kg to > 1700 kg

6 – NEDC is same as ECE15+EUDC but includes sampling of cold start emissions, whereas in ECE15+EUDC the vehicle is idled for 40 sec prior to commencing sampling

7 – Limits vary according to mass. Range given for ≤ 1305 kg to > 1760 kg

8 – The diurnal test changed from 1 hour to 24 hour

3.2.4 Heavy Duty Diesel Vehicles Source Type

The heavy duty diesel (HDD) source type comprises:

- Rigid trucks 3.5 tonne < GVM < 25 tonne. This includes ADR NB class trucks (3.5 tonne < GVM ≤ 12 tonne) and NC class (12 < GVM ≤ 25 tonne). These are referred to as "Rigid" in the inventory model;
- Articulated (and heavy truck trailer combinations) > 25 tonne GVM. These belong to ADR class NC. These are referred to as "Articulated Trucks" or "Artic" in the inventory model; and
- Heavy diesel buses > 5000 kg GVM. These belong to ADR class ME, heavy omnibus (GVM > 5000 kg). This inventory class primarily represents urban route buses.

The inventory model calculates separately the emissions from these three vehicle types prior to combining into the HDD source type. The VKT of the rigid and artic vehicle types are each modelled by the Freight Movement Model (TDC, 2010b). The VKT of the buses is derived from collation of the urban bus service timetables and mapping these onto the road network. Allowance for "dead running" is made for buses. The VKT for these vehicle types contribute 4.9%, 2.2%, and 0.4% to the total 2008 GMR motor vehicle fleet VKT, from rigids, artics and buses respectively, totally 7.5% of the 2008 vehicle fleet GMR VKT.

HDD vehicles are disproportionate contributors of NO_x and PM emissions due to their inherent combustion characteristics, high operating mass (and hence high fuel usage) and level of emission control technology in response to the emission regulations. The emissions characteristics of Australian HDD vehicles have been studied only to a limited degree. The Diesel NEPM measured emissions of 17 NB class rigid trucks, 14 NC class of 12-25 tonne, 10 NC heavy prime movers of > 25 tonne, and 7 ME class buses (NEPC, 2000). The South Australian Test and Repair program (Zito & Markov, 2008) measured emissions from 35 NB class and 20 NC class rigids, 107 NC class artics, and 21 ME buses. The PM measurements in the South Australian program were conducted using the Diesel NEPM light scattering photometry method, and as such have higher degree of uncertainty than conventional PM measurements by the gravimetric certification method. A test program by Sydney heavy buses measured emissions from 15 Euro 0 and Euro II buses (DTA, 2008). The above Australian data was supplemented with emission factor data from the European COPERT4 (Nztiachristos & Samaras, 2009) and ARTEMIS (INRESTS, 2007) models to derive emission factors for this inventory.

The emissions from HDD vehicles are regulated by engine dynamometer testing, reflecting that the same engine model could be used in many different vehicles. The Australian regulations applicable to HDD vehicles are shown in Table 3-4. Large reductions in PM and NO_x are seen to apply from 2007/08.

Table 3-4: ADR emission limits applicable to heavy duty diesel vehicles

ADR	Date of Introduction[1]	Vehicle Classes	Test Cycle	CO (g/kW.h)	HC (g/kW.h)	NO_x (g/kW.h)	PM (g/kW.h)
ADR30	1/7/88	NB, NC, ME	Full Load	Smoke test only			
ADR70/00[2]	1/7/95 - 1/7/96	NB, NC, ME	ECE R49 13 mode	4.5	1.1	8.0	0.36/0.612[3]
ADR80/00[4]	1/1/02 - 1/1/03	NB, NC, ME	ESC 13 mode[5] ETC transient	2.1 5.45	0.66 0.78	5.0 5.0	0.10/0.13[6] 0.16/0.21
ADR80/02[7]	1/1/07 - 1/1/08	NB, NC, ME	ESC 13 mode[5] ETC transient	1.5 4.0	0.46 0.55	3.5 3.5	0.02 0.03
ADR80/03[8]	1/1/10 - 1/1/11	NB, NC, ME	ESC 13 mode[5] ETC transient	1.5 4.0	0.46 0.55	2.0 2.0	0.02 0.03

1 – Where two dates are shown, the first applies to all new model vehicles, the second to all vehicles

2 – ADR70/00 adopted Euro I regulations as minimum requirement. Euro I limits shown

3 – 0.36 g/kW.h applies to engines > 85 kW, 0.612 to engine < 85 kW

4 – ADR80/00 adopted Euro III as base standard.

5 – Different limits apply to the two test types

6 – The higher PM limit applies to engines with swept volume < 0.75 L per cylinder and rated power speed of > 3000 rpm

7 – ADR80/02 adopted Euro IV

8 – ADR80/03 adopted Euro V

3.2.5 Other Vehicles Source Type

The inventory source type *Other Vehicles* ("Oth" or "Other") includes:

- Heavy duty commercial petrol vehicles (HDCP) (GVM > 3500 kg), primarily ADR class NB; and
- Motor cycles (MC), ADR class LC.

The on-road mobile inventory model calculates the emissions for these two vehicle type separately prior to combining them to form the *Other Vehicles* source type.

Heavy duty commercial petrol vehicles are present in the GMR fleet in very low numbers, of order 1100 for the inventory year 2008. These vehicles are treated as petrol rigid trucks for VKT modelling and contribute less than 0.2% to total 2008 GMR motor vehicle fleet VKT. No Australian data is available for these vehicles and thus the emissions are estimated using emission factors from the US MOBILE 6.2 model (US EPA, 1995, 1998, 1999). The regulations governing the emissions from HDCP are shown in Table 3-5.

Table 3-5: ADR emission limits applicable to heavy duty commercial petrol vehicles

ADR	Date of Introduction[1]	Vehicle Classes	Test Cycle	CO (g/kW.h)	HC (g/kW.h)	NO_x (g/kW.h)	Evap (g)
ADR36/00[2]	1/7/88	NB, NC, ME	9 mode engine cycle	1.0%	180 ppm C6	N/A	N/A
ADR80/00[3]	1/1/03 - 1/1/04	NB, NC, ME	US FTP Transient[4]	19.2	1.47	6.67	3.0-4.0[5]
ADR80/01[3]	1/1/05 - 1/1/06	NB, NC, ME	US FTP Transient[4]	19.2	1.47	6.67	3.0-4.0[5]
ADR80/02	1/1/07 - 1/1/07	NB, NC, ME	NEDC	5.22 g/km	0.29 g/km	0.21 g/km	2.0
ADR80/03	1/1/10 - 1/1/11	NB, NC, ME	NEDC	2.27 g/km	0.16 g/km	011. g/km	2.0

1 – Where two dates are shown, the first applies to all new model vehicles, the second to all vehicles

2 – ADR36/00 sets limits for weighted average raw exhaust gas concentrations of CO and HC only

3 – ADR80/00/01 adopts US CFR Part 86 Subpart A 40 CFR 86.096-10 Emission standards for 1996 and later model year Otto-cycle heavy-duty engines and vehicles; and Sub Part N 40 CFR 86.1300 series Emission Regulations for new Otto-cycle and diesel heavy duty engines; gaseous and particulate exhaust test procedures

4 – This is a transient engine dynamometer test and should not be confused with the US light duty FTP75 chassis dynamometer drive cycle

5 – The evaporative limit shown is for 3 24 hour diurnal plus a hot soak. The two limits are for vehicle with GVM < 6.36 tonne and GVM > 6.36 tonne. A running loss limit of 0.031 g/km also applies.

Motorcycle VKT is modelled by the STM (BTS, 2011) as calibrated with the household travel survey. Motorcycles contribute 0.5% to the total GMR motor vehicle fleet 2008 VKT. No emission regulations apply in Australia; however, motorcycles being sold in Australia are increasingly advertised as meeting overseas emission regulations. No Australian data is available on the emissions performance of motorcycles, and thus data from the European ARTEMIS model (Elst, 2006) is used to estimate the emissions of Australia motorcycles.

3.2.6 *Evaporative Emissions Source Type*

Evaporative VOC emissions from all petrol fuelled vehicles (PPV, PLCV, MC and HDCP) are combined into the evaporative emissions source type. Evaporative emissions from petrol fuelled vehicles constitute a very significant fraction of the total on-road mobile VOC emissions.

Four evaporative loss mechanisms are modelled in the inventory:

- Diurnal emissions
- Hot soak losses
- Resting losses
- Running losses

Diurnal emissions occur while the vehicle is stationary with the engine shut off as a result of thermal expansion of the fuel vapour in the fuel tank due to diurnal changes in ambient temperature. This mechanism is also known as "tank breathing", or "breathing losses". Without any control system these vapours are vented directly to the air. Vehicles have used activated carbon canisters on the fuel tank vent line to trap these VOC emissions since the 1980's.

Hot soak emissions are generated when a vehicle is parked and the engine shut off at the end of a trip. Heat is transferred from the engine and exhaust system to the fuel system causing fuel evaporation. Older vehicles with carburettors with float chambers have significant hot soak losses, while with modern fuel injected systems hot soak losses contribute much smaller amounts to the total evaporative emission.

Resting losses occur due to permeation (diffusion through fuel lines and fuel tanks), and seepage and minor fuels leaks, and do not require a rise in temperature to occur. Resting losses are however a strong function of ambient temperature, and also of fuel composition and Reid Vapour Pressure (RVP). These emissions occur concurrently with diurnal, hot soak and running loss emissions, and recent studies have shown that this mechanism can form a major part of diurnal and hot soak losses (CRC, 2004; CRC, 2008). Ethanol in the fuel in particular has been shown to strongly increase permeation losses (CRC, 2004; CRC, 2006; CRC 2010; CRC, 2010a), and this effect can take up to 4 weeks operation on ethanol containing fuels to fully develop.

Running losses are defined as the evaporative emissions which occur whilst a vehicle is being driven. The heat emitted from the engine and exhaust system, and the changing airflow over, and more significantly, under the vehicle result in variations in fuel temperature. Heat rise from surplus fuel returned from the engine to the fuel tank also contributes. Running losses are a strong function of ambient temperature rising exponentially with temperature (Hausberger et. al., 2005), which makes them a significant component of total evaporative emissions in high ambient temperatures. Running losses are also a strong function of vehicle speed, with much lower emissions at highway/motorway speeds relative to urban conditions.

3.2.7 *Non-Exhaust Particulate Matter Emissions Source Type*

Non-exhaust particulate matter emissions are estimated for three formation mechanisms:

- Brake wear
- Tyre wear
- Road wear

Brake wear PM is generated during forced deceleration from mechanical wear of primarily the brake pads or linings, and to a lesser degree from the brake disc or drum. The composition of brake generated PM is complex and variable with a large number of different brake lining compositions manufactured (Luhana et. al., 2004). The amount of PM emitted from brake wear is a function of vehicle characteristics, notably mass, operating conditions and driving style, and brake component composition and characteristics. Not all brake wear material is emitted as airborne PM, with estimates ranging around 50-70% of total wear mass (Luhana et. al., 2004). The airborne brake wear PM is largely in the respirable size range, with 98% by mass of total suspended particles (TSP) from this mechanism being classified as PM_{10}, whilst 39% is estimated to be $PM_{2.5}$ (Ntziachristos & Boulter, 2009).

Tyre wear occurs at the interface of the tyre and the road surface and is a complex process influenced by factors such as tyre and road composition and characteristics, vehicle operating characteristics such as braking, acceleration and cornering, and other vehicle characteristics such as wheel alignment, vehicle weight and suspension type and condition. Estimates of the airborne PM_{10} fraction range of tyre wear material are variable but estimated to be of order 30% (Luhana et. al., 2004). Of the total suspended particle mass, 60% is estimated to be PM_{10} and 42% $PM_{2.5}$ (Ntziachristos & Boulter, 2009).

Road wear has been studied considerably less than brake or tyre wear, and PM emission rate estimates are considered to have high uncertainty (Ntziachristos & Boulter, 2009). No conclusive markers are accepted for road wear material and difficulties arise in separating the resuspended dust from fresh road wear emissions. Road surface materials and characteristics vary greatly but can generally be divided into asphalt based (most common in Australia) or concrete based. Luhana et al (2004) estimated road wear PM_{10} emissions to be of order 3.1 mg per vehicle km (mg/vkm) for light duty vehicle and 29 mg/vkm for heavy duty vehicles. The European COPERT 4 model (Ntziachristos & Boulter, 2009) provides road wear TSP emission rates ranging from 15 mg/vkm for light duty vehicles to 76 mg/vkm for heavy duty vehicles. The COPERT 4 PM size distribution for road wear suggests 50% of TSP is PM_{10} (7.5-38 mg/vkm) and $PM_{2.5}$ to be 27% of TSP mass.

3.3 Fleet Age Distribution and Projection

The fleet of vehicles of any particular type is a mix of model years from new to over 35 years old. Older vehicles have higher emissions than newer as a result of having been built to earlier more lenient emission limits, and also due to accumulated deterioration of the vehicle and emissions control technologies. In order to determine the fleet total emissions, a fleet profile must be generated to describe the age of the fleet to then allow assigning of age specific emission factors.

A fleet model has been developed that generates age profiles for each of the nine vehicle types for which emissions are separately modelled prior to aggregation to the seven vehicle source type groupings described above. The fleet model internally models 17 vehicle types to accommodate subclasses and fuel types, e.g. petrol passenger vehicles comprise cars and 4WD/SUV, both petrol and LPG fuelled. The LPG fuelled vehicles emissions are modelled as petrol as existing limited LPG data shows no significant difference in emissions performance (NSW EPA, 1997). The fleet model is based on the RTA registration records, and includes only vehicles whose registered address is within the inventory GMR. The 17 vehicle types modelled are listed in Table 3-6.

For each vehicle class an attrition function has been derived from historical RTA registration records. The attrition function is in the form of proportion of vehicles surviving per year as a function of age and is shown in Figure 3-2. The rise in annual proportion surviving after approximately 23-25 years for passenger cars and motorcycles, and to a lesser extent LCV, is due to restoration and re-registration of older vehicles.

For all vehicle types in the inventory model, the GMR wide age profile is applied uniformly across the GMR with no spatial variation. A fixed VKT as a function of vehicle age is also applied for each vehicle type, with newer vehicles accumulating greater VKT per year than older vehicles.

Table 3-6: Vehicle types in fleet model

Source Type	Vehicle Group[1]	Vehicle Types[2]
Petrol Passenger Vehicles	Petrol Passenger Vehicles	Petrol cars and people movers
		LPG cars
		Petrol 4WD
		LPG 4WD
Light Duty Diesels	Diesel Passenger Vehicles	Diesel cars and people movers
		Diesel 4WD
	Diesel LCV	Diesel LCV
Petrol Light Commercial Vehicles	Petrol Light Commercial Vehicles	Petrol LCV
		LPG LCV
Heavy Duty Diesel	Rigid Trucks	Diesel Rigids (3.5 < GVM ≤ 25 tonne)
	Articulated Trucks	Articulated and truck trailer combinations (GCM > 25 tonne)
	Heavy Buses	Diesel Buses (GVM > 5 tonne)
Other	Heavy Duty Commercial Petrol	Petrol Rigids (GVM > 3.5 tonne)
		LPG Rigids (GVM > 3.5 tonne)
	Motorcycles	Motorcycles
None	Not modelled	Petrol Buses
		CNG Buses

1 – Emissions are modelled for these 9 groups
2 – Fleet numbers are modelled for each of these 17 groups

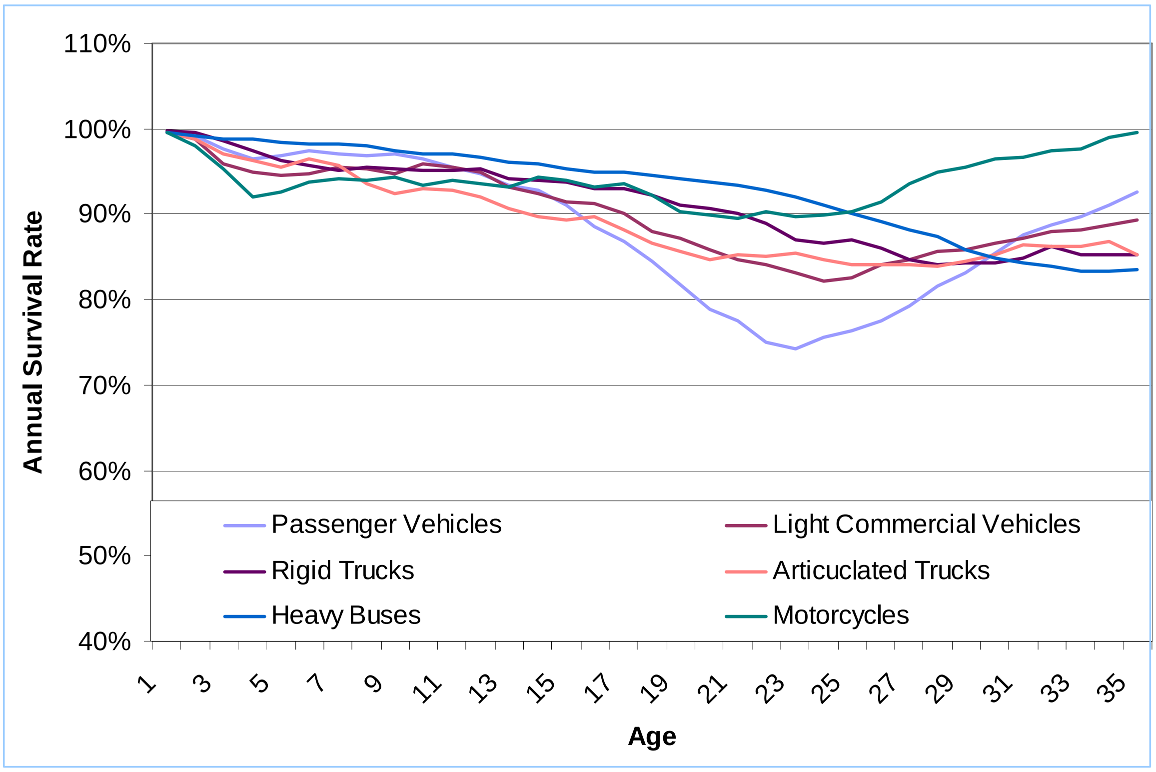

Figure 3-2: Vehicle attrition functions

Growth rates in the total fleet size for each vehicle class modelled are estimated based on population projections for passenger vehicles and economic activity (state gross product) for commercial vehicles. These fleet growth projections are used to model projections of the future fleet. For passenger vehicles, the total passenger vehicle fleet growth is predicted by Equation 3-2:

$$PV\ Nos._{Yr} = PV\ Nos._{Yr-1} \times (1 + \%PopGr_{Yr}) \times \left(\frac{PV\_Pop_{Yr}}{PV\_Pop_{Yr-1}} \right) \qquad \text{Equation 3-2}$$

Where:

$\%PopGr$	=	% population growth predicted by ABS projection 'B' for Sydney	(%/year)
PV_Pop	=	passenger vehicles per head of population	
and		$PV\_Pop_{Yr} = \frac{0.5943}{\left(1 + e^{(250.4 - 0.1262 \times Yr)}\right)}$	(cars/person)

The passenger vehicle numbers per head of population function is derived from regression of the trend in number of passenger vehicles per head of population for Sydney over 1999 to 2007 from the 2009 release Household Travel Survey (TDC, 2009), which gave an R^2 of 0.972, and asymptotes to 0.594 vehicles per head of population.

The total passenger vehicle fleet is then divided into the six sub-classes shown in Table 3-6 by sales projections of the % of 4WD in the vehicle fleet, and the % of petrol, LPG, and diesel vehicles in each of the car and 4WD fleets. These projections are shown in Figure 3-3. The strong growth in light duty diesel sales from 2005 to 2011 is assumed to continue strongly into the projected years estimates.

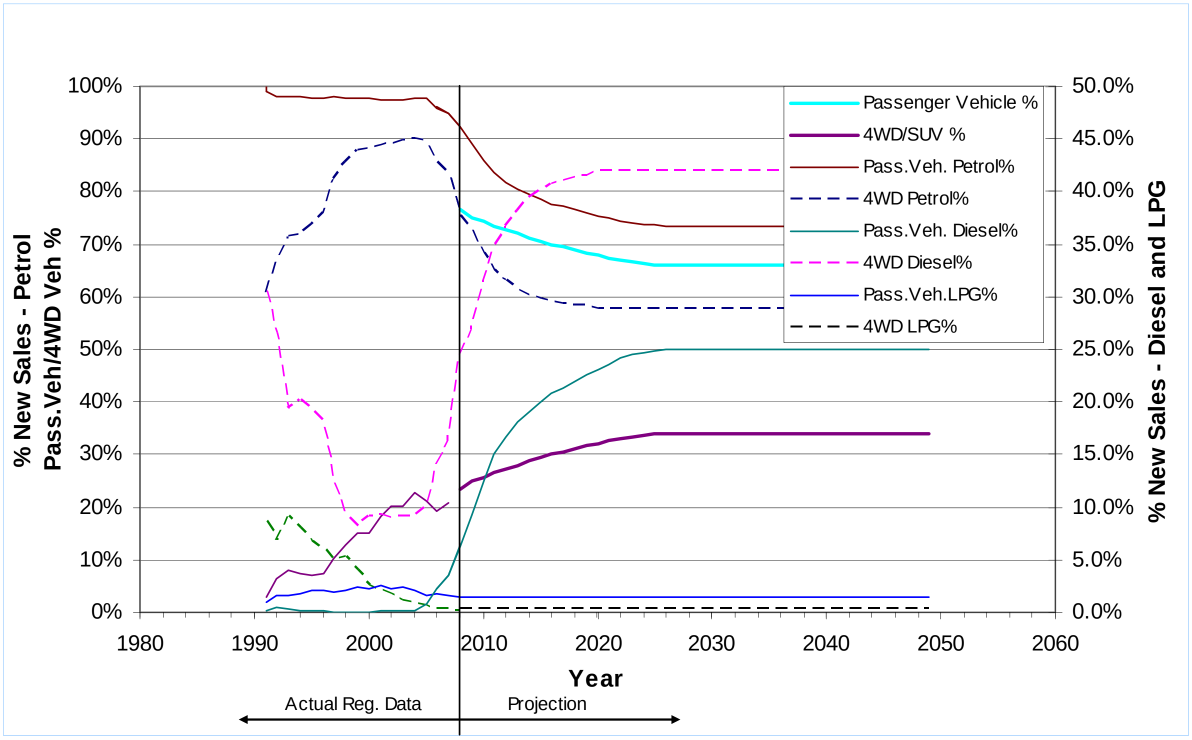

Figure 3-3: Passenger vehicle fleet sales proportions projections

The projection of the commercial vehicle fleet (light and heavy duty commercial vehicles) is based on the methodology developed by the Gargett & Cosgrove (2003). This model predicts growth in the road transport freight task (tonne-kilometres) as a function of GDP increase (ΔGDP) and change in truck freight rates (ΔRate%) by:

$$\textit{Freight Task Change} = [1 + (\Delta GDP\% \times 1.21)] \times [1 + (\Delta Rate\% \times -0.89)] \qquad \text{Equation 3-3}$$

This equation indicates that the growth in road freight task grows by 1.21 times the growth in economic activity and that for a 1% decrease in road freight rates ($/tonne-kilometre) the road freight task increases by 0.89%.

The change in road freight task is then distributed amongst the freight vehicle classes of LCV, Rigids and Articulated Trucks according to the base tonne-kilometre share from Gargett & Cosgrove (2003) and the rate of change per annum of the % share between vehicle types, taking into account projected changes in payload for each vehicle type. The model was calibrated to be consistent with the growth in VKT predicted by the TDC FMM (TDC, 2010a, 2010b) with the assumption of constant VKT per vehicle per annum. The resulting growth in the commercial vehicle fleet numbers is presented in Figure 3-4.

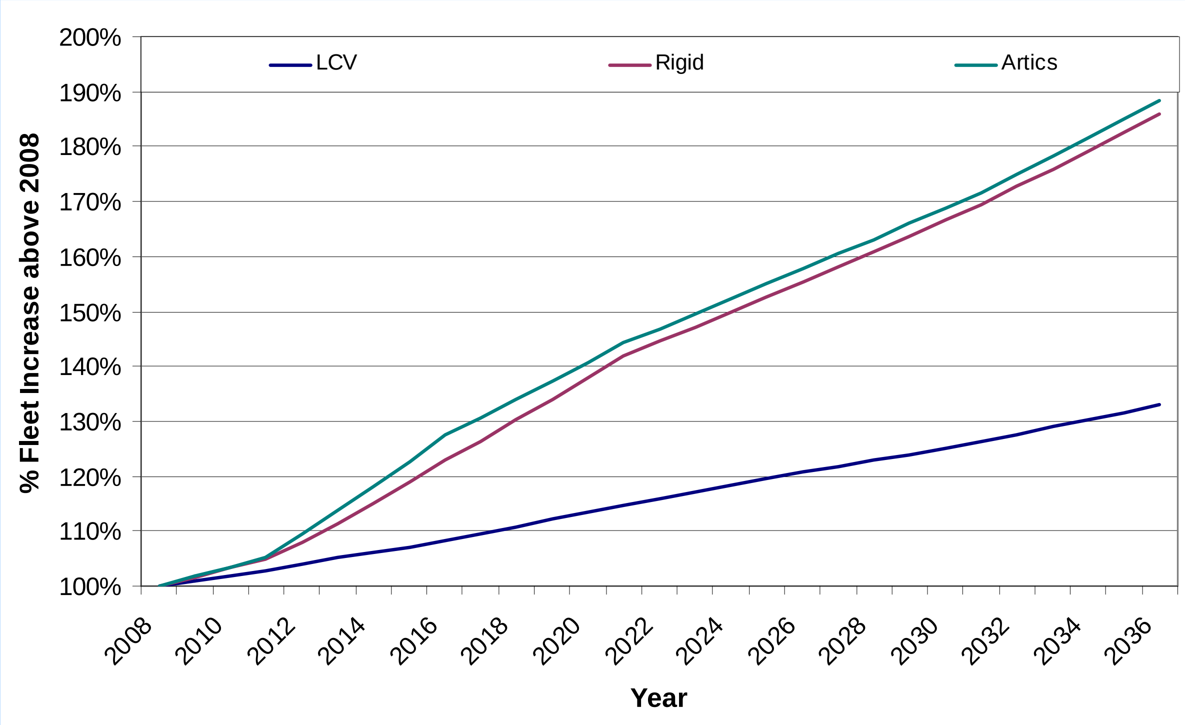

Figure 3-4: Projected growth in commercial vehicle fleet

3.4 Vehicle Activity (VKT) Modelling

The measure of vehicle activity is vehicle kilometres travelled (VKT). The VKT data generated as input to the on-road mobile inventory model is on a 1 x 1 km grid basis, by hour of the day for an average weekday, for nine vehicle types and five road types.

The VKT data is generated by the NSW Department of Transport's Bureau of Transport Statistics (BTS, formerly Transport Data Centre or TDC) using two demand models:

- Strategic Travel Model (STM) (BTS, 2011) – estimates passenger vehicle activity; and
- Freight Movement Model (TDC, 2010a, 2010b) – estimates commercial vehicle activity.

Both models generate travel activity data for an average weekday. Average weekend day VKT is derived from RTA traffic count data and also from BTS classified vehicle traffic counts (BTS, 2010). Public transport bus VKT is handled separately and is generated by mapping the scheduled bus timetable onto the road network with allowance for dead running. The trip length distribution of the VKT is also generated as input to the cold start modelling. An overview of the modelling approach used by BTS is given below. Specific data from the traffic modelling used as input to the emissions modelling are presented for the respective source types in Section 4 of this report.

3.4.1 Strategic Travel Model – Passenger Movement

The STM is a collection of demographic, behavioural and traffic network models that predict total travel demand for seven purposes and assigns the demand based on travel choice models to nine travel modes. The purposes and modes are shown in Table 3-7.

Table 3-7: STM demand models and travel modes

Travel Purpose	Travel Mode
Work	Car driver
Business	Car passenger
Primary Education	Rail
Secondary Education	Bus
Tertiary Education	Light Rail
Shopping	Ferry
Other	Bike
	Walk
	Taxi

Geographically the STM model uses 2690 travel zones defined across the Sydney Greater Metropolitan Area (GMA- this differs from the inventory GMR). Estimates and projections of spatially resolved population and employment provide input to develop travel demand for each of the purposes listed both between and within the travel zones. The travel zones are typically much smaller than postcode areas.

The resulting travel demand predictions generate car trip matrices. These are a table of trips between origin to destination travel zones, and within the travel zones, by four periods of the day; AM peak, inter-peak, PM peak, and evening, corresponding to hours of 7:00 to 8:59, 9:00 to 14:59, 15:00 to 17:59, and 18:00 to 6:59 respectively. Hourly profiles within these base time periods are derived from the Household Travel Survey.

The car trips defined in the matrices are assigned onto the physical road network using the Roads and Traffic Authority road network model on the EMME2 traffic modelling platform. This generates a database of vehicle flow by the hour on each link within the road network. A link is defined as a section of road between intersections or corners. For each link, an average speed of traffic is predicted by the EMME2 network model according to volume delay functions for each road link as characterised by the number of lanes and road type. The link data is subsequently transformed into VKT by inventory 1 x 1 km gridcell for the five inventory road types.

The "car" VKT thus generated is then split firstly into motorcycle or car using HTS data, and cars are then split to petrol or diesel in proportion to the fleet fuel mix predicted by the fleet model described in Section 3.3. Overlap between cars and light commercial vehicles used for passenger movement trips is estimated from the HTS data and adjustments to the VKT of both vehicle classes made.

The total VKT for the GMR for passenger vehicles for the 2008 inventory base year is given in Table 3-8 for the average weekday.

Table 3-8: Passenger vehicle VKT for average weekday

Year	Petrol Passenger Vehicles	Diesel Passenger Vehicles	Motorcycles	Total Passenger Vehicles
2008	82,781,704	2,358,380	557,476	85,697,561
2011	82,114,902	5,083,677	570,992	87,769,571
2016	78,136,782	11,500,458	586,846	90,224,085
2021	74,755,288	18,444,173	610,141	93,809,602
2026	73,607,326	24,837,673	644,481	99,089,480
2031	72,797,156	28,747,210	664,796	102,209,163
2036	74,238,976	31,349,100	691,129	106,279,205

3.4.2 *Freight Movement Model*

The Freight Movement model generates VKT for light commercial vehicles, rigid trucks and articulated trucks using a similar modelling approach as described above for passenger trips. The most recent release (February 2010) of the commercial vehicle trip matrices have been used to generate VKT for the on-road mobile inventory (TDC, 2010a, 2010b).

The base input parameters for estimation of road freight transport activity are measures of business activity. For LCV activity, a *trip attraction rate* concept is used. Trip attraction for LCVs is based on the number of households and the number of businesses in each travel zone measured by the number of employees. A single attraction rate is assigned to households (representing service vehicle activity) in terms of LCV trips per weekday per household. Businesses are grouped into four classes, office, industrial, retail and hospitality each with their own LCV attraction rate of trips per weekday per employee.

For rigid and articulated trucks a more detailed business classification is used based on industry ANZSIC class, with a total of 33 classifications. Production and consumption models predict the amount of freight generated for each industry class. Employment and industry production data provide the input to the production and consumption models. A distribution model then estimates freight movement based on distribution patterns between industry classes. A loading model distributes the resulting freight amongst rigid and articulated trucks, taking into account dead running, trip chaining, vehicle load capacity and other parameters derived from industry surveys.

The output from the FMM for both LCV and heavy commercial vehicles are trip matrices of the same form as for cars. These matrices are assigned onto the road network along with the car matrices from the STM model.

The total VKT for the GMR for commercial vehicles for the 2008 inventory base year is given in Table 3-9 for the average weekday. Note that the VKT given for the LCV includes the overlap passenger trip VKT, and has been adjusted to match the average annual VKT per vehicle based on the number of LCV registered in the GMR.

3.4.3 *Public Transit Bus VKT*

Bus VKT is generated by assigning published bus route timetables onto the road network. An allowance for dead running of 22.8% is made based on dead running information published by the

State Transit Authority (STA, 2010). Projected VKT is based on historical growth rates in the Transit Bus annual reports from 2003 to 2010 giving an average annual growth rate of 0.89%.

Table 3-9: Commercial vehicle VKT for average weekday

Year	Petrol Light Commercial Vehicles	Diesel Light Commercial Vehicles	Heavy Duty Petrol Commercial	Rigid Trucks	Articulated Trucks	Transit Buses	Total Commercial Vehicles
2008	14,580,614	4,912,186	191,677	5,547,158	2,512,337	489,788	28,233,760
2011	13,654,862	6,366,930	172,515	5,988,737	2,679,402	503,199	29,365,645
2016	11,754,010	9,235,294	169,832	7,057,071	3,244,418	528,505	31,989,129
2021	10,323,772	12,168,106	179,275	8,159,088	3,676,073	552,828	35,059,142
2026	9,116,834	14,501,908	188,152	8,945,458	4,021,564	578,137	37,352,054
2031	8,436,627	16,231,873	200,972	9,748,148	4,366,575	604,478	39,588,673
2036	8,334,586	17,629,857	219,588	10,705,208	4,797,022	632,436	42,318,697

3.5 Road Type Definitions

The on-road mobile inventory model defines five road types. These follow, in general, the definitions from the original 1992 air emissions inventory of the Metropolitan Air Quality Study (Carnovale et. al., 1996). The definitions and mapping to the RTA road network road types have been revised.

The road types defined and broad descriptions are shown in Table 3-11. The road type numbers are those defined in the RTA EMME2 road network model, and are assigned to the five inventory road types as shown. The RTA arterial road types are allocated across three inventory road categories in the proportions shown. The inventory arterial road type has been assigned RTA network road types of sub-arterial road type, which tend to have traffic characteristics more like local/residential roads than arterial roads within the RTA road network model.

The EMME2 model estimates average travel speeds on each road link according to a volume-delay model defined by road characteristics. The RTA calibrates this model with travel time surveys. The 24 hour VKT weighted average speed for each road type for the 2008 base year are shown in Table 3-10. Although the same road types in the RTA road network model assigned to commercial arterial and commercial highway in the proportions 66%/33% respectively, the VKT for the commercial highway road type has been defined to be for the one third of the VKT with the highest average speeds. Hence the average speed for the commercial highway road type is higher than for the commercial arterial.

The coefficient of variation of the hourly average speeds for each road type are shown in Table 3-10 and give an indication of the relative degree of congestion between the road types. Local/residential roads are seen to have relatively low congestion, whilst commercial arterial roads are seen to have the highest congestion.

Table 3-10: 24 Hour VKT weighted average speeds, 2008

Road Type	24 Hour VKT Weighted Average Speed (km/h)	COV (%) of the Hourly Average Speeds
Local/Residential	24.1	1.8%
Arterial	38.0	11.5%
Commercial Arterial	35.3	16.3%
Commercial Highway	56.9	9.4%
Freeway/motorway	66.3	10.6%
All roads	45.5	-

Table 3-11: Road type definitions and VKT contribution

Inventory Road Type	RTA Functional Class	Definition/Description	RTA road type equivalency			
			Road Type No.[1]	RTA Road Type Name[2]	% Daily VKT	Sum VKT
Local/Residential	Local roads	Secondary roads with prime purpose of access to property. Characterised by low congestion and low levels of heavy vehicles. Generally one lane each way, undivided with speed limits of 50 km/h maximum. Regular intersections, mostly unsignalised, low intersection delays.	16 (100%) 1 (100%) 23 (100%) 19 (100%) 21 (100%)	Centroid connector Local Local road Local road CBD road	6.9% 4.0% 1.0% 0.1% 0.1%	**12.1%**
Arterial	Sub-Arterial & Arterial	Provide connection from local roads to arterial roads, and may provide support role to arterial (RTA defined) roads for movement of traffic during peak periods. Distribute traffic within residential, commercial and industrial areas. Speed limits 50-70 km/h, 1-2 lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than Residential, but significant congestion impact at high volume to capacity ratios (V/C)	2 (100%) 24 (100%) 5 (25%) 4 (25%) 7 (25%) 25 (25%) 3 (100%) 6 (25%)	Sub-arterial (non-commercial) Secondary collector ART (divided) ART (undivided) State highway (divided) Arterial (urban) SART (sub-arterial) State highway (undivided)	13.1% 3.7% 3.3% 3.1% 2.1% 1.9% 0.7% 0.2%	**28.1%**
Commercial Arterial	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to high congestion in peak periods. Speed limits 60-80 km/h, typically dual carriageway. Regular intersections, many signalised, characterised by stop-start flow, moderate to high intersection delays and queuing with higher V/C ratios	5 (50%) 4 (50%) 7 (50%) 25 (50%) 6 (50%)	ART (divided) ART (undivided) State highway (divided) Arterial (urban) State highway (undivided)	6.7% 6.2% 4.2% 3.8% 0.4%	**21.2%**
Commercial Highway	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to moderate congestion in peak periods. Speed limits 70-90 km/h, predominantly dual carriageway. Lesser intersections than commercial arterial with smoother flow, but subject to some congestion at high V/C.	5 (25%) 4 (25%) 7 (25%) 25 (25%) 6 (25%)	ART (divided) ART (undivided) State highway (divided) Arterial (urban) State highway (undivided)	3.3% 3.1% 2.1% 1.9% 0.2%	**10.6%**
Freeway/ motorway	Motorway	High volume arterial roads with primary purpose of inter-regional traffic movement with strict access control (i.e. no direct property access). Speed limits 80-110 km/h, predominantly 2+ lanes and divided. Relatively free flowing and steady in non-congested, slowing with congestion approaching V/C limit, but minimal stopping	11 (100%) 26 (100%) 29 (100%) 9 (100%) 20 (100%) 14 (100%) 28 (100%) 10 (100%)	Freeway Arterial Rural Freeway class road Expressway Freeway/State highway Harbour bridges Freeway/Expressway class road Freeway ramp	8.9% 6.6% 4.8% 3.8% 1.2% 1.1% 0.6% 0.6%	**28.1%**

[1] – Road type number code in RTA database. The (%) is the amount of VKT on this RTA road type assigned to the respective inventory road type

[2] – The name in the RTA network database reflects not only the functional classification but also the administrative classification

3.6 Base Exhaust Emission Factors

Base emission factors are emission factors for a certain type of vehicle manufactured in a particular year operating under defined, or base, conditions. Generally, several model years are grouped into age classes representing vehicles with similar emissions performance; typically by the particular ADR certification level.

A major revision to the structure of the 2008 inventory is the separate estimation of the extra exhaust emissions formed by vehicle operation at less than fully warm operating conditions. The total emissions are the sum of the hot running and cold start extra emissions (Equation 3-4):

$$E_{total} = E_{Hot} + E_{Cold} \qquad \text{Equation 3-4}$$

The cold start extra emissions are modelled for petrol passenger vehicles, light duty diesels and petrol light commercial vehicles only.

The previous inventory base emission factors were estimated from emission measurements of vehicles from a cold start, and hence incorporated an integral allowance for cold running. The base emission factors in this inventory represent hot running only, and hence cannot be directly compared to the previous inventory. The base emission factors ($EF_{Base,Hot}$) are derived to represent driving on local/residential roads under the applicable CUEDC residential drive cycle or equivalent, at an ambient temperature of 23.0 °C, and are calculated according to Equation 3-5.

$$EF_{Base,Hot} = Max\{(EF_{0km} + DR \times km) \times (1 - HE\%) + EF_{HE} \times HE\%,\ EF_C\} \qquad \text{Equation 3-5}$$

Where:

$EF_{Base,Hot}$	=	Hot running emission factor for CUEDC local/residential roads or equivalent data/cycle	(g/km)
EF_{0km}	=	Emission factor of a new vehicle at "0" km mileage	(g/km)
DR	=	Emission factor Deterioration rate	(g/km/km)
$HE\%$	=	Estimate of % of high emitters in the fleet	(%)
EF_{HE}	=	High emitter emission factor estimate	(g/km)
EF_C	=	Emission factor ceiling; limit to the deterioration of the emission factor	(g/km)

Base emission factors were derived for the compounds listed in Table 3-12.

Table 3-12: Base emission compounds

Base Emission Compounds	
Hydrocarbons (HC) ≡ Volatile organic compounds (VOC)	Carbon Monoxide (CO)
Oxides of Nitrogen (NO_x)	Exhaust PM_{10}
Non-exhaust PM_{10}	Sulfur dioxide (SO_2)
Carbon dioxide (CO_2)	Ammonia (NH_3)
Nitrous oxide (N_2O)	

Deterioration rates are not applied to non-exhaust PM, SO_2, CO_2 or NH_3 on any vehicle type, and are not applied to any pollutants for diesel vehicles. SO_2 emission factors are calculated from the fuel consumption and the sulfur content of the fuel, with allowance for sulfate production of 3.4% for petrol vehicles and 3.5% for diesel vehicles.

The base emission factors were derived from available Australian and overseas data as summarised in Table 3-13. Detail of the emission factors derived is given in Section 4 of this report.

For the petrol vehicles of age groups represented in the NISE2 test fleet, the hot running residential segment of the Australian Combined Urban Emissions Drive Cycle (CUEDC) was used to directly derive the base emission factors. Similarly for Australian diesel vehicle data, the respective diesel CUEDC residential segment was used. The base emission factors are at the average speed of the source data drive cycle. For earlier data such as the NISE1, where only cold start ADR37/xx cycle data was measured, conversion factors were derived to estimate the representative base emission factor.

Table 3-13: Key data sources for estimation of emission factors

Vehicle Type	Data sources
Petrol passenger vehicles and LCV	NISE2 (DEWHA, 2009) for vehicles ~1992 on, supplemented by; NISE1 (FORS, 1996) for vehicles from 1980-1992, and NSW and Victorian EPA test programs
Diesel passenger vehicles and LCV	Diesel NEPM project 2.2 (NEPC, 2000) South Australia Diesel NEPM Test & Repair program, (Zito, 2008) COPERT4, (Ntziachristos & Samaras, 2009) ARTEMIS, (INRETS, 2007)
Heavy duty petrol commercial vehicles	MOBILE 6.2, (USEPA, 1998, 1999, 2003) AP42 (US EPA, 1995)
Heavy duty diesel vehicles	Diesel NEPM project 2.2 (NEPC, 2000) South Australia Diesel NEPM Test & Repair program, (Zito, 2008) COPERT4, (Ntziachristos & Samaras, 2009) ARTEMIS, (Rexeis et. al., 2005) Sydney Buses measurements (DTA, 2008)
Motorcycles	ARTEMIS (Elst et. al., 2006) COPERT4 (Ntziachristos & Samaras, 2009)

3.7 Composite Emission Factors

Composite emission factors are a weighted average emission factor for the entire fleet of particular vehicle type. The composite factors are calculated by Equation 3-6 to account for the age profile and annual VKT by vehicle age profile.

$$EF_{Composite,i,k} = \frac{\sum_{Yr} \left(EF_{Base,i,k,Yr} \times Fleet\%_{k,Yr} \times VKT_{k,Yr} \right)}{\sum_{Yr} \left(Fleet\%_{k,Yr} \times VKT_{k,Yr} \right)} \qquad \text{Equation 3-6}$$

Where:

$EF_{Base,i,k,Yr}$	=	Hot running base emission factor for pollutant *i*, for vehicle type *k* of model year *Yr*	(g/km)
$Fleet\%_{k,Yr}$	=	% of total fleet of vehicle type *k* of model year *Yr*	(%)
$VKT_{k,Yr}$	=	The annual VKT travelled by vehicle of type *k* and model year *Yr*	(km)

3.8 Speed Correction Factors

The average speed of traffic as an indicator of traffic conditions has a strong influence on emissions, particularly at low speeds in congested stop-start conditions. Smooth flowing traffic at highway speeds typically produces much lower emissions per VKT than urban congested conditions. Many international inventory models, such as the European COPERT4 and ARTEMIS are based on an average speed model, whereby the emissions are a function of average speed on any particular road segment, and thereby account for congestion and driving conditions.

Speed correction curves are derived as described in Section 3.8.1 below. Speed corrections are applied in the NSW on-road mobile inventory model in two stages. Firstly the curves are used to derive splitting factors that determine base emission factors for the five inventory road types at their respective 24 hour VKT weighted average speed. Secondly, the speed correction curves are applied to this base emission factor for each road type in the running of the inventory integration model software, to correct for speed variation from the base speeds per road type in each grid cell and across the hours of the day.

3.8.1 Speed Correction Curves

Speed correction curves were derived to adjust the base hot running emission factor to account for the impact on emission rates of average speed on any particular road segment. These speed correction curves were derived by matching curves from the European ARTEMIS model to Australian vehicle certification classes and adjusting these curves to match Australian data where available.

An example of the speed correction curve for CO from petrol passenger vehicles is shown in Figure 3-5. The emission factors are plotted normalised to the CUEDC residential cycle of average speed 27.8 km/h, being the base emission factor. The NISE2 data is shown plotted for the four segments of the CUEDC cycle, congested average speed 20.5 km/h, arterial 25.1 km/h, residential 27.8 km/h and freeway 71.6 km/h. Speed curves from the ARTEMIS average speed model (INRETS, 2007) for vehicle certification from pre-Euro to Euro 4 are also plotted normalised to 27.8 km/h.

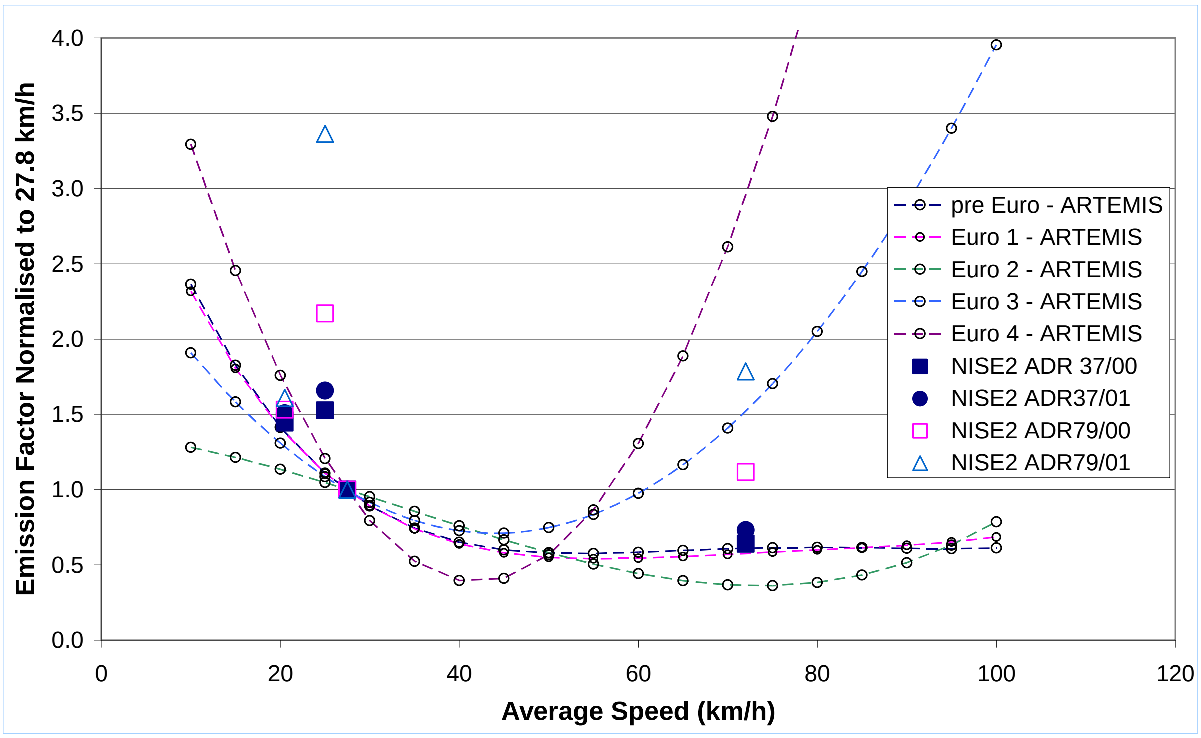

Figure 3-5: PPV CO emission factor speed curves and NISE2 data

Figure 3-5 shows that in general, the NISE2 data approximately follows the speed relationships of similar technology classes in the ARTEMIS model, except for the CUEDC arterial cycle. The NISE2 arterial cycle data (av. speed 25.1 km/h) is seen to produce results much higher than the residential or congested cycles between which it sits in average speed. Examination of the CUEDC cycle and NISE2 data indicates that this is likely to be due to the more dynamic nature of the arterial cycle and the incidence of high acceleration events. The newer technology vehicles are seen to be considerably more sensitive to the more aggressive nature of this drive cycle, although this is relative to very low emissions on the other cycles where sharp emission events due to high acceleration do not occur.

From the data in Figure 3-5 the relevant ARTEMIS curve is adjusted to match the NISE2 data. Hence, the ARTEMIS Euro 1 is adjusted for the ADR37/00 and 37/01, and the Euro 3 is adjusted to form separate curves for ADR79/00 and 79/01. The Euro 4 curve is adopted directly for ADR79/02 which stipulates Euro 4 limits but for which no Australian data is currently available. The adjusted curves are shown in Figure 3-6. Sixth order polynomial regressions are used to generate equations for each speed curve thus derived.

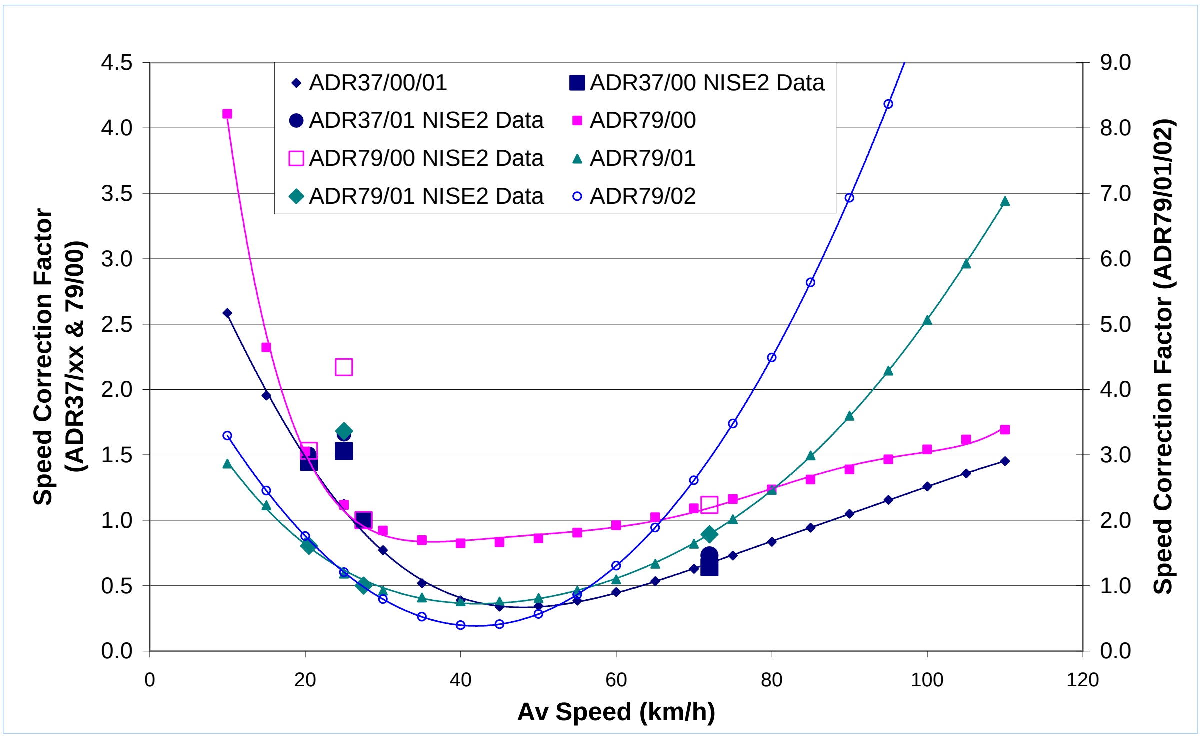

Figure 3-6: Adjusted PPV CO speed curves

3.8.2 *Base Road Type Splitting Factors*

A multiplier, historically called a splitting factor in previous inventories, is applied to the base composite emission factor to derive an emission factor for the five inventory road types at their respective 24 hour VKT weighted average speeds (given in Table 3-10), as shown by Equation 3-7.

$$EF_{Hot,i,j,k} = EF_{Base,Hot,i} \times SF_{i,j,k}$$ Equation 3-7

Where:

$EF_{Base,\ Hot,\ i}$	=	Hot running composite emission factor for local/residential roads at source data average speed, for pollutant *i*	(g/km)
$SF_{i,j,k}$	=	Splitting factor for pollutant *i* on road type *j* for vehicle type *k*	(factor)

The available emission data is speed adjusted to match the base 24 hour VKT weighted average speed for each road type. The derivation of the splitting factor for each road type accounts for deviations from the general speed curve of any particular road type, for example the passenger vehicle CUEDC arterial cycle as discussed above. The splitting factor derivation is shown in Table 3-14. The splitting factor is derived individually for each emissions age class, and combined to produce a fleet composite splitting factor, and hence fleet composite emission factors for the five road types.

The assumptions of the relevant CUEDC cycle data to assign to each road type are based on consideration of typical traffic conditions and road characteristics such as intersection densities and delay, numbers of lanes and typical speed limits (RTA, 2010).

Table 3-14: Derivation of splitting factors for inventory road types

Road Type	Splitting Factor Derivation	Notes:
Local/Residential	$SF_i = \frac{SCF_{i,\,Local\ Base\ Speed\,(km/h)}}{SCF_{i,\,CUEDC\ Residential\ Speed\,(km/h)}}$	*i = pollutant* *SCF_i = Speed Correction Factor for pollutant i, at speed indicated*
Arterial	$SF_i = \left(\frac{EF_{i,CUEDC\ Arterial}}{EF_{i,CUEDC\ Residential}}\right) \times \left(\frac{SCF_{i,\,Arterial\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Arterial\ Speed\,(km/h)}}\right) \times \%VKT_{RTA\ Arterial\ Type}$ $+ \left(\frac{SCF_{i,\,Arterial\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Residential\ Speed\,(km/h)}}\right) \times \%VKT_{RTA\ Sub-arterial\ Type}$	Vehicle behaviour on arterial road types is assumed to be represented by a mix of residential and arterial CUEDC emissions data. *$\% VKT_{RTA,\ Arterial\ Type}$ = The % of the VKT assigned to the inventory arterial type from RTA roads of type arterial, nos. 4-7, 25 – assigned CUEDC arterial emission factors* *$\% VKT_{RTA,\ Sub\text{-}Arterial\ Type}$ = The % of the VKT assigned to the inventory arterial type from RTA roads of type sub-arterial, nos 2,3,24– assigned CUEDC residential emission factors*
Commercial Arterial	$SF_i = \left(\frac{EF_{i,CUEDC\ Arterial}}{EF_{i,CUEDC\ Residential}}\right) \times \left(\frac{SCF_{i,\,Commerical\ Arterial\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Arterial\ Speed\,(km/h)}}\right)$	Emissions behaviour on commercial arterial road types assumed to be represented by CUEDC arterial cycle
Commercial Highway	$SF_i = \left(\frac{EF_{i,CUEDC\ Arterial}}{EF_{i,CUEDC\ Residential}}\right) \times \left(\frac{SCF_{i,\,Commercial\ HW\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Arterial\ Speed\,(km/h)}}\right) \times \%VKT_{RTA\ Arterial\ Type}$ $+ \left(\frac{EF_{i,CUEDC\ Freewayl}}{EF_{i,CUEDC\ Residential}}\right) \times \left(\frac{SCF_{i,\,Commercial\ HW\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Freeway\ Speed\,(km/h)}}\right) \times \%VKT_{RTA\ Freeway\ Type}$	Vehicle behaviour on commercial HW road types is assumed to be represented by a mix of arterial and FW CUEDC emissions data. *$\% VKT_{RTA,\ Arterial\ Type}$ = The % of the VKT assigned to the inventory commercial HW type from RTA arterial type roads (=32%) - assigned CUEDC arterial emission factors* *$\% VKT_{RTA,\ Freeway\ Type}$ = The % of the VKT assigned to the inventory commercial HW type from RTA MW/FW class roads (=68%) - assigned CUEDC freeway emission factors* *VKT splits calculated by solving* $Base\ Speed_{CommercialHW} = \%VKT_{Arterial} \times Speed_{CUEDC\ Arterial}$ $+ (1 - \%VKT_{Arterial}) \times Speed_{CUEDC\ Freeway}$
Freeway/Motorway	$SF_i = \left(\frac{EF_{i,CUEDC\ Freeway}}{EF_{i,CUEDC\ Residential}}\right) \times \left(\frac{SCF_{i,\,Freeway\ Base\ Speed\,(km/h)}}{SCF_{i,CUEDC\ Freewayl\ Speed\,(km/h)}}\right)$	Emissions behaviour on Freeway road types assumed to be represented by CUEDC arterial cycle

3.9 Cold Start Emissions Estimation

Vehicles produce considerably higher emissions when the vehicle has not reached fully hot operating conditions due to higher engine out emission rates from fuel-air ratio enrichment and higher friction, and lower catalyst efficiency when not up to optimum temperature. Although total emissions are decreasing greatly with new technology vehicles, the difference between emission rates when the vehicle is cold and when the vehicle is hot is increasing. This is demonstrated in Figure 3-7 which shows the NISE2 data for VOC emissions for the 3.8 km CUEDC residential cycle from both cold start and hot start. The hot emissions as a percentage of the cold are seen to decrease from 22% for the ADR37/00 vehicles to 6% for the ADR79/01 vehicles. Hence, the proportion of emissions generated while a vehicle is operating less than fully hot is increasing rapidly with new technology vehicles. In order to accurately estimate both the total emissions, and the spatial and temporal allocation of these emissions, a cold start model has been implemented in this inventory update.

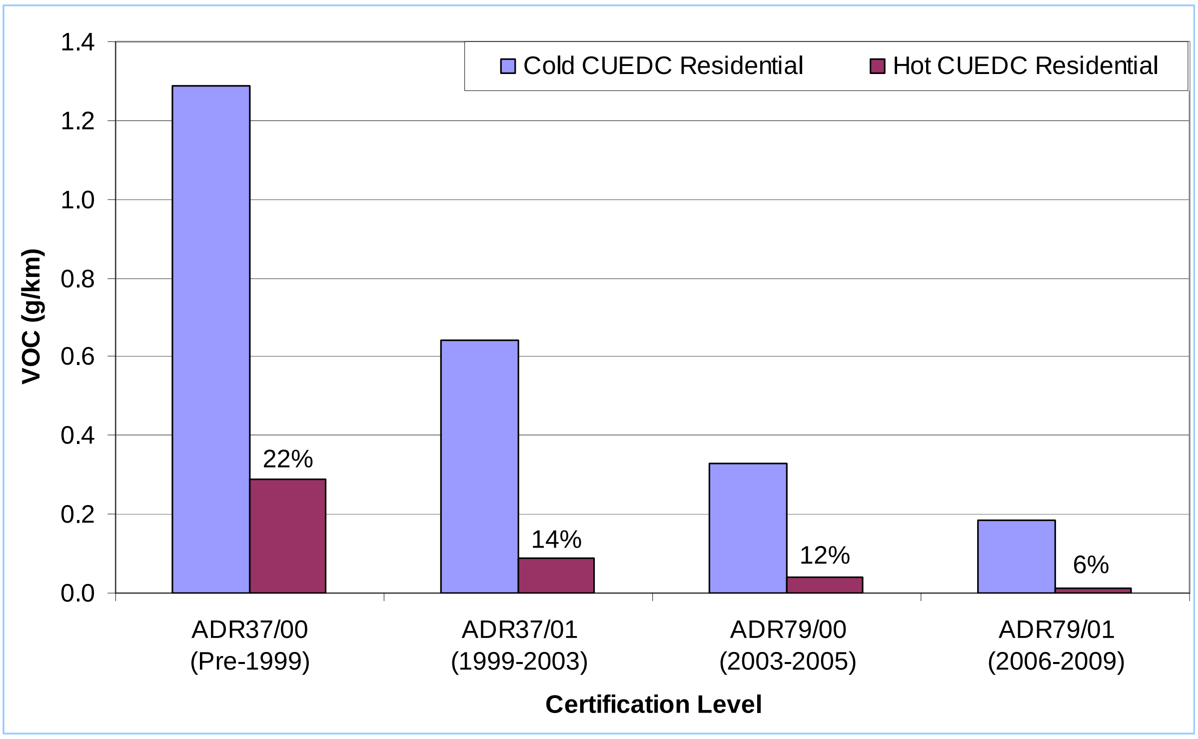

Figure 3-7: NISE 2 data for hot and cold emissions for CUEDC residential cycle

The emissions generated when the vehicle is less than fully hot are calculated as Cold Start Extra Emissions (CSEE); the extra emissions produced above those produced when the vehicle is operated under the same driving conditions fully hot, and are a function of:

- Vehicle technology (ADR level as proxy);
- Temperature of the engine and catalyst at start of trip, in turn function of parking time and ambient temperature;
- Distance from start of trip (degree of "warm-up");
- Ambient temperature; and
- Vehicle operating conditions (average speed).

The CSEE is calculated based around a ratio of cold running to hot running emission factors, termed the cold start emission factor ratio. The CSEE formula is given in Equation 3-8.

$$CSEE_{i,j,k} = \sum_{dist}\sum_{Hr}\left[VKT_{dist,j,k} \times EF_{Hot,i,j,k} \times \left[\left(\frac{\left|EF_{Cold,dist,i,j,k}\right|_{12hrs,23°C}}{EF_{Hot,i,j,k}}\right) - 1\right] \times CSPF_{i,k,Hr} \times CSTC_{i,k,Hr}\right] \quad \text{Equation 3-8}$$

Where:

$CSEE_{i,j,k}$	=	Cold Start Extra Emissions, for pollutant i, road j, vehicle type k	(g)
$VKT_{dist,k}$	=	VKT for vehicle type k driven on road j within distance categories from the start of a trip of 0-1.5 km, 1.5-2.5 km, 2.5-4.0 km, 4.0-5.5 km, 5.5-7.5 km	(km)
$EF_{Hot,i,j,k}$	=	Hot running base Emission Factor for pollutant i, on road type j, for vehicle type k (**not speed adjusted**)	(g/km)
$EF_{Cold,dist,i,j,k}$	=	Emission Factor over distance category dist from cold start after 12 hours parking at 23°C	(g/km)
$\left(\frac{\left\|EF_{Cold,dist,i,j,k}\right\|_{12hrs,23°C}}{EF_{Hot,i,j,k}}\right)$	=	Base cold start emission factor ratio (CSBase)	(ratio
$CSPF_{i,k,Hr}$	=	Cold start parking factor for hour of day Hr. Adjusts cold start for weighted average length of time vehicles parked prior to trip start	(factor)
$CSTC_{i,k,Hr}$	=	Cold start temperature correction factor for ambient temperature for the hour of day and season.	(factor)

Cold start emissions are calculated for petrol and diesel passenger vehicles and light commercial vehicles only. Cold start emissions are calculated for all four vehicle classes for pollutant species HC, CO, NO_x, CO_2, and additionally for petrol LDV only, NH_3 and N_2O. Fuel consumption and SO_2 cold start extra emissions are calculated indirectly from the other species. Cold start emissions are not calculated for the freeway/motorway road type as it is assumed that all vehicles are fully hot on these roads. The VKT data for the trip start distance categories, by inventory region spatial grid cell, by hour of the day are provided from the BTS modelling.

3.9.1 Base Cold Start Emission Factor Ratio

The base cold start emission factor ratios (CSBase) $\left(\frac{\left|EF_{Cold,dist,i,j,k}\right|_{12hrs,23°C}}{EF_{Hot,i,j,k}}\right)$ for the petrol vehicles are calculated from NISE2 modal (second by second) CUEDC emissions data over each of the cold start distance categories. The CSBase is based on a start from fully cold (≥ 12 hours parked) and at an ambient temperature of 23°C. Separate CSBase are generated for the petrol passenger vehicles and for the petrol LCV.

As the average speeds in the CUEDC for these distance categories do not match the inventory 24 hour VKT weighted average speeds for the four road types for which cold start is calculated, a speed correction is applied derived from the COPERT4 cold start model, Equation 3-9. A CSBase is thus generated for each of the four road types considered for cold start calculations.

$$\left(\frac{\left|EF_{Cold,dist,i,j,k}\right|_{12hrs,23°C}}{EF_{Hot,i,j,k}}\right)=\left(\frac{\left|EF_{Cold,dist,i,k}\right|_{12hrs,23°C}}{EF_{Hot,i,k}}\right)_{NISE2,CUEDC\ Dist\ Av\ Speed}\times\frac{\left(\frac{EF_{Cold}}{EF_{Hot}}\right)_{COPERT,Av\ Speed\ road\ type\ j,23^oC}}{\left(\frac{EF_{Cold}}{EF_{Hot}}\right)_{COPERT,Av\ Speed\ CUEDC\ dist,23^oC}}$$ Equation 3-9

Where:

$\left(\frac{EF_{Cold}}{EF_{Hot}}\right)_{COPERT,Av\,Speed,23^oC}$	=	Cold start emission factor ratio predicted by COPERT, for pollutant *i*, vehicle type *k*, at the relevant average speed and 23°C	(ratio)

The COPERT4 model predicts higher cold start emissions for petrol vehicle operation at higher average speeds, in agreement with research by Weilenmann et al (2005) and others. This is explained by higher engine loads at higher average speeds, and hence higher mass flows of uncatalysed exhaust during the cold start phase. It should be noted the ARTEMIS model, whilst of a quite different form to the COPERT4 model, generates very similar cold start speed corrections.

For the diesel vehicles, the ARTEMIS cold start model 1 is applied to derive the base cold start emission factor ratio (INRETS, 2007). The ARTEMIS model predicts cold start excess emissions as a function of average vehicle speed and ambient temperature. In general the CSBase factors are much lower for diesel vehicles than for petrol vehicles.

3.9.2 Cold Start Parking Factors

As the base cold start emission factor ratios are generated for a vehicle start from completely cold, i.e. parked for minimum of twelve hours at 23°C, an adjustment is necessary to account for those vehicles which start a trip partially warm after a lesser parking period.

A distribution of the parking duration prior to the start of each trip for 13 time periods during the day was generated by the Bureau of Transport Statistics from five years of pooled data from the Household Travel Survey. The parking time distribution for passenger vehicles is shown in Figure 3-8. Each group of coloured bars is the distribution for the respective time period listed on the x-axis. Each bar in the group is the % of trips started after a parking time given in the legend. A separate distribution was determined for the average weekday and average weekend day.

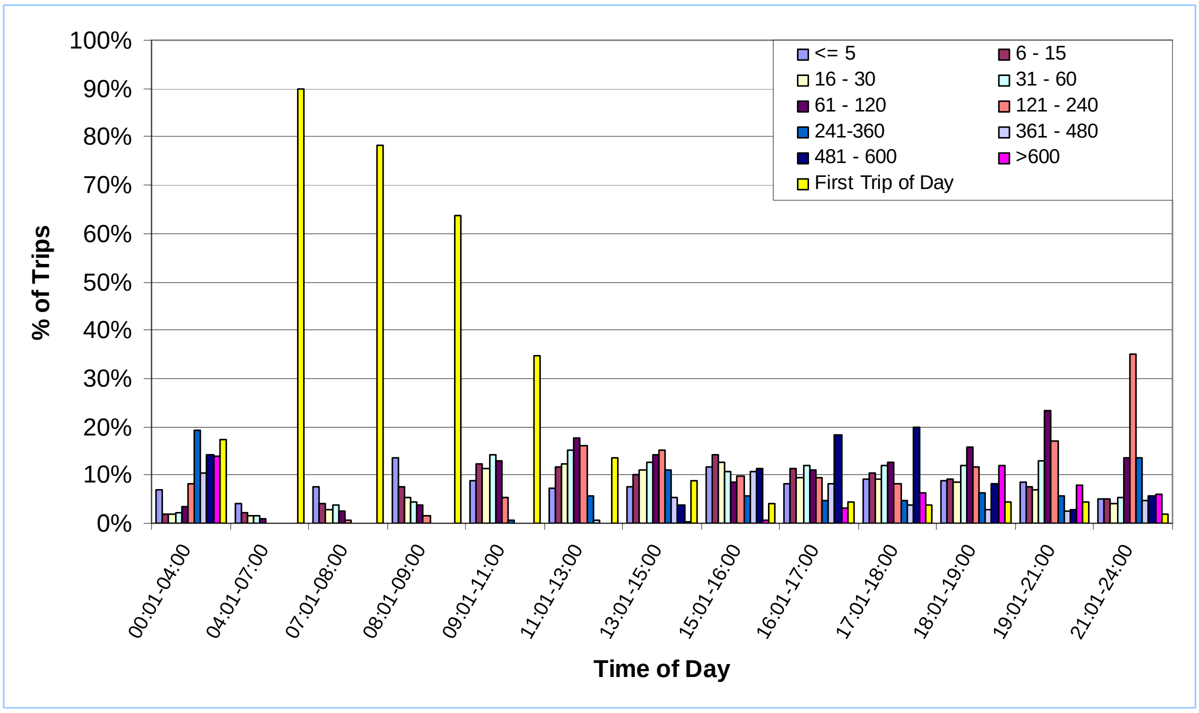

Figure 3-8: Parking time distribution for passenger vehicles on an average weekday

Up until 11 am, it is seen that "First trip of the day" dominates, with small contributions from short parking durations. These short stops intuitively would relate to dropping children to school, or stopping at a shop on the way to work. Later in the day, a more even parking time distribution is seen, and from 4pm, significant contributions from parking durations of greater than 480 minutes (8 hours) representing the homewards work commute.

The parking time distribution is combined with the ARTEMIS cold start parking factor equation given in Annex 36 of INRETS (2007) to arrive at a weighted cold start parking factor (CSPF) (Equation 3-10):

$$CSPF_{i,k,Hr} = \sum_{ParkingPeriod} \left(\%Trips_{ParkingPeriod} \times ParkingTimeFactor_{ARTEMIS,i,k,ParkingPeriod} \right) \qquad \text{Equation 3-10}$$

Where:

$\%Trips_{Parking\ Period}$	=	% of trips started in hour *Hr*, after parking for a period within *ParkingPeriod*	(%)
$ParkingTimeFactor_{ARTEMIS,i,k,ParkingPeriod}$	=	A multiplier reducing the cold start excess emissions, for pollutant *i* for vehicle type *k* as a function of how long the vehicle has been parked	(multiplier)

3.9.3 Cold Start Temperature Correction

The ambient temperature has a strong impact on cold start emissions. As the base cold start emission factor ratios are derived from data measured at the certification temperature of 23°C, a cold start temperature correction (CSTC) is applied to adjust the cold start extra emissions for the hourly regional average temperature for each of the three seasons defined in the on-road mobile model (see Section 3.10.1). Cold start data above the certification standard temperature of 23°C is very limited as the majority of the research originates from Europe where the concern is more at lower temperatures. The linear regressions against temperature of COPERT and ARTEMIS are not applicable above 23°C, as negative cold start emissions result.

The corrections are calculated from exponential regression to the data of Weilenmann et al (2001, 2004, 2005, 2008, 2009) from tests over the temperature range -20° to +23°C. An example is shown in Figure 3-9 for the cold start emissions of HC as a function of ambient temperature normalised to 23°. An exponential regression results in a good fit and is intuitively and theoretically appropriate as the decrease in cold start emissions would be expected to asymptote at higher temperatures with some cold start extra emissions still generated from cold start at higher ambient temperatures.

CSTC are generated for each certification class (as represented by year of manufacture) over the range 5-35°C. An hourly fleet composite CSTC is generated weighted by the relative cold start excess emissions generated by each vehicle age class based on the vehicle type fleet profile (Equation 3-11). This composite CSTC is calculated for each hourly temperature profile of the three seasons defined in Section 3.10.1.

$$CSTC_{Weighted,i,k,Hr} = \frac{\sum_{Yr}\left[CSTC_{i,k,Yr,Hr} \times \left(CSBase_{i,Local,k,Yr} - 1\right) \times \left(EF_{hot,t,Local,k,Yr} \times Fleet\%_{k,Yr} \times VKT_{k,Yr}\right)\right]}{\sum_{Yr}\left[\left(CSBase_{i,Local,k,Yr} - 1\right) \times \left(EF_{hot,t,Local,k,Yr} \times Fleet\%_{k,Yr} \times VKT_{k,Yr}\right)\right]} \qquad \text{Equation 3-11}$$

Where:

$CSTC_{i,k,Yr,Hr}$	=	The CSTC for pollutant *i*, for vehicle type *k* of model *Yr*, at ambient temperature at *Hr* of day	(factor)
$CSBase_{i,Local,k,Yr}$	=	Cold start base emission factor ratio for pollutant *i*, on Local road type, for vehicle type *k* of model *Yr*	(ratio)
$EF_{hot,I,Local,k,Yr}$	=	Base hot running emission factor for pollutant *i*, on Local road type, for vehicle type *k*, of model *Yr*	(g/km)
$Fleet\%_{k,Yr}$	=	% of total fleet of vehicle type *k* of model year *Yr*	(%)
$VKT_{k,Yr}$	=	The annual VKT travelled by vehicle of type *k* and model year *Yr*	(km/year)

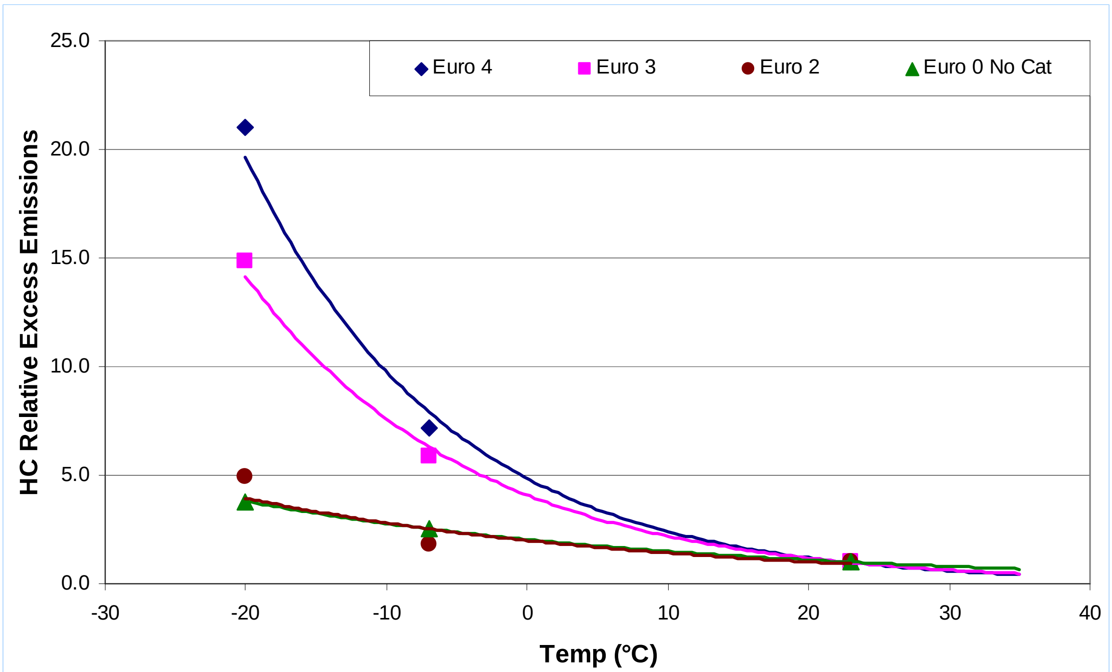

Figure 3-9: Cold excess emissions of HC from petrol passenger cars vs temperature

3.10 Other Exhaust Emission Correction Factors

3.10.1 Ambient Temperature Corrections

In addition to the ambient temperature corrections applied to cold start extra emissions as described above, ambient correction is also applied to the hot running emission factors and to the evaporative emission factors. Three seasons are defined each with hourly temperature profiles, being an average of monthly diurnal temperatures across the GMR from TAPM data for 2008. The seasons are:

- Summer – four months comprising November 15th to March 14th, aligning to the NSW summer low petrol volatility period;
- Autumn & Spring – five months, Autumn March 15th to May 30th, Spring September 1st to November 14th; and
- Winter – three months, June 1st to August 31st.

The GMR wide average hourly temperatures for each of the seasons defined above are given in Table 3-15. The daily average temperatures are calculated weighted by the hourly VKT.

Ambient temperature has only a modest effect on the hot running emissions of CO, CO_2 and NO_x of the modern fleet, with a more significant effect on HC for Euro 3 & Euro 4 vehicles predicted by the COPERT4 and ARTEMIS models. However, in light of the more dominant ambient temperature impact on cold start emissions, a seasonal correction only is applied based on the seasonal average daily temperature, weighted by daily VKT profiles. The corrections are calculated from the ARTEMIS model (INRETS, 2007).

Cold start temperature corrections have been discussed above in Section 3.9.3.

Table 3-15: Hourly GMR average temperatures by season

Hour	Summer	Autumn and Spring	Winter
0	16.9	12.5	8.6
1	16.5	12.2	8.3
2	16.3	11.9	8.1
3	16.0	11.7	7.9
4	15.8	11.6	7.7
5	16.8	11.6	7.6
6	20.6	13.1	7.5
7	25.1	16.4	9.3
8	29.0	20.0	12.8
9	31.6	22.8	16.0
10	33.2	24.4	18.3
11	34.0	25.2	19.5
12	34.1	25.6	19.9
13	33.7	25.4	19.6
14	32.7	24.7	18.8
15	31.2	23.4	17.5
16	29.1	21.5	15.2

Hour	Summer	Autumn and Spring	Winter
17	26.5	18.8	12.4
18	23.2	16.2	10.9
19	20.4	14.7	10.1
20	19.0	13.9	9.6
21	18.2	13.4	9.2
22	17.7	13.0	8.9
23	17.3	12.7	8.7
Daily VKT weighted average	28.1	20.3	14.3

3.10.2 *Temporal Emission Profiles*

Temporal profiles are generated for diurnal, weekly and monthly emissions.

The diurnal profile incorporates the combined effect of the hourly VKT patterns and hourly average speeds (i.e. congestion impact), and the hourly ambient temperature and parking time distribution effects on cold start emissions. Two profiles are produced, one for an average weekday, and one for an average weekend day. Classified traffic count data (BTS, 2010) are used to produce a week end day VKT profile from the base average week day VKT data (see Section 3.4) for each vehicle type. A separate profile is produced for each of the base emission species listed in Table 3-12, for each of the inventory source types.

The weekly emission profile produces a total daily emission for a week day or a week end day, taking into account aggregated effect of the respective daily VKT profile and hourly temperature profile.

The monthly profile combines the impact of seasonal daily ambient temperature profiles on the cold start emissions, the average VKT weighted daily seasonal temperature on hot running emissions, and monthly VKT variations determined from analysis of the RTA traffic count data for 2008 from all 365 permanent count sites (RTA, 2010).

3.10.3 *Fuel Properties Corrections*

The impact of fuel properties on the emissions of motor vehicle has been extensively studied (ACEA & EUROPIA, 1996, ACEA, 2000, Boulter & Latham, 2009, AQIRP, 1997, CONCAWE 2003, CONCAWE, 2004, CONCAWE, 2005, CONCAWE, 2005a, CRC2005, CRC 2006a). The on-road mobile inventory model adopts the fuel effect equations from the European Programme on Emissions, Fuels and Engine Technologies (EPEFE) (ACEA & EUROPIA, 1996), as also used by the latest COPERT4 ,the UK National Air Emissions Inventory (NAEI), (Boulter & Latham, 2009), and partially adopted by ARTEMIS for heavy duty diesel vehicles.

The EPEFE equations predict changes in emissions of CO, HC, and NO_x for petrol vehicles, and additionally PM for diesel vehicles. The direction of the impact for a positive change in each of the properties is shown in Table 3-16. Negligible change is denoted -, a small impact with a single arrow, and a strong impact with a double arrow.

The EPEFE equations were used to adjust the petrol vehicle emission factors derived from the NISE2 project for the small difference in fuel properties between the NISE2 test fuel (summer grade) to the average Sydney petrol fuel properties for 2008. In this way, the inventory model base fuel properties are defined to be those of the NISE2 study. The petrol fuel properties are given in Table 3-17. Seasonal changes in fuel properties were also adjusted for using the EPEFE equations.

Table 3-16: Fuel properties affecting emissions

Emission	Petrol Vehicles					
	E100	E150	Olefin (%)	Aromatic (%)	Sulfur	Oxygen (%)
HC	↓	↓	↓	↑	↑	↓↓
NO_x	↑	↑	↑	↓	↑	-
CO	↑	↓	-	↑	↑	↓↓
Emission	**Diesel Vehicles – LD/HD**					
	Density	**PAH (%)**	**Cetane Number**	**T95**	**Sulfur**	
HC	↑↑/↓↓	↓/↑	↓↓/↓	↓/↓↓	-/-	
NO_x	↓/↑	↑/↓	-/-	↓/↑	-/-	
CO	↑↑/↓	↓/-	↓↓/↓↓	↑/↓	-/-	
PM	↑↑/↑	↑/↑	↑/-	↑/-	↑/↑	

Where:

- E100, E150 are volatility measures; the % of petrol evaporated at 100°C and 150°C; and
- T95 is the temperature at which 95% of the diesel has been distilled.

Table 3-17: Petrol properties – model base and Sydney 2008

Fuel Property	Base Value			
	Inventory Base (NISE2)	Sydney 2008		
		Summer	Autumn & Spring	Winter
E100	51.4%	52.7%	55.9%	55.9%
E150	84.0%	89.1%	89.2%	89.2%
Olefin (%v/v)	16.1%	15.9%	16.3%	16.3%
Aromatic (%v/v)	28.1%	30.2%	27.9%	27.9%
Sulfur (ppm)	103	45	53	52
Oxygen (%m/m)	0.0%	0.0%	0.0%	0.0%
RVP (kPa)	63.1	60	71	74

The model base diesel fuel properties are given in Table 3-18. Seasonal variation is negligible impact and hence is not modelled. The diesel emission factors were drawn from a variety of sources, and full diesel fuel properties were not available for some of these. An assumption of typical commercial fuel of the source jurisdiction was made as to the base fuel properties, and adjustments made for PM in response to sulfur level only.

Table 3-18: Diesel properties – model base and Sydney 2008

Property	Base Value	Sydney 2008
Density (kg/m^3)	835	840
Sulfur (ppm)	50	25
T95 (°C)	340	340
Cetane Number	50	54
PAH (%m/m)	5	4.8

3.10.3.1 *Effect of E10 on Exhaust Emissions*

The effect of E10 on exhaust emissions is predicted independently of the EPEFE equations using Australian data from the NSW Petrohol Study (Brown et. al., 1998) and the commonwealth government's Ethanol Health Impacts Study (CSIRO & Orbital, 2008). Heavy duty commercial petrol and motorcycles are assumed not to use E10 fuel as the majority of these vehicles are not E10 compatible (FCAI).

The results from the Petrohol study are given in Table 3-19. The vehicles in this study were tested to the ADRR37 drive cycle and are hence not directly applicable to the base emission factor, or directly comparable to the CSIRO & Orbital study. A large decrease in CO emissions was found, and a smaller decrease in THC, while a small increase in CO_2 was observed. No significant change was found in NO_x emissions.

The results from CSIRO & Orbital (2008) are summarised in Table 3-20. The vehicles were tested to the CUEDC drive cycle and are hence compatible with the base emission factors derived from the NISE2 study. The data from all vehicles was averaged together as no significant difference was found between the age groups tested. The average ratios of the emissions when operating on E10 to those when operating on ethanol free fuel are given, along with the P-value from a paired T-test (shown in green when a significant difference is found, red when not significant). No significant difference was found under any operating condition for NO_x ($P > 0.05$) or for any pollutant under congested conditions.

VKT weighting factors by road type were applied to obtain an overall E10 adjustment factor that is applied to the petrol base emission factors. The adopted E10 factors are given in Table 3-21.

Table 3-19: Summary of petrohol study data

Pollutant	Change relative to E0 (± 95% CI)		
	Pre-1986 Vehicle	1986-1995 Vehicles	All Vehicles
THC	-11% (±5%)	-13% (±5%)	-12% (±4%)
NO_x	-1% (±6%)	+5% (±17%)	+3% (±4%)
CO	-37% (±10%)	-27% (±11%)	-32% (±9%)
CO_2	+2% (±1%)	+1% (±1%)	+1% (±1%)

Table 3-20: Summary of ethanol health impact study – all vehicles (1999-2006)

Road Type	THC		CO		NOx		CO2		FC		PM	
	Av Ratio E10:E0	P	Av Ratio E10:E0	P	Av Ratio E10:E0	P	Av Ratio E10:E0	P	Av Ratio E10:E0	P	Av Ratio E10:E0	P
Residential (cold)	0.9191	0.000	0.9277	0.017	1.0122	0.607	0.9863	0.001	1.0194	0.000	0.7021	0.002
Arterial	0.8559	0.048	0.8120	0.059	1.1320	0.091	0.9911	0.041	1.0252	0.000	0.6015	0.000
Freeway/ Motorway	0.8871	0.008	0.7988	0.005	0.9349	0.412	0.9864	0.000	1.0210	0.000	0.6702	0.000
Congested	0.9365	0.081	0.9211	0.313	1.0942	0.220	0.9916	0.078	1.0272	0.000	0.8574	0.060
All	0.9081	0.001	0.8868	0.003	0.9912	0.869	0.9878	0.001	1.0221	0.000	0.6885	0.000

Table 3-21: E10 exhaust emission adjustment factors

Model Year	THC	CO	NO_x	CO_2	PM
< 1996	0.932	0.800	1.00	0.988	0.671
1996 on	0.932	0.888	1.00	0.988	0.671

3.11 Evaporative Emissions Estimation

The evaporative emission model developed adopts the general structure and equations of the European ARTEMIS model (Hausberger et. al., 2005), which in turn adopts largely from the US MOBILE 6 model (US EPA, 2001, 2001a-e). Evaporative emissions are predicted for each of the four recognised evaporative loss mechanisms:

1. Diurnal losses. The evaporative emissions generated by fuel tank breathing losses, driven by ambient temperature change and subsequent vapour generation and pressure changes, that are not trapped by the carbon canister (canister "breakthrough"), or escape via vapour leaks. Note that the conventional regulatory diurnal test procedures measure combined breathing losses and resting or permeation losses. Diurnal emissions occur independently of vehicle activity.
2. Hot soak. These are the emissions that occur immediately after the vehicle is switched off at the end of a trip, and arise due to the dissipation of accumulated drive train heat resulting in heating and evaporation of fuel in the fuel system.
3. Running losses. These occur during vehicle operation. During normal operation a vehicle will purge the carbon canister and burn the trapped fuel in the engine during travel. In a functioning system, running losses appear to be dominated by permeation losses (CRC, 2008).
4. Resting losses. These are the losses by permeation of fuel molecules through the materials of the fuel system. These occur independently of vehicle operation and on any particular vehicle appear to be primarily a function of temperature (but not temperature change driven), and are not a function of fuel volatility. These losses are concurrent to, and generally measured as a combined emission with the other mechanisms.

The ARTEMIS model defines three emission/age classes, and assigned appropriate MOBILE 6 equations to each class as shown in Table 3-22. The MOBILE 6 model has many more emission/age classes, however the ARTEMIS model did not consider enough European data was available to justify more categories (Hausberger, 2005).

Table 3-22: ARTEMIS and MOBILE 6 model emission classes

ARTEMIS Emission Class	MOBILE 6 Emission Class
Pre-Euro & Euro 1-4 Failure	FI 86-95 - fail pressure test
Euro 1+2	FI 86-95 - pass both tests
Euro 3+4	Enhanced vehicles – adjusted to ARTEMIS data

In the NSW on-road mobile inventory model, the four inventory petrol vehicle types are divided into emission classes based on the relevant emission certification regulations, or ADR, and observed equivalent performance in the Australian data sets. A corresponding ARTEMIS emission class is assigned to each of the inventory vehicle emission classes defined, with the exception of resting losses for ADR27 vehicles where additional MOBILE 6 emission classes were adopted.

Within each inventory emission class, vehicles are divided into those with functioning ("passing") or "failed" (or uncontrolled) categories, after the ARTEMIS/MOBILE6 approach. Those vehicles classed as failing are modelled by the ARTEMIS pre-Euro/Failure equations, and those passing by the matching emissions class, either Euro 1+2 or Euro 3+4. The available Australian data is used to set the passing and failing threshold such that the ARTEMIS equations provide as close an estimate to the data as possible. A multiplier is then calculated to apply to the base ARTEMIS equations to calibrate to the Australian test data. Note that the evaporative emissions testing in Australia has been limited to diurnal and hot soak tests only according to the applicable certification regulations.

For all of the evaporative emissions mechanisms, the emission rates are calculated as a function of the hourly GMR wide average temperature for each of the three seasons defined in Section 3.10.1.

3.11.1 Evaporative Model Details

3.11.1.1 Diurnal Losses

The ARTEMIS and MOBILE 6 diurnal model equations are based on vapour pressure parameters as defined below (Equations 3-12 to 3-14):

$$VP = RVP \times e^{A \times \left(\frac{1}{T_{abs}} - \frac{1}{310.9}\right)}$$ Equation 3-12

Where:

RVP	=	Reid vapour pressure of fuel	(kPa)
T_{abs}	=	Absolute temperature	(K)
A	=	$-3565.271 + 10.23 \times RVP$	

and:

$$VP_{mean} = \frac{VP_{T\max} + VP_{T\min}}{2}$$ mean vapour pressure over the temperature cycle (kPa) Equation 3-13

and:

$$\Delta VP = VP_{T\max} - VP_{T\min}$$ difference in vapour pressure over the temperature cycle (kPa) Equation 3-14

The diurnal breathing losses (exclusive of resting, or permeation, losses) are predicted from the vapour pressure parameters above by Equation 3-15:

$$E_{diurnal} = A + B \times \frac{(VP_{mean} \times \Delta VP)^2}{1000} \text{ (g/day)}$$ Equation 3-15

Where :

Table 3-23: ARTEMIS Diurnal loss equation coefficients

Emission Class	A	B
Pre-Euro & Euro 1-4 Failure	0.478	0.015
Euro 1+2	0.388	0.005
Euro 3+4	0.037	0.00136

Table 3-23 lists the ARTEMIS diurnal loss equation coefficients. The evaporative emission classes defined in the on-road mobile inventory model, the assigned ARTEMIS class equation and multiplier applied to match the Australian data are shown in Table 3-24, Table 3-25, Table 3-26 and Table 3-27 for petrol passenger vehicles, petrol LCV, motorcycles and heavy duty commercial petrol respectively. Motorcycles are modelled as 50% of failing (uncontrolled) car as per ARTEMIS, while HDCP are assumed to be 150% of the same model year PLCV. It is seen that the multipliers required to adjust the base ARTEMIS model to the available Australian data are generally very close to 1, except for the ADR79 where the Australian data indicates a significantly better emissions performance than the ARTEMIS E3+4 model predicts.

Table 3-24: Petrol passenger vehicle evaporative emission classes and diurnal models

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre -1988 (NISE1 data)	Euro 1+2	1.08	Pre-Euro	1.10
ADR37/00 – 1989 - 1993 (NISE1 data)	Euro 1+2	1.00	Pre-Euro	1.08
ADR37/00/01 – 1994 - 2003 (NISE2 data)	Euro 3+4	1.00	Pre-Euro	1.00
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	0.50	Pre-Euro	1.00

Table 3-25: Petrol LCV evaporative emission classes and diurnal models

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre -1988 (No data)	N/A	N/A	Pre-Euro	1.10
ADR37/00 – 1989 - 1998 (NISE2 data)	Euro 1+2	1.00	Pre-Euro	1.08
ADR37/01 – 1999 - 2003 (NISE2 data)	Euro 3+4	1.00	Pre-Euro	1.00
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	0.50	Pre-Euro	1.00

Table 3-26: Motorcycle evaporative emission classes and diurnal models

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
All (no data)	N/A	N/A	Pre-Euro	0.50

Table 3-27: HDCP evaporative emission classes and diurnal models

Inventory Evaporative Emission Class[1]	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre - 1988 (No data)	N/A	N/A	Pre-Euro	1.65
ADR37/00 – 1989 - 1998 (No data)	Euro 1+2	1.50	Pre-Euro	1.62
ADR37/01 – 1999 - 2003 (No data)	Euro 3+4	1.50	Pre-Euro	1.50
ADR79/00/01 – 2004 on (No data)	Euro 3+4	0.75	Pre-Euro	1.50

1 – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.1.2 Diurnal Model Failure Rates

The ARTEMIS model adopts the MOBILE 6 "fail pressure test" equations, as shown in Equation 3-16 and Equation 3-17.

$$Euro\ 1+2\ Failure\ Rate = \frac{0.6045}{1+17.33\times e^{\left[-0.01362\times Age^{2}\right]}} \quad \text{Equation 3-16}$$

$$Euro\ 3+4\ Failure\ Rate = \frac{0.6045}{1+17.33\times e^{\left[-0.01362\times\left(\frac{Age}{2}\right)^{2}\right]}} \quad \text{Equation 3-17}$$

The generic form of the above is defined to have coefficients A, B, C as shown in Equation 3-18.

$$Generic Failure\ Rate = \frac{A}{1+B\times e^{\left[C\times\left(\frac{Age}{D}\right)^{2}\right]}} \quad \text{Equation 3-18}$$

The above ARTEMIS equations were adjusted to fit the fail rate derived in matching the "failed" and "passing" models to the Australian data, at the average age of the vehicles in each class. The coefficients to Equation 3-18 for each inventory vehicle class are shown in Table 3-28, Table 3-29, Table 3-30 and Table 3-31.

Table 3-28: Petrol passenger vehicle diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
ADR27 – pre - 1988 (NISE1 data)	0.80	5	-0.025	1
ADR37/00 – 1989 - 1993 (NISE1 data)	0.70	7	-0.01362	1
ADR37/00/01 – 1994 - 2003 (NISE2 data)	0.605	7	-0.01362	1
ADR79/00/01 – 2004 on (NISE2 data)[1]	0.605	17.33	-0.01362	1.5

1 – Insufficient age range in data to derive a failure rate, so a conservative assumption was made to change the Age denominator from the 2 of ARTEMIS/MOBILE to 1.5

Table 3-29: Petrol LCV diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
ADR27 – pre - 1988 (No data)	N/A. Failure rate set to 1, i.e. all uncontrolled			
ADR37/00 – 1989 - 1998 (NISE2 data)	0.80	3	-0.027	1
ADR37/01 – 1999 - 2003 (NISE2 data)	0.75	4.5	-0.03	1
ADR79/00/01 – 2004 on (NISE2 data)	0.605	17.33	-0.01362	1.5

Table 3-30: Motorcycle diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
All (no data)	N/A. Failure rate set to 1, i.e. all uncontrolled			

Table 3-31: HDCP diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class[1]	A	B	C	D
ADR27 – pre - 1988 (No data)	N/A. Failure rate set to 1, i.e. all uncontrolled			
ADR37/00 – 1989 - 1998 (No data)	0.80	3	-0.027	1
ADR37/01 – 1999 - 2003 (No data)	0.75	4.5	-0.03	1
ADR79/00/01 – 2004 on (No data)	0.605	17.33	-0.01362	1.5

[1] – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.1.3 *Diurnal Evaporative Temporal Profile*

The diurnal emissions are driven by the daily temperature profile. The MOBILE 6 method (US EPA, 2001a) is used to determine the hourly diurnal emissions ignoring consideration of interrupted diurnals. The MOBILE6 approach determines the hourly proportions of the total day's diurnal evaporative emission with regression derived equations as a function of various temperature change parameters. The MOBILE 6 equations for carburettor failing pressure test, fuel injection failing pressure test and fuel injection passing both tests are shown in Equation 3-19, Equation 3-20 and Equation 3-21 respectively.

$$\%E_{Diurnal,Hour} = 0.010549 + 0.0036871 \times (T_{Hour-1} - T_{Hour-2}) \times (T_{Hour-1} - T_{\min}) + 0.0031644 \times (T_{Hour-1} - T_{\min}) + 0.0057186 \times (T_{Hour} - T_{Hour-1})^2 \quad \text{Equation 3-19}$$

$$\%E_{Diurnal,Hour} = 0.006515 + 0.0038656 \times (T_{Hour-1} - T_{Hour-2}) \times (T_{Hour-1} - T_{\min}) + 0.0035334 \times (T_{Hour-1} - T_{\min}) \times 0.004306 \times (T_{Hour} - T_{Hour-1})^2 + 0.0018598 \times (T_{Hour-1} - T_{Hour-2})^2 \quad \text{Equation 3-20}$$

$$\%E_{Diurnal,Hour} = 0.008001 + 0.0035298 \times (T_{Hour-1} - T_{\min}) + 0.0017334 \times (T_{Hour-1} - T_{Hour-2}) \times (T_{Hour-1} - T_{Min}) - 0.0001944 \times VP_{Mean} \times (T_{Hour-1} - T_{Hour-2})^2 + 0.010735 \times (T_{Hour-1} - T_{Hour}) + 0.0001008 \times VP_{Mean} \times (T_{Hour-1} - T_{Min}) \quad \text{Equation 3-21}$$

Where:

T_{Hour}, T_{Hour-1}, T_{Hour-2}	=	Ambient temperature at end of current hour, previous hour and hour prior to that	(°C)
VP_{Mean}	=	Fuel vapour pressure at the entire diurnal cycle mid-point temperature, as defined in Equation 3-13	(kPa)

Equation 3-19 (carburettor failing pressure test) is applied to ADR27 failing vehicles, Equation 3-20 (fuel injection failing pressure test) is applied to all other failing vehicles, and Equation 3-21 is applied to all passing vehicles.

3.11.1.4 Multiple Day and Interrupted Diurnals

Insufficient information is available on individual vehicle usage to enable modelling of multiple day or interrupted diurnal cycles, and hence these are not modelled in the on-road mobile inventory.

3.11.1.5 Resting Losses

The ARTEMIS & MOBILE 6 (US EPA, 2001) resting loss model predicts hourly resting losses as a function of ambient temperature only according to Equation 3-22.

$$E_{\text{Re seting}} = K \times [A + 0.0051 \times T_{ambient}] \qquad \text{Equation 3-22}$$

Where:

$T_{ambinet}$	=	Temperature	(°C)
K	=	Multiplier used in ARTEMIS to adjust base MOBILE 6 (further adjusted as required to estimate for Australian vehicles)	(multiplier)

The inventory evaporative emission classes defined in the on-road mobile inventory model, the base ARTEMIS/MOBILE 6 model, and the coefficients applied to Equation 3-22 are shown in Table 3-32, Table 3-33, Table 3-34 and Table 3-35 for petrol passenger vehicles, petrol LCV, motorcycles and heavy duty commercial petrol respectively. Motorcycles are modelled as 50% of failing (uncontrolled) cars as per ARTEMIS, while HDCP are assumed to be 150% of the same model year PLCV.

Table 3-32: Petrol passenger vehicle evaporative emission classes and resting loss models

Inventory Evaporative Emission Class	Passing			Failing		
	Base Model	Multiplier		Base Model	Multiplier	
		K	A		K	A
ADR27 – pre - 1988 (NISE1 data)	M6 Carb '80-'85 Pass	1.08	0.0304	M6 Carb '80-'85 Fail	1.1	0.0684
ADR37/00 – 1989 - 1993 (NISE1 data)	Euro 1+2	1.0	-0.0507	Pre-Euro	1.08	-0.0193
ADR37/00/01 – 1994 - 2003 (NISE2 data)	Euro 3+4	0.25	-0.0507	Pre-Euro	1.0	-0.0193
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	0.125	-0.0507	Pre-Euro	1.0	-0.0193

Table 3-33: Petrol LCV evaporative emission classes and resting loss models

Inventory Evaporative Emission Class	Passing			Failing		
	Base Model	Multiplier		Base Model	Multiplier	
		K	A		K	A
ADR27 – pre - 1988 (NISE1 data)	N/A	N/A	N/A	M6 Carb '80-'85 Fail	1.1	0.0684
ADR37/00 – 1989 - 1998 (NISE2 data)	Euro 1+2	1.0	-0.0507	Pre-Euro	1.08	-0.0193
ADR37/01 – 1999 - 2003 (NISE2 data)	Euro 3+4	0.25	-0.0507	Pre-Euro	1.0	-0.0193
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	0.125	-0.0507	Pre-Euro	1.0	-0.0193

Table 3-34: Motorcycle evaporative emission classes and resting loss models

Inventory Evaporative Emission Class	Passing			Failing		
	Base Model	Multiplier		Base Model	Multiplier	
		K	A		K	A
All (No data)	N/A	N/A	N/A	M6 Carb '80-'85 Fail	0.55	0.0684

Table 3-35: HDCP evaporative emission classes and resting loss models

Inventory Evaporative Emission Class	Passing			Failing		
	Base Model	Multiplier		Base Model	Multiplier	
		K	A		K	A
ADR27 – pre - 1988 (NISE1 data)	M6 Carb '80-'85 Pass	1.62	0.0304	M6 Carb '80-'85 Fail	1.65	0.0684
ADR37/00 – 1989 - 1993 (NISE1 data)	Euro 1+2	1.5	-0.0507	Pre-Euro	1.62	-0.0193
ADR37/00/01 – 1994 - 2003 (NISE2 data)	Euro 3+4	0.375	-0.0507	Pre-Euro	1.5	-0.0193
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	0.188	-0.0507	Pre-Euro	1.5	-0.0193

[1] – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.1.6 Resting Loss Model Failure Rates

The diurnal loss failure rates presented in Section 3.11.1.2 are also applied to resting losses.

3.11.1.7 Hot Soak Losses

The hot soak emissions are modelled by the ARTEMIS hot soak model, which predicts the hot soak losses for a one hour period following the end of a vehicle trip, additional to the resting losses which would occur independent of the trip end. As some vehicles are not parked for a full hour before the start of the next trip, and vehicles which are parked for longer may continue to produce hot soak emissions, the base one hour emission is modified by factors from the Handbook on Emission Factors (HBEFA) as summarised in Hausberger (2005). The modified base hot soak emission factor thus represents emissions on the basis of grams per trip rather than grams per one hour test.

3.11.1.8 Base One Hour Hot Soak Model

The base ARTEMIS one hour hot soak model for passenger vehicles and LCV is shown below (Equation 3-23). Motorcycles use a separate model.

$$E_{Hot\ Soak,\ Pre-Euro} = 0.88 \times e^{[0.06(RVP-62)+0.0926 \times T_{ambinet} - 0.8]} \quad \text{(g/hr)}$$

$$E_{Hot\ Soak,\ Euro1+2} = \frac{(-0.098 + 0.12 \times RVP) \times (T_{ambient} + 17.8)}{740} \quad \text{(g/hr)} \qquad \text{Equation 3-23}$$

$$E_{Hot\ Soak,\ Euro3+4} = 0.25 \times E_{Hot\ Soak,\ Euro1+2} \quad \text{(g/hr)}$$

Where:

RVP	=	Reid vapour pressure of fuel	(kPa)
$T_{ambient}$	=	Ambient temperature	(°C)

The evaporative emission classes defined in the on-road mobile inventory model, the assigned ARTEMIS class equation and multiplier applied to fit to Australian data are shown in Table 3-36, Table 3-37, Table 3-38 and Table 3-39 for petrol passenger vehicles, petrol LCV, motorcycles and heavy duty commercial petrol respectively. Motorcycles have high hot soak emissions due to the position of the fuel tank above the engine, and are modelled as 112% of failing (uncontrolled) cars as a road type VKT weighted average of the ARTEMIS urban and rural/motorway motorcycle hot soak factors (Hausberger, 2005). HDCP are assumed to be 150% of the same model year PLCV. It is seen that the multipliers required to adjust the base ARTEMIS model to the available Australian data are generally close to 1, except for the ADR79 where the Australian data indicates a better emissions performance than the ARTEMIS model predicts.

Table 3-36: Petrol passenger vehicle evaporative emission classes and hot soak models

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre - 1988 (NISE1 data)	Euro 1+2	1.08	Pre-Euro	1.10
ADR37/00 – 1989 - 1993 (NISE1 data)	Euro 1+2	1.00	Pre-Euro	1.08
ADR37/00/01 – 1994 - 2003 (NISE2 data)	Euro 3+4	1.07	Pre-Euro	0.60
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	1.00	Pre-Euro	0.50

Table 3-37: Petrol LCV evaporative emission classes and hot soak models

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre - 1988 (No data)	N/A	N/A	Pre-Euro	1.10
ADR37/00 – 1989 - 1998 (NISE2 data)	Euro 1+2	1.00	Pre-Euro	1.08
ADR37/01 – 1999 - 2003 (NISE2 data)	Euro 3+4	1.07	Pre-Euro	0.60
ADR79/00/01 – 2004 on (NISE2 data)	Euro 3+4	1.00	Pre-Euro	0.50

Table 3-38: Motorcycle evaporative emission classes and resting loss models

Inventory Evaporative Emission Class	Passing		Failing	
	Base Model	Multiplier	Base Model	Multiplier
All (No data)	N/A	N/A	Pre-Euro	1.123

Table 3-39: HDCP evaporative emission classes and hot soak models

Inventory Evaporative Emission Class[1]	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre-1988 (No data)	N/A	N/A	Pre-Euro	1.65
ADR37/00 – 1989-1998 (No data)	Euro 1+2	1.50	Pre-Euro	1.62
ADR37/01 – 1999-2003 (No data)	Euro 3+4	1.61	Pre-Euro	0.90
ADR79/00/01 – 2004 on (No data)	Euro 3+4	1.50	Pre-Euro	0.75

[1] – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.1.9 Hot Soak Parking Time Adjustment

The German-Swiss-Austrian handbook of emission factors (HBEFA) model predicts hot soak emissions at 15°C as a function of time using Equation 3-24 (Hausberger et. al., 2005).

$E_{Hot\,Soak,\,HBEFA} = A \times \left[1 - e^{-B \times \Delta t}\right] + C$	(g)	Equation 3-24

Where:

Δt	=	Soak time in minutes	(min)
A	=	10.948 for uncontrolled vehicles 0.836 for controlled vehicles	
B	=	0.0360 for uncontrolled vehicles 0.0203 for controlled vehicles	
C	=	-0.302 for uncontrolled vehicles 0 for controlled vehicles	

The hot soak emissions as a function of time predicted by Equation 3-24 are normalised to 60 minutes, and combined with the hour of the day trip end parking duration distribution to arrive at an hourly weighted average hot soak parking time adjustment factor as shown in Equation 3-25.

$HSPF_{k,Hr} = \sum_{ParkingPeriod} \left(\%Trips_{ParkingPeriod,\,Hr} \times \frac{E_{Hot\,Soak,\,HBEFA,\,ParkingPeriod}}{E_{Hot\,Soak,\,HBEFA,\,60\,minutes}} \right)$	Equation 3-25

Where:

$\%Trips_{Parking\ Period,\ Hr}$	=	% of trips ending in hour *Hr* that park for *ParkingPeriod* prior to next trip	(%)

3.11.1.10 Hot Soak Model Failure Rates

The failure rates for hot soak emissions are predicted using the generic formula given in Equation 3-18. The coefficients of this equation were adjusted to match the fail rate derived in fitting the "failed" and "passing" models to the Australian data, at the average age of the vehicles in each class. The coefficients to Equation 3-18 for each inventory vehicle class are given in Table 3-40, Table 3-41, Table 3-42 and Table 3-43.

Table 3-40: Petrol passenger vehicle diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
ADR27 – pre - 1988 (NISE1 data)	0.80	5	-0.025	1
ADR37/00 – 1989 - 1993 (NISE1 data)	0.70	7	-0.01362	1
ADR37/00/01 – 1994 - 2003 (NISE2 data)	0.605	13	-0.01362	1
ADR79/00/01 – 2004 on (NISE2 data)[1]	0.605	17.33	-0.01362	1.5

[1] – Insufficient data to derive a failure rate, so a conservative assumption was made to change the Age denominator from the 2 of ARTEMIS/MOBILE to 1.5

Table 3-41: Petrol LCV diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
ADR27 – pre - 1988 (No data)	N/A. Failure rate set to 1, i.e. all uncontrolled			
ADR37/00 – 1989 - 1998 (NISE2 data)	0.80	3	-0.027	1
ADR37/01 – 1999 - 2003 (NISE2 data)	0.75	4.5	-0.03	1
ADR79/00/01 – 2004 on (NISE2 data)	0.605	17.33	-0.01362	1.5

Table 3-42: Motorcycle diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class	A	B	C	D
All (no data)	N/A. Failure rate set to 1, i.e. all uncontrolled			

Table 3-43: HDCP diurnal model failure rate equation coefficients

Inventory Evaporative Emission Class[1]	A	B	C	D
ADR27 – pre - 1988 (No data)	N/A. Failure rate set to 1, i.e. all uncontrolled			
ADR37/00 – 1989 - 1998 (No data)	0.80	3	-0.027	1
ADR37/01 – 1999 - 2003 (No data)	0.75	4.5	-0.03	1
ADR79/00/01 – 2004 on (No data)	0.605	17.33	-0.01362	1.5

[1] – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.1.11 Running Losses

The ARTEMIS model is adopted in absence of any Australian data on running losses. The ARTEMIS running loss model is based on the earlier CORINAIR work (EEA, 2002), with modifying parameters to adjust the base model for running speed from US EPA studies (Hausberger, 2005).

The ARTEMIS equation is shown in Equation 3-26 and the coefficients are given in Table 3-44.

$$E_{Running} = A \times 0.136 \times e^{\left(-5.967 + B \times 0.04259 \times RVP + C \times 0.1773 \times T_{Ambinet\,^\circ C}\right)} \qquad \text{Equation 3-26}$$

Where:

RVP	=	Petrol Reid Vapour Pressure	(kPa)

and:

Table 3-44: Coefficients for base running loss equation

Inventory Evaporative Emission Class	Road Type (Av Speed)	A	B	C
Pre-Euro Uncontrolled and Failing Euro 1-4	Urban (11.5 km/h)	11	1.2	0.72
	Road (31.5 km/h)	10	0.98	0.67
	Motorway (77 km/h)	4.5	0.95	0.67
Euro 1-4 (Controlled)	Urban (11.5 km/h)	1	1.1	0.79
	Road (31.5 km/h)	0.5	0.95	0.71
	Motorway (77 km/h)	0.1	0.8	0.67

The ARTEMIS model is based on relatively old data corresponding to Pre-Euro to Euro1. For vehicles with evaporative control systems the ARTEMIS model predicts the same running loss for all of Euro 1 to Euro 4 vehicles, and hence does not predict any improvement in running losses for the more modern vehicles. This is at odds with the models and data for the other evaporative loss mechanisms. CRC (2008, 2010, 2010a) and US EPA (2001e) demonstrated significant reductions in running loss emissions with improved technology classes, with the percentage reduction with successive technology classes being of similar order to that of the diurnal emissions. As the Australian data and models described above for diurnal and hot soak show significant improvement for the later emission classes, the Euro 1-4 ARTEMIS model is taken to represent ADR27 and ADR37/00, and multipliers applied to the later emission classes of approximately the same order as the change in the diurnal emissions. The base ARTEMIS equation used and multiplier applied for each inventory vehicle emission class are shown in Table 3-45, Table 3-46, Table 3-47 and Table 3-48.

Table 3-45: Petrol passenger vehicle running loss base model and multipliers

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre - 1988	Euro 1-4	1.0	Pre-Euro	1. 0
ADR37/00 – 1989 - 1993	Euro 1-4	1.0	Pre-Euro	1.0
ADR37/00/01 – 1994 - 2003	Euro 1-4	0.50	Pre-Euro	1.0
ADR79/00/01 – 2004 on	Euro 1-4	0.25	Pre-Euro	1.0

Table 3-46: Petrol LCV running loss base model and multipliers

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre - 1988	Euro 1-4	1.0	Pre-Euro	1. 0
ADR37/00 – 1989 - 1998	Euro 1-4	1.0	Pre-Euro	1.0
ADR37/01 – 1999 - 2003	Euro 1-4	0.50	Pre-Euro	1.0
ADR79/00/01 – 2004 on	Euro 1-4	0.25	Pre-Euro	1.0

Table 3-47: Motorcycle running loss base model and multipliers

Inventory Evaporative Emission Class	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
All	N/A	N/A	Pre-Euro	0.50

Table 3-48: HDCP evaporative emission classes and diurnal models

Inventory Evaporative Emission Class[1]	Passing		Failing	
	ARTEMIS Eqn	Multiplier	ARTEMIS Eqn	Multiplier
ADR27 – pre-1988	Euro 1-4	1.5	Pre-Euro	1. 5
ADR37/00 – 1989-1998	Euro 1-4	1.5	Pre-Euro	1.5
ADR37/01 – 1999-2003	Euro 1-4	0.75	Pre-Euro	1.5
ADR79/00/01 – 2004 on	Euro 1-4	0.375	Pre-Euro	1.5

[1] – No Australian data for any HDCP. Emissions assumed to be 1.5 x that of the same model year PLCV

3.11.2 Effect of E10 Fuel on Evaporative Emissions

The addition of ethanol to petrol causes a significant increase in evaporative emissions. E10 blends cause an increase in RVP of approximately 6-7 kPa, and additionally cause a very significant increase in evaporative emissions generated by fuel permeation (CRC, 2004, 2006, 2008, 2010, 2010a). There have been two Australian studies that investigated the impact of E10 blends on evaporative emissions.

The 1998 NSW EPA conducted study (Brown et al 1998) measured the evaporative emissions from 56 ADR27 and ADR37/00 vehicles after they had been serviced. E10 resulted in an increase in the diurnal emissions (one hour ADR37 test procedure) of 15% to 17% for ADR27 and ADR37 vehicle respectively, whilst the hot soak emissions increased by 51% for ADR27 and 34% for ADR37/00 vehicles.

The commonwealth governments Ethanol Health Impacts Study (CSIRO & Orbital, 2008) tested 3 ADR37/01 and 3 ADR79/01 vehicles using the ADR79/01 evaporative test procedures (24 hour diurnal). New carbon canisters had been fitted to all vehicles prior to testing. E10 resulted in increases of 82% and 139% in hot soak emissions for ADR37/01 and ADR79/01 vehicles respectively, and increases of 75% and 60% in diurnal emissions. Due to the small sample size, only the ADR79/01 diurnal change is significant at the 95% confidence level (P=0.016).

Both of the above studies conducted limited preconditioning of the vehicles between fuel changes. The CRC projects found that up to one month's conditioning is required for the permeation impact of E10 to stabilise. The CRC studies found increases in evaporative losses for E10 blends from eight US "enhanced" vehicles (1999-2005, taken to be equivalent to ADR79/xx vehicles) as summarised in Table 3-49. US enhanced vehicles are those required to comply with the enhanced evaporative test regulations that include a 3 day diurnal and running loss test, and as such are more tightly controlled than the requirements of the Australian ADRs.

Table 3-49: Average impact of E10 from CRC studies

Vehicle Generation	Change in Evaporative Emission due to E10			
	Resting Loss (Static Permeation)	Day 1 Diurnal (permeation/total)	Hot Soak[1]	Running Loss
US "Enhanced (1999-2005, ~equivalent to ADR79/xx)	+116%	101% / 1026%[2]	134%	32%

[1] – "true hot soak" – additional emissions above the resting loss

[2] – Total loss impacted largely by 2 vehicles with very large canister break-through emissions

The impact of E10 on the evaporative emissions for the on-road mobile model, estimated from the above data sources, is shown in Table 3-50.

Table 3-50: On-road mobile evaporative emissions E10 factors

Inventory Evaporative Emission Class	Resting Loss E10 Increase	Running Loss E10 Increase	Diurnal Loss[1] E10 Increase	Hot Soak[1] Loss E10 Increase
ADR27 – pre - 1988	120%	32%	16%	50%
ADR37/00 – 1989 - 1993	120%	32%	16%	34%
ADR37/00/01 – 1994 - 2003	120%	32%	63%	53%
ADR79/00/01 – 2004 on	120%	32%	45%	53%

[1] – The diurnal and hot soak increases are those additional to the underlying resting loss increase.

The diurnal and hot soak E10 increase estimates are derived from the Australian data by subtracting the contribution of the resting loss to the E10 increase.

3.11.3 Spatial Allocation of Evaporative Emissions

Diurnal, hot soak and resting losses are independent of vehicle activity and occur as point sources at the location where the vehicle is parked, while running losses occur over the course of a journey and are hence on a kilometre basis distributed over the trip route. Information on where vehicles are parked during the course of a day was not available for this inventory, and hence the point source evaporative emissions were not able to be spatially allocated directly. The emissions from these sources was converted to a grams per kilometre basis and thus spatially allocated as a function of VKT in a similar manner to the 1992 and 2003 NSW inventories.

3.12 Non-Exhaust PM Emissions Estimation

Non-exhaust PM generated by tyre, brake and road wear is calculated adopting the Tier 2 methodology of Ntziachristos & Boulter (2009), which incorporates the most up to date state of knowledge of this emissions source, as published previously in the European PARTICULATES study by Luhana et al (2004). A brief discussion of this source type is given above in Section 3.2.7.

3.12.1 Tyre Wear

Base total suspended matter (TSP; approximately PM_{30}) tyre wear emission factors at a speed of 80 km/h are given in Table 3-51.

Table 3-51: Base tyre wear TSP emission factors

Vehicle Type	Tyre Wear TSP emission factor (g/km)
Two wheeled vehicles	0.0046
Passenger cars	0.0107
Light duty trucks	0.0169
Heavy duty vehicles	Equation 3-27

$$EF_{TSP,Tyre,HDV} = \frac{No.of\ axles}{2} \times LCF_{Tyre} \times EF_{TSP,Tyre,Passenger\ cars} \qquad \text{Equation 3-27}$$

Where:

$$LCF_{Tyre} = 1.41 + (1.38 \times Load\ Factor) \qquad Load\ Factor = 0.5 \qquad \text{(factor)}$$

The *Load Factor* in the heavy duty vehicles load correction factor (*LCF)* is taken to be 0.5, representing vehicles operating fully loaded for 50% of their VKT.

The number of axles is estimated from the GVM distribution of the rigid and articulated truck fleet and is given in Table 3-52. Buses are estimated to have 2.1 axles, assuming 90% of buses are 2 axle and 10% 3 axle.

Table 3-52: Estimated number of axles for heavy duty fleet

Rigid Trucks			Articulated Trucks		
GVM	Assumed No. Axles	Fleet %	GVM	Assumed No. Axles	Fleet %
3.5 - 7.5 tonne	2	51.2%	25 - 40 tonne	5	13%
7.5 - 12 tonne	2	21.8%	40 - 50 tonne	6	70%
12 - 20 tonne	3	15.2%	> 50 tonne	9	17%
20 - 25 tonne	3.5	11.8%	Average all	6.4	-
Average all	2.33	-			

The size distribution of the tyre wear TSP is given in Table 3-53.

Table 3-53: Tyre wear PM size distribution

Particle Size Class	Mass fraction of TSP
TSP	1.00
PM_{10}	0.600
$PM_{2.5}$	0.420
$PM_{1.0}$	0.060

Speed correction of the tyre wear is estimated by Ntziachristos & Boulter (2009) as given in Table 3-54.

Table 3-54: Speed correction for tyre wear PM emissions

Average Speed	Speed Correction
V < 40 kmh	1.39
40 < V ≤ 90 km/h	$-0.00974 \times V + 1.78$
V > 90 km/h	0.902

The base tyre wear PM_{10} emission factors calculated with adopted methodology of Ntziachristos & Boutler are compared to the US EPA MOBILE 6.2 (based on the old PART5 model, US EPA, 1995) in Table 3-55. The estimates compare well for light duty vehicles; however the new methodology estimates 50-80% higher emission factors for heavy duty vehicles.

Table 3-55: Comparison of adopted PM_{10} tyre wear emission factors with MOBILE 6.2

Vehicle Type	Ntziachristos & Boulter	MOBILE 6.2
Motorcycles	0.0028	0.0025
Passenger Cars	0.0064	0.0050
LDV	0.0101	0.0050
HDV - Rigids	0.0162	0.0091
HDV Artics	0.0460	0.0303
Buses	0.0146	0.0079

3.12.2 Brake Wear

Base total suspended matter (TSP; approximately PM_{30}) brake wear emission factors at a speed of 80 km/h are given in Table 3-56.

Table 3-56: Base brake wear TSP emission factors

Vehicle Type	Brake Wear TSP emission factor (g/km)
Two wheeled vehicles	0.0037
Passenger cars	0.0075
Light duty trucks	0.0117
Heavy duty vehicles	Equation 3-28

$$EF_{TSP,Brake,HDV} = 3.13 \times LCF_{Tyre} \times EF_{TSP,Brake,Passenger\ cars}$$ Equation 3-28

Where:

$LCF_{Tyre} = 1.0 + (0.79 \times Load\ Factor)$ *Load Factor = 0.5* (factor)

The size distribution of the brake wear TSP is given in Table 3-57.

Table 3-57: Brake wear PM size distribution

Particle Size Class	Mass fraction of TSP
TSP	1.00
PM_{10}	0.980
$PM_{2.5}$	0.390
$PM_{1.0}$	0.100

Speed correction of the brake wear is estimated by Ntziachristos & Boulter (2009) as given in Table 3-58.

Table 3-58: Speed correction for brake wear PM emissions

Average Speed	Speed Correction
V < 40 kmh	1.67
40 < V ≤ 95 km/h	$-0.0270 \times V + 2.75$
V > 95 km/h	0.185

The base brake wear PM_{10} emission factors calculated with adopted methodology of Ntziachristos & Boulter are compared to the US EPA MOBILE 6.2 in Table 3-59. MOBILE 6.2 PM emission factors are based on the old PART5 model (US EPA, 1995) and the brake wear measurements date from 1985. The estimates compare well for light duty vehicles. MOBILE 6 used one fixed emission factor for all vehicles, which would intuitively underestimate heavy duty vehicles, and it is seen that the new heavy duty vehicle brake wear estimates are four times higher than the MOBILE 6.

Table 3-59: Comparison of adopted PM_{10} brake wear emission factors with MOBILE 6.2

Vehicle Type	Ntziachristos & Boulter	MOBILE 6.2
Motorcycles	0.0036	0.0078
Passenger Cars	0.0074	0.0078
LDV	0.0115	0.0078
HDV - Rigids	0.0330	0.0078
HDV Artics	0.0330	0.0078
Buses	0.0330	0.0078

3.12.3 Road Wear

Base total suspended matter (TSP; approximately PM_{30}) road wear emission factors at a speed of 80 km/h are given in Table 3-60.

Table 3-60: Base road wear TSP emission factors

Vehicle Type	Brake Wear TSP emission factor (g/km)
Two wheeled vehicles	0.0060
Passenger cars	0.015
Light duty trucks	0.015
Heavy duty vehicles	0.0760

The size distribution of the road wear TSP is given in Table 3-61.

Table 3-61: Road wear PM size distribution

Particle Size Class	Mass fraction of TSP
TSP	1.00
PM_{10}	0.50
$PM_{2.5}$	0.27

No speed correction is suggested by Ntziachristos & Boulter. The road wear speed correction is estimated by the brake wear correction as given in Table 3-62.

Table 3-62: Speed correction for road wear PM emissions

Average Speed	Speed Correction
V < 40 kmh	1.67
$40 < V \leq 95$ km/h	$-0.0270 \times V + 2.75$
V > 95 km/h	0.185

3.13 Emission Speciation

In addition to the base emission species listed in Table 3-12 of Section 3.6 above, speciation profiles were derived for individual compounds contributing to the following emission sources (Table 3-63):

Table 3-63: Speciation profiles

Emission Source	Compound Types	Source Type Profiles
Exhaust VOC emissions	VOC, semi-volatile organic compounds, poly aromatic compounds	(1) - All petrol vehicles E0 fuel (2) - All petrol vehicles E10 fuel (3) - All diesel vehicles
Evaporative VOC emissions	VOC	(1) - All petrol vehicles
Exhaust PM emissions	Inorganic compounds, semi-volatile organic compounds, poly aromatic compounds	(1) - All petrol vehicles (2) - All diesel vehicles
Non-exhaust PM emissions	Limited inorganic compounds and poly aromatic compounds	(1) - All vehicles
Exhaust NO_x emissions	NO/NO_2	(1) - All petrol vehicles (2) - Light duty diesel vehicles (3) - Heavy duty diesel vehicles

The speciated composition of the combustion emission sources listed are complex interactions of fuel properties and composition with engine combustion characteristics influenced by:

- design and technology parameters:
  - fuel-air mixture preparation and fuel injection system design parameters, e.g. injector nozzle, injection pressures, injection timing and number of injections
  - combustion chamber design and in-cylinder charge motion, macro and micro turbulence
  - aftertreatment devices employed
- operating parameters:
  - speed and load, duty cycle, driving conditions
  - cylinder pressure (function of throttle in petrol and transient turbocharger response etc)
  - engine temperature
  - fuel air mixture
- engine condition.

In addition to the complexity of the operating, fuel and engine technology, variability and uncertainty are introduced into the data by the variety of emissions sampling and analytical techniques employed. Hence large uncertainties are generally associated with the overall speciation profiles, and large data sets are required in order to average out any potential biases that may arise from limited data sets.

The speciation data was drawn from various Australian and international projects and databases. Where fuel properties were available, the data was filtered to exclude fuels that were not representative of Australian market fuels.

Petrol exhaust VOC and evaporative VOC speciation was taken from work performed for the Australian commonwealth government's Ethanol Health Impacts Study (CSIRO & Orbital, 2008). PAH and PM inorganics speciation was derived from the Gasoline/Diesel PM Split study performed by the Desert Research Institute (DRI) for the US National Renewable Energy Laboratory (NREL), (Fujita et. al., 2006).

Diesel vehicle speciation data is drawn largely from a very large international database collating data from many international projects (CRC, 2007).

Non-exhaust PM emission's speciation was adopted from Ntziachristos & Boulter (2009).

4 DATA SOURCES AND RESULTS

In this section the activity and emission factor data derived according to the methodology outlined in Section 3 are presented. The total emissions calculated using these data are presented for the entire GMR and the Sydney, Newcastle, Wollongong and Non Urban regions for each on-road mobile source type. The Non Urban region is defined as the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. Emissions are presented for the following pollutants only:

- 1,3-butadiene
- Acetaldehyde
- Benzene
- Carbon monoxide (CO)
- Formaldehyde
- Isomers of xylene
- Lead & compounds
- Oxides of nitrogen (NO_x)
- Particulate matter ≤ 10 µm (PM_{10})
- Particulate matter ≤ 2.5 µm ($PM_{2.5}$)
- Polycyclic aromatic hydrocarbons (PAH)
- Sulfur dioxide (SO_2)
- Toluene
- Total suspended particulate (TSP)
- Total volatile organic compounds (VOC)

These substances have been selected since they are:

- The most common air pollutants found in airsheds according to the National Pollutant Inventory NEPM (NEPC, 2008);
- Referred to in National Environment Protection Measures (NEPMs) for ambient air quality (NEPC, 2003) and air toxics (NEPC, 2004); and
- They have been classified as priority air pollutants (NEPC, 2006).

Total on-road mobile emissions of all substances emitted from all source types in the GMR are presented in Appendix A.

4.1 Exhaust Emissions from Petrol Passenger Vehicles

4.1.1 *Fleet Profile*

The fleet age profiles obtained from RTA registration records are shown for the individual vehicle types and for the total aggregated petrol passenger vehicle source type in Table 4-1. As discussed in Section 3.3, the LPG vehicles are modelled as petrol fuelled.

The percentage of the fleet assumed to be E10 compatible is taken from CSIRO & Orbital (2008) and is given in Figure 4-1. E10 fuel accounted for 11.3% of the total petrol sales in NSW in 2008 (RETS, 2008). The distribution of E10 VKT across the fleet age range is calculated by assuming an equal percentage uptake for each model year, of those vehicles that are E10 suitable from the model year, and balancing the total to the total E10 fuel usage, taking into account that newer vehicles do higher annual VKT than older vehicles. The percentage of the VKT using E10 by each age class is shown in the last column of Table 4-1.

Table 4-1: Petrol passenger vehicle fleet profile, 2008

YOM	Petrol Cars	LPG Cars	Petrol 4WD	LPG 4WD	Profile (%)	VKT per Annum	%VKT using E10
2008	126,878	2,064	31,437	125	6.445%	9,650	14.23%
2007	125,919	1,988	32,648	117	6.451%	18,407	13.95%
2006	130,281	2,031	31,188	146	6.571%	17,589	13.66%
2005	148,969	1,637	35,426	183	7.477%	16,840	13.66%
2004	138,329	1,747	36,078	168	7.080%	16,157	13.38%
2003	136,530	2,365	30,873	233	6.826%	15,533	11.53%
2002	122,257	1,950	27,826	261	6.115%	14,964	11.17%
2001	118,065	2,367	23,483	270	5.789%	14,446	10.96%
2000	127,908	1,549	20,562	180	6.031%	13,974	10.39%
1999	118,164	1,536	18,806	302	5.573%	13,542	10.10%
1998	129,032	1,422	16,145	355	5.900%	13,146	9.68%
1997	111,135	1,227	10,375	209	4.937%	12,782	9.39%
1996	91,402	1,193	5,633	187	3.952%	12,444	9.39%
1995	89,125	1,066	4,959	192	3.828%	12,127	9.11%
1994	79,603	874	4,555	223	3.423%	11,828	8.68%
1993	62,311	652	3,854	209	2.691%	11,540	7.83%
1992	52,210	572	2,317	123	2.217%	11,259	6.69%
1991	44,798	348	790	56	1.847%	10,981	6.12%
1990	43,039	329	623	95	1.770%	10,701	6.26%
1989	32,051	243	507	79	1.320%	10,413	5.12%
1988	19,959	137	292	44	0.820%	10,113	4.13%
1987	11,637	99	106	9	0.476%	9,797	4.55%
1986	9,982	63	142	14	0.410%	9,459	4.13%
1985	9,056	82	229	32	0.377%	9,094	0.00%
1984	5,522	64	133	24	0.231%	8,699	0.00%
1983	3,503	39	78	21	0.146%	8,267	0.00%
1982	3,114	48	69	19	0.130%	7,794	0.00%
1981	2,425	43	45	16	0.102%	7,276	0.00%
1980	1,762	33	28	3	0.073%	6,708	0.00%
1979	1,089	55	15	5	0.047%	6,084	0.00%
1978	1,031	56	32	6	0.045%	5,400	0.00%
1977	1,002	71	21	6	0.044%	4,652	0.00%
1976	1,068	38	26	5	0.046%	3,834	0.00%
1975	1,017	35	19	3	0.043%	2,941	0.00%
≤ 1974	18,717	345	46	6	0.767%	1,970	0.00%

[1] – Vehicles assumed to enter fleet evenly across year, hence average annual mileage is 50% of new vehicle

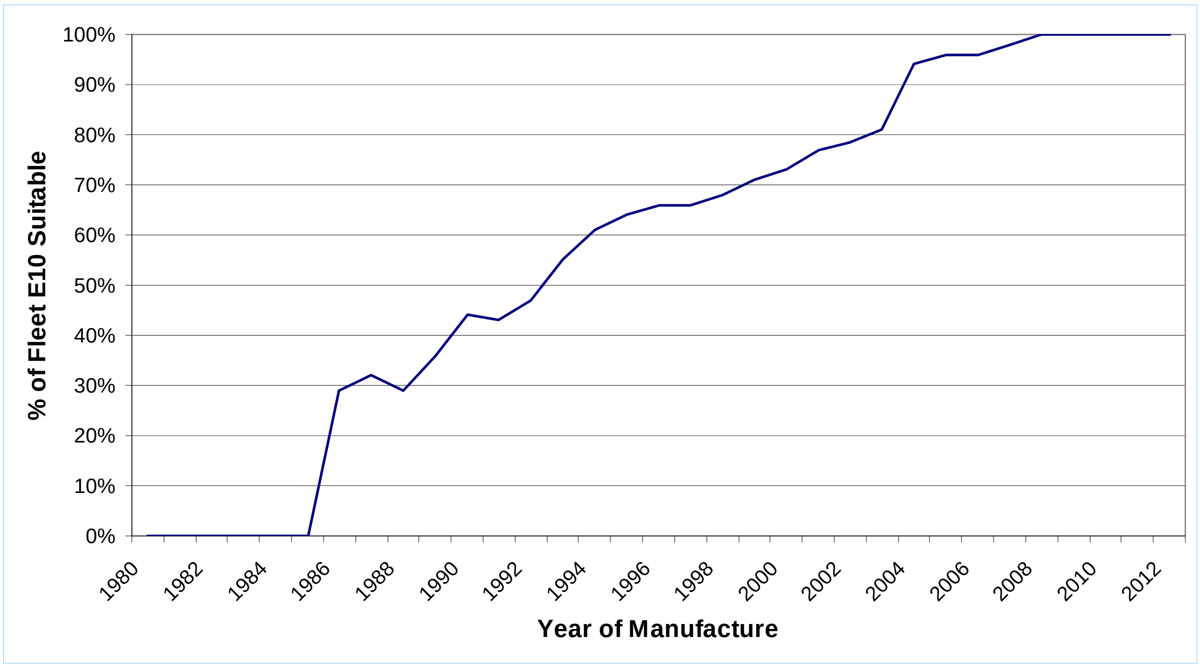

Figure 4-1: Percentage of petrol vehicle fleet assumed to be E10 compatible

4.1.2 VKT Data

The total 2008 GMR VKT for petrol passenger vehicles on an average week day and average weekend day are given in Table 4-2 and the hourly profile is shown graphically in Figure 4-2. The hourly average speed by road type across the entire GMR area is given in Table 4-3.

Table 4-2: Petrol passenger vehicle average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	348,485	0.42%	902,226	1.28%
1	156,707	0.19%	430,005	0.61%
2	106,273	0.13%	252,610	0.36%
3	83,247	0.10%	134,944	0.19%
4	463,870	0.56%	361,819	0.51%
5	1,761,072	2.13%	746,695	1.06%
6	3,427,599	4.14%	1,179,094	1.68%
7	6,924,060	8.36%	2,513,434	3.57%
8	8,641,078	10.44%	4,631,618	6.58%
9	4,635,634	5.60%	4,093,265	5.82%
10	3,797,939	4.59%	4,591,708	6.53%
11	3,892,256	4.70%	5,246,761	7.46%
12	3,664,858	4.43%	4,940,228	7.02%
13	3,854,178	4.66%	4,783,035	6.80%

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
14	4,470,806	5.40%	4,671,993	6.64%
15	6,817,230	8.24%	5,910,538	8.40%
16	7,019,222	8.48%	5,797,877	8.24%
17	7,859,622	9.49%	6,303,417	8.96%
18	5,671,729	6.85%	4,406,933	6.27%
19	3,368,389	4.07%	2,775,552	3.95%
20	1,961,117	2.37%	1,765,006	2.51%
21	1,556,104	1.88%	1,440,952	2.05%
22	1,568,820	1.90%	1,579,802	2.25%
23	731,409	0.88%	880,617	1.25%
Total	**82,781,704**		**70,340,128**	

Table 4-3: Hourly average speeds by road type

Hour	Residential	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
0	24.9	45.8	45.4	66.0	78.1
1	24.9	46.3	45.8	66.7	79.4
2	24.8	46.7	46.0	67.0	80.1
3	24.8	47.2	46.4	67.6	81.1
4	24.8	45.9	45.4	66.1	78.7
5	24.7	44.4	43.8	63.8	76.2
6	24.5	41.6	39.3	61.8	72.0
7	23.8	34.6	30.3	52.0	59.5
8	23.4	32.3	28.0	48.0	55.7
9	24.1	37.9	35.7	56.1	67.0
10	24.3	39.9	37.5	59.0	69.7
11	24.3	39.3	36.9	58.1	68.8
12	24.3	40.0	37.5	59.0	69.7
13	24.3	39.7	37.2	58.6	69.3
14	24.1	38.2	36.0	56.6	67.4
15	24.0	36.6	32.6	56.0	63.6
16	23.9	36.0	32.1	55.1	62.7
17	23.7	35.2	31.3	53.8	61.4
18	24.2	39.3	36.7	57.8	68.3
19	24.6	42.7	42.0	61.2	73.3
20	24.7	44.3	43.8	63.8	75.6
21	24.8	44.8	44.3	64.5	76.3
22	24.8	44.7	44.3	64.5	76.2
23	24.9	45.5	45.1	65.6	77.3

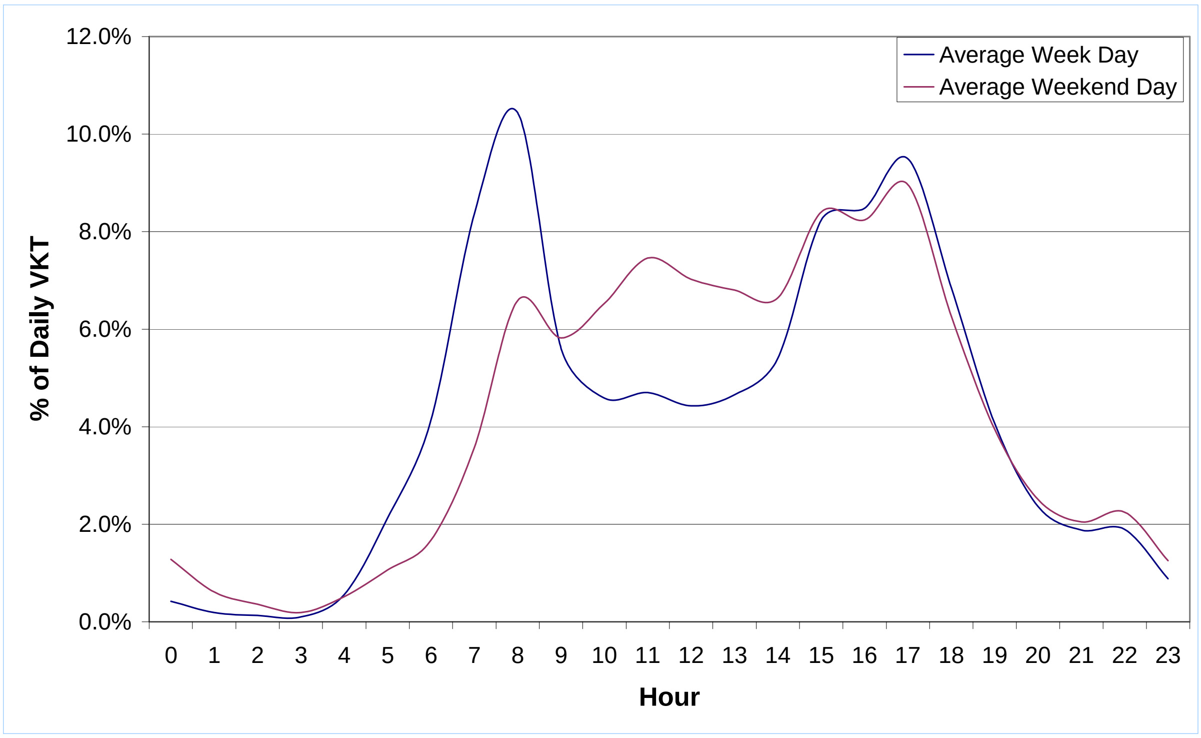

Figure 4-2: Petrol passenger vehicle diurnal VKT profiles

4.1.3 Emission Factors

4.1.3.1 Hot Running

Base hot running exhaust emission factors for ADR37/00 and newer vehicles, for all base pollutants excepting SO_2 and NH_3, were derived from analysis of the NISE2 hot CUEDC residential cycle data and are shown in Table 4-4. Emission factors for SO_2 are calculated from the fuel consumption and fuel sulfur content with allowance for sulfate formation. Emission factors for NH_3 were derived from the work of Heeb et al (2006, 2006a, 2008), Huai et al (2003), Karlsonn (2004) and CRC (2003).

Emission factors for earlier ADR27 vehicles are derived by developing conversion factors to apply to the previous inventory emission factors, which had been derived from test data from NISE1 and NSW and Victoria EPA test programs. For each age group, the emission factors derived are a weighted average by proportions of cars and SUV's, and also by vehicle size distribution. These base emission factors relate to an ambient temperature of 23.0°C and the petrol properties of the NISE2 study, given in Table 3-17.

Fleet composite base emission factors incorporating fleet age profile, age specific annual VKT and deterioration are given in Table 4-5. Fleet composite splitting factors were derived as detailed in Section 3.8.2 and are also given in Table 4-5.

The fuel property adjustment factors calculated for the average 2008 Sydney petrol properties and applied to the base hot running emission factors are given in Table 4-6. The seasonal temperature corrections are given in Table 4-7. The coefficients for the fleet composite 6th order speed correction functions are given in Table 4-8.

Table 4-4: Base hot running exhaust emission factors for petrol passenger vehicles

Emission Age Class	ADR	NOx		VOC		CO		Exhaust PM_{10}		N_2O		NH_3	CO_2
		EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (mg/km)	DR (mg/km²)	EF (mg/km)	EF (g/km)
1975	ADR27	0.442	5.91×10^{-06}	0.2195	8.09×10^{-06}	2.956	8.11×10^{-05}	0.0041	2.89×10^{-08}	9.641	0.00	2.0	176.6
1982	ADR27B	0.438	5.87×10^{-06}	0.1690	6.23×10^{-06}	2.714	7.44×10^{-05}	0.0041	2.89×10^{-08}	9.641	0.00	2.0	174.0
1989	ADR37/00	0.204	2.45×10^{-06}	0.0625	9.79×10^{-07}	0.807	1.16×10^{-05}	0.0021	1.44×10^{-08}	30.0	4.62×10^{-05}	56.8	207.8
1993	ADR37/00	0.185	2.23×10^{-06}	0.0616	9.62×10^{-07}	0.738	1.06×10^{-05}	0.0018	1.12×10^{-08}	30.0	4.62×10^{-05}	56.8	204.4
1996	ADR37/00	0.167	2.00×10^{-06}	0.0554	8.66×10^{-07}	0.664	9.55×10^{-06}	0.0018	1.12×10^{-08}	30.0	4.62×10^{-05}	56.8	201.4
1999	ADR37/01	0.065	1.11×10^{-06}	0.0185	3.78×10^{-07}	0.258	4.11×10^{-06}	0.0015	7.95×10^{-09}	27.0	5.57×10^{-05}	39.7	206.1
2002	ADR37/01	0.061	1.02×10^{-06}	0.0167	3.42×10^{-07}	0.234	3.72×10^{-06}	0.0015	7.95×10^{-09}	27.0	5.57×10^{-05}	39.7	204.0
2004	ADR79/00	0.028	4.77×10^{-07}	0.0183	2.69×10^{-07}	0.250	4.05×10^{-06}	0.0006	5.00×10^{-09}	5.00	3.06×10^{-05}	39.7	201.3
2006	ADR79/01	0.022	3.27×10^{-07}	0.00877	8.44×10^{-08}	0.134	1.61×10^{-06}	0.0006	5.00×10^{-09}	2.00	1.23×10^{-05}	32.3	198.3
2010	ADR79/02	0.0074	1.10×10^{-07}	0.00580	5.36×10^{-08}	0.116	1.34×10^{-06}	0.0006	5.00×10^{-09}	2.00	1.23×10^{-05}	11.7	194.6

Table 4-5: Fleet composite base emission factors and composite splitting factors for petrol passenger vehicles, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	0.4209	1.112	1.169	1.455	1.418	1.360
VOC	0.1857	1.128	0.834	1.027	0.606	0.520
CO	2.1130	1.279	0.621	0.866	0.533	0.606
PM_{10}	0.003719	1.082	1.001	0.999	1.094	1.194
N_2O (mg/km)	0.02306	1.076	1.119	1.430	0.972	0.782
NH_3 (mg/km)	0.04242	1.000	1.033	1.007	1.402	1.681
CO_2	201.7	1.124	0.857	0.964	0.782	0.767

Table 4-6: Petrol fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	0.9438	0.9328	0.9325
NO_x	1.0232	1.0439	1.0436
CO	0.963	0.955	0.955

Table 4-7: Petrol passenger vehicle composite fleet seasonal average daily temperature corrections

Pollutant	Residential, Arterial, Commercial Arterial Roads			Commercial Highway, Freeway/Motorway Roads		
	Summer	Autumn & Spring	Winter	Summer	Autumn & Spring	Winter
VOC	0.9392	1.0323	1.1033	0.9885	1.0061	1.0195
NO_x	0.9551	1.0238	1.0762	1.0113	0.9940	0.9808
CO	0.9666	1.0177	1.0567	1.0131	0.9931	0.9778
CO_2	0.9927	1.0039	1.0124	0.9909	1.0048	1.0154

Table 4-8: Petrol passenger vehicle composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	-1.1230×10^{-11}	4.1019×10^{-09}	-5.4729×10^{-07}	2.8306×10^{-05}	1.8821×10^{-04}	-7.1044×10^{-02}	2.4665
NO_x	8.7480×10^{-11}	-3.7285×10^{-08}	6.4252×10^{-06}	-5.7171×10^{-04}	2.7746×10^{-02}	-6.8678×10^{-01}	7.7154
CO	-1.4266×10^{-11}	5.4846×10^{-09}	-7.3651×10^{-07}	2.9377×10^{-05}	1.9513×10^{-03}	-1.8768×10^{-01}	4.3314
CO_2	1.3874×10^{-11}	-7.0180×10^{-09}	1.4027×10^{-06}	-1.4382×10^{-04}	8.2046×10^{-03}	-2.5283×10^{-01}	4.0825
PM	3.9527×10^{-11}	-1.6093×10^{-08}	2.6434×10^{-06}	-2.2318×10^{-04}	1.0400×10^{-02}	-2.5336×10^{-01}	3.4930

4.1.3.2 Cold Running

The base cold start emission factor ratios for all cold start pollutants considered excepting NH_3 were derived from the NISE2 modal data for vehicles ADR37/00 and newer. NH_3 cold start emissions were estimated from Huai et al (2003), Durbin et al (2004) and Heeb et al (2006, 2008). ADR27 vehicles were modelled using the ARTEMIS Euro 0 No-cat model (INRETS, 2007). The fleet composite cold base start emission factor ratios are given in Table 4-9 while the individual age class data is given in APPENDIX C.

The cold start parking factors (CSPF) were derived by applying the ARTEMIS model (INRETS, 2007) to the hourly parking time prior to a trip start distribution estimated from the Sydney HTS data (e.g. TDC, 2010). The parking time distributions for week days and weekend days are given in APPENDIX C. The fleet composite CSPF are given in Table 4-10. No CSPF are derived for NH_3 or N_2O.

The cold start temperature corrections (CSTC) were derived from work by Weilenmann et al (2001, 2004, 2005, 2008, 2009). The seasonal fleet composite CSTC are given in Table 4-11, Table 4-12 and Table 4-13.

Table 4-9: Fleet composite base cold start emission factor ratio – petrol passenger vehicles

Road Type	0 - 1.5 km							1.5 - 2.5 km							2.5 - 4.0 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	9.04	6.10	3.95	1.31	1.39	0.68	2.20	2.87	1.35	1.00	1.18	1.20	2.49	2.20	2.01	1.40	1.02	1.13	1.14	1.80	2.20
Arterial	10.76	9.42	5.83	1.31	1.39	0.37	2.21	3.31	1.84	1.22	1.18	1.20	2.98	2.21	2.28	1.87	1.26	1.13	1.14	2.21	2.21
Commercial Arterial	10.58	9.05	5.67	1.31	1.39	0.38	2.23	3.20	1.71	1.18	1.18	1.20	2.98	2.23	2.22	1.76	1.21	1.13	1.14	2.21	2.23
Commercial Highway	12.40	11.47	6.49	1.31	1.39	0.15	2.24	3.75	2.14	1.34	1.18	1.20	2.04	2.24	2.53	2.16	1.38	1.13	1.14	2.04	2.24

Road Type	4.0 - 5.5 km							5.5 - 7.5 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	1.27	1.36	1.01	1.04	1.04	1.07	1.05	1.01	1.12	1.00	1.02	1.02	1.00	1.05
Arterial	1.41	1.78	1.22	1.04	1.04	1.36	1.05	1.11	1.39	1.11	1.02	1.02	1.00	1.05
Commercial Arterial	1.38	1.68	1.17	1.04	1.04	1.35	1.05	1.09	1.31	1.07	1.02	1.02	1.00	1.05
Commercial Highway	1.54	2.01	1.34	1.04	1.04	1.75	1.05	1.18	1.55	1.22	1.02	1.02	1.00	1.05

Table 4-10: Fleet composite cold start parking factors – petrol passenger vehicles

Hour	THC	CO	NO_x	CO_2	FC
0	0.7026	0.7751	0.8961	0.5256	0.5256
1	0.7026	0.7751	0.8961	0.5256	0.5256
2	0.7026	0.7751	0.8961	0.5256	0.5256
3	0.7026	0.7751	0.8961	0.5256	0.5256
4	0.8061	0.9084	0.9292	0.6849	0.6849
5	0.8061	0.9084	0.9292	0.6849	0.6849
6	0.8061	0.9084	0.9292	0.6849	0.6849
7	0.7800	0.8081	0.8803	0.7273	0.7273
8	0.6644	0.6797	0.7910	0.6163	0.6163
9	0.5170	0.4747	0.7695	0.4628	0.4628
10	0.5170	0.4747	0.7695	0.4628	0.4628
11	0.4509	0.4157	0.7792	0.3350	0.3350
12	0.4509	0.4157	0.7792	0.3350	0.3350
13	0.4838	0.4816	0.7905	0.3537	0.3537
14	0.4838	0.4816	0.7905	0.3537	0.3537
15	0.4517	0.4599	0.7219	0.3518	0.3518
16	0.5170	0.5237	0.7849	0.4086	0.4086
17	0.5217	0.5212	0.7864	0.4190	0.4190
18	0.5212	0.5076	0.7986	0.4104	0.4104
19	0.4970	0.4676	0.8151	0.3582	0.3582
20	0.4970	0.4676	0.8151	0.3582	0.3582
21	0.5986	0.6206	0.8756	0.4013	0.4013
22	0.5986	0.6206	0.8756	0.4013	0.4013
23	0.5986	0.6206	0.8756	0.4013	0.4013

Table 4-11: Fleet composite cold start temperature correction – petrol passenger vehicles – summer season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	16.9	16.5	16.3	16.0	15.8	16.8	20.6	25.1	29.0	31.6	33.2	34.0	34.1	33.7	32.7	31.2	29.1	26.5	23.2	20.4	19.0	18.2	17.7	17.3
VOC	1.24	1.26	1.27	1.28	1.29	1.24	1.09	0.93	0.81	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.81	0.88	0.99	1.10	1.15	1.18	1.21	1.22
CO	1.23	1.24	1.26	1.27	1.27	1.23	1.09	0.93	0.81	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.81	0.89	0.99	1.09	1.15	1.18	1.20	1.21
NO_x	1.10	1.11	1.11	1.11	1.12	1.10	1.04	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	1.00	1.04	1.07	1.08	1.09	1.09
CO_2	1.11	1.12	1.12	1.13	1.13	1.11	1.04	0.96	0.90	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.94	1.00	1.05	1.07	1.09	1.10	1.10
FC	1.16	1.18	1.18	1.19	1.20	1.17	1.06	0.95	0.86	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.86	0.92	0.99	1.07	1.11	1.13	1.14	1.15

Table 4-12: Fleet composite cold start temperature correction – petrol passenger vehicles – autumn and spring season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	12.5	12.2	11.9	11.7	11.6	11.6	13.1	16.4	20.0	22.8	24.4	25.2	25.6	25.4	24.7	23.4	21.5	18.8	16.2	14.7	13.9	13.4	13.0	12.7
VOC	1.45	1.46	1.48	1.49	1.49	1.49	1.42	1.26	1.11	1.01	0.95	0.93	0.91	0.92	0.94	0.98	1.05	1.16	1.27	1.34	1.38	1.40	1.42	1.44
CO	1.43	1.44	1.46	1.46	1.47	1.47	1.40	1.25	1.11	1.01	0.95	0.93	0.92	0.92	0.94	0.98	1.05	1.15	1.26	1.33	1.36	1.39	1.40	1.42
NO_x	1.17	1.18	1.18	1.18	1.19	1.19	1.16	1.11	1.05	1.00	0.98	0.97	0.97	0.97	0.97	0.99	1.03	1.07	1.11	1.14	1.15	1.16	1.16	1.17
CO_2	1.20	1.21	1.21	1.22	1.22	1.22	1.19	1.12	1.05	1.00	0.98	0.96	0.96	0.96	0.97	0.99	1.03	1.08	1.13	1.16	1.17	1.18	1.19	1.20
FC	1.30	1.31	1.32	1.33	1.33	1.33	1.28	1.18	1.08	1.00	0.97	0.95	0.94	0.94	0.96	0.99	1.04	1.11	1.19	1.23	1.26	1.27	1.28	1.29

Table 4-13: Fleet composite cold start temperature correction – petrol passenger vehicles – winter season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	8.6	8.3	8.1	7.9	7.7	7.6	7.5	9.3	12.8	16.0	18.3	19.5	19.9	19.6	18.8	17.5	15.2	12.4	10.9	10.1	9.6	9.2	8.9	8.7
VOC	1.66	1.68	1.69	1.70	1.71	1.72	1.72	1.62	1.43	1.28	1.18	1.13	1.12	1.13	1.16	1.21	1.32	1.45	1.53	1.57	1.60	1.62	1.64	1.66
CO	1.63	1.65	1.66	1.67	1.68	1.69	1.69	1.59	1.41	1.27	1.17	1.12	1.11	1.12	1.15	1.21	1.30	1.43	1.51	1.55	1.57	1.60	1.61	1.63
NO_x	1.24	1.24	1.24	1.25	1.25	1.25	1.25	1.22	1.17	1.11	1.08	1.06	1.05	1.06	1.07	1.09	1.13	1.17	1.20	1.21	1.22	1.23	1.23	1.23
CO_2	1.28	1.29	1.30	1.30	1.30	1.31	1.31	1.27	1.19	1.13	1.09	1.06	1.06	1.06	1.08	1.10	1.15	1.20	1.23	1.25	1.26	1.27	1.28	1.28
FC	1.43	1.44	1.45	1.46	1.46	1.47	1.47	1.41	1.29	1.19	1.12	1.09	1.08	1.09	1.11	1.15	1.22	1.30	1.35	1.38	1.40	1.41	1.42	1.43

4.1.3.3 Speciation Profiles

The VOC speciation profile for petrol passenger vehicles is derived from data generated by the commonwealth ethanol health impacts study (CSIRO & Orbital, 2008), whilst SVOC not included in the CSIRO study, PAH and PM inorganics speciation is derived from the US Gasoline/Diesel PM Split study (Fujita et. al., 2006). The speciation profile for the substances reported in this section is shown in Table 4-14, whilst the full speciation profile is given in APPENDIX D.

Table 4-14: Petrol vehicle speciation data for selected compounds

Substance	Petrol no ethanol (E0)		E10 Petrol (E10)	
	Mass fraction (% VOC)	Mass fraction (% PM_{10})	Mass fraction (% VOC)	Mass fraction (% PM_{10})
1,3 butadiene	1.265047	N/A	1.198678	N/A
Acetaldehyde	0.475506	N/A	1.291372	N/A
Benzene	4.952975	N/A	4.539592	N/A
Formaldehyde	1.4642	N/A	1.815354	N/A
Isomers of xylene	7.596421	N/A	7.22157	N/A
Lead & compounds	N/A	0.035375	N/A	0.035375
Particulate matter ≤ 2.5 µm	N/A	95.3	N/A	95.3
Polycyclic aromatic hydrocarbons	0.560292	37.218	0.560292	37.218
Toluene	9.178649	N/A	8.787243	N/A
Total suspended particulate	N/A	100	N/A	100

4.1.4 Emission Estimates

Estimated emissions from the source type *petrol passenger vehicle exhaust* within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-15.

Table 4-15: Estimated exhaust emissions from source type petrol passenger vehicle exhaust

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	98.0	6.75	3.69	12.9	121
ACETALDEHYDE	43.8	3.02	1.65	5.78	54.2
BENZENE	382	26.3	14.4	50.5	474
CARBON MONOXIDE	75,067	4,997	2,861	10,512	93,437
FORMALDEHYDE	117	8.06	4.40	15.4	145
ISOMERS OF XYLENE	589	40.5	22.2	77.7	729
LEAD & COMPOUNDS	0.033	0.0026	0.0015	0.0061	0.043
OXIDES OF NITROGEN	21,575	1,666	938	3,336	27,515
PARTICULATE MATTER ≤ 10 µm	92.3	7.27	4.14	17.2	121
PARTICULATE MATTER ≤ 2.5 µm	87.9	6.93	3.95	16.4	115
POLYCYCLIC AROMATIC HYDROCARBONS	39.0	2.86	1.59	6.08	49.5
SULFUR DIOXIDE	144	9.73	5.15	21.8	181
TOLUENE	712	49.0	26.8	94.0	881
TOTAL SUSPENDED PARTICULATE	92.3	7.27	4.14	17.2	121
TOTAL VOLATILE ORGANIC COMPOUNDS	7,789	537	293	1,029	9,647

The monthly profile for the base emission species is given in Table 4-16, the weekly profile is given in Table 4-17, and the daily profile is shown in Table 4-18. The speciated compounds have the same profile as the base emission species; i.e. all speciated exhaust VOC have the same profile as the total VOC, speciated PM metals and inorganic compounds share the exhaust PM_{10} profiles.

Table 4-16: Monthly profile for exhaust emissions from petrol passenger vehicles

Month	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
1	0.06637	0.07107	0.07380	0.07948	0.07010	0.07836	0.07948	0.07948
2	0.06579	0.07046	0.07317	0.07879	0.06949	0.07769	0.07879	0.07879
3	0.08146	0.08384	0.08552	0.08810	0.08572	0.08759	0.08810	0.08810
4	0.08317	0.08291	0.08329	0.08245	0.08726	0.08261	0.08245	0.08245
5	0.08790	0.08763	0.08803	0.08715	0.09223	0.08732	0.08715	0.08715
6	0.09599	0.09020	0.08596	0.07985	0.08425	0.08106	0.07985	0.07985
7	0.10045	0.09439	0.08995	0.08356	0.08817	0.08482	0.08356	0.08356
8	0.10170	0.09556	0.09106	0.08460	0.08926	0.08587	0.08460	0.08460
9	0.08341	0.08315	0.08353	0.08269	0.08751	0.08285	0.08269	0.08269
10	0.08645	0.08618	0.08658	0.08571	0.09070	0.08587	0.08571	0.08571
11	0.07798	0.08035	0.08200	0.08459	0.08206	0.08408	0.08459	0.08459
12	0.06934	0.07426	0.07712	0.08304	0.07324	0.08188	0.08304	0.08304

Table 4-17: Weekly profile for exhaust emissions from petrol passenger vehicles

Days	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
Weekdays	0.75066	0.75206	0.74477	0.74625	0.74828	0.74816	0.74633	0.74527
Weekend days	0.24934	0.24794	0.25523	0.25375	0.25172	0.25184	0.25367	0.25473

Table 4-18: Daily profile for exhaust emissions from petrol passenger vehicles

Hour	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
0	0.00795	0.00783	0.00712	0.00664	0.00605	0.00601	0.00642	0.00645
1	0.00376	0.00370	0.00334	0.00308	0.00281	0.00279	0.00297	0.00300
2	0.00243	0.00238	0.00213	0.00195	0.00177	0.00176	0.00187	0.00190
3	0.00167	0.00162	0.00144	0.00129	0.00118	0.00117	0.00124	0.00127
4	0.00796	0.00777	0.00632	0.00570	0.00532	0.00526	0.00550	0.00555
5	0.02650	0.02584	0.02096	0.01910	0.01805	0.01787	0.01865	0.01864
6	0.04852	0.04757	0.03845	0.03557	0.03472	0.03443	0.03525	0.03512
7	0.08974	0.08880	0.07199	0.07087	0.07635	0.07598	0.07145	0.06946
8	0.10337	0.10863	0.09193	0.09430	0.10428	0.10421	0.09435	0.09161
9	0.05408	0.05246	0.05594	0.05607	0.05646	0.05649	0.05647	0.05785
10	0.04693	0.04531	0.05029	0.05063	0.04963	0.04968	0.05077	0.05211
11	0.04589	0.04537	0.05329	0.05374	0.05239	0.05254	0.05396	0.05534
12	0.04281	0.04224	0.05030	0.05071	0.04900	0.04915	0.05083	0.05218
13	0.04482	0.04499	0.05163	0.05180	0.05026	0.05041	0.05197	0.05332
14	0.05022	0.05070	0.05652	0.05671	0.05606	0.05622	0.05709	0.05849
15	0.07042	0.07375	0.07804	0.08212	0.08278	0.08304	0.08267	0.08203
16	0.07803	0.08064	0.08186	0.08353	0.08529	0.08546	0.08407	0.08336
17	0.09160	0.09386	0.09154	0.09282	0.09630	0.09639	0.09343	0.09253
18	0.06550	0.06377	0.06664	0.06712	0.06529	0.06528	0.06720	0.06650
19	0.03939	0.03730	0.04173	0.04109	0.03793	0.03791	0.04058	0.04025
20	0.02383	0.02252	0.02536	0.02474	0.02241	0.02239	0.02417	0.02408
21	0.02135	0.02072	0.02088	0.01984	0.01798	0.01794	0.01932	0.01927
22	0.02218	0.02152	0.02157	0.02048	0.01856	0.01852	0.01994	0.01988
23	0.01104	0.01071	0.01073	0.01013	0.00912	0.00910	0.00981	0.00982

The contribution of cold start extra emissions to the total exhaust emissions for petrol passenger vehicles is shown in Figure 4-3.

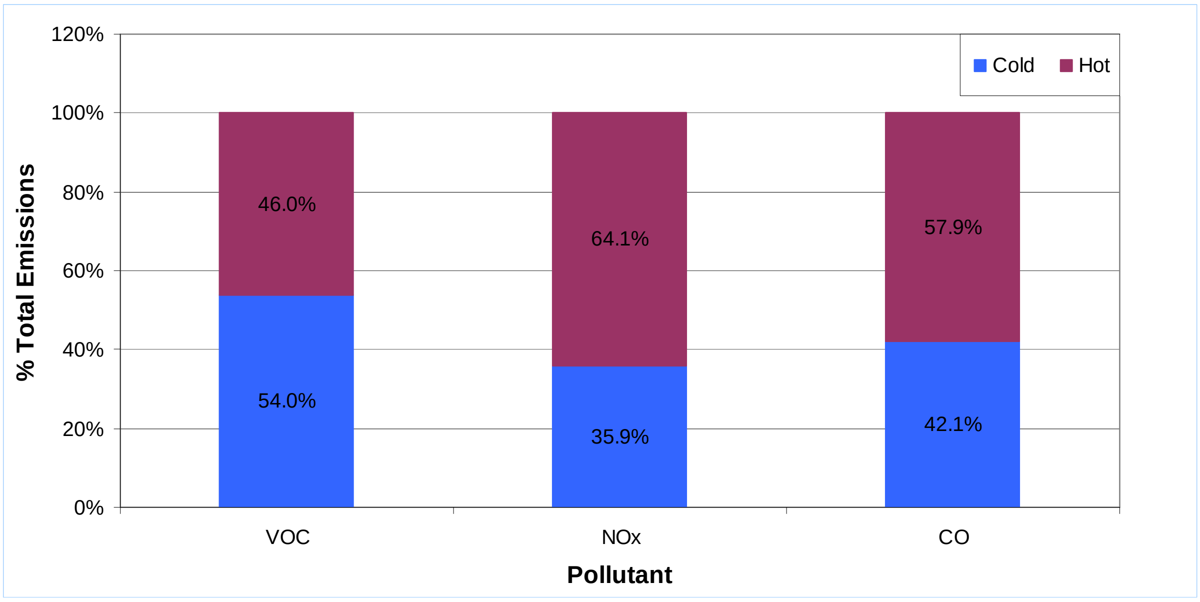

Figure 4-3: Contribution of cold running emissions to total petrol passenger vehicle emissions

4.2 Exhaust Emissions from Light Duty Diesel Vehicles

4.2.1 Fleet Profile

The fleet age profile for the individual vehicle types comprising the light duty diesel vehicle source type and the VKT per annum profile are shown in Table 4-19.

Table 4-19: Light duty diesel vehicle fleet profile, 2008

YOM	Diesel Cars	Diesel 4WD	VKT per Annum	Profile (%)	Diesel LCV	VKT per Annum	Profile (%)
2008	8,670	10,242	9,650	26.690%	14,914	12,963	15.202%
2007	4,639	6,381	18,407	15.553%	13,370	24,884	13.628%
2006	3,115	5,101	17,589	11.595%	11,585	23,882	11.808%
2005	1,252	4,045	16,840	7.476%	6,971	22,917	7.105%
2004	313	3,619	16,157	5.549%	5,600	21,988	5.708%
2003	306	3,089	15,533	4.791%	4,231	21,093	4.312%
2002	211	2,710	14,964	4.123%	3,666	20,229	3.736%
2001	160	2,385	14,446	3.592%	2,542	19,396	2.591%
2000	95	2,040	13,974	3.013%	2,796	18,591	2.850%
1999	71	1,661	13,542	2.444%	2,645	17,813	2.696%
1998	86	1,576	13,146	2.345%	2,534	17,060	2.583%
1997	54	1,346	12,782	1.976%	2,218	16,329	2.261%
1996	72	1,146	12,444	1.719%	2,178	15,620	2.220%
1995	126	1,109	12,127	1.742%	2,220	14,930	2.262%
1994	168	1,081	11,828	1.764%	2,312	14,258	2.357%
1993	162	895	11,540	1.493%	2,157	13,602	2.198%
1992	197	783	11,259	1.384%	2,587	12,959	2.636%
1991	43	329	10,981	0.526%	2,499	12,329	2.547%
1990	25	264	10,701	0.408%	2,499	11,709	2.547%
1989	38	230	10,413	0.378%	2,058	11,098	2.098%
1988	31	165	10,113	0.276%	1,387	10,494	1.413%
1987	16	58	9,797	0.106%	738	9,894	0.752%
1986	22	89	9,459	0.156%	1,064	9,298	1.084%
1985	19	108	9,094	0.180%	1,378	8,703	1.405%
1984	24	88	8,699	0.159%	819	8,108	0.835%
1983	21	36	8,267	0.080%	334	7,511	0.340%
1982	23	40	7,794	0.089%	329	6,909	0.336%
1981	76	33	7,276	0.154%	289	6,302	0.295%
1980	60	14	6,708	0.105%	115	5,687	0.117%
1979	18	5	6,084	0.033%	30	5,300	0.030%
1978	17	3	5,400	0.028%	18	4,600	0.018%
1977	10	2	4,652	0.017%	7	4,000	0.007%
1976	10	2	3,834	0.017%	5	3,500	0.005%
1975	3	1	2,941	0.006%	2	3,000	0.002%
≤ 1974	18	7	1,970	0.034%	15	2,500	0.015%

[1] – Vehicles assumed to enter fleet evenly across year, hence average annual mileage is 50% of new vehicle

4.2.2 VKT Data

The total 2008 GMR VKT for diesel passenger vehicles on an average week day and average weekend day are given in Table 4-20 and the hourly profile is shown graphically in Figure 4-4. It is assumed that diesel and petrol passenger vehicles have the same usage patterns and annual VKT per vehicle, and hence have identical hourly VKT profile. The total 2008 GMR VKT for diesel LCV vehicles on an average week day and average weekend day are given in Table 4-21 and the hourly profile is shown graphically in Figure 4-5. The average speeds by hour of the day for each road type are given previously in Table 4-3.

Table 4-20: Diesel passenger vehicle average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	9,928	0.42%	25,704	1.28%
1	4,464	0.19%	12,250	0.61%
2	3,028	0.13%	7,197	0.36%
3	2,372	0.10%	3,844	0.19%
4	13,215	0.56%	10,308	0.51%
5	50,171	2.13%	21,273	1.06%
6	97,649	4.14%	33,591	1.68%
7	197,261	8.36%	71,606	3.57%
8	246,177	10.44%	131,951	6.58%
9	132,065	5.60%	116,614	5.82%
10	108,200	4.59%	130,814	6.53%
11	110,887	4.70%	149,476	7.46%
12	104,409	4.43%	140,743	7.02%
13	109,802	4.66%	136,265	6.80%
14	127,369	5.40%	133,101	6.64%
15	194,217	8.24%	168,386	8.40%
16	199,972	8.48%	165,177	8.24%
17	223,914	9.49%	179,579	8.96%
18	161,583	6.85%	125,550	6.27%
19	95,963	4.07%	79,073	3.95%
20	55,871	2.37%	50,284	2.51%
21	44,332	1.88%	41,052	2.05%
22	44,694	1.90%	45,007	2.25%
23	20,837	0.88%	25,088	1.25%
Total	**2,358,380**		**2,003,930**	

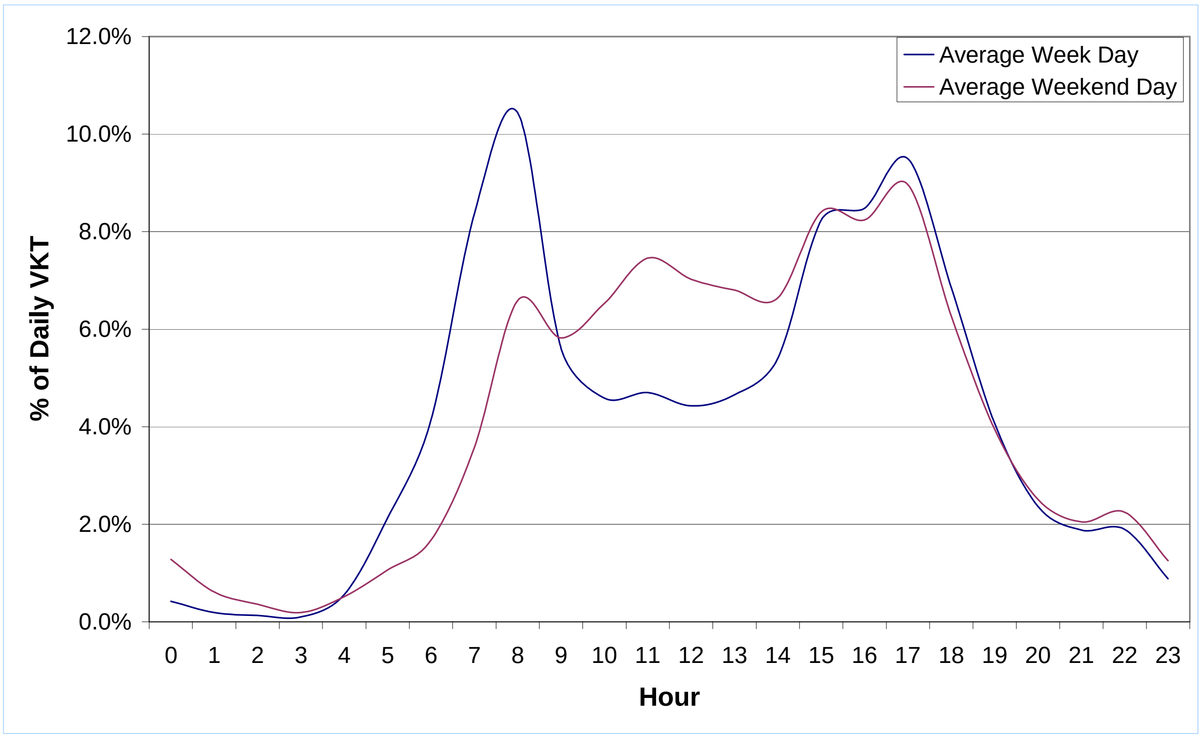

Figure 4-4: Diesel passenger vehicle diurnal VKT profiles

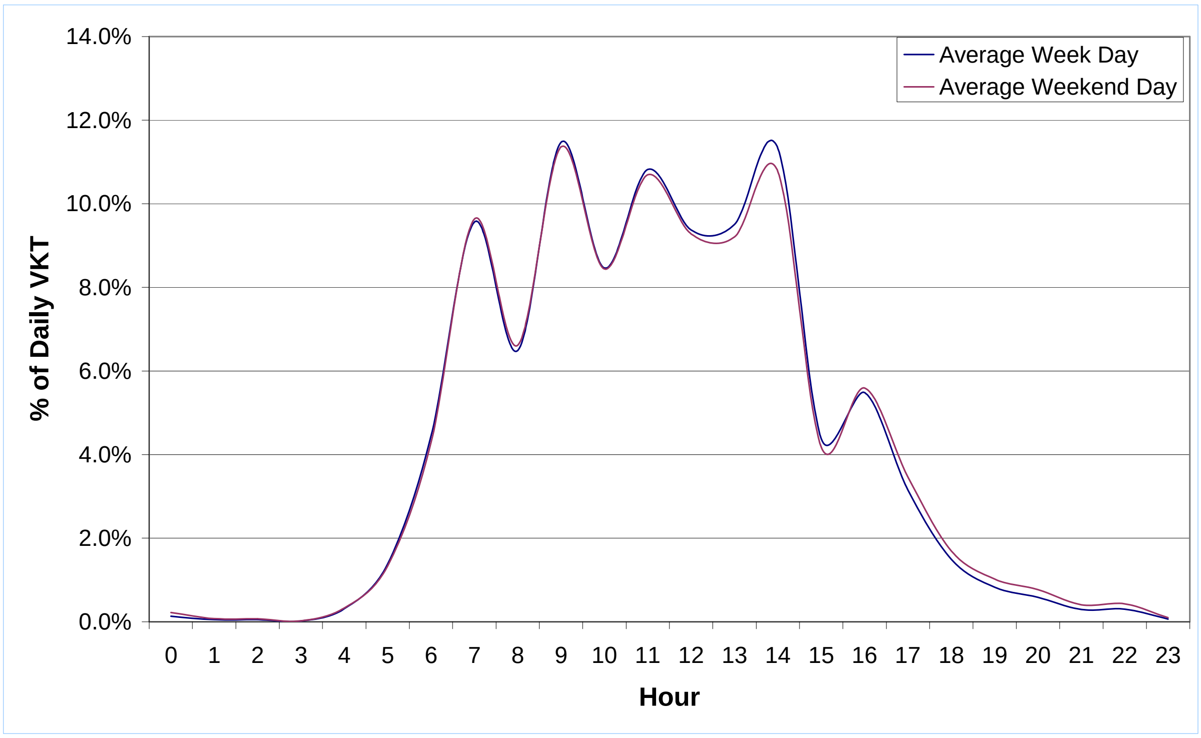

Figure 4-5: Diesel LCV diurnal VKT profiles

Table 4-21: Diesel LCV average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	6,464	0.13%	6,205	0.22%
1	2,514	0.05%	2,112	0.08%
2	2,647	0.05%	1,946	0.07%
3	1,007	0.02%	688	0.02%
4	15,249	0.31%	9,210	0.33%
5	67,938	1.38%	37,094	1.33%
6	218,278	4.44%	119,398	4.29%
7	469,662	9.56%	268,177	9.63%
8	318,587	6.49%	184,144	6.61%
9	563,636	11.47%	316,200	11.36%
10	415,799	8.46%	234,926	8.44%
11	531,570	10.82%	297,679	10.69%
12	460,480	9.37%	258,330	9.28%
13	466,896	9.50%	256,326	9.21%
14	556,526	11.33%	299,967	10.77%
15	215,056	4.38%	116,345	4.18%
16	269,435	5.49%	155,733	5.59%
17	154,904	3.15%	96,505	3.47%
18	73,402	1.49%	47,124	1.69%
19	40,623	0.83%	28,436	1.02%
20	28,786	0.59%	21,474	0.77%
21	14,508	0.30%	11,288	0.41%
22	14,970	0.30%	11,946	0.43%
23	3,247	0.07%	2,702	0.10%
Total	**4,912,186**		**2,783,956**	

4.2.3 Emission Factors

4.2.3.1 Hot Running

Base hot running exhaust emission factors for light duty diesel vehicles were estimated from a number of sources as the available Australian data is limited. Diesel passenger car emission factors were estimated from the European COPERT, ARTEMIS and UK National Air Emissions Inventory emission factors as Australian measurements are limited to 8 vehicles tested in the South Australia Test & Repair program.

Diesel 4WD emission factors for vehicles up to ADR79/00 are estimated from the South Australia test & Repair program for NO_x and CO, with THC and PM being estimated from the European models. ADR79/02 emission factors are scaled from the ADR79/00 by the ratio of Euro 4 to Euro 2 predicted by the European models. N_2O and NH_3 are estimated from the COPERT4 model.

For each age group, the car and 4WD emission factors derived are combined as a weighted average by proportion of the cars and SUV's, and are given in Table 4-22. These base emission factors relate to an ambient temperature of 23.0°C and the base diesel properties given in Table 3-18.

Diesel LCV emission factors were estimated from the South Australia test & repair program for NO_x and CO, with THC and PM being estimated from the European models (Zito & Markov, 2008). The age class base exhaust emission factors are given in Table 4-24. These base emission factors relate to an ambient temperature of 23.0°C and the base diesel properties given in Table 3-18.

Fleet composite emission factors and splitting factors are given in Table 4-23 and Table 4-25 for diesel passenger vehicles and diesel LCV respectively.

Fuel adjustment factors applied to the 2008 base year to correct for differences between the 2008 Sydney average diesel fuel properties and the inventory base fuels (see Table 3-18) are given in Table 4-26. Seasonal ambient temperature corrections applicable to both vehicle types are given in Table 4-27 and the coefficients for the fleet composite 6th order speed correct function are given in Table 4-28 and Table 4-29 for diesel passenger vehicles and diesel LCV respectively.

Table 4-22: Base hot running exhaust emission factors for diesel passenger vehicles

Emission Age Class	ADR	NOx	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	Pre - ADR70	1.514	0.202	0.791	0.1945	0	1.0	276.2
1986	Pre - ADR70	1.514	0.202	0.791	0.1945	0	1.0	268.7
1993	Pre - ADR70	1.514	0.202	0.791	0.1945	2.205	1.0	264.0
1996	ADR70/00	1.035	0.101	0.521	0.0955	4.205	1.0	262.0
2003	ADR79/00	1.006	0.115	0.240	0.0498	8.488	1.0	233.0
2007	ADR79/01	0.795	0.028	0.051	0.0202	8.488	1.0	206.0
2010	ADR79/02	0.772	0.027	0.049	0.0214	8.488	1.0	196.7

Table 4-23: Fleet composite base emission factor and composite splitting factors for diesel passenger vehicles, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	0.9665	1.081	1.021	1.172	1.065	1.065
VOC	0.0850	1.129	0.781	0.818	0.533	0.467
CO	0.2597	1.314	0.864	1.055	0.864	0.765
PM_{10}	0.0574	1.160	0.853	0.937	0.765	0.746
N_2O (mg/km)	7.07	1.000	0.840	0.871	0.622	0.587
NH_3 (mg/km)	1.00	1.000	1.000	1.000	1.000	1.000
CO_2	228.2	1.085	0.918	1.006	0.838	0.789

Table 4-24: Base hot running exhaust emission factors for diesel LCV

Emission Age Class	ADR	NOx	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	Pre - ADR70	1.801	0.207	0.808	0.500	0	1.0	291.0
1985	Pre - ADR70	1.801	0.207	0.808	0.400	0	1.0	283.8
1988	Pre - ADR70	1.801	0.207	0.808	0.400	0	1.0	281.7
1991	Pre - ADR70	1.801	0.207	0.808	0.3075	0	1.0	279.6
1994	Pre - ADR70	1.801	0.207	0.808	0.3075	2.205	1.0	274.4
1996	ADR70/00	1.906	0.132	0.585	0.1122	4.205	1.0	266.8
2003	ADR79/00	1.077	0.108	0.383	0.1033	8.488	1.0	263.0
2007	ADR79/01	0.969	0.049	0.181	0.0407	8.488	1.0	251.2
2010	ADR79/02	0.969	0.049	0.181	0.0407	8.488	1.0	242.7

Table 4-25: Fleet composite base emission factor and composite splitting factors for diesel LCV, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	1.311	1.129	0.910	0.990	0.897	0.904
VOC	0.1101	1.138	0.775	0.824	0.516	0.432
CO	0.4257	1.179	0.929	1.108	0.870	0.775
PM_{10}	0.1255	1.219	0.968	1.243	1.081	1.014
N_2O (mg/km)	6.396	1.000	0.845	0.875	0.635	0.600
NH_3 (mg/km)	1.00	1.000	1.000	1.000	1.000	1.000
CO_2	264.2	1.085	0.906	0.975	0.818	0.773

Table 4-26: Light duty diesel vehicle fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	0.895	0.895	0.895
NO_x	0.996	0.996	0.996
CO	0.897	0.897	0.897
PM_{10}	1.070	1.070	1.070

Table 4-27: Diesel passenger vehicle and LCV seasonal average daily temperature corrections

Pollutant	Residential, Arterial, Commercial Arterial Roads			Commercial Highway, Freeway/Motorway Roads		
	Summer	Autumn & Spring	Winter	Summer	Autumn & Spring	Winter
VOC	0.8615	1.0735	1.2351	0.8383	1.0858	1.2746
NO_x	0.9924	1.0040	1.0129	0.9924	1.0040	1.0129
CO	0.8261	1.0923	1.2952	0.6137	1.2050	1.6558
CO_2	0.9923	1.0041	1.0131	0.9913	1.0046	1.0148

Table 4-28: Diesel passenger vehicle composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	5.9266×10^{-11}	-2.3695×10^{-08}	3.7998×10^{-06}	-3.1343×10^{-04}	1.4230×10^{-02}	-3.5377×10^{-01}	4.6074
NO_x	5.2497×10^{-11}	-2.1600×10^{-08}	3.5922×10^{-06}	-3.0755×10^{-04}	1.4488×10^{-02}	-3.5763×10^{-01}	4.5266
CO	2.5217×10^{-10}	-1.0603×10^{-07}	1.7980×10^{-05}	-1.5696×10^{-03}	7.4320×10^{-02}	-1.8124	$1.8642 \times 10^{+01}$
CO_2	1.4013×10^{-11}	-6.5721×10^{-09}	1.2519×10^{-06}	-1.2380×10^{-04}	6.7554×10^{-03}	-1.9725×10^{-01}	3.3002
PM	1.0198×10^{-10}	-4.1592×10^{-08}	6.8910×10^{-06}	-5.8930×10^{-04}	2.7538×10^{-02}	-6.7585×10^{-01}	7.6851

Table 4-29: Diesel LCV composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	6.4276×10^{-11}	-2.5948×10^{-08}	4.2073×10^{-06}	-3.5108×10^{-04}	1.6079×10^{-02}	-3.9972×10^{-01}	5.0809
NO_x	7.5553×10^{-11}	-3.1508×10^{-08}	5.3099×10^{-06}	-4.6166×10^{-04}	2.1995×10^{-02}	-5.4876×10^{-01}	6.4913
CO	1.2346×10^{-10}	-5.1475×10^{-08}	8.6514×10^{-06}	-7.4877×10^{-04}	3.5265×10^{-02}	-8.6250×10^{-01}	9.4499
CO_2	1.4013×10^{-11}	-6.5721×10^{-09}	1.2519×10^{-06}	-1.2380×10^{-04}	6.7554×10^{-03}	-1.9725×10^{-01}	3.3002
PM	1.1144×10^{-10}	-4.8434×10^{-08}	8.5368×10^{-06}	-7.7876×10^{-04}	3.8828×10^{-02}	-1.0014	$1.1317 \times 10^{+01}$

4.2.3.2 Cold Running

The base cold start emission factor ratios for all cold start pollutants considered were derived from the ARTEMIS cold start model 1 (INRETS, 2007). No cold start effect is considered for NH_3 or N_2O. The fleet composite base cold start emission factor ratios are given in Table 4-30 and Table 4-31 for diesel passenger vehicles and diesel LCV respectively. The individual age class data is given in APPENDIX C.

The cold start parking factors (CSPF) were derived by applying the ARTEMIS model (INRETS, 2007) to the hourly parking time prior to a trip start distribution derived from the Sydney HTS data (TDC, 2010). The parking time distributions for week days and weekend days are given in APPENDIX C. The fleet composite CSPF are given in Table 4-32 and Table 4-33 for diesel passenger vehicles and diesel LCV's respectively. No CSPF are derived for NH_3 or N_2O.

The cold start temperature corrections were derived from work by Weilenmann et al (2001, 2004, 2005, 2008, 2009). No temperature correction is made for NO_x. The seasonal fleet composite CSTC are given in Table 4-34, Table 4-35 and Table 4-36 for diesel passenger vehicles, and in Table 4-37, Table 4-38 and Table 4-39 for diesel LCV.

Table 4-30: Fleet composite base cold start emission factor ratio – diesel passenger vehicles

Road Type	0 - 1.5 km							1.5 - 2.5 km							2.5 - 4.0 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	3.14	4.42	1.03	1.27	1.27	1.0	1.0	1.59	1.73	1.02	1.14	1.14	1.0	1.0	1.24	1.22	1.01	1.08	1.08	1.0	1.0
Arterial	3.85	4.88	1.14	1.33	1.33	1.0	1.0	1.73	1.94	1.09	1.18	1.18	1.0	1.0	1.27	1.28	1.06	1.10	1.10	1.0	1.0
Commercial Arterial	3.68	4.58	1.14	1.32	1.32	1.0	1.0	1.69	1.87	1.09	1.17	1.17	1.0	1.0	1.26	1.27	1.06	1.09	1.09	1.0	1.0
Commercial Highway	4.95	8.60	1.14	1.36	1.36	1.0	1.0	2.00	2.68	1.09	1.20	1.20	1.0	1.0	1.36	1.45	1.06	1.11	1.11	1.0	1.0

Road Type	4.0 - 5.5 km							5.5 - 7.5 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	1.11	1.07	1.00	1.04	1.04	1.0	1.0	1.05	1.02	1.00	1.02	1.02	1.0	1.0
Arterial	1.11	1.07	1.03	1.05	1.05	1.0	1.0	1.05	1.02	1.01	1.02	1.02	1.0	1.0
Commercial Arterial	1.11	1.07	1.03	1.05	1.05	1.0	1.0	1.05	1.02	1.01	1.02	1.02	1.0	1.0
Commercial Highway	1.14	1.10	1.03	1.05	1.05	1.0	1.0	1.07	1.02	1.01	1.02	1.02	1.0	1.0

Table 4-31: Fleet composite base cold start emission factor ratio – diesel LCV

Road Type	0 - 1.5 km							1.5 - 2.5 km							2.5 - 4.0 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	3.22	4.37	1.04	1.28	1.28	1.0	1.0	1.70	1.72	1.03	1.15	1.15	1.0	1.0	1.32	1.22	1.01	1.08	1.08	1.0	1.0
Arterial	3.85	4.74	1.12	1.33	1.33	1.0	1.0	1.83	1.89	1.08	1.18	1.18	1.0	1.0	1.35	1.27	1.05	1.10	1.10	1.0	1.0
Commercial Arterial	3.69	4.25	1.12	1.32	1.32	1.0	1.0	1.78	1.80	1.08	1.17	1.17	1.0	1.0	1.32	1.25	1.05	1.10	1.10	1.0	1.0
Commercial Highway	4.92	6.56	1.12	1.36	1.36	1.0	1.0	2.11	2.32	1.08	1.20	1.20	1.0	1.0	1.45	1.39	1.05	1.11	1.11	1.0	1.0

Road Type	4.0 - 5.5 km							5.5 - 7.5 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	1.15	1.07	1.00	1.04	1.04	1.0	1.0	1.07	1.02	1.00	1.02	1.02	1.0	1.0
Arterial	1.16	1.06	1.03	1.05	1.05	1.0	1.0	1.08	1.02	1.01	1.02	1.02	1.0	1.0
Commercial Arterial	1.14	1.06	1.03	1.05	1.05	1.0	1.0	1.07	1.02	1.01	1.02	1.02	1.0	1.0
Commercial Highway	1.20	1.09	1.03	1.05	1.05	1.0	1.0	1.10	1.02	1.01	1.02	1.02	1.0	1.0

Table 4-32: Fleet composite cold start parking factors – diesel passenger vehicles

Hour	THC	CO	NO_x	CO_2	FC
0	0.4394	0.7927	0.3121	0.7340	0.7340
1	0.4394	0.7927	0.3121	0.7340	0.7340
2	0.4394	0.7927	0.3121	0.7340	0.7340
3	0.4394	0.7927	0.3121	0.7340	0.7340
4	0.6911	0.9091	0.6996	0.9030	0.9030
5	0.6911	0.9091	0.6996	0.9030	0.9030
6	0.6911	0.9091	0.6996	0.9030	0.9030
7	0.7341	0.8102	0.7826	0.8067	0.8067
8	0.6015	0.6830	0.6370	0.6785	0.6785
9	0.3700	0.4850	0.3460	0.4747	0.4747
10	0.3700	0.4850	0.3460	0.4747	0.4747
11	0.2071	0.4344	0.1411	0.4036	0.4036
12	0.2071	0.4344	0.1411	0.4036	0.4036
13	0.2343	0.4982	0.1473	0.4617	0.4617
14	0.2343	0.4982	0.1473	0.4617	0.4617
15	0.2536	0.4710	0.1968	0.4481	0.4481
16	0.3182	0.5355	0.2735	0.5134	0.5134
17	0.3307	0.5327	0.2953	0.5122	0.5122
18	0.3068	0.5224	0.2505	0.4955	0.4955
19	0.2337	0.4881	0.1624	0.4542	0.4542
20	0.2337	0.4881	0.1624	0.4542	0.4542
21	0.2749	0.6480	0.1489	0.5839	0.5839
22	0.2749	0.6480	0.1489	0.5839	0.5839
23	0.2749	0.6480	0.1489	0.5839	0.5839

Table 4-33: Fleet composite cold start parking factors – diesel LCV

Hour	THC	CO	NO_x	CO_2	FC
0	0.3910	0.7084	0.2776	0.6560	0.6560
1	0.3910	0.7084	0.2776	0.6560	0.6560
2	0.3910	0.7084	0.2776	0.6560	0.6560
3	0.3910	0.7084	0.2776	0.6560	0.6560
4	0.6559	0.8638	0.6640	0.8582	0.8582
5	0.6559	0.8638	0.6640	0.8582	0.8582
6	0.6559	0.8638	0.6640	0.8582	0.8582
7	0.2690	0.4147	0.2511	0.4025	0.4025
8	0.2417	0.4106	0.2100	0.3935	0.3935
9	0.1342	0.3219	0.0867	0.3026	0.3026
10	0.1342	0.3219	0.0867	0.3026	0.3026
11	0.1067	0.2966	0.0578	0.2774	0.2774
12	0.1067	0.2966	0.0578	0.2774	0.2774
13	0.0892	0.2759	0.0433	0.2562	0.2562
14	0.0892	0.2759	0.0433	0.2562	0.2562
15	0.1428	0.4160	0.0511	0.3782	0.3782
16	0.1957	0.4996	0.0911	0.4554	0.4554
17	0.2212	0.5089	0.1233	0.4666	0.4666
18	0.2316	0.5095	0.1344	0.4714	0.4714
19	0.2213	0.5186	0.1133	0.4755	0.4755
20	0.2213	0.5186	0.1133	0.4755	0.4755
21	0.2477	0.5679	0.1278	0.5160	0.5160
22	0.2477	0.5679	0.1278	0.5160	0.5160
23	0.2477	0.5679	0.1278	0.5160	0.5160

Table 4-34: Fleet composite cold start temperature correction – diesel passenger vehicles – summer season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	16.9	16.5	16.3	16.0	15.8	16.8	20.6	25.1	29.0	31.6	33.2	34.0	34.1	33.7	32.7	31.2	29.1	26.5	23.2	20.4	19.0	18.2	17.7	17.3
VOC	1.21	1.23	1.24	1.24	1.25	1.22	1.09	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.99	1.09	1.14	1.17	1.19	1.20
CO	1.16	1.17	1.18	1.19	1.19	1.17	1.07	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.99	1.07	1.11	1.13	1.14	1.15
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.26	1.27	1.29	1.30	1.30	1.26	1.10	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.98	1.11	1.17	1.20	1.22	1.24
FC	1.26	1.27	1.29	1.30	1.30	1.26	1.10	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.98	1.11	1.17	1.20	1.22	1.24

Table 4-35: Fleet composite cold start temperature correction – diesel passenger vehicles – autumn and spring season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	12.5	12.2	11.9	11.7	11.6	11.6	13.1	16.4	20.0	22.8	24.4	25.2	25.6	25.4	24.7	23.4	21.5	18.8	16.2	14.7	13.9	13.4	13.0	12.7
VOC	1.37	1.38	1.39	1.40	1.40	1.40	1.35	1.23	1.10	1.01	0.95	0.93	0.93	0.93	0.94	0.98	1.05	1.15	1.24	1.29	1.32	1.34	1.35	1.36
CO	1.28	1.29	1.30	1.30	1.31	1.31	1.27	1.18	1.08	1.00	0.96	0.94	0.94	0.94	0.95	0.99	1.04	1.11	1.18	1.22	1.25	1.26	1.27	1.28
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.45	1.46	1.48	1.48	1.49	1.49	1.42	1.28	1.12	1.00	0.93	0.90	0.90	0.90	0.92	0.97	1.06	1.18	1.29	1.36	1.39	1.41	1.43	1.44
FC	1.45	1.46	1.48	1.48	1.49	1.49	1.42	1.28	1.12	1.00	0.93	0.90	0.90	0.90	0.92	0.97	1.06	1.18	1.29	1.36	1.39	1.41	1.43	1.44

Table 4-36: Fleet composite cold start temperature correction – diesel passenger vehicles – winter season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	8.6	8.3	8.1	7.9	7.7	7.6	7.5	9.3	12.8	16.0	18.3	19.5	19.9	19.6	18.8	17.5	15.2	12.4	10.9	10.1	9.6	9.2	8.9	8.7
VOC	1.51	1.52	1.53	1.53	1.54	1.54	1.54	1.48	1.36	1.25	1.16	1.12	1.11	1.12	1.15	1.19	1.27	1.37	1.43	1.45	1.47	1.49	1.50	1.50
CO	1.39	1.40	1.40	1.41	1.41	1.42	1.42	1.37	1.28	1.19	1.13	1.09	1.08	1.09	1.11	1.15	1.21	1.29	1.33	1.35	1.36	1.37	1.38	1.39
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.62	1.63	1.64	1.65	1.66	1.66	1.67	1.59	1.44	1.30	1.20	1.14	1.13	1.14	1.17	1.23	1.33	1.46	1.52	1.55	1.58	1.59	1.61	1.62
FC	1.62	1.63	1.64	1.65	1.66	1.66	1.67	1.59	1.44	1.30	1.20	1.14	1.13	1.14	1.17	1.23	1.33	1.46	1.52	1.55	1.58	1.59	1.61	1.62

Table 4-37: Fleet composite cold start temperature correction – diesel LCV – summer season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	16.9	16.5	16.3	16.0	15.8	16.8	20.6	25.1	29.0	31.6	33.2	34.0	34.1	33.7	32.7	31.2	29.1	26.5	23.2	20.4	19.0	18.2	17.7	17.3
VOC	1.21	1.22	1.23	1.24	1.25	1.21	1.08	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.99	1.09	1.14	1.17	1.18	1.20
CO	1.18	1.19	1.20	1.21	1.22	1.19	1.07	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.99	1.08	1.12	1.14	1.16	1.17
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.25	1.27	1.28	1.29	1.30	1.26	1.10	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.98	1.10	1.16	1.20	1.22	1.23
FC	1.25	1.27	1.28	1.29	1.30	1.26	1.10	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.98	1.10	1.16	1.20	1.22	1.23

Table 4-38: Fleet composite cold start temperature correction – diesel LCV – autumn and spring season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	12.5	12.2	11.9	11.7	11.6	11.6	13.1	16.4	20.0	22.8	24.4	25.2	25.6	25.4	24.7	23.4	21.5	18.8	16.2	14.7	13.9	13.4	13.0	12.7
VOC	1.36	1.37	1.38	1.39	1.39	1.39	1.34	1.23	1.10	1.01	0.95	0.93	0.93	0.93	0.94	0.98	1.05	1.14	1.23	1.29	1.31	1.33	1.34	1.35
CO	1.32	1.33	1.33	1.34	1.34	1.34	1.30	1.20	1.09	1.01	0.96	0.94	0.94	0.94	0.95	0.99	1.04	1.13	1.20	1.25	1.28	1.29	1.30	1.31
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.44	1.45	1.46	1.47	1.48	1.48	1.41	1.27	1.12	1.00	0.93	0.91	0.91	0.91	0.92	0.97	1.06	1.17	1.28	1.35	1.38	1.40	1.41	1.43
FC	1.44	1.45	1.46	1.47	1.48	1.48	1.41	1.27	1.12	1.00	0.93	0.91	0.91	0.91	0.92	0.97	1.06	1.17	1.28	1.35	1.38	1.40	1.41	1.43

Table 4-39: Fleet composite cold start temperature correction – diesel LCV – winter season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	8.6	8.3	8.1	7.9	7.7	7.6	7.5	9.3	12.8	16.0	18.3	19.5	19.9	19.6	18.8	17.5	15.2	12.4	10.9	10.1	9.6	9.2	8.9	8.7
VOC	1.50	1.51	1.51	1.52	1.53	1.53	1.53	1.47	1.35	1.24	1.16	1.12	1.11	1.12	1.14	1.19	1.27	1.37	1.42	1.44	1.46	1.48	1.49	1.49
CO	1.44	1.44	1.45	1.45	1.46	1.46	1.47	1.41	1.31	1.21	1.14	1.10	1.09	1.10	1.12	1.17	1.24	1.32	1.36	1.39	1.40	1.42	1.42	1.43
NO_x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2	1.60	1.62	1.62	1.63	1.64	1.65	1.65	1.57	1.43	1.29	1.19	1.14	1.12	1.14	1.17	1.23	1.32	1.44	1.51	1.54	1.56	1.58	1.59	1.60
FC	1.60	1.62	1.62	1.63	1.64	1.65	1.65	1.57	1.43	1.29	1.19	1.14	1.12	1.14	1.17	1.23	1.32	1.44	1.51	1.54	1.56	1.58	1.59	1.60

4.2.3.3 Speciation Profiles

The VOC speciation profile for light duty diesel vehicles is derived from the CRC E-75 database (CRC, 2007). As limited data was available for light duty diesel, the speciation from the extensive heavy duty diesel database was adopted. The speciation profile for the substances reported in this section is shown in Table 4-40, whilst the full speciation profile is given in APPENDIX D.

Table 4-40: Diesel vehicle speciation data for selected compounds

Substance	Diesel Vehicles	
	Mass fraction (% VOC)	Mass fraction (% PM_{10})
1,3 butadiene	0.402828	N/A
Acetaldehyde	3.813449	N/A
Benzene	1.066778	N/A
Formaldehyde	9.857486	N/A
Isomers of xylene	0.38359	N/A
Lead & compounds	N/A	0.017854
Particulate matter ≤ 2.5 µm	N/A	97
Polycyclic aromatic hydrocarbons	1.65302	5.451313
Toluene	0.46912	N/A
Total suspended particulate	N/A	101

4.2.4 Emission Estimates

Estimated emissions from the source type *light duty diesel vehicle exhaust* within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-41.

Table 4-41: Estimated exhaust emissions from source type light duty diesel vehicle exhaust

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	0.677	0.042	0.022	0.077	0.819
ACETALDEHYDE	6.41	0.400	0.210	0.733	7.75
BENZENE	1.79	0.112	0.059	0.205	2.17
CARBON MONOXIDE	951	66.1	38.2	121	1,176
FORMALDEHYDE	16.6	1.03	0.542	1.90	20.0
ISOMERS OF XYLENE	0.645	0.04	0.021	0.074	0.78
LEAD & COMPOUNDS	0.044	0.0031	0.0019	0.0060	0.055
OXIDES OF NITROGEN	2,417	177	107	359	3,060
PARTICULATE MATTER ≤ 10 µm	247	17.3	10.4	33.5	308
PARTICULATE MATTER ≤ 2.5 µm	239	16.8	10.1	32.5	299
POLYCYCLIC AROMATIC HYDROCARBONS	8.12	0.558	0.329	1.07	10.1
SULFUR DIOXIDE	7.25	0.505	0.281	0.973	9.01
TOLUENE	0.788	0.049	0.026	0.090	0.954
TOTAL SUSPENDED PARTICULATE	249	17.5	10.5	33.9	311
TOTAL VOLATILE ORGANIC COMPOUNDS	168	10.5	5.50	19.2	203

The monthly profile for the base emission species is given in Table 4-42, the weekly profile is given in Table 4-43, and the daily profile is shown in Table 4-44. The speciated compounds have the same profile as the base emission species; i.e. each speciated exhaust VOC has the same profile as the total VOC, and each speciated PM metals and inorganic compound share the exhaust PM_{10} profile.

Table 4-42: Monthly profile for exhaust emissions from light duty diesel vehicles

Month	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
1	0.06377	0.05521	0.07868	0.08128	0.07823	0.07823	0.07948	0.07948
2	0.06322	0.05473	0.07801	0.08058	0.07756	0.07756	0.07879	0.07879
3	0.08086	0.07685	0.08774	0.08890	0.08748	0.08748	0.08810	0.08810
4	0.08460	0.08567	0.08258	0.08215	0.08255	0.08255	0.08245	0.08245
5	0.08942	0.09055	0.08728	0.08683	0.08726	0.08726	0.08715	0.08715
6	0.09703	0.10658	0.08068	0.07797	0.08133	0.08133	0.07985	0.07985
7	0.10153	0.11153	0.08443	0.08159	0.08510	0.08510	0.08356	0.08356
8	0.10279	0.11291	0.08548	0.08260	0.08616	0.08616	0.08460	0.08460
9	0.08485	0.08592	0.08282	0.08239	0.08279	0.08279	0.08269	0.08269
10	0.08794	0.08905	0.08584	0.08540	0.08581	0.08581	0.08571	0.08571
11	0.07734	0.07332	0.08423	0.08539	0.08398	0.08398	0.08459	0.08459
12	0.06664	0.05769	0.08222	0.08493	0.08174	0.08174	0.08304	0.08304

Table 4-43: Weekly profile for exhaust emissions from light duty diesel vehicles

Days	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
Weekdays	0.78564	0.78771	0.79403	0.80445	0.79238	0.79237	0.79151	0.78979
Weekend days	0.21436	0.21229	0.20597	0.19555	0.20762	0.20763	0.20849	0.21021

Table 4-44: Daily profile for exhaust emissions from light duty diesel vehicles

Hour	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
0	0.00286	0.00316	0.00297	0.00213	0.00296	0.00296	0.00317	0.00327
1	0.00125	0.00137	0.00129	0.00088	0.00129	0.00129	0.00139	0.00143
2	0.00094	0.00106	0.00096	0.00073	0.00096	0.00096	0.00102	0.00104
3	0.00052	0.00058	0.00053	0.00035	0.00053	0.00053	0.00057	0.00059
4	0.00442	0.00468	0.00384	0.00331	0.00387	0.00387	0.00395	0.00399
5	0.01751	0.01849	0.01505	0.01362	0.01524	0.01525	0.01540	0.01545
6	0.04882	0.05113	0.04090	0.04052	0.04177	0.04176	0.04106	0.04074
7	0.10438	0.09922	0.09175	0.09817	0.09272	0.09272	0.08740	0.08693
8	0.08991	0.08454	0.07925	0.08038	0.08066	0.08066	0.07525	0.07604
9	0.09515	0.09487	0.09638	0.10393	0.09530	0.09529	0.09458	0.09337
10	0.06998	0.07035	0.07306	0.07648	0.07186	0.07185	0.07297	0.07220
11	0.08370	0.08539	0.09007	0.09652	0.08845	0.08844	0.08941	0.08818
12	0.07264	0.07444	0.07901	0.08375	0.07745	0.07744	0.07887	0.07788
13	0.07338	0.07544	0.08006	0.08493	0.07860	0.07859	0.07988	0.07890
14	0.08845	0.08994	0.09446	0.10161	0.09311	0.09310	0.09331	0.09214
15	0.05422	0.05319	0.05528	0.05043	0.05629	0.05629	0.05695	0.05789
16	0.06513	0.06536	0.06430	0.06129	0.06558	0.06559	0.06508	0.06579
17	0.05335	0.05175	0.05124	0.04377	0.05321	0.05322	0.05326	0.05474
18	0.02975	0.02883	0.03054	0.02289	0.03129	0.03130	0.03310	0.03420
19	0.01612	0.01651	0.01794	0.01288	0.01795	0.01796	0.01955	0.02019
20	0.01006	0.01065	0.01146	0.00849	0.01131	0.01131	0.01234	0.01269
21	0.00708	0.00775	0.00797	0.00536	0.00794	0.00794	0.00868	0.00901
22	0.00733	0.00803	0.00824	0.00555	0.00821	0.00822	0.00898	0.00931
23	0.00304	0.00328	0.00347	0.00202	0.00345	0.00345	0.00383	0.00402

The contribution of cold start extra emissions to the total exhaust emissions for light duty diesel vehicles is shown in Figure 4-6.

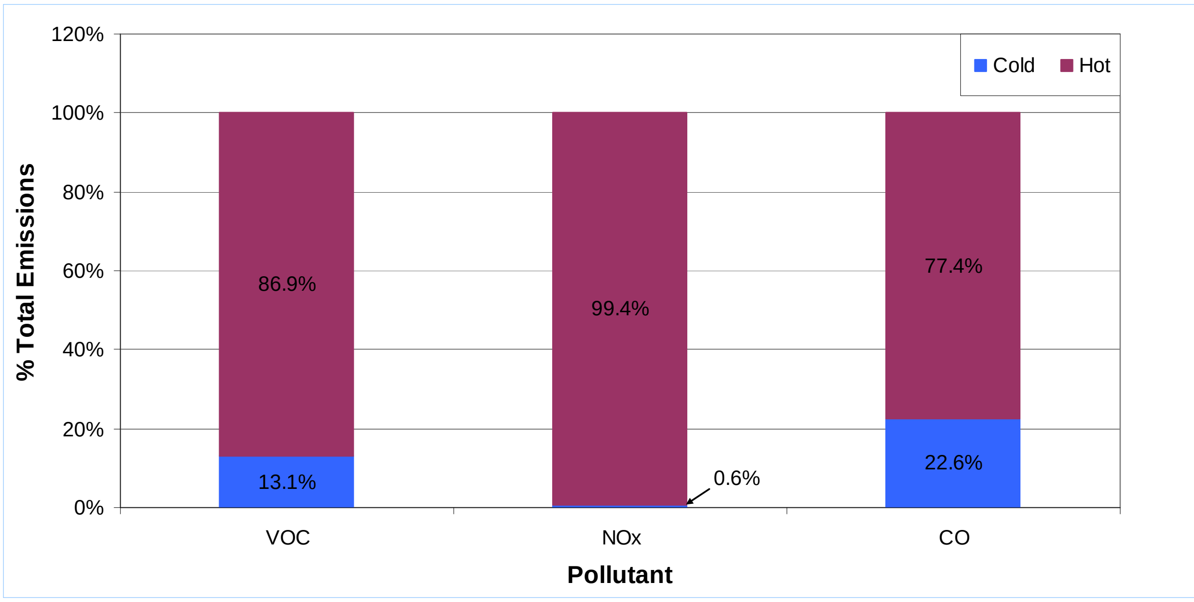

Figure 4-6: Contribution of cold running emissions to total light duty diesel vehicle emissions

4.3 Exhaust Emissions from Petrol Light Commercial Vehicles

4.3.1 Fleet Profile

The fleet age profile for petrol LCV vehicle and the VKT per annum profile are shown in Table 4-45. The percentage of VKT by vehicles using E10 is calculated as described in Section 4.1.1 and is given in the last column of Table 4-45.

Table 4-45: Petrol LCV fleet profile, 2008

YOM	Petrol LCV	Profile (%)	VKT per Annum	%VKT using E10
2008	16,571	6.257%	12,963	14.28%
2007	16,872	6.337%	24,884	13.99%
2006	18,160	6.771%	23,882	13.71%
2005	19,220	6.878%	22,917	13.71%
2004	19,961	7.045%	21,988	13.42%
2003	18,968	6.765%	21,093	11.57%
2002	15,408	5.561%	20,229	11.21%
2001	13,767	5.030%	19,396	11.00%
2000	14,366	5.254%	18,591	10.42%
1999	16,142	5.779%	17,813	10.14%
1998	13,735	4.931%	17,060	9.71%
1997	11,035	3.981%	16,329	9.43%
1996	10,396	3.749%	15,620	9.43%
1995	9,588	3.460%	14,930	9.14%
1994	8,968	3.244%	14,258	8.71%
1993	6,203	2.229%	13,602	7.85%
1992	7,038	2.536%	12,959	6.71%
1991	6,936	2.493%	12,329	6.14%
1990	7,177	2.603%	11,709	6.28%
1989	6,147	2.246%	11,098	5.14%
1988	3,452	1.260%	10,494	4.14%
1987	1,668	0.601%	9,894	4.57%
1986	1,952	0.701%	9,298	4.14%
1985	2,654	0.961%	8,703	0.00%
1984	1,812	0.667%	8,108	0.00%
1983	1,004	0.369%	7,511	0.00%
1982	912	0.344%	6,909	0.00%
1981	765	0.290%	6,302	0.00%
1980	556	0.221%	5,687	0.00%
1979	369	0.156%	5,300	0.00%
1978	315	0.146%	4,600	0.00%
1977	289	0.125%	4,000	0.00%
1976	277	0.117%	3,500	0.00%
1975	225	0.091%	3,000	0.00%
≤ 1974	2,174	0.803%	2,500	0.00%

[1] – Vehicles assumed to enter fleet evenly across year, hence average annual mileage is 50% of new vehicle

4.3.2 *VKT Data*

The total 2008 GMR VKT for petrol light commercial vehicles on an average week day and average weekend day are given in Table 4-46 and the hourly profile is shown graphically in Figure 4-7. It is assumed that diesel and petrol LCV have the same usage patterns and annual VKT per vehicle, and hence have identical hourly VKT variation. The average speeds by hour of the day for each road type are given previously in Table 4-3.

Table 4-46: Petrol LCV average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	19,186	0.13%	18,419	0.22%
1	7,463	0.05%	6,269	0.08%
2	7,857	0.05%	5,775	0.07%
3	2,988	0.02%	2,041	0.02%
4	45,262	0.31%	27,338	0.33%
5	201,658	1.38%	110,105	1.33%
6	647,904	4.44%	354,404	4.29%
7	1,394,076	9.56%	796,017	9.63%
8	945,648	6.49%	546,585	6.61%
9	1,673,015	11.47%	938,561	11.36%
10	1,234,197	8.46%	697,321	8.44%
11	1,577,835	10.82%	883,588	10.69%
12	1,366,823	9.37%	766,788	9.28%
13	1,385,866	9.50%	760,841	9.21%
14	1,651,909	11.33%	890,379	10.77%
15	638,341	4.38%	345,342	4.18%
16	799,751	5.49%	462,256	5.59%
17	459,796	3.15%	286,453	3.47%
18	217,875	1.49%	139,876	1.69%
19	120,580	0.83%	84,406	1.02%
20	85,444	0.59%	63,741	0.77%
21	43,065	0.30%	33,505	0.41%
22	44,436	0.30%	35,460	0.43%
23	9,639	0.07%	8,020	0.10%
Total	**14,580,614**		**8,263,488**	

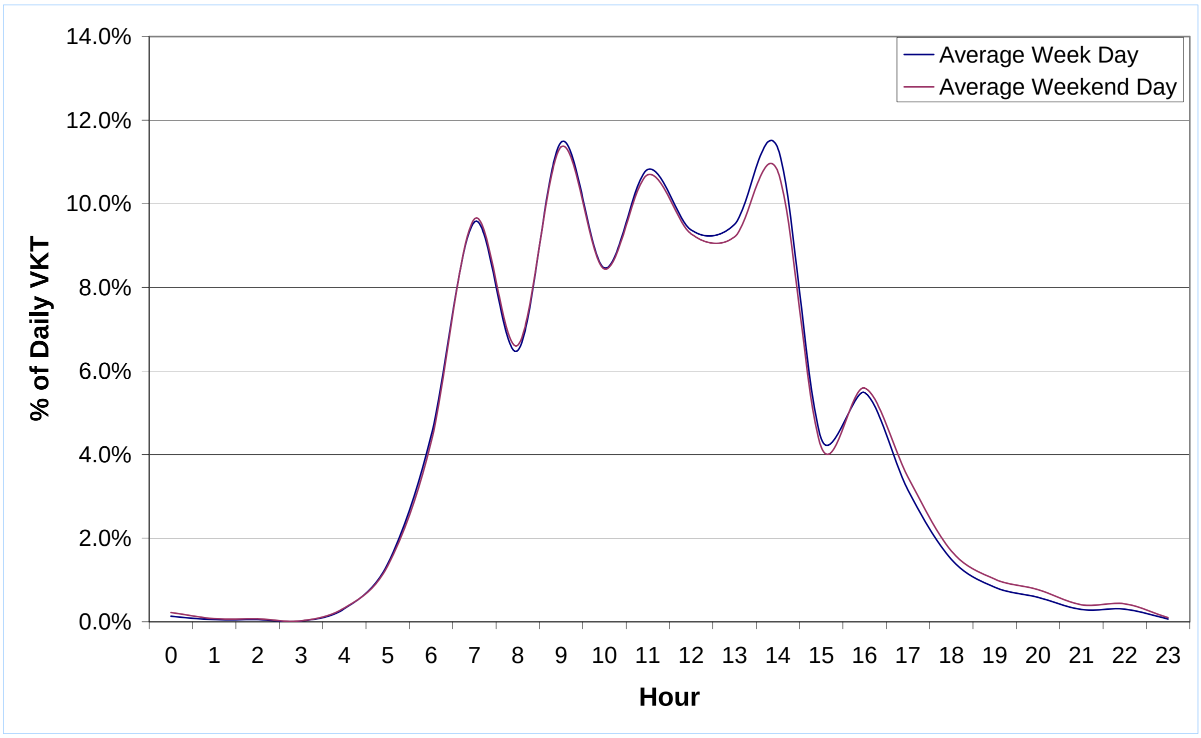

Figure 4-7: Petrol LCV diurnal VKT profiles

4.3.3 *Emission Factors*

4.3.3.1 *Hot Running*

Base hot running exhaust emission factors for ADR37/00 and newer petrol light commercial vehicles, for all base pollutants excepting SO_2 and NH_3, were derived from analysis of the NISE2 hot CUEDC residential cycle data and are shown in Table 4-47. Emission factors for SO_2 are calculated from the fuel consumption and fuel sulfur content with allowance for sulfate formation. Emission factors for NH_3 were derived from the work of Heeb et al (2006, 2006a, 2008), Huai et al (2003), Karlsonn (2004) and CRC (2003).

Emission factors for earlier ADR27 vehicles are derived by developing conversion factors to apply to the previous inventory emission factors, which had been derived from test data from NISE1 and NSW and Victoria EPA test programs. These base emission factors relate to an ambient temperature of 23.0°C and the petrol properties of the NISE2 study, given in Table 3-17.

Fleet composite base emission factors incorporating fleet age profile, age specific annual VKT and deterioration are given in Table 4-48. Fleet composite splitting factors were derived as detailed in Section 3.8.2 and are also given in Table 4-48.

The fuel property adjustment factors calculated for the average 2008 Sydney petrol properties and applied to the base hot running emission factors are given in Table 4-49. The seasonal temperature corrections are given in Table 4-50. The coefficients for the fleet composite 6th order speed correction functions are given in Table 4-51.

Table 4-47: Base hot running exhaust emission factors for petrol LCV

Emission Age Class	ADR	NO_x		VOC		CO		Exhaust PM_{10}		N_2O		NH_3	CO_2
		EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (mg/km)	DR (mg/km²)	EF (mg/km)	EF (g/km)
1975	ADR27	0.857	5.34×10^{-06}	0.797	6.51×10^{-06}	7.954	7.51×10^{-05}	0.0075	7.50×10^{-08}	9.641	0.00	2.0	238.8
1982	ADR27B	0.779	4.85×10^{-06}	0.725	5.92×10^{-06}	7.298	6.89×10^{-05}	0.0075	7.50×10^{-08}	9.641	0.00	2.0	243.0
1989	ADR37/00	0.525	5.78×10^{-06}	0.198	3.54×10^{-06}	2.940	3.99×10^{-05}	0.0050	5.00×10^{-08}	6.500	4.54×10^{-05}	56.8	263.3
1993	ADR37/00	0.500	5.50×10^{-06}	0.190	3.40×10^{-06}	2.800	3.80×10^{-05}	0.0050	5.00×10^{-08}	6.500	4.54×10^{-05}	56.8	272.3
1996	ADR37/00	0.475	5.23×10^{-06}	0.181	3.23×10^{-06}	2.660	3.61×10^{-05}	0.0050	5.00×10^{-08}	6.500	4.54×10^{-05}	56.8	275.0
1999	ADR37/01	0.187	4.16×10^{-06}	0.104	1.87×10^{-06}	1.040	2.08×10^{-05}	0.0025	3.00×10^{-08}	35.000	5.53×10^{-05}	39.7	281.1
2002	ADR37/01	0.171	3.80×10^{-06}	0.095	1.71×10^{-06}	0.950	1.90×10^{-05}	0.0025	3.00×10^{-08}	35.000	5.53×10^{-05}	39.7	278.3
2004	ADR79/00	0.080	1.20×10^{-06}	0.040	5.50×10^{-07}	0.440	6.00×10^{-06}	0.0010	1.20×10^{-08}	5.000	4.90×10^{-05}	29.7	283.2
2006	ADR79/01	0.020	3.00×10^{-07}	0.0090	1.80×10^{-07}	0.200	3.00×10^{-06}	0.0010	1.20×10^{-08}	2.000	4.16×10^{-05}	32.3	279.0
2010	ADR79/02	0.0074	1.10×10^{-07}	0.0060	1.14×10^{-07}	0.173	2.50×10^{-06}	0.0010	1.20×10^{-08}	2.000	4.16×10^{-05}	11.7	261.7

Table 4-48: Fleet composite base emission factor and composite splitting factors for petrol LCV, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	1.2902	1.148	0.977	1.134	1.111	1.169
VOC	0.7064	1.162	0.807	1.021	0.589	0.508
CO	8.941	1.212	0.815	1.066	0.763	0.727
PM_{10}	0.0122	1.085	0.999	0.998	1.084	1.179
N_2O (mg/km)	18.93	1.128	1.150	1.504	1.003	0.797
NH_3 (mg/km)	41.71	1.000	1.015	0.992	1.370	1.644
CO_2	277.2	1.124	0.855	0.958	0.785	0.774

Table 4-49: Petrol fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	0.9438	0.9328	0.9325
NO_x	1.0232	1.0439	1.0436
CO	0.963	0.955	0.955

Table 4-50: Petrol LCV composite fleet seasonal average daily temperature corrections

Pollutant	Residential, Arterial, Commercial Arterial Roads			Commercial Highway, Freeway/Motorway Roads		
	Summer	Autumn & Spring	Winter	Summer	Autumn & Spring	Winter
VOC	0.9392	1.0323	1.1033	0.9885	1.0061	1.0195
NO_x	0.9551	1.0238	1.0762	1.0113	0.9940	0.9808
CO	0.9666	1.0177	1.0567	1.0131	0.9931	0.9778
CO_2	0.9927	1.0039	1.0124	0.9909	1.0048	1.0154

Table 4-51: Petrol LCV composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	1.0893×10^{-11}	-4.9875×10^{-09}	9.6929×10^{-07}	-1.0292×10^{-04}	6.4087×10^{-03}	-2.2619×10^{-01}	4.0622
NO_x	8.6599×10^{-11}	-3.6306×10^{-08}	6.1883×10^{-06}	-5.4465×10^{-04}	2.6340×10^{-02}	-6.6337×10^{-01}	7.6741
CO	1.9023×10^{-11}	-8.3314×10^{-09}	1.6062×10^{-06}	-1.7405×10^{-04}	1.1004×10^{-02}	-3.7175×10^{-01}	5.7540
CO_2	1.3874×10^{-11}	-7.0180×10^{-09}	1.4027×10^{-06}	-1.4382×10^{-04}	8.2046×10^{-03}	-2.5283×10^{-01}	4.0825
PM	4.0083×10^{-11}	-1.6319×10^{-08}	2.6797×10^{-06}	-2.2619×10^{-04}	1.0533×10^{-02}	-2.5666×10^{-01}	3.5302

4.3.3.2 Cold Running

The base cold start emission factor ratios for all cold start pollutants considered excepting NH_3 were derived from the NISE2 modal data for vehicles ADR37/00 and newer. NH_3 cold start emissions were estimated from Huai et al (2003), Durbin et al (2004) and Heeb et al (2006, 2008). ADR27 vehicles were modelled using the ARTEMIS Euro 0 No-cat model (INRETS, 2007). The fleet composite cold base start emission factor ratios are given in Table 4-52 while the individual age class data is given in APPENDIX B.

The cold start parking factors (CSPF) were derived by applying the ARTEMIS model (INRETS, 2007) to the hourly parking time prior to a trip start distribution estimated from the Sydney HTS data (e.g. TDC, 2010). The parking time distributions for week days and weekend days are given in APPENDIX B. The fleet composite CSPF are given in Table 4-53. No CSPF are derived for NH_3 or N_2O.

The cold start temperature corrections were derived from work by Weilenmann et al (2001, 2004, 2005, 2008, 2009). The seasonal fleet composite CSTC are given Table 4-54, Table 4-55 and Table 4-56.

Table 4-52: Fleet composite base cold start emission factor ratio – petrol LCV

Road Type	0 - 1.5 km							1.5 - 2.5 km							2.5 - 4.0 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	3.74	3.07	1.83	1.33	1.39	0.69	2.83	1.48	1.04	1.01	1.13	1.11	2.48	2.83	1.33	1.01	1.03	1.11	1.09	1.79	2.83
Arterial	4.85	6.61	2.25	1.37	1.43	0.38	2.86	1.34	1.18	1.06	1.16	1.14	2.98	2.86	1.63	1.10	1.11	1.13	1.12	2.21	2.86
Commercial Arterial	4.94	5.96	2.20	1.36	1.43	0.39	2.88	1.26	1.12	1.05	1.16	1.14	2.98	2.88	1.53	1.08	1.09	1.13	1.11	2.20	2.88
Commercial Highway	5.31	8.15	2.63	1.38	1.44	0.16	2.85	1.79	1.22	1.17	1.18	1.16	2.05	2.85	2.69	1.10	1.27	1.15	1.14	2.05	2.85

Road Type	4.0 - 5.5 km							5.5 - 7.5 km						
	THC	CO	NO_x	CO_2	FC	NH_3	N_2O	THC	CO	NO_x	CO_2	FC	NH_3	N_2O
Residential/Local	1.02	1.00	1.02	1.04	1.03	1.07	1.03	1.02	1.01	1.04	1.04	1.04	1.00	1.03
Arterial	1.06	1.01	1.19	1.06	1.05	1.35	1.03	1.02	1.01	1.05	1.05	1.05	1.00	1.03
Commercial Arterial	1.04	1.01	1.15	1.06	1.05	1.34	1.03	1.02	1.01	1.04	1.05	1.04	1.00	1.03
Commercial Highway	1.29	1.04	1.34	1.08	1.07	1.74	1.03	1.07	1.02	1.26	1.07	1.06	1.00	1.03

Table 4-53: Fleet composite cold start parking factors – petrol LCV

Hour	THC	CO	NO_x	CO_2	FC
0	0.4882	0.6267	0.8130	0.4759	0.4759
1	0.4882	0.6267	0.8130	0.4759	0.4759
2	0.4882	0.6267	0.8130	0.4759	0.4759
3	0.4882	0.6267	0.8130	0.4759	0.4759
4	0.6755	0.8568	0.8860	0.6532	0.6532
5	0.6755	0.8568	0.8860	0.6532	0.6532
6	0.6755	0.8568	0.8860	0.6532	0.6532
7	0.3387	0.3400	0.6849	0.3569	0.3569
8	0.3205	0.3296	0.6870	0.3373	0.3373
9	0.2393	0.2145	0.6823	0.2589	0.2589
10	0.2393	0.2145	0.6823	0.2589	0.2589
11	0.2152	0.1859	0.6777	0.2364	0.2364
12	0.2152	0.1859	0.6777	0.2364	0.2364
13	0.1978	0.1637	0.6638	0.2219	0.2219
14	0.1978	0.1637	0.6638	0.2219	0.2219
15	0.2665	0.2972	0.7443	0.2754	0.2754
16	0.3178	0.3856	0.7684	0.3190	0.3190
17	0.3328	0.4090	0.7577	0.3360	0.3360
18	0.3419	0.4134	0.7739	0.3460	0.3460
19	0.3424	0.4095	0.7946	0.3430	0.3430
20	0.3424	0.4095	0.7946	0.3430	0.3430
21	0.3683	0.4599	0.7933	0.3663	0.3663
22	0.3683	0.4599	0.7933	0.3663	0.3663
23	0.3683	0.4599	0.7933	0.3663	0.3663

Table 4-54: Fleet composite cold start temperature correction – petrol LCV – summer season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	16.9	16.5	16.3	16.0	15.8	16.8	20.6	25.1	29.0	31.6	33.2	34.0	34.1	33.7	32.7	31.2	29.1	26.5	23.2	20.4	19.0	18.2	17.7	17.3
VOC	1.28	1.30	1.32	1.33	1.34	1.29	1.10	0.91	0.78	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.78	0.87	0.99	1.11	1.18	1.22	1.24	1.26
CO	1.21	1.22	1.23	1.24	1.25	1.21	1.08	0.94	0.83	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.83	0.90	0.99	1.08	1.13	1.16	1.18	1.19
NO_x	1.18	1.19	1.20	1.21	1.21	1.19	1.08	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.00	1.08	1.12	1.15	1.16	1.17
CO_2	1.16	1.17	1.18	1.19	1.20	1.17	1.06	0.95	0.86	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.86	0.92	0.99	1.07	1.11	1.13	1.14	1.15
FC	1.18	1.19	1.20	1.21	1.22	1.18	1.07	0.94	0.85	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.85	0.91	0.99	1.07	1.12	1.14	1.16	1.17

Table 4-55: Fleet composite cold start temperature correction – petrol LCV – autumn and spring season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	12.5	12.2	11.9	11.7	11.6	11.6	13.1	16.4	20.0	22.8	24.4	25.2	25.6	25.4	24.7	23.4	21.5	18.8	16.2	14.7	13.9	13.4	13.0	12.7
VOC	1.54	1.56	1.57	1.59	1.60	1.59	1.50	1.31	1.13	1.01	0.94	0.91	0.90	0.90	0.93	0.98	1.06	1.19	1.32	1.41	1.45	1.48	1.50	1.52
CO	1.39	1.40	1.41	1.42	1.43	1.42	1.36	1.23	1.10	1.01	0.96	0.94	0.92	0.93	0.95	0.99	1.05	1.14	1.24	1.30	1.33	1.35	1.36	1.38
NO_x	1.31	1.32	1.33	1.33	1.34	1.34	1.29	1.20	1.09	1.01	0.97	0.95	0.95	0.95	0.95	0.99	1.05	1.13	1.20	1.25	1.27	1.29	1.30	1.31
CO_2	1.30	1.31	1.32	1.33	1.33	1.33	1.28	1.18	1.08	1.00	0.97	0.95	0.94	0.94	0.96	0.99	1.04	1.11	1.18	1.23	1.26	1.27	1.28	1.29
FC	1.33	1.34	1.35	1.36	1.37	1.36	1.31	1.20	1.08	1.01	0.96	0.94	0.93	0.94	0.95	0.99	1.04	1.12	1.20	1.25	1.28	1.30	1.31	1.32

Table 4-56: Fleet composite cold start temperature correction – petrol LCV – winter season

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temp	8.6	8.3	8.1	7.9	7.7	7.6	7.5	9.3	12.8	16.0	18.3	19.5	19.9	19.6	18.8	17.5	15.2	12.4	10.9	10.1	9.6	9.2	8.9	8.7
VOC	1.81	1.82	1.84	1.85	1.87	1.88	1.88	1.75	1.52	1.33	1.21	1.15	1.13	1.15	1.18	1.25	1.38	1.55	1.64	1.69	1.73	1.76	1.78	1.80
CO	1.57	1.58	1.59	1.60	1.61	1.61	1.62	1.53	1.37	1.24	1.16	1.11	1.10	1.11	1.14	1.19	1.28	1.39	1.46	1.49	1.52	1.53	1.55	1.56
NO_x	1.43	1.43	1.44	1.45	1.45	1.45	1.46	1.41	1.30	1.21	1.14	1.11	1.10	1.10	1.13	1.17	1.23	1.32	1.36	1.38	1.40	1.41	1.42	1.42
CO_2	1.44	1.44	1.45	1.46	1.46	1.47	1.47	1.41	1.29	1.19	1.12	1.09	1.08	1.09	1.11	1.15	1.22	1.30	1.35	1.38	1.40	1.41	1.42	1.43
FC	1.48	1.49	1.50	1.51	1.51	1.52	1.52	1.45	1.32	1.21	1.14	1.10	1.09	1.10	1.12	1.16	1.24	1.34	1.39	1.42	1.44	1.46	1.47	1.48

4.3.3.3 Speciation Profiles

The VOC speciation profile derived for petrol passenger vehicles is adopted for petrol LCV, and is given in Section 4.1.3.3.

4.3.4 Emission Estimates

Estimated emissions from the source type *petrol LCV exhaust* within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-57.

Table 4-57: Estimated Exhaust Emissions from source type petrol LCV exhaust

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	34.8	2.18	1.19	3.71	41.9
ACETALDEHYDE	15.6	0.976	0.531	1.66	18.7
BENZENE	136	8.52	4.63	14.5	164
CARBON MONOXIDE	39,923	2,650	1,564	4,595	48,731
FORMALDEHYDE	41.6	2.61	1.42	4.42	50.0
ISOMERS OF XYLENE	209	13.1	7.13	22.3	252
LEAD & COMPOUNDS	0.018	0.0014	0.00091	0.0027	0.023
OXIDES OF NITROGEN	6,799	530	346	1,004	8,679
PARTICULATE MATTER ≤ 10 µm	49.5	3.91	2.58	7.73	63.7
PARTICULATE MATTER ≤ 2.5 µm	47.2	3.72	2.46	7.37	60.7
POLYCYCLIC AROMATIC HYDROCARBONS	17.0	1.21	0.744	2.26	21.2
SULFUR DIOXIDE	33.3	2.27	1.36	4.24	41.2
TOLUENE	253	15.9	8.62	26.9	304
TOTAL SUSPENDED PARTICULATE	49.5	3.91	2.58	7.73	63.7
TOTAL VOLATILE ORGANIC COMPOUNDS	2,768	174	94.4	295	3,331

The monthly profile for the base emission species is given in Table 4-58, the weekly profile is given in Table 4-59, and the daily profile is shown in Table 4-60. The speciated compounds have the same profile as the base emission species; i.e. all speciated exhaust VOC have the same profile as the total VOC, speciated PM metals and inorganic compounds share the exhaust PM_{10} profile.

Table 4-58: Monthly profile for exhaust emissions from petrol LCV

Month	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
1	0.07210	0.07542	0.07521	0.07948	0.07027	0.07836	0.07948	0.07948
2	0.07148	0.07477	0.07456	0.07879	0.06966	0.07769	0.07879	0.07879
3	0.08442	0.08605	0.08622	0.08810	0.08580	0.08758	0.08810	0.08810
4	0.08296	0.08269	0.08320	0.08245	0.08724	0.08260	0.08245	0.08245
5	0.08768	0.08740	0.08793	0.08715	0.09221	0.08731	0.08715	0.08715
6	0.08876	0.08482	0.08426	0.07985	0.08406	0.08107	0.07985	0.07985
7	0.09288	0.08876	0.08817	0.08356	0.08796	0.08484	0.08356	0.08356
8	0.09403	0.08986	0.08926	0.08460	0.08906	0.08589	0.08460	0.08460
9	0.08320	0.08293	0.08344	0.08269	0.08749	0.08284	0.08269	0.08269
10	0.08623	0.08596	0.08648	0.08571	0.09069	0.08586	0.08571	0.08571
11	0.08092	0.08255	0.08270	0.08459	0.08214	0.08407	0.08459	0.08459
12	0.07533	0.07880	0.07858	0.08304	0.07342	0.08188	0.08304	0.08304

Table 4-59: Weekly profile for exhaust emissions from petrol LCV

Days	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
Weekdays	0.80076	0.80027	0.81253	0.81518	0.81300	0.81312	0.81521	0.81522
Weekend days	0.19924	0.19973	0.18747	0.18482	0.18700	0.18688	0.18479	0.18478

Table 4-60: Daily profile for exhaust emissions from petrol LCV

Hour	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
0	0.00157	0.00173	0.00158	0.00152	0.00140	0.00140	0.00149	0.00150
1	0.00060	0.00066	0.00060	0.00057	0.00053	0.00053	0.00056	0.00057
2	0.00062	0.00068	0.00061	0.00059	0.00054	0.00054	0.00057	0.00058
3	0.00023	0.00026	0.00023	0.00022	0.00020	0.00020	0.00021	0.00022
4	0.00385	0.00423	0.00339	0.00323	0.00304	0.00303	0.00314	0.00319
5	0.01680	0.01826	0.01461	0.01399	0.01334	0.01329	0.01375	0.01384
6	0.05440	0.05823	0.04598	0.04436	0.04375	0.04361	0.04413	0.04422
7	0.11135	0.10900	0.09705	0.09502	0.10239	0.10231	0.09473	0.09327
8	0.07755	0.07683	0.06803	0.06533	0.07285	0.07284	0.06430	0.06309
9	0.11129	0.10943	0.11349	0.11434	0.11366	0.11369	0.11484	0.11525
10	0.07831	0.07784	0.08340	0.08479	0.08191	0.08194	0.08495	0.08541
11	0.09845	0.09747	0.10614	0.10805	0.10486	0.10493	0.10836	0.10884
12	0.08406	0.08353	0.09202	0.09381	0.09018	0.09024	0.09395	0.09447
13	0.08463	0.08392	0.09279	0.09467	0.09126	0.09132	0.09488	0.09534
14	0.10369	0.10211	0.11036	0.11213	0.11022	0.11029	0.11261	0.11302
15	0.04344	0.04360	0.04329	0.04312	0.04405	0.04407	0.04329	0.04325
16	0.05757	0.05857	0.05559	0.05472	0.05659	0.05659	0.05489	0.05479
17	0.03505	0.03562	0.03275	0.03195	0.03355	0.03354	0.03202	0.03191
18	0.01545	0.01578	0.01539	0.01527	0.01504	0.01503	0.01531	0.01521
19	0.00827	0.00860	0.00881	0.00871	0.00815	0.00815	0.00865	0.00861
20	0.00587	0.00617	0.00643	0.00632	0.00580	0.00580	0.00622	0.00623
21	0.00306	0.00329	0.00329	0.00323	0.00296	0.00295	0.00316	0.00317
22	0.00318	0.00343	0.00342	0.00335	0.00307	0.00307	0.00328	0.00329
23	0.00070	0.00076	0.00076	0.00074	0.00067	0.00067	0.00072	0.00072

The contribution of cold start extra emissions to the total exhaust emissions for petrol LCV is shown in Figure 4-8.

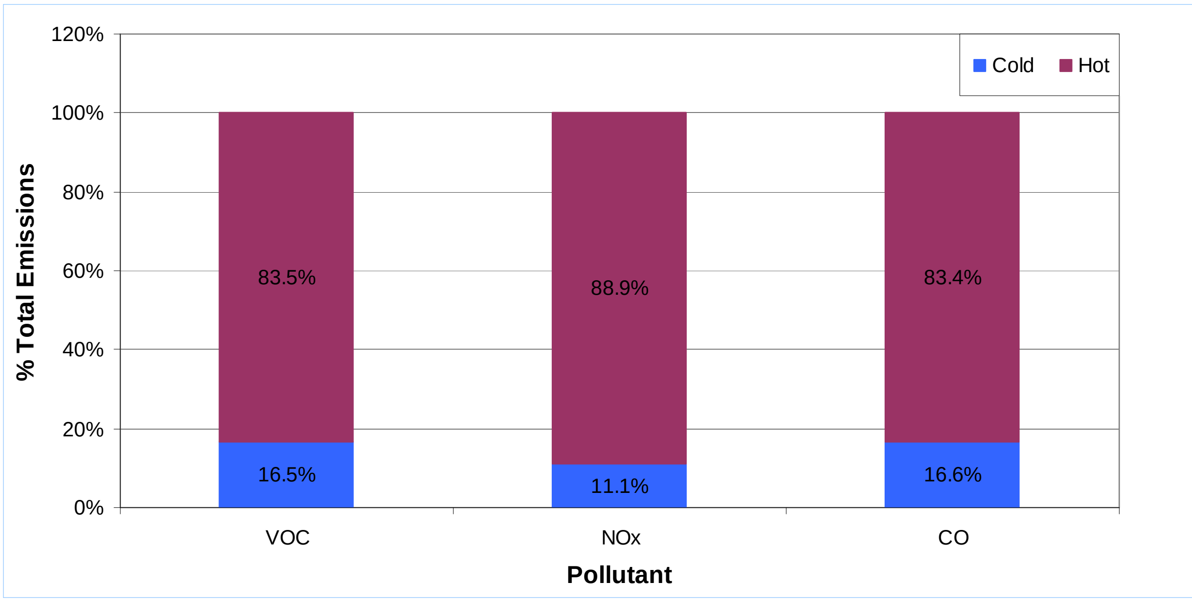

Figure 4-8: Contribution of cold running emissions to total petrol LCV emissions

4.4 Exhaust Emissions from Heavy Duty Diesel Vehicles

4.4.1 Fleet Profile

The fleet age profile for the individual vehicle types comprising the aggregated heavy duty diesel vehicle source type, and the VKT per annum profiles are shown in Table 4-61.

Table 4-61: Heavy-duty diesel vehicle fleet profile, 2008

YOM	Rigid Trucks	VKT per Annum	Profile (%)	Articulated Trucks	VKT per Annum	Profile (%)	Heavy Buses	VKT per Annum	Profile (%)
2008	4,060	17,250	6.353%	999	79,272	9.070%	268	17,800	5.171%
2007	3,875	34,200	6.063%	959	148,751	8.713%	259	35,550	4.995%
2006	3,606	33,896	5.642%	931	139,430	8.454%	248	35,500	4.792%
2005	4,804	33,644	7.516%	956	130,566	8.683%	173	35,450	3.336%
2004	4,854	33,162	7.595%	997	122,148	9.059%	175	35,400	3.380%
2003	3,472	32,471	5.432%	892	114,160	8.104%	142	35,350	2.746%
2002	4,252	31,594	6.653%	623	106,591	5.661%	151	35,300	2.907%
2001	2,812	30,551	4.399%	415	99,426	3.769%	172	35,253	3.311%
2000	3,092	29,364	4.838%	451	92,654	4.095%	345	35,078	6.662%
1999	3,095	28,055	4.842%	463	86,260	4.206%	204	34,735	3.943%
1998	2,747	26,645	4.297%	489	80,232	4.442%	302	34,242	5.827%
1997	2,009	25,157	3.143%	318	74,555	2.885%	245	33,616	4.730%
1996	1,785	23,611	2.793%	303	69,218	2.752%	208	32,875	4.006%
1995	1,978	22,029	3.094%	354	64,206	3.214%	257	32,036	4.967%
1994	2,221	20,433	3.475%	377	59,508	3.421%	241	31,116	4.652%
1993	1,594	18,844	2.495%	208	55,108	1.885%	204	30,133	3.935%
1992	1,553	17,285	2.430%	118	50,995	1.067%	191	29,104	3.695%
1991	1,177	15,776	1.842%	82	47,154	0.743%	128	28,047	2.467%
1990	1,755	14,339	2.746%	144	43,574	1.312%	139	26,979	2.678%
1989	1,891	12,996	2.959%	164	40,240	1.485%	166	25,917	3.209%
1988	1,493	11,768	2.336%	111	37,140	1.009%	160	24,879	3.079%
1987	940	10,678	1.471%	68	34,259	0.618%	105	23,882	2.029%
1986	986	9,746	1.543%	82	31,586	0.742%	118	22,944	2.268%
1985	1,259	8,994	1.970%	105	29,106	0.951%	142	22,082	2.747%
1984	684	8,444	1.070%	64	26,808	0.581%	89	21,200	1.711%
1983	341	8,117	0.534%	29	24,676	0.259%	62	20,500	1.203%
1982	369	8,036	0.577%	29	22,699	0.261%	88	19,700	1.698%
1981	405	7,600	0.633%	39	20,862	0.355%	48	19,000	0.926%
1980	279	7,400	0.436%	56	19,154	0.505%	42	18,000	0.814%
1979	133	7,200	0.209%	47	17,560	0.426%	42	17,300	0.807%
1978	91	7,000	0.142%	29	16,068	0.263%	34	16,400	0.654%
1977	82	6,700	0.128%	24	14,663	0.221%	8	15,300	0.157%
1976	75	6,500	0.118%	24	13,334	0.220%	4	14,500	0.078%
1975	41	6,300	0.064%	19	12,066	0.169%	5	14,000	0.097%
≤ 1974	105	6,000	0.164%	44	10,848	0.398%	17	13,500	0.323%

[1] – Vehicles assumed to enter fleet evenly across year, hence average annual mileage is 50% of new vehicle

4.4.2 VKT Data

The total 2008 GMR VKT for rigid trucks, articulated trucks, and heavy buses, which together comprise the source type heavy duty diesel vehicles, on an average week day and average weekend day are given in Table 4-62, Table 4-63 and Table 4-64 respectively, and the hourly profiles are shown graphically in Figure 4-9, Figure 4-10 Figure 4-11. The average speeds by hour of the day for each road type for trucks are assumed to be the same as for passenger vehicles given previously in Table 4-3. To account for the additional stops of buses, the average speed for buses is assumed to be 80% of that of passenger vehicles for all road types excluding Freeway/Highway, which is assumed to be the same as for passenger vehicles.

Table 4-62: Rigid truck average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	31,324	0.56%	29,350	1.66%
1	31,863	0.57%	23,579	1.33%
2	40,241	0.73%	22,937	1.30%
3	56,061	1.01%	27,134	1.53%
4	94,913	1.71%	33,884	1.91%
5	222,229	4.01%	58,224	3.29%
6	391,341	7.05%	103,314	5.83%
7	384,196	6.93%	116,411	6.57%
8	395,163	7.12%	124,081	7.01%
9	452,811	8.16%	129,957	7.34%
10	446,795	8.05%	130,911	7.39%
11	447,336	8.06%	127,491	7.20%
12	428,083	7.72%	122,860	6.94%
13	424,695	7.66%	113,394	6.40%
14	421,320	7.60%	105,751	5.97%
15	331,558	5.98%	84,216	4.76%
16	272,105	4.91%	85,713	4.84%
17	202,123	3.64%	78,424	4.43%
18	170,197	3.07%	71,142	4.02%
19	101,637	1.83%	52,038	2.94%
20	66,422	1.20%	39,056	2.21%
21	52,428	0.95%	33,554	1.89%
22	45,220	0.82%	30,342	1.71%
23	37,101	0.67%	27,010	1.53%
Total	**5,547,158**		**1,770,771**	

Table 4-63: Articulated truck average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	37,980	1.51%	18,383	2.71%
1	34,743	1.38%	16,503	2.43%
2	34,993	1.39%	15,397	2.27%
3	49,176	1.96%	16,474	2.43%
4	75,368	3.00%	22,987	3.39%
5	115,551	4.60%	31,661	4.67%
6	131,337	5.23%	39,139	5.77%
7	176,968	7.04%	55,391	8.17%
8	188,237	7.49%	54,589	8.05%
9	175,264	6.98%	45,218	6.67%
10	183,829	7.32%	42,648	6.29%
11	182,765	7.27%	41,488	6.12%
12	175,835	7.00%	37,101	5.47%
13	171,627	6.83%	31,579	4.66%
14	159,388	6.34%	27,255	4.02%
15	125,861	5.01%	25,172	3.71%
16	99,442	3.96%	22,971	3.39%
17	76,292	3.04%	21,285	3.14%
18	64,613	2.57%	18,673	2.75%
19	58,174	2.32%	18,092	2.67%
20	52,911	2.11%	18,043	2.66%
21	49,024	1.95%	19,316	2.85%
22	47,980	1.91%	19,288	2.84%
23	44,978	1.79%	19,700	2.90%
Total	**2,512,337**		**678,353**	

Table 4-64: Heavy bus average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	2,682	0.55%	1,712	0.54%
1	1,264	0.26%	807	0.26%
2	1,082	0.22%	690	0.22%
3	1,156	0.24%	738	0.23%
4	2,288	0.47%	700	0.22%
5	8,242	1.68%	2,523	0.80%
6	23,228	4.74%	7,110	2.25%
7	41,269	8.43%	10,573	3.34%
8	43,378	8.86%	11,113	3.51%
9	32,937	6.72%	26,396	8.34%
10	27,282	5.57%	21,863	6.91%
11	26,434	5.40%	21,184	6.70%
12	26,537	5.42%	21,267	6.72%
13	26,851	5.48%	21,518	6.80%
14	27,523	5.62%	22,057	6.97%
15	35,871	7.32%	25,393	8.03%
16	39,848	8.14%	28,209	8.92%
17	40,000	8.17%	28,316	8.95%
18	33,303	6.80%	26,116	8.26%
19	17,974	3.67%	14,095	4.46%
20	11,714	2.39%	9,160	2.90%
21	8,780	1.79%	6,866	2.17%
22	5,724	1.17%	4,476	1.42%
23	4,423	0.90%	3,459	1.09%
Total	**489,788**		**316,342**	

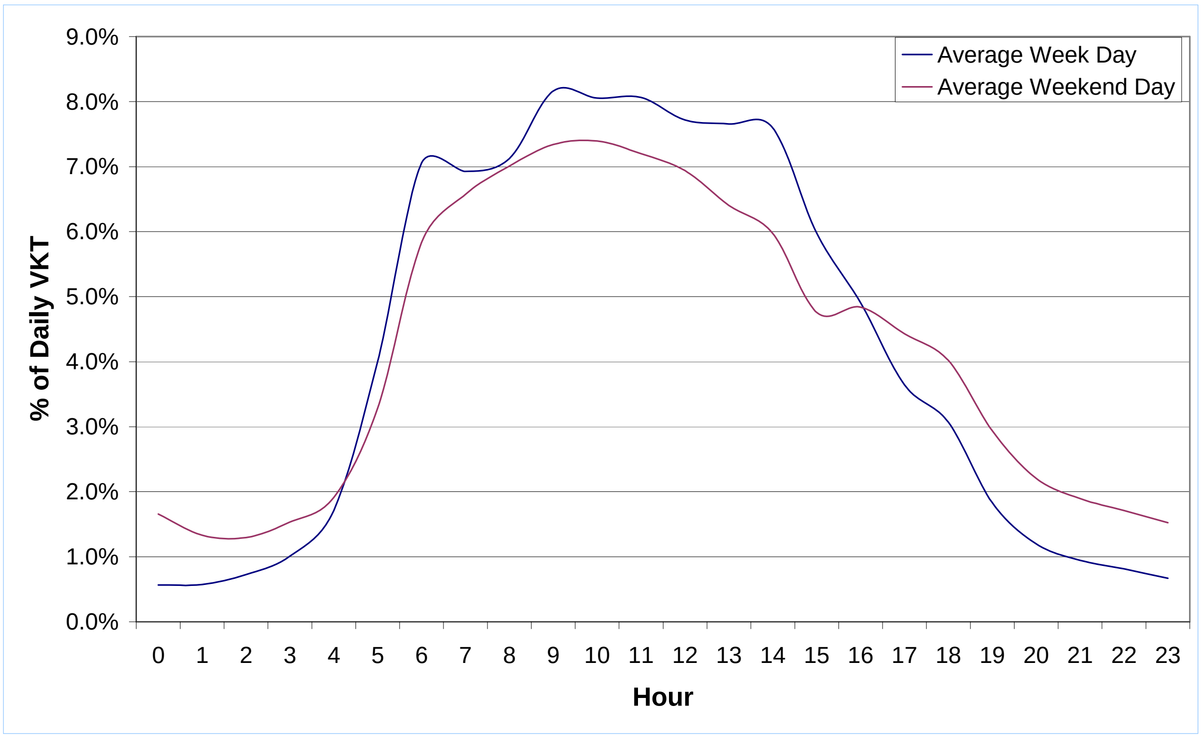

Figure 4-9: Rigid truck diurnal VKT profiles

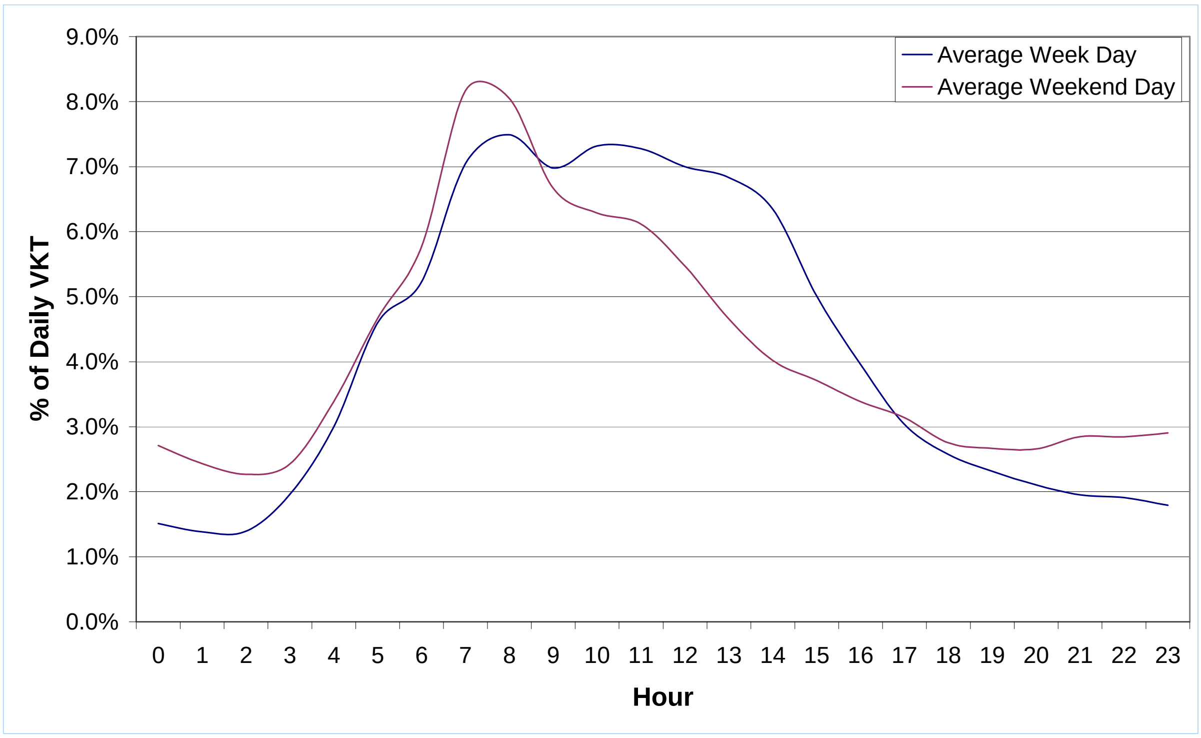

Figure 4-10: Articulated truck diurnal VKT profiles

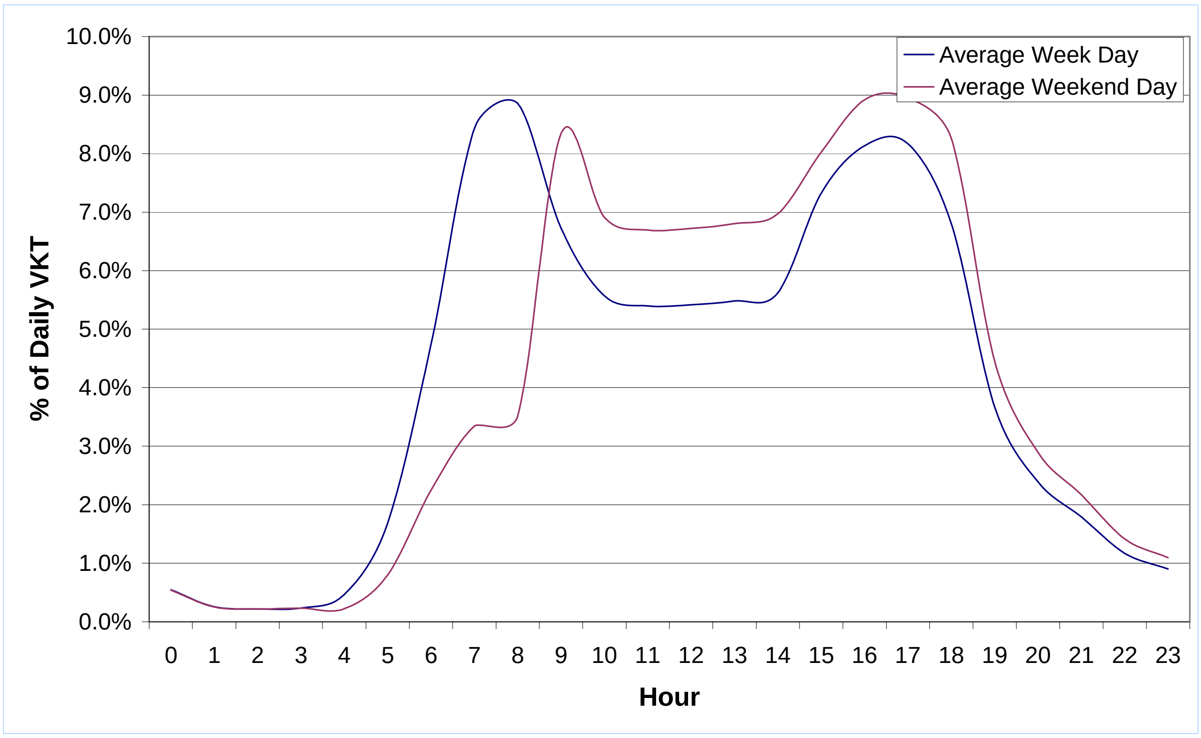

Figure 4-11: Heavy bus diurnal VKT profiles

4.4.3 *Emission Factors*

4.4.3.1 *Hot Running*

Base hot running exhaust emission factors for rigid and articulated trucks, for all base pollutants excepting SO_2 and NH_3, were estimated from Australian CUEDC drive cycle data from the Diesel NEPM (NEPC, 2000) and South Australian test and repair program (Zito et. al., 2008), supplemented by estimates from the European ARTEMIS model (Rexeis, 2005), and are shown in Table 4-65 and Table 4-66. Emission factors for pre-ADR70 and ADR70 heavy buses were taken from CUEDC measurements performed on 15 Sydney buses (DTA, 2008). Emission factors for ADR80/00 and newer buses were scaled by the ARTEMIS model from the ADR70 data; i.e. ADR80/00 = ADR70 x ARTEMIS EIII / ARTEMIS EII. Bus base emission factors are given in Table 4-67. The base emission factors for these vehicle types are weighted averages by sub-classes of vehicle operating mass, with an assumption of an average of 50% loaded operation. No deterioration factors are estimated.

Emission factors for SO_2 are calculated from the fuel consumption and fuel sulfur content with allowance for sulfate formation. Emission factors for NH_3 and N_2O were estimated by the COPERT 4 model (Ntziachristos & Samaras, 2009).

Fleet composite emission factors and splitting factors are given in Table 4-68, Table 4-69 and Table 4-70 for rigid trucks, articulated trucks and heavy diesel buses respectively. The fuel property adjustment factors calculated for the average 2008 Sydney diesel properties and applied to the base hot running emission factors are given in Table 4-71. No seasonal temperature corrections are applied. The coefficients for the fleet composite 6th order speed correction functions are given in Table 4-72, Table 4-73 and Table 4-74.

Table 4-65: Base hot running exhaust emission factors for rigid trucks

Emission Age Class	ADR	NO_x	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	Pre - ADR70	7.630	1.804	5.071	1.420	25.357	3.0	872.8
1988	Pre - ADR70	7.630	1.203	3.381	0.710	6.082	3.0	842.8
1996	ADR70/00	5.351	0.858	3.304	0.384	5.551	3.0	828.1
2003	ADR80/00	5.530	0.354	1.581	0.183	3.029	3.0	816.7
2008	ADR80/02	3.073	0.018	0.119	0.035	6.444	3.0	753.0
2011	ADR80/03	1.853	0.019	0.121	0.035	16.767	3.0	773.0

Table 4-66: Base hot running exhaust emission factors for articulated trucks

Emission Age Class	ADR	NO_x	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	Pre - ADR70	23.400	1.911	21.218	1.302	30.000	3.0	1952.6
1988	Pre - ADR70	23.400	1.274	14.145	0.651	17.693	3.0	1890.0
1996	ADR70/00	16.592	0.967	4.921	0.584	17.693	3.0	1880.0
2003	ADR80/00	14.331	0.862	7.402	0.399	9.000	3.0	1995.0
2008	ADR80/02	9.225	0.045	0.490	0.073	19.451	3.0	1934.0
2011	ADR80/03	5.383	0.045	0.496	0.074	50.804	3.0	1934.0

Table 4-67: Base hot running exhaust emission factors for heavy buses

Emission Age Class	ADR	NO_x	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	Pre - ADR70	22.812	1.464	5.688	0.794	30.000	3.0	1034.9
1988	Pre - ADR70	22.812	0.976	3.792	0.397	10.795	3.0	1034.9
1996	ADR70/00	10.930	0.440	0.973	0.172	10.795	3.0	1082.4
2003	ADR80/00	9.405	0.402	1.072	0.152	5.000	3.0	1158.0
2008	ADR80/02	6.452	0.0168	0.233	0.045	11.467	3.0	1099.8
2011	ADR80/03	3.883	0.0172	0.235	0.046	30.866	3.0	1119.2

Table 4-68: Fleet composite base emission factor and composite splitting factors for rigid trucks, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	5.730	1.000	0.865	0.921	0.802	0.791
VOC	0.6850	1.000	0.689	0.753	0.501	0.444
CO	2.493	1.000	0.804	0.909	0.635	0.588
PM_{10}	0.3626	1.000	0.896	1.042	0.850	0.829
N_2O (mg/km)	6.957	1.000	0.990	0.992	0.976	0.947
NH_3 (mg/km)	3.0	1.000	1.000	1.000	1.000	1.000
CO_2	818.8	1.000	0.817	0.858	0.694	0.677

Table 4-69: Fleet composite base emission factor and composite splitting factors for articulated trucks, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	15.37	1.105	0.986	1.047	0.912	0.878
VOC	0.8760	1.300	0.862	0.875	0.627	0.581
CO	6.985	1.158	0.777	0.640	0.438	0.397
PM_{10}	0.4548	1.226	0.847	0.822	0.605	0.579
N_2O (mg/km)	13.41	1.000	0.985	0.988	0.965	0.928
NH_3 (mg/km)	3.0	1.000	1.000	1.000	1.000	1.000
CO_2	1958.4	1.131	0.910	0.909	0.742	0.712

Table 4-70: Fleet composite base emission factor and composite splitting factors for heavy buses, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	15.00	1.326	1.067	1.151	0.918	0.823
VOC	0.6758	1.561	1.071	1.133	0.864	0.709
CO	2.256	1.424	1.205	1.524	1.046	0.764
PM_{10}	0.2925	1.203	1.110	1.303	1.301	1.384
N_2O (mg/km)	14.92	1.000	0.980	0.984	0.954	0.934
NH_3 (mg/km)	3.0	1.000	1.000	1.000	1.000	1.000
CO_2	1084.5	1.301	1.090	1.213	0.948	0.839

Table 4-71: Heavy duty diesel vehicle fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	0.950	0.950	0.950
NO_x	1.010	1.010	1.010
CO	0.9444	0.9444	0.9444
PM_{10}	0.999	0.999	0.999

Table 4-72: Rigid truck composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	4.6475×10^{-11}	-1.7883×10^{-08}	2.8015×10^{-06}	-2.3017×10^{-04}	1.0664×10^{-02}	-2.7845×10^{-01}	3.9141
NO_x	1.8025×10^{-11}	-6.4697×10^{-09}	9.4640×10^{-07}	-7.4055×10^{-05}	3.4572×10^{-03}	-9.7511×10^{-02}	2.0899
CO	1.1215×10^{-11}	-3.2983×10^{-09}	3.5784×10^{-07}	-1.8980×10^{-05}	7.9510×10^{-04}	-4.0213×10^{-02}	1.6379
CO_2	1.6225×10^{-11}	-5.4435×10^{-09}	7.4525×10^{-07}	-5.4014×10^{-05}	2.3915×10^{-03}	-7.2161×10^{-02}	1.8756
PM	-6.2167×10^{-12}	3.0595×10^{-09}	-5.4431×10^{-07}	4.3597×10^{-05}	-1.3729×10^{-03}	-1.4194×10^{-03}	1.3667

Table 4-73: Articulated truck composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	7.6637×10^{-11}	-2.9187×10^{-08}	4.5129×10^{-06}	-3.6464×10^{-04}	1.6522×10^{-02}	-4.1685×10^{-01}	5.5373
NO_x	1.4472×10^{-11}	-5.7931×10^{-09}	9.5461×10^{-07}	-8.3554×10^{-05}	4.1732×10^{-03}	-1.1719×10^{-01}	2.4019
CO	1.0679×10^{-10}	-3.7737×10^{-08}	5.2045×10^{-06}	-3.5306×10^{-04}	1.2380×10^{-02}	-2.3229×10^{-01}	2.9863
CO_2	2.0051×10^{-11}	-7.0463×10^{-09}	9.7968×10^{-07}	-6.9467×10^{-05}	2.8176×10^{-03}	-7.6174×10^{-02}	2.0142
PM	5.4399×10^{-11}	-1.9740×10^{-08}	2.8576×10^{-06}	-2.1213×10^{-04}	8.8192×10^{-03}	-2.1697×10^{-01}	3.4677

Table 4-74: Heavy diesel bus composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	4.8338×10^{-11}	-1.8669×10^{-08}	2.9434×10^{-06}	-2.4465×10^{-04}	1.1582×10^{-02}	-3.1272×10^{-01}	4.6936
NO_x	1.6699×10^{-11}	-7.0553×10^{-09}	1.2252×10^{-06}	-1.1265×10^{-04}	5.8749×10^{-03}	-1.7061×10^{-01}	3.0823
CO	1.2595×10^{-11}	-7.8508×10^{-09}	1.7417×10^{-06}	-1.8533×10^{-04}	1.0243×10^{-02}	-2.9131×10^{-01}	4.3704
CO_2	-2.7555×10^{-12}	-1.6574×10^{-11}	2.0776×10^{-07}	-3.7590×10^{-05}	2.8889×10^{-03}	-1.0933×10^{-01}	2.5712
PM	-9.2555×10^{-11}	2.9834×10^{-08}	-3.5508×10^{-06}	1.8163×10^{-04}	-2.8760×10^{-03}	-4.5793×10^{-02}	2.3369

4.4.3.2 Speciation Profiles

The VOC and PM speciation profile for heavy duty diesel vehicles is derived from the CRC E-75 database (CRC, 2007). The speciation profile for the substances reported in this section is shown in Table 4-40, whilst the full speciation profile is given in APPENDIX D.

Table 4-75: Diesel vehicle speciation data for selected compounds

Substance	Diesel Vehicles	
	Mass fraction (% VOC)	Mass fraction (% PM_{10})
1,3 butadiene	0.402828	N/A
Acetaldehyde	3.813449	N/A
Benzene	1.066778	N/A
Formaldehyde	9.857486	N/A
Isomers of xylene	0.38359	N/A
Lead & compounds	N/A	0.017854
Particulate matter ≤ 2.5 µm	N/A	97
Polycyclic aromatic hydrocarbons	1.65302	5.451313
Toluene	0.46912	N/A
Total suspended particulate	N/A	101

4.4.4 *Emission Estimates*

Estimated emissions from the source type *heavy duty diesel vehicle exhaust* within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-76.

Table 4-76: Estimated exhaust emissions from source type heavy duty diesel vehicle exhaust

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	3.49	0.293	0.141	0.805	4.72
ACETALDEHYDE	33.0	2.77	1.33	7.62	44.7
BENZENE	9.23	0.775	0.373	2.13	12.5
CARBON MONOXIDE	4,081	375	184	1,065	5,705
FORMALDEHYDE	85.3	7.16	3.45	19.7	116
ISOMERS OF XYLENE	3.32	0.279	0.134	0.766	4.50
LEAD & COMPOUNDS	0.106	0.010	0.0052	0.029	0.15
OXIDES OF NITROGEN	14,423	1,511	783	4,702	21,419
PARTICULATE MATTER ≤ 10 µm	592	57.2	29.0	163	841
PARTICULATE MATTER ≤ 2.5 µm	574	55.5	28.1	159	816
POLYCYCLIC AROMATIC HYDROCARBONS	23.3	2.16	1.08	6.11	32.6
SULFUR DIOXIDE	24.6	2.53	1.30	7.77	36.2
TOLUENE	4.06	0.341	0.164	0.937	5.50
TOTAL SUSPENDED PARTICULATE	598	57.8	29.3	165	850
TOTAL VOLATILE ORGANIC COMPOUNDS	866	72.7	35.0	200	1,173

The monthly profile for the base emission species is given in Table 4-77, the weekly profile is given in Table 4-78, and the daily profile is shown in Table 4-79. The speciated compounds have the same profile as the base emission species; i.e. each speciated exhaust VOC has the same profile as the total VOC, and each of the speciated PM metal and inorganic compounds share the exhaust PM_{10} profile.

Table 4-77: Monthly profile for exhaust emissions from heavy duty diesel vehicles

Month	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
1	0.07948	0.07948	0.07948	0.07948	0.07948	0.07948	0.07948	0.07948
2	0.07879	0.07879	0.07879	0.07879	0.07879	0.07879	0.07879	0.07879
3	0.08810	0.08810	0.08810	0.08810	0.08810	0.08810	0.08810	0.08810
4	0.08245	0.08245	0.08245	0.08245	0.08245	0.08245	0.08245	0.08245
5	0.08715	0.08715	0.08715	0.08715	0.08715	0.08715	0.08715	0.08715
6	0.07985	0.07985	0.07985	0.07985	0.07985	0.07985	0.07985	0.07985
7	0.08356	0.08356	0.08356	0.08356	0.08356	0.08356	0.08356	0.08356
8	0.08460	0.08460	0.08460	0.08460	0.08460	0.08460	0.08460	0.08460
9	0.08269	0.08269	0.08269	0.08269	0.08269	0.08269	0.08269	0.08269
10	0.08571	0.08571	0.08571	0.08571	0.08571	0.08571	0.08571	0.08571
11	0.08459	0.08459	0.08459	0.08459	0.08459	0.08459	0.08459	0.08459
12	0.08304	0.08304	0.08304	0.08304	0.08304	0.08304	0.08304	0.08304

Table 4-78: Weekly profile for exhaust emissions from heavy duty diesel vehicles

Days	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
Weekdays	0.88294	0.88639	0.88250	0.88454	0.88633	0.88633	0.88543	0.88367
Weekend days	0.11706	0.11361	0.11750	0.11546	0.11367	0.11367	0.11457	0.11633

Table 4-79: Daily profile for exhaust emissions from heavy duty diesel vehicles

Hour	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
0	0.00903	0.00981	0.01103	0.00898	0.01066	0.01067	0.00950	0.01059
1	0.00813	0.00890	0.00987	0.00823	0.00966	0.00966	0.00872	0.00957
2	0.00868	0.00944	0.01027	0.00904	0.01016	0.01016	0.00952	0.01013
3	0.01170	0.01274	0.01384	0.01221	0.01372	0.01372	0.01286	0.01366
4	0.01838	0.01992	0.02148	0.01928	0.02135	0.02135	0.02026	0.02132
5	0.03533	0.03723	0.03850	0.03837	0.03884	0.03885	0.03967	0.03953
6	0.05721	0.05782	0.05677	0.06204	0.05805	0.05804	0.06273	0.05969
7	0.07841	0.07690	0.07284	0.07215	0.07373	0.07373	0.06995	0.07055
8	0.08723	0.08426	0.07788	0.07698	0.07923	0.07923	0.07278	0.07365
9	0.07558	0.07515	0.07383	0.07693	0.07463	0.07462	0.07681	0.07501
10	0.07230	0.07311	0.07259	0.07562	0.07351	0.07351	0.07623	0.07442
11	0.07253	0.07316	0.07221	0.07541	0.07330	0.07330	0.07587	0.07395
12	0.06894	0.06968	0.06925	0.07221	0.07009	0.07009	0.07280	0.07105
13	0.06796	0.06847	0.06787	0.07097	0.06870	0.06870	0.07144	0.06962
14	0.06741	0.06714	0.06563	0.06944	0.06666	0.06665	0.06942	0.06722
15	0.05955	0.05782	0.05654	0.05758	0.05645	0.05645	0.05667	0.05617
16	0.05196	0.04964	0.04932	0.04938	0.04839	0.04839	0.04828	0.04843
17	0.04311	0.04050	0.04107	0.03951	0.03940	0.03939	0.03828	0.03928
18	0.03339	0.03208	0.03387	0.03275	0.03221	0.03221	0.03257	0.03341
19	0.02122	0.02140	0.02340	0.02146	0.02229	0.02229	0.02190	0.02312
20	0.01576	0.01632	0.01832	0.01578	0.01738	0.01738	0.01632	0.01782
21	0.01345	0.01412	0.01599	0.01333	0.01517	0.01518	0.01389	0.01541
22	0.01206	0.01287	0.01451	0.01189	0.01389	0.01390	0.01249	0.01392
23	0.01068	0.01152	0.01311	0.01044	0.01253	0.01254	0.01104	0.01248

4.5 Exhaust Emissions from Other Vehicles

4.5.1 Fleet Profile

The fleet age profile for the individual vehicle types comprising the *other vehicles* source type, and the VKT per annum profile are shown in Table 4-80.

Table 4-80: Other vehicle fleet profile, 2008

YOM	Heavy duty commercial petrol	VKT per Annum	Profile (%)	Motorcycles	VKT per Annum	Profile (%)
2008	41	17,250	3.756%	15,167	2,581	14.349%
2007	40	34,200	3.585%	13,749	4,881	13.007%
2006	37	33,896	3.336%	10,387	4,646	9.827%
2005	26	33,644	2.397%	9,144	4,454	8.651%
2004	64	33,162	5.898%	6,986	4,299	6.609%
2003	37	32,471	3.355%	5,492	4,178	5.196%
2002	72	31,594	6.505%	4,815	4,087	4.556%
2001	35	30,551	3.369%	4,557	4,021	4.311%
2000	15	29,364	1.652%	4,021	3,977	3.804%
1999	23	28,055	2.159%	4,014	3,949	3.797%
1998	34	26,645	2.905%	3,610	3,934	3.416%
1997	28	25,157	2.424%	2,776	3,928	2.626%
1996	16	23,611	1.483%	2,457	3,926	2.325%
1995	19	22,029	1.622%	2,339	3,925	2.213%
1994	24	20,433	2.062%	1,677	3,919	1.586%
1993	14	18,844	1.239%	1,297	3,905	1.227%
1992	16	17,285	1.522%	1,254	3,879	1.186%
1991	20	15,776	1.798%	1,316	3,836	1.245%
1990	18	14,339	1.517%	1,112	3,773	1.052%
1989	27	12,996	2.371%	960	3,684	0.908%
1988	32	11,768	2.863%	985	3,566	0.932%
1987	12	10,678	1.113%	664	3,415	0.628%
1986	24	9,746	2.105%	653	3,226	0.618%
1985	42	8,994	4.070%	878	2,996	0.830%
1984	27	8,444	2.670%	701	2,719	0.663%
1983	16	8,117	1.602%	532	2,392	0.503%
1982	24	8,036	2.646%	517	2,011	0.489%
1981	46	7,600	3.968%	606	1,571	0.573%
1980	36	7,400	2.673%	516	1,069	0.488%
1979	41	7,200	3.567%	215	600	0.204%
1978	39	7,000	3.382%	246	400	0.232%
1977	28	6,700	2.458%	115	300	0.109%
1976	27	6,500	2.237%	182	250	0.172%
1975	23	6,300	1.954%	205	200	0.194%
≤ 1974	118	6,000	7.737%	1,557	100	1.473%

[1] – Vehicles assumed to enter fleet evenly across year, hence average annual mileage is 50% of new vehicle

4.5.2 VKT Data

The total 2008 GMR VKT for heavy duty commercial petrol vehicles and motorcycles, which together comprise the source type other vehicles, on an average week day and average weekend day are given in Table 4-81 and Table 4-82 respectively, and the hourly profiles are shown graphically in Figure 4-12 and Figure 4-13. The average speeds by hour of the day for each road type are given previously in Table 4-3.

Table 4-81: Heavy duty commercial petrol vehicle average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	1,082	0.56%	1,014	1.66%
1	1,101	0.57%	815	1.33%
2	1,390	0.73%	793	1.30%
3	1,937	1.01%	938	1.53%
4	3,280	1.71%	1,171	1.91%
5	7,679	4.01%	2,012	3.29%
6	13,522	7.05%	3,570	5.83%
7	13,276	6.93%	4,022	6.57%
8	13,655	7.12%	4,288	7.01%
9	15,646	8.16%	4,491	7.34%
10	15,439	8.05%	4,524	7.39%
11	15,457	8.06%	4,405	7.20%
12	14,792	7.72%	4,245	6.94%
13	14,675	7.66%	3,918	6.40%
14	14,558	7.60%	3,654	5.97%
15	11,457	5.98%	2,910	4.76%
16	9,402	4.91%	2,962	4.84%
17	6,984	3.64%	2,710	4.43%
18	5,881	3.07%	2,458	4.02%
19	3,512	1.83%	1,798	2.94%
20	2,295	1.20%	1,350	2.21%
21	1,812	0.95%	1,159	1.89%
22	1,563	0.82%	1,048	1.71%
23	1,282	0.67%	933	1.53%
Total	**191,677**		**61,187**	

Table 4-82: Motorcycle average daily GMR VKT

Hour	Average Week Day		Average Weekend Day	
	VKT	% Daily	VKT	% Daily
0	7,803	1.40%	20,203	4.31%
1	-	0.00%	-	0.00%
2	-	0.00%	-	0.00%
3	-	0.00%	-	0.00%
4	1,510	0.27%	1,178	0.25%
5	22,846	4.10%	9,687	2.07%
6	61,210	10.98%	21,056	4.49%
7	38,801	6.96%	14,085	3.00%
8	26,255	4.71%	14,073	3.00%
9	28,197	5.06%	24,898	5.31%
10	36,095	6.47%	43,638	9.30%
11	5,162	0.93%	6,958	1.48%
12	18,049	3.24%	24,330	5.19%
13	22,926	4.11%	28,451	6.07%
14	40,836	7.33%	42,673	9.10%
15	31,962	5.73%	27,711	5.91%
16	60,412	10.84%	49,900	10.64%
17	44,120	7.91%	35,384	7.54%
18	32,887	5.90%	25,553	5.45%
19	18,316	3.29%	15,092	3.22%
20	16,829	3.02%	15,146	3.23%
21	5,278	0.95%	4,887	1.04%
22	8,293	1.49%	8,352	1.78%
23	29,691	5.33%	35,748	7.62%
Total	**557,476**		**469,003**	

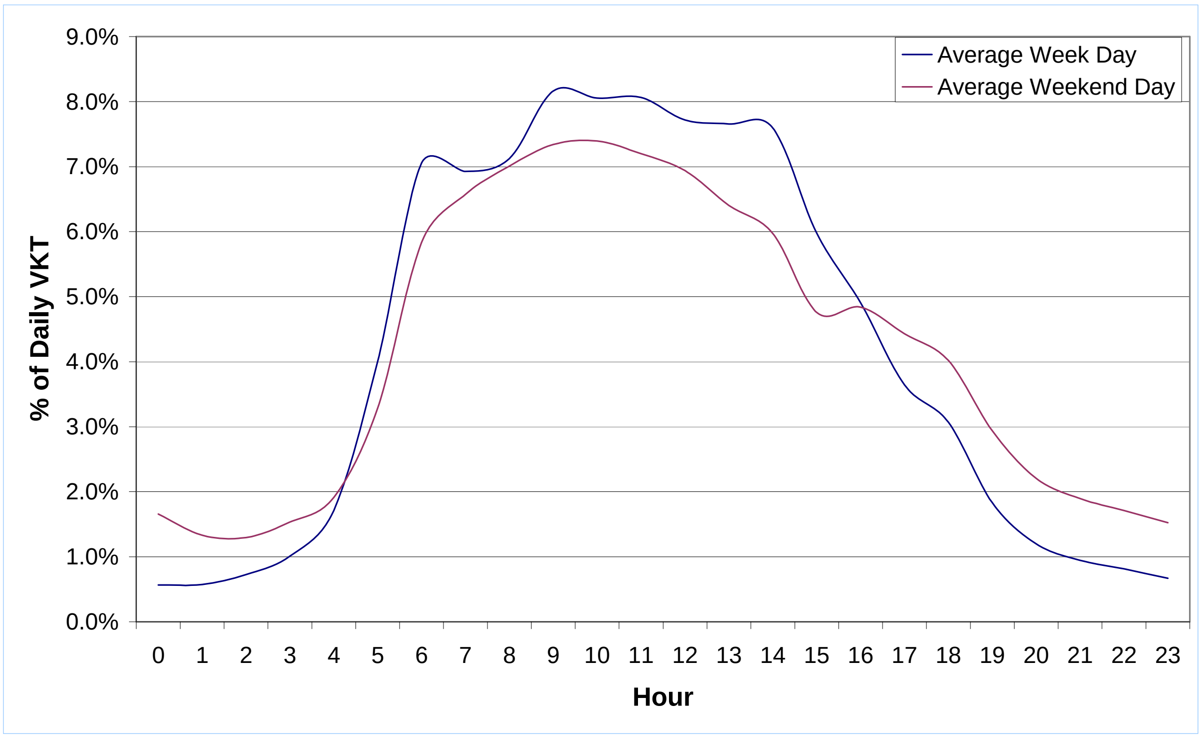

Figure 4-12: Heavy duty commercial petrol diurnal VKT profiles

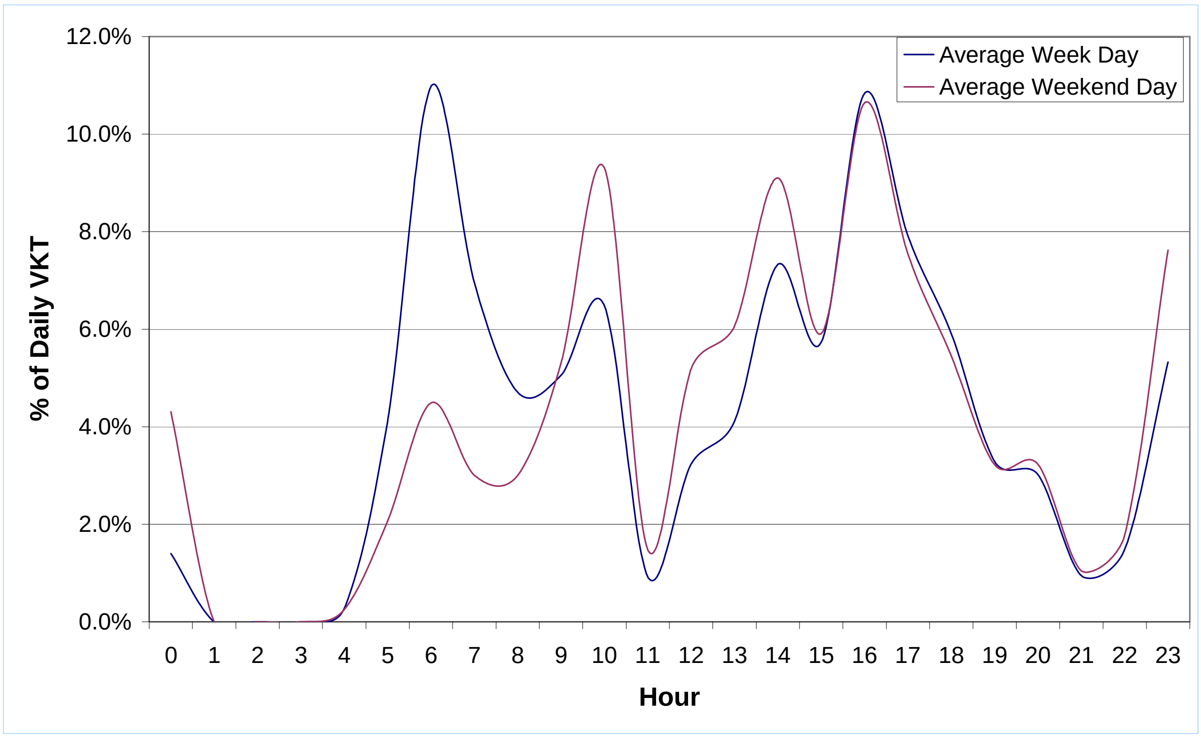

Figure 4-13: Motorcycle diurnal VKT profiles

4.5.3 Emission Factors

4.5.3.1 Hot Running

The emission factors for the heavy duty commercial petrol (HDCP) vehicle type are estimated from the US EPA MOBILE 6.2 model by year of manufacture and registered GVM (US EPA, 1995, 1998, 1999). Emission factors for motorcycles are estimated from the ARTEMIS model (Elst, 2006). The motorcycle fleet profile by engine size and year of manufacture, assumed equivalency to the ARTEMIS Euro based emission classes, and the proportion of two-stroke engines are given in Table 4-83, Table 4-84 and Table 4-85.

Base emission factors by age class are given in Table 4-86 and Table 4-87, and fleet composite emission factors and splitting factors are given in Table 4-88 and Table 4-89 for HDCP and motorcycles respectively. Fuel property adjustments are given in Table 4-90 and Table 4-91, and the coefficients for the fleet composite speed correction functions are given in Table 4-92 and Table 4-93. No ambient temperature correction data are available for either vehicle type.

Table 4-83: Motorcycle fleet age and engine capacity profile

Engine Size	Year of Manufacture			
	≤ 2000	2001-2004	2005-2007	2008
≤ 150 cc	16%	22%	48%	14%
151-250 cc	45%	18%	31%	7%
251-750 cc	34%	23%	34%	9%
> 750 cc	39%	24%	29%	9%

Table 4-84: Motorcycle fleet Euro equivalency assumptions

Euro Equivalent	Year of Manufacture			
	≤ 2000	2001-2004	2005-2007	2008
Euro 0	100%	60%	30%	10%
Euro 1	0%	40%	30%	20%
Euro 2	0%	0%	40%	30%
Euro 3	0%	0%	0%	40%

Table 4-85: Motorcycle fleet 2-stroke proportions

Engine Size	Year of Manufacture			
	≤ 2000	2001-2004	2005-2007	2008
≤ 150 cc	50%	40%	30%	30%
151-250 cc	35%	25%	20%	20%
251-750 cc	0%	0%	0%	0%
> 750 cc	0%	0%	0%	0%

Table 4-86: Base hot running exhaust emission factors for heavy duty commercial petrol trucks

Emission Age Class	ADR	NO_x		VOC		CO		Exhaust PM_{10}		N_2O		NH_3	CO_2
		EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (g/km)	DR (g/km²)	EF_{0km} (mg/km)	DR (mg/km²)	EF (mg/km)	EF (g/km)
1975	N/A	4.600	0	7.75	0	153.600	0.00	0.200	0	18.029	0	3.740	357.0
1987	N/A	3.230	1.86×10^{-06}	1.7	6.00×10^{-06}	28.000	4.00×10^{-05}	0.073	0	18.029	0	3.740	476.6
1990	ADR36/00	2.790	1.88×10^{-06}	0.72	3.50×10^{-06}	19.500	4.00×10^{-05}	0.057	0	18.029	0	3.740	486.2
1993	ADR36/00	2.220	1.62×10^{-06}	0.54	2.63×10^{-06}	14.500	3.00×10^{-05}	0.036	0	18.029	0	3.740	493.5
2003	ADR80/00	1.780	1.67×10^{-06}	0.46	1.79×10^{-06}	9.700	2.18×10^{-05}	0.005	0	18.029	0	3.740	479.6

Table 4-87: Base hot running exhaust emission factors for motorcycles

Emission Age Class	ADR	NO_x	VOC	CO	Exhaust PM_{10}	N_2O	NH_3	CO_2
		EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (g/km)	EF_{0km} (mg/km)	EF (mg/km)	EF (g/km)
1975	N/A	0.170	4.892	23.76	0.042	2.0	2.0	95.6
2001	N/A	0.178	3.605	19.47	0.032	2.0	2.0	103.2
2005	N/A	0.166	2.443	13.68	0.022	2.0	2.0	104.5
2008	N/A	0.124	1.485	8.52	0.014	2.0	2.0	113.9

Table 4-88: Fleet composite base emission factor and composite splitting factors for heavy duty commercial petrol trucks, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	2.845	0.957	1.033	1.017	1.138	1.187
VOC	2.591	1.423	0.786	0.883	0.463	0.393
CO	43.78	1.363	0.820	0.900	0.573	0.536
PM_{10}	0.0534	1.085	0.999	0.998	1.084	1.179
N_2O (mg/km)	18.03	1.000	1.000	1.000	1.000	1.000
NH_3 (mg/km)	3.74	1.000	1.000	1.000	1.000	1.000
CO_2	459.7	1.124	0.855	0.958	0.785	0.774

Table 4-89: Fleet composite base emission factor and composite splitting factors for motorcycles, 2008

Pollutant	Composite base hot emission factor (g/km)	Composite splitting factor				
		Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
NO_x	0.1661	1.000	1.032	1.017	1.271	1.479
VOC	3.341	1.000	0.690	0.735	0.497	0.444
CO	17.48	1.000	0.829	0.848	0.810	0.842
PM_{10}	0.0296	1.000	1.000	1.000	1.000	1.000
N_2O (mg/km)	2.0	1.000	1.000	1.000	1.000	1.000
NH_3 (mg/km)	2.0	1.000	1.000	1.000	1.000	1.000
CO_2	102.5	1.000	0.794	0.819	0.734	0.741

Table 4-90: Heavy duty commercial petrol vehicle fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	0.9438	0.9328	0.9325
NO_x	1.0232	1.0439	1.0436
CO	0.963	0.955	0.955
PM_{10}	0.9438	0.9328	0.9325

Table 4-91: Motorcycle petrol fuel property adjustments

Pollutant	Summer	Autumn & Spring	Winter
VOC	1.0	1.0	1.0
NO_x	1.0	1.0	1.0
CO	1.0	1.0	1.0
PM_{10}	1.0	1.0	1.0

Table 4-92: Heavy duty commercial petrol truck composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	1.0893×10^{-11}	-4.9875×10^{-09}	9.6929×10^{-07}	-1.0292×10^{-04}	6.4087×10^{-03}	-2.2619×10^{-01}	4.0622
NO_x	8.6599×10^{-11}	-3.6306×10^{-08}	6.1883×10^{-06}	-5.4465×10^{-04}	2.6340×10^{-02}	-6.6337×10^{-01}	7.6741
CO	1.9023×10^{-11}	-8.3314×10^{-09}	1.6062×10^{-06}	-1.7405×10^{-04}	1.1004×10^{-02}	-3.7175×10^{-01}	5.7540
CO_2	1.3874×10^{-11}	-7.0180×10^{-09}	1.4027×10^{-06}	-1.4382×10^{-04}	8.2046×10^{-03}	-2.5283×10^{-01}	4.0825
PM	4.0083×10^{-11}	-1.6319×10^{-08}	2.6797×10^{-06}	-2.2619×10^{-04}	1.0533×10^{-02}	-2.5666×10^{-01}	3.5302

Table 4-93: Motorcycle composite fleet speed correction function coefficients

Pollutant	V^6 coefficient	V^5 coefficient	V^4 coefficient	V^3 coefficient	V^2 coefficient	V^1 coefficient	V^0 coefficient
VOC	0.0	0.0	0.0	0.0	0.0	0.0	1.0
NO_x	0.0	0.0	0.0	0.0	0.0	0.0	1.0
CO	0.0	0.0	0.0	0.0	0.0	0.0	1.0
CO_2	0.0	0.0	0.0	0.0	0.0	0.0	1.0
PM	0.0	0.0	0.0	0.0	0.0	0.0	1.0

4.5.3.2 *Speciation Profiles*

Due to the lack of measurements of speciated emissions on these vehicle types, and considering that the total VOC from this source type is less than 2% of the total on-road mobile, the petrol passenger vehicle speciation profile is adopted. Ethanol is assumed not to be used in these vehicle types as manufacturer approval is very limited. The speciation profile for the substances reported in this section is shown in Table 4-14, whilst the full speciation profile is given in APPENDIX D.

Table 4-94: Petrol vehicle speciation data for selected compounds

Substance	Petrol no ethanol (E0)	
	Mass fraction (% VOC)	Mass fraction (% PM_{10})
1,3 butadiene	1.265047	N/A
Acetaldehyde	0.475506	N/A
Benzene	4.952975	N/A
Formaldehyde	1.4642	N/A
Isomers of xylene	7.596421	N/A
Lead & compounds	N/A	0.035375
Particulate matter ≤ 2.5 µm	N/A	95.3
Polycyclic aromatic hydrocarbons	0.560292	37.218
Toluene	9.178649	N/A
Total suspended particulate	N/A	100

4.5.4 Emission Estimates

Estimated emissions from the source type *Other vehicle exhaust* within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-95.

Table 4-95: Estimated exhaust emissions from source type other vehicle exhaust

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	5.18	0.377	0.178	0.815	6.55
ACETALDEHYDE	1.95	0.142	0.067	0.307	2.46
BENZENE	20.3	1.47	0.696	3.19	25.6
CARBON MONOXIDE	3,691	280	140	651	4,762
FORMALDEHYDE	5.99	0.436	0.206	0.944	7.58
ISOMERS OF XYLENE	31.1	2.26	1.07	4.90	39.3
LEAD & COMPOUNDS	0.0025	0.0002	0.0001	0.0005	0.0033
OXIDES OF NITROGEN	178	18.2	9.92	52.0	259
PARTICULATE MATTER ≤ 10 µm	6.99	0.592	0.314	1.49	9.39
PARTICULATE MATTER ≤ 2.5 µm	6.67	0.564	0.300	1.42	8.95
POLYCYCLIC AROMATIC HYDROCARBONS	2.45	0.193	0.098	0.459	3.20
SULFUR DIOXIDE	1.13	0.091	0.046	0.224	1.49
TOLUENE	37.6	2.73	1.29	5.92	47.5
TOTAL SUSPENDED PARTICULATE	6.99	0.592	0.314	1.49	9.39
TOTAL VOLATILE ORGANIC COMPOUNDS	409	29.8	14.1	64.5	518

The monthly profile for the base emission species is given in Table 4-96, the weekly profile is given in Table 4-97, and the daily profile is shown in Table 4-98. The speciated compounds have the same profile as the base emission species; i.e. each speciated exhaust VOC have the same profile as the total VOC, and each of the speciated PM metal and inorganic compounds share the exhaust PM_{10} profile.

Table 4-96: Monthly profile for exhaust emissions from other vehicle exhaust

Month	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
1	0.07959	0.07965	0.07856	0.07948	0.07135	0.07948	0.07948	0.07948
2	0.07890	0.07896	0.07789	0.07879	0.07074	0.07879	0.07879	0.07879
3	0.08813	0.08814	0.08786	0.08810	0.08632	0.08810	0.08810	0.08810
4	0.08240	0.08237	0.08292	0.08245	0.08714	0.08245	0.08245	0.08245
5	0.08709	0.08706	0.08764	0.08715	0.09210	0.08715	0.08715	0.08715
6	0.07980	0.07976	0.08028	0.07985	0.08280	0.07985	0.07985	0.07985
7	0.08350	0.08347	0.08401	0.08356	0.08664	0.08356	0.08356	0.08356
8	0.08454	0.08450	0.08505	0.08460	0.08772	0.08460	0.08460	0.08460
9	0.08263	0.08261	0.08316	0.08269	0.08739	0.08269	0.08269	0.08269
10	0.08565	0.08562	0.08619	0.08571	0.09058	0.08571	0.08571	0.08571
11	0.08462	0.08464	0.08434	0.08459	0.08267	0.08459	0.08459	0.08459
12	0.08316	0.08322	0.08209	0.08304	0.07456	0.08304	0.08304	0.08304

Table 4-97: Weekly profile for exhaust emissions from other vehicle exhaust

Days	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
Weekdays	0.77253	0.80227	0.86641	0.80175	0.82424	0.83069	0.79694	0.84844
Weekend days	0.22747	0.19773	0.13359	0.19825	0.17576	0.16931	0.20306	0.15156

Table 4-98: Daily profile for exhaust emissions from other vehicle exhaust

Hour	VOC	CO	NO_x	PM	SO_2	CO_2	NH_3	N_2O
0	0.01848	0.01549	0.00932	0.01584	0.01323	0.01255	0.01624	0.01088
1	0.00103	0.00239	0.00599	0.00267	0.00348	0.00378	0.00232	0.00478
2	0.00123	0.00286	0.00718	0.00320	0.00417	0.00452	0.00278	0.00571
3	0.00166	0.00387	0.00974	0.00434	0.00564	0.00613	0.00376	0.00774
4	0.00487	0.00790	0.01606	0.00863	0.01034	0.01100	0.00782	0.01328
5	0.03546	0.03609	0.04007	0.03765	0.03686	0.03697	0.03705	0.03831
6	0.08793	0.08271	0.07330	0.08436	0.07908	0.07791	0.08491	0.07589
7	0.06250	0.06570	0.06519	0.06223	0.06647	0.06698	0.06288	0.06631
8	0.05037	0.05854	0.06527	0.05268	0.06185	0.06335	0.05275	0.06327
9	0.05688	0.06257	0.07602	0.06257	0.06734	0.06870	0.06158	0.07254
10	0.07332	0.07406	0.07909	0.07521	0.07564	0.07597	0.07466	0.07760
11	0.02251	0.03680	0.06991	0.03755	0.04797	0.05116	0.03493	0.06058
12	0.04392	0.05156	0.07118	0.05268	0.05805	0.05984	0.05100	0.06550
13	0.05110	0.05659	0.07130	0.05754	0.06148	0.06280	0.05628	0.06709
14	0.07771	0.07609	0.07438	0.07633	0.07566	0.07547	0.07645	0.07511
15	0.05839	0.05868	0.05705	0.05756	0.05861	0.05866	0.05799	0.05822
16	0.09803	0.08572	0.05648	0.08468	0.07617	0.07346	0.08716	0.06527
17	0.07162	0.06313	0.04239	0.06203	0.05645	0.05457	0.06383	0.04864
18	0.05286	0.04739	0.03534	0.04772	0.04328	0.04206	0.04868	0.03898
19	0.02983	0.02707	0.02184	0.02776	0.02508	0.02446	0.02807	0.02320
20	0.02714	0.02348	0.01613	0.02407	0.02075	0.01992	0.02453	0.01798
21	0.00957	0.00973	0.01082	0.01017	0.00992	0.00995	0.01000	0.01030
22	0.01418	0.01284	0.01047	0.01325	0.01186	0.01156	0.01335	0.01095
23	0.04940	0.03876	0.01549	0.03927	0.03062	0.02823	0.04097	0.02187

4.6 Evaporative Emissions from All Petrol Vehicles

Evaporative emissions from each petrol vehicle type is calculated individually and then summed to give the evaporative emission source type emissions. Fleet data, activity data and emission estimates from this source type are presented below.

4.6.1 Fleet Profile

The petrol vehicle fleet by vehicle type and fuel type is given in Table 4-99.

Table 4-99: Petrol vehicle fleet profile

YOM	Petrol Passenger Vehicles – E0 Fuel	Petrol Passenger Vehicles – E10 Fuel	Petrol LCV - E0 Fuel	Petrol LCV - E10 Fuel	Motorcycles - E0 Fuel only	Heavy Duty Commercial Petrol - E0 Fuel only
2008	108,821	18,057	14,205	2,366	15,167	41
2007	108,357	17,562	14,511	2,361	13,749	40
2006	112,481	17,800	15,670	2,490	10,387	37
2005	128,616	20,353	16,585	2,635	9,144	26
2004	119,823	18,506	17,282	2,679	6,986	64
2003	120,791	15,739	16,774	2,194	5,492	37
2002	108,598	13,659	13,681	1,727	4,815	72
2001	105,127	12,938	12,253	1,514	4,557	35
2000	114,619	13,289	12,868	1,498	4,021	15
1999	106,224	11,940	14,505	1,637	4,014	23
1998	116,545	12,487	12,401	1,334	3,610	34
1997	100,696	10,439	9,995	1,040	2,776	28
1996	82,817	8,585	9,416	980	2,457	16
1995	81,007	8,118	8,712	876	2,339	19
1994	72,692	6,911	8,187	781	1,677	24
1993	57,434	4,877	5,716	487	1,297	14
1992	48,718	3,492	6,566	472	1,254	16
1991	42,057	2,741	6,510	426	1,316	20
1990	40,344	2,695	6,726	451	1,112	18
1989	30,409	1,642	5,831	316	960	27
1988	19,135	824	3,309	143	985	32
1987	11,107	530	1,592	76	664	12
1986	9,570	412	1,871	81	653	24
1985	9,056	-	2,654	-	878	42
1984	5,522	-	1,812	-	701	27
1983	3,503	-	1,004	-	532	16
1982	3,114	-	912	-	517	24
1981	2,425	-	765	-	606	46
1980	1,762	-	556	-	516	36
1979	1,089	-	369	-	215	41
1978	1,031	-	315	-	246	39
1977	1,002	-	289	-	115	28
1976	1,068	-	277	-	182	27
1975	1,017	-	225	-	205	23
≤ 1974	18,717	-	2,174	-	1,557	118

4.6.2 *Activity Data*

Diurnal and resting emissions are independent of vehicle activity (VKT) and emissions are calculated for every vehicle of the fleet given in Table 4-99.

Hot soak emissions occur at the end of each trip. Data for trips ending per hour for each of the evaporative emission vehicle type is given in Table 4-100.

Table 4-100: Hourly trips ending by vehicle type

Hour	Petrol Passenger Vehicles	Petrol LCV	Motorcycles	Heavy Duty Commercial Petrol
0	38,542	2,270	252	9
1	16,943	883	111	10
2	11,501	928	75	12
3	8,996	353	59	17
4	50,373	5,359	330	29
5	193,461	23,928	1,266	67
6	378,574	76,890	2,478	118
7	699,261	164,525	4,578	319
8	867,952	111,324	5,682	327
9	550,221	197,336	3,602	424
10	454,276	146,324	2,974	421
11	461,390	186,804	3,020	421
12	436,394	162,028	2,857	403
13	459,241	164,212	3,006	400
14	532,484	194,978	3,486	395
15	742,089	75,479	4,858	216
16	766,100	94,455	5,015	177
17	853,553	54,198	5,588	131
18	618,818	25,837	4,051	51
19	367,594	14,311	2,406	31
20	214,421	10,134	1,404	20
21	169,199	5,105	1,108	16
22	170,911	5,267	1,119	14
23	82,289	1,142	539	11

Running emissions are a direct function of VKT and the VKT data presented in previous source type sections are used as the relevant activity data.

4.6.3 *Emission Factors*

The evaporative emission factors for each evaporative mechanism are given in this section. All emission factors are calculated according to the methodology presented in Section 3.11 with the ambient temperature profiles as given in Table 3-15 and the seasonal RVP given in Table 3-17.

4.6.3.1 *Diurnal Emissions*

The daily diurnal emission factors (grams per day) for the 2008 vehicle fleet by year of manufacture are given in Table 4-101 for the vehicle fleet operating on ethanol free fuel, and in Table 4-102 for vehicles operate on E10 fuel. Note it is assumed that no pre-1986 vehicles operating on E10 fuel, and it is also assumed that no motorcycles or heavy duty commercial petrol vehicles operate on E10. The emission factors given are calculated according to the methodology given in Section 3.11, and are fleet aggregate emission factors including vehicles classified as both failed and passing.

The fleet composite emission factors across all age groups are given in Table 4-103 and Table 4-104 for the E0 and E10 fleet respectively. Note the E10 fleet comprises only post-1985 vehicles and is hence weighted to lower emitting vehicles relative to the E0 fleet, and hence the difference in fleet composite emission factors is lower than might be expected from the E10 factors provided in Table 3-50.

The diurnal hourly profiles for the ethanol free fuel fleet and the E10 fleet are given in Table 4-105 and Table 4-106 respectively. These hourly profiles apply to the vehicle type fleet composite total daily diurnal emissions (Table 4-103 and Table 4-104) and may vary slightly for specific year classes.

Table 4-101: Seasonal diurnal emission factors – ethanol free fuel fleet (E0)

YOM	Summer Season Diurnal Emissions (g/day)				Autumn-Spring Season Diurnal Emissions (g/day)				Winter Season Diurnal Emissions (g/day)			
	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP
2008	1.21	1.21	8.63	1.81	1.21	1.21	8.63	1.81	1.21	1.21	8.63	1.81
2007	1.21	1.21	8.63	1.82	1.21	1.21	8.63	1.82	1.21	1.21	8.63	1.82
2006	1.23	1.23	8.63	1.84	1.23	1.23	8.63	1.84	1.23	1.23	8.63	1.84
2005	1.25	1.25	8.63	1.88	1.25	1.25	8.63	1.88	1.25	1.25	8.63	1.88
2004	1.28	1.28	8.63	1.92	1.28	1.28	8.63	1.92	1.28	1.28	8.63	1.92
2003	3.05	5.65	8.63	8.48	3.05	5.65	8.63	8.48	3.05	5.65	8.63	8.48
2002	3.30	6.68	8.63	10.0	3.30	6.68	8.63	10.0	3.30	6.68	8.63	10.0
2001	3.62	7.87	8.63	11.8	3.62	7.87	8.63	11.8	3.62	7.87	8.63	11.8
2000	4.02	9.09	8.63	13.6	4.02	9.09	8.63	13.6	4.02	9.09	8.63	13.6
1999	4.51	10.2	8.63	15.2	4.51	10.2	8.63	15.2	4.51	10.2	8.63	15.2
1998	5.10	13.8	8.63	20.7	5.10	13.8	8.63	20.7	5.10	13.8	8.63	20.7
1997	5.77	14.2	8.63	21.2	5.77	14.2	8.63	21.2	5.77	14.2	8.63	21.2
1996	6.50	14.4	8.63	21.6	6.50	14.4	8.63	21.6	6.50	14.4	8.63	21.6
1995	7.23	14.5	8.63	21.8	7.23	14.5	8.63	21.8	7.23	14.5	8.63	21.8
1994	7.93	14.6	8.63	21.9	7.93	14.6	8.63	21.9	7.93	14.6	8.63	21.9
1993	12.1	14.6	8.63	21.9	12.1	14.6	8.63	21.9	12.1	14.6	8.63	21.9
1992	12.5	14.6	8.63	22.0	12.5	14.6	8.63	22.0	12.5	14.6	8.63	22.0
1991	12.9	14.6	8.63	22.0	12.9	14.6	8.63	22.0	12.9	14.6	8.63	22.0
1990	13.1	14.7	8.63	22.0	13.1	14.7	8.63	22.0	13.1	14.7	8.63	22.0
1989	13.3	14.7	8.63	22.0	13.3	14.7	8.63	22.0	13.3	14.7	8.63	22.0
1988	13.4	14.7	8.63	22.0	13.4	14.7	8.63	22.0	13.4	14.7	8.63	22.0
≤ 1987	15.0	17.3	8.63	25.9	15.0	17.3	8.63	25.9	15.0	17.3	8.63	25.9

Table 4-102: Seasonal diurnal emission factors – E10 fuel fleet

YOM	Summer (g/day)		Autumn-Spring (g/day)		Winter (g/day)	
	PPV	PLCV	PPV	PLCV	PPV	PLCV
2008	1.75	1.75	0.932	0.932	0.500	0.500
2007	1.76	1.76	0.938	0.938	0.503	0.503
2006	1.78	1.78	0.950	0.950	0.509	0.509
2005	1.81	1.81	0.966	0.966	0.518	0.518
2004	1.85	1.85	0.988	0.988	0.530	0.530
2003	4.97	9.21	2.65	4.92	1.42	2.64
2002	5.38	10.9	2.87	5.81	1.54	3.13
2001	5.89	12.8	3.14	6.85	1.69	3.68
2000	6.55	14.8	3.49	7.91	1.88	4.26
1999	7.35	16.6	3.92	8.85	2.11	4.76
1998	8.31	16.0	4.43	8.56	2.38	4.64
1997	9.40	16.4	5.02	8.80	2.70	4.77
1996	10.6	16.7	5.65	8.95	3.04	4.84
1995	11.8	16.9	6.29	9.03	3.39	4.89
1994	12.9	16.9	6.90	9.07	3.71	4.91
1993	14.0	17.0	7.54	9.09	4.11	4.92
1992	14.5	17.0	7.81	9.10	4.25	4.92
1991	14.9	17.0	8.02	9.10	4.36	4.92
1990	15.2	17.0	8.16	9.10	4.44	4.92
1989	15.4	17.0	8.26	9.10	4.49	4.92
1988	15.5	17.0	8.32	9.10	4.52	4.92
1987	17.4	20.0	9.31	10.7	5.04	5.76
1986	17.4	20.0	9.31	10.7	5.04	5.76
≤ 1985	0	0	0	0	0	0

Table 4-103: Fleet aggregate diurnal emission factors – ethanol free fuel fleet (E0), 2008

Vehicle Type	Summer (g/day)	Autumn-Spring (g/day)	Winter (g/day)
PPV	5.063	2.708	1.462
PLCV	8.830	4.723	2.550
MC	8.632	4.610	2.482
HDCP	18.77	10.03	5.408

Table 4-104: Fleet aggregate diurnal emission factors – E10 fuel fleet, 2008

Vehicle Type	Summer (g/day)	Autumn-Spring (g/day)	Winter (g/day)
PPV	5.784	3.090	1.664
PLCV	9.308	4.977	2.685
MC	N/A	N/A	N/A
HDCP	N/A	N/A	N/A

Table 4-105: Hourly temporal profile for diurnal emissions – ethanol free fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.45%	0.00%	0.00%	0.29%	0.00%	0.00%	1.02%	0.00%	0.00%	0.72%	0.00%	0.00%
6	4.88%	1.89%	0.00%	4.96%	1.76%	0.00%	6.37%	2.25%	0.00%	5.79%	2.05%	0.00%
7	10.57%	6.63%	2.84%	12.00%	6.89%	2.64%	13.68%	8.40%	3.29%	12.98%	7.78%	3.02%
8	15.66%	12.89%	9.17%	17.60%	14.33%	9.56%	18.39%	15.52%	11.26%	18.06%	15.03%	10.56%
9	17.17%	17.21%	15.71%	18.31%	18.80%	17.35%	18.20%	18.88%	17.78%	18.24%	18.84%	17.60%
10	15.15%	16.98%	18.95%	15.22%	17.64%	20.10%	14.68%	17.03%	19.48%	14.91%	17.28%	19.73%
11	12.19%	13.52%	17.80%	11.64%	13.24%	17.98%	10.89%	12.50%	16.84%	11.20%	12.80%	17.31%
12	9.42%	10.72%	13.64%	8.59%	10.03%	13.03%	7.77%	9.24%	11.89%	8.11%	9.57%	12.36%
13	6.68%	8.87%	9.51%	5.73%	8.06%	8.59%	4.92%	7.27%	7.62%	5.25%	7.60%	8.02%
14	4.57%	6.48%	6.35%	3.64%	5.65%	5.44%	2.94%	4.99%	4.71%	3.23%	5.27%	5.02%
15	2.42%	3.72%	3.81%	1.64%	2.99%	3.12%	1.15%	2.59%	2.80%	1.35%	2.75%	2.94%
16	0.85%	1.09%	2.05%	0.39%	0.61%	1.96%	0.00%	1.33%	2.54%	0.16%	1.03%	2.30%
17	0.00%	0.00%	0.18%	0.00%	0.00%	0.23%	0.00%	0.00%	1.78%	0.00%	0.00%	1.14%
18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 4-106: Hourly temporal profile for diurnal emissions – E10 fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.43%	0.00%	0.00%	0.22%	0.00%	0.00%
6	4.73%	1.89%	0.00%	4.77%	1.72%	0.00%
7	9.95%	6.41%	2.84%	11.55%	6.66%	2.59%
8	14.94%	12.31%	8.90%	17.17%	13.94%	9.29%
9	16.81%	16.70%	15.17%	18.12%	18.52%	17.03%
10	15.18%	16.82%	18.66%	15.28%	17.61%	19.99%
11	12.43%	13.68%	17.85%	11.83%	13.38%	18.10%
12	9.77%	11.01%	13.92%	8.84%	10.25%	13.27%
13	7.07%	9.20%	9.88%	5.99%	8.30%	8.86%
14	4.93%	6.81%	6.69%	3.89%	5.87%	5.68%
15	2.72%	3.99%	4.05%	1.83%	3.16%	3.27%
16	1.04%	1.18%	2.03%	0.51%	0.60%	1.90%
17	0.00%	0.00%	0.02%	0.00%	0.00%	0.02%
18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

4.6.3.2 Hot Soak Emissions

The daily average hot soak emission factors (grams per soak) for the 2008 vehicle fleet by year of manufacture are given in Table 4-107 for the vehicle fleet operating on ethanol free fuel, and in Table 4-108 for vehicles operating on E10 fuel. Note it is assumed that no pre-1986 vehicles operate on E10 fuel, and it is also assumed that no motorcycles or heavy duty commercial petrol vehicles operate on E10. The emission factors given are calculated according to the methodology given in Section 3.11, and are fleet aggregate emission factors including vehicles classified as both failed and passing.

The fleet composite daily average hot soak emission factors across all age groups are given in Table 4-109 and Table 4-110 for the E0 and E10 fleet respectively. Note the E10 fleet comprises only post-1985 vehicles and is hence weighted to lower emitting vehicles relative to the E0 fleet, and hence the difference in fleet composite emission factors is lower than might be expected from the E10 factors provided in Table 3-50.

The hot soak hourly fleet composite emission factors for the ethanol free fuel fleet and the E10 fleet are given in Table 4-111 and Table 4-112 respectively. To obtain the hourly total hot soak emissions profile, the hourly trip end profile must additionally be factored.

Table 4-107: Seasonal hot soak daily average emission factors – ethanol free fuel fleet (E0)

YOM	Summer Season Hot Soak Emissions (g/soak)				Autumn-Spring Season Hot Soak Emissions (g/ soak)				Winter Season Hot Soak Emissions (g/ soak)			
	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP
2008	0.182	0.199	4.98	0.298	0.174	0.187	4.58	0.281	0.140	0.149	3.15	0.224
2007	0.183	0.200	4.98	0.301	0.175	0.189	4.58	0.283	0.141	0.150	3.15	0.225
2006	0.185	0.203	4.98	0.304	0.177	0.191	4.58	0.286	0.142	0.152	3.15	0.228
2005	0.188	0.207	4.98	0.310	0.180	0.194	4.58	0.291	0.144	0.154	3.15	0.231
2004	0.192	0.211	4.98	0.317	0.184	0.198	4.58	0.297	0.146	0.157	3.15	0.235
2003	0.291	1.04	4.98	1.56	0.275	0.933	4.58	1.40	0.210	0.654	3.15	0.981
2002	0.320	1.26	4.98	1.89	0.302	1.13	4.58	1.69	0.228	0.787	3.15	1.18
2001	0.359	1.52	4.98	2.28	0.337	1.36	4.58	2.04	0.252	0.941	3.15	1.41
2000	0.409	1.78	4.98	2.67	0.383	1.59	4.58	2.39	0.283	1.10	3.15	1.65
1999	0.475	2.01	4.98	3.02	0.444	1.80	4.58	2.70	0.324	1.24	3.15	1.86
1998	0.559	4.30	4.98	6.46	0.521	3.85	4.58	5.77	0.376	2.65	3.15	3.98
1997	0.663	4.49	4.98	6.73	0.616	4.01	4.58	6.01	0.441	2.76	3.15	4.14
1996	0.787	4.60	4.98	6.89	0.731	4.10	4.58	6.16	0.519	2.82	3.15	4.24
1995	0.928	4.66	4.98	6.99	0.860	4.16	4.58	6.24	0.606	2.86	3.15	4.29
1994	1.08	4.69	4.98	7.03	0.995	4.18	4.58	6.28	0.698	2.88	3.15	4.32
1993	2.95	4.70	4.98	7.05	2.73	4.20	4.58	6.30	1.91	2.89	3.15	4.33
1992	3.12	4.71	4.98	7.06	2.88	4.20	4.58	6.31	2.01	2.89	3.15	4.33
1991	3.25	4.71	4.98	7.07	3.00	4.21	4.58	6.31	2.09	2.89	3.15	4.34
1990	3.34	4.71	4.98	7.07	3.08	4.21	4.58	6.31	2.14	2.89	3.15	4.34
1989	3.39	4.71	4.98	7.07	3.14	4.21	4.58	6.31	2.18	2.89	3.15	4.34
1988	3.43	4.71	4.98	7.07	3.17	4.21	4.58	6.31	2.20	2.89	3.15	4.34
≤ 1987	3.99	5.88	4.98	8.83	3.68	5.24	4.58	7.86	2.55	3.58	3.15	5.37

Table 4-108: Seasonal hot soak daily average emission factors – E10 fuel fleet

YOM	Summer (g/soak)		Autumn-Spring (g/soak)		Winter (g/soak)	
	PPV	PLCV	PPV	PLCV	PPV	PLCV
2008	0.278	0.304	0.267	0.286	0.214	0.229
2007	0.280	0.307	0.268	0.288	0.216	0.230
2006	0.283	0.310	0.271	0.292	0.218	0.232
2005	0.288	0.316	0.276	0.297	0.220	0.235
2004	0.294	0.323	0.281	0.303	0.224	0.240
2003	0.446	1.59	0.422	1.43	0.322	1.00
2002	0.490	1.93	0.462	1.73	0.349	1.20
2001	0.549	2.32	0.516	2.08	0.386	1.44
2000	0.626	2.72	0.587	2.44	0.434	1.68
1999	0.726	3.08	0.679	2.75	0.496	1.89
1998	0.855	5.77	0.797	5.15	0.576	3.55
1997	1.01	6.01	0.943	5.37	0.675	3.70
1996	1.20	6.16	1.12	5.50	0.793	3.78
1995	1.42	6.24	1.32	5.57	0.927	3.83
1994	1.65	6.28	1.52	5.61	1.07	3.86
1993	3.95	6.30	3.65	5.63	2.56	3.87
1992	4.18	6.31	3.86	5.63	2.70	3.87
1991	4.35	6.31	4.02	5.64	2.80	3.87
1990	4.47	6.32	4.13	5.64	2.87	3.88
1989	4.55	6.32	4.20	5.64	2.92	3.88
1988	4.60	6.32	4.25	5.64	2.95	3.88
1987	5.99	8.83	5.53	7.9	3.82	5.37
1986	5.99	8.83	5.53	7.9	3.82	5.37
≤ 1985	0	0	0	0	0	0

Table 4-109: Fleet aggregate hot soak daily average emission factors – ethanol free fuel fleet (E0), 2008

Vehicle Type	Summer (g/soak)	Autumn-Spring (g/ soak)	Winter (g/ soak)
PPV	0.709	0.660	0.474
PLCV	1.969	1.762	1.222
MC	4.975	4.582	3.147
HDCP	3.77	3.37	2.327

Table 4-110: Fleet aggregate hot soak daily average emission factors – E10 fuel fleet, 2008

Vehicle Type	Summer (g/ soak)	Autumn-Spring (g/ soak)	Winter (g/ soak)
PPV	0.733	0.685	0.501
PLCV	2.094	1.879	1.311
MC	N/A	N/A	N/A
HDCP	N/A	N/A	N/A

Table 4-111: Hourly fleet composite hot soak emission factors (g/soak) – ethanol free fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.345	0.417	0.355	0.707	0.888	0.745	1.983	2.551	2.121	0.744	0.941	0.787
1	0.336	0.407	0.348	0.685	0.863	0.729	1.917	2.476	2.072	0.276	0.350	0.295
2	0.329	0.399	0.342	0.670	0.845	0.715	1.869	2.420	2.030	0.224	0.285	0.240
3	0.324	0.393	0.338	0.657	0.831	0.704	1.829	2.376	1.997	0.060	0.077	0.065
4	0.301	0.367	0.315	0.613	0.778	0.660	1.711	2.231	1.876	0.501	0.642	0.543
5	0.323	0.368	0.312	0.664	0.780	0.651	1.869	2.238	1.848	1.037	1.226	1.019
6	0.428	0.413	0.310	0.917	0.887	0.647	2.650	2.567	1.837	2.639	2.554	1.851
7	0.570	0.500	0.332	1.278	1.109	0.706	3.793	3.268	2.027	2.932	2.538	1.602
8	0.716	0.614	0.401	1.659	1.404	0.881	5.016	4.213	2.582	2.527	2.133	1.328
9	0.883	0.767	0.514	2.090	1.794	1.165	6.395	5.456	3.479	4.369	3.743	2.416
10	1.005	0.873	0.621	2.401	2.064	1.432	7.382	6.306	4.315	3.759	3.224	2.226
11	1.062	0.925	0.679	2.549	2.196	1.578	7.856	6.731	4.781	5.100	4.386	3.139
12	1.071	0.955	0.699	2.572	2.274	1.628	7.928	6.975	4.938	4.659	4.112	2.933
13	0.993	0.907	0.656	2.380	2.159	1.527	7.330	6.623	4.628	4.404	3.990	2.811
14	0.916	0.854	0.615	2.184	2.024	1.424	6.708	6.196	4.303	4.850	4.489	3.144
15	0.804	0.765	0.548	1.897	1.797	1.255	5.793	5.475	3.770	2.973	2.815	1.957
16	0.718	0.691	0.483	1.671	1.601	1.085	5.061	4.841	3.225	3.987	3.818	2.573
17	0.609	0.582	0.405	1.384	1.318	0.887	4.141	3.937	2.596	2.546	2.423	1.620
18	0.494	0.496	0.379	1.090	1.100	0.819	3.205	3.242	2.375	2.442	2.467	1.826
19	0.409	0.452	0.367	0.877	0.987	0.786	2.535	2.884	2.268	1.808	2.042	1.619
20	0.367	0.425	0.352	0.776	0.920	0.750	2.219	2.677	2.159	1.727	2.059	1.673
21	0.372	0.438	0.366	0.775	0.941	0.773	2.198	2.720	2.214	1.098	1.341	1.099
22	0.359	0.426	0.358	0.743	0.913	0.754	2.098	2.634	2.153	1.257	1.555	1.280
23	0.348	0.416	0.351	0.717	0.889	0.738	2.019	2.562	2.105	0.320	0.400	0.331

Table 4-112: Hourly fleet composite hot soak emission factors (g/soak) – E10 fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.386	0.456	0.392	0.780	0.969	0.816
1	0.376	0.446	0.385	0.757	0.943	0.799
2	0.370	0.438	0.378	0.740	0.924	0.784
3	0.364	0.432	0.374	0.726	0.909	0.773
4	0.338	0.403	0.348	0.678	0.851	0.724
5	0.360	0.404	0.344	0.732	0.853	0.714
6	0.466	0.449	0.343	1.000	0.966	0.710
7	0.602	0.533	0.363	1.376	1.198	0.771
8	0.740	0.641	0.430	1.772	1.505	0.954
9	0.899	0.788	0.540	2.221	1.912	1.252
10	1.017	0.891	0.645	2.546	2.194	1.531
11	1.071	0.940	0.701	2.700	2.332	1.685
12	1.080	0.969	0.720	2.723	2.413	1.737
13	1.002	0.921	0.677	2.521	2.291	1.630
14	0.928	0.869	0.637	2.317	2.150	1.521
15	0.821	0.784	0.572	2.017	1.913	1.345
16	0.741	0.715	0.510	1.783	1.710	1.168
17	0.638	0.611	0.435	1.485	1.416	0.961
18	0.527	0.529	0.411	1.179	1.188	0.890
19	0.445	0.487	0.400	0.956	1.071	0.857
20	0.404	0.459	0.385	0.849	1.000	0.819
21	0.412	0.476	0.402	0.851	1.024	0.846
22	0.398	0.464	0.393	0.817	0.995	0.825
23	0.387	0.454	0.387	0.790	0.970	0.808

4.6.3.3 Resting Loss Emissions

The resting loss emission factors (grams per day) for the 2008 vehicle fleet by year of manufacture are given in Table 4-113 for the vehicle fleet operating on ethanol free fuel, and in Table 4-114 for vehicles operating on E10 fuel. Note it is assumed that no pre-1986 vehicles operate on E10 fuel, and it is also assumed that no motorcycles or heavy duty commercial petrol vehicles operate on E10. The emission factors given are calculated according to the methodology given in Section 3.11, and are fleet aggregate emission factors including vehicles classified as both failed and passing.

The resting loss hourly profiles for the ethanol free fuel fleet and the E10 fleet are given in Table 4-115 and Table 4-116 respectively. These hourly profiles apply to the vehicle type aggregated total fleet daily diurnal emissions and may vary slightly between specific year classes.

Table 4-113: Seasonal resting loss emission factors – ethanol free fuel fleet (E0)

YOM	Summer Season Resting Loss Emissions (g/day)				Autumn-Spring Season Resting Loss Emissions (g/ day)				Winter Season Resting Loss Emissions (g/ day)			
	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP	PPV	PLCV	MC	HDCP
2008	0.289	0.289	2.52	0.434	0.165	0.165	2.07	0.247	0.078	0.078	1.72	0.117
2007	0.290	0.290	2.52	0.436	0.166	0.166	2.07	0.249	0.079	0.079	1.72	0.118
2006	0.293	0.293	2.52	0.439	0.167	0.167	2.07	0.251	0.080	0.080	1.72	0.120
2005	0.296	0.296	2.52	0.444	0.169	0.169	2.07	0.254	0.081	0.081	1.72	0.122
2004	0.300	0.300	2.52	0.450	0.172	0.172	2.07	0.259	0.083	0.083	1.72	0.125
2003	0.662	1.03	2.52	1.55	0.391	0.652	2.07	0.979	0.199	0.369	1.72	0.554
2002	0.697	1.18	2.52	1.77	0.416	0.756	2.07	1.13	0.215	0.437	1.72	0.655
2001	0.743	1.35	2.52	2.03	0.448	0.875	2.07	1.31	0.236	0.514	1.72	0.772
2000	0.800	1.52	2.52	2.29	0.488	1.00	2.07	1.50	0.262	0.594	1.72	0.891
1999	0.870	1.68	2.52	2.52	0.538	1.11	2.07	1.66	0.294	0.665	1.72	1.00
1998	0.954	2.40	2.52	3.60	0.597	1.55	2.07	2.32	0.333	0.904	1.72	1.36
1997	1.05	2.43	2.52	3.65	0.664	1.58	2.07	2.37	0.377	0.929	1.72	1.39
1996	1.15	2.45	2.52	3.68	0.737	1.60	2.07	2.40	0.424	0.945	1.72	1.42
1995	1.26	2.47	2.52	3.70	0.811	1.61	2.07	2.41	0.473	0.953	1.72	1.43
1994	1.36	2.47	2.52	3.71	0.881	1.61	2.07	2.42	0.518	0.957	1.72	1.44
1993	2.26	2.47	2.52	3.71	1.42	1.62	2.07	2.42	0.795	0.959	1.72	1.44
1992	2.30	2.47	2.52	3.71	1.45	1.62	2.07	2.42	0.824	0.960	1.72	1.44
1991	2.33	2.47	2.52	3.71	1.48	1.62	2.07	2.43	0.846	0.961	1.72	1.44
1990	2.35	2.48	2.52	3.71	1.50	1.62	2.07	2.43	0.861	0.961	1.72	1.44
1989	2.36	2.48	2.52	3.71	1.51	1.62	2.07	2.43	0.871	0.961	1.72	1.44
1988	2.37	2.48	2.52	3.71	1.52	1.62	2.07	2.43	0.878	0.961	1.72	1.44
≤ 1987	4.81	5.03	2.52	7.55	3.93	4.14	2.07	6.21	3.24	3.45	1.72	5.17

Table 4-114: Seasonal resting loss emission factors – E10 fuel fleet

YOM	Summer (g/day)		Autumn-Spring (g/day)		Winter (g/day)	
	PPV	PLCV	PPV	PLCV	PPV	PLCV
2008	0.636	0.636	0.363	0.363	0.172	0.172
2007	0.639	0.639	0.365	0.365	0.173	0.173
2006	0.644	0.644	0.368	0.368	0.176	0.176
2005	0.651	0.651	0.373	0.373	0.179	0.179
2004	0.660	0.660	0.379	0.379	0.183	0.183
2003	1.456	2.274	0.860	2.576	0.437	1.290
2002	1.534	2.597	0.915	2.716	0.472	1.408
2001	1.634	2.970	0.985	2.878	0.518	1.544
2000	1.760	3.353	1.074	3.045	0.576	1.684
1999	1.915	3.692	1.183	3.192	0.647	1.808
1998	2.099	5.285	1.313	3.407	0.732	1.988
1997	2.311	5.356	1.461	3.474	0.829	2.044
1996	2.539	5.400	1.622	3.514	0.934	2.078
1995	2.771	5.423	1.785	3.537	1.040	2.097
1994	2.989	5.436	1.938	3.548	1.140	2.106
1993	4.978	5.441	3.121	3.553	1.748	2.111
1992	5.060	5.444	3.198	3.556	1.813	2.113
1991	5.122	5.445	3.256	3.557	1.861	2.114
1990	5.165	5.445	3.296	3.557	1.895	2.114
1989	5.193	5.445	3.322	3.557	1.917	2.114
1988	5.211	5.446	3.339	3.557	1.931	2.114
1987	10.593	11.066	8.648	9.114	7.119	7.580
1986	10.593	11.066	8.648	9.114	7.120	7.580
≤ 1985	0	0	0	0	0	0

Table 4-115: Hourly temporal profile for resting loss emissions – ethanol free fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	2.62%	2.54%	2.32%	2.74%	2.72%	2.56%	3.38%	3.51%	3.58%	3.18%	3.29%	3.35%
1	2.54%	2.43%	2.23%	2.67%	2.62%	2.47%	3.34%	3.46%	3.54%	3.13%	3.23%	3.29%
2	2.48%	2.34%	2.16%	2.61%	2.55%	2.39%	3.31%	3.43%	3.50%	3.09%	3.19%	3.25%
3	2.43%	2.28%	2.10%	2.56%	2.49%	2.33%	3.28%	3.40%	3.47%	3.06%	3.15%	3.21%
4	2.39%	2.23%	2.05%	2.52%	2.45%	2.27%	3.26%	3.38%	3.45%	3.03%	3.13%	3.18%
5	2.60%	2.24%	2.00%	2.72%	2.45%	2.22%	3.37%	3.39%	3.42%	3.16%	3.13%	3.15%
6	3.42%	2.73%	1.98%	3.48%	2.89%	2.19%	3.79%	3.59%	3.41%	3.69%	3.40%	3.13%
7	4.43%	3.84%	2.55%	4.41%	3.88%	2.82%	4.30%	4.04%	3.70%	4.33%	3.99%	3.50%
8	5.28%	5.06%	4.33%	5.19%	4.96%	4.37%	4.73%	4.53%	4.27%	4.88%	4.64%	4.29%
9	5.85%	5.99%	6.10%	5.72%	5.78%	5.85%	5.02%	4.90%	4.79%	5.24%	5.14%	5.03%
10	6.19%	6.51%	7.38%	6.04%	6.25%	6.93%	5.20%	5.12%	5.17%	5.46%	5.43%	5.56%
11	6.36%	6.78%	8.05%	6.19%	6.49%	7.49%	5.28%	5.22%	5.36%	5.57%	5.57%	5.84%
12	6.38%	6.91%	8.24%	6.21%	6.60%	7.65%	5.30%	5.28%	5.42%	5.58%	5.64%	5.92%
13	6.29%	6.87%	8.09%	6.13%	6.57%	7.53%	5.25%	5.26%	5.38%	5.53%	5.62%	5.86%
14	6.08%	6.63%	7.66%	5.94%	6.36%	7.17%	5.14%	5.16%	5.25%	5.39%	5.49%	5.68%
15	5.75%	6.20%	6.91%	5.63%	5.98%	6.53%	4.97%	4.99%	5.03%	5.18%	5.26%	5.37%
16	5.30%	5.56%	5.64%	5.21%	5.40%	5.47%	4.74%	4.73%	4.65%	4.89%	4.91%	4.84%
17	4.72%	4.65%	4.09%	4.68%	4.59%	4.17%	4.45%	4.36%	4.19%	4.52%	4.42%	4.19%
18	4.00%	3.78%	3.29%	4.02%	3.82%	3.49%	4.08%	4.01%	3.96%	4.06%	3.96%	3.85%
19	3.39%	3.26%	2.86%	3.45%	3.37%	3.13%	3.77%	3.80%	3.83%	3.67%	3.68%	3.67%
20	3.07%	2.99%	2.65%	3.16%	3.13%	2.93%	3.61%	3.69%	3.74%	3.47%	3.54%	3.56%
21	2.91%	2.83%	2.52%	3.00%	2.98%	2.79%	3.52%	3.63%	3.68%	3.36%	3.45%	3.48%
22	2.80%	2.71%	2.43%	2.90%	2.88%	2.68%	3.47%	3.58%	3.63%	3.29%	3.39%	3.42%
23	2.71%	2.61%	2.35%	2.82%	2.79%	2.59%	3.42%	3.54%	3.59%	3.23%	3.33%	3.37%

Table 4-116: Hourly temporal profile for resting loss emissions – E10 fuel fleet

Hour	Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	2.48%	2.29%	1.85%	2.59%	2.35%	1.95%
1	2.39%	2.16%	1.76%	2.51%	2.23%	1.85%
2	2.32%	2.06%	1.68%	2.45%	2.14%	1.76%
3	2.27%	1.99%	1.62%	2.39%	2.07%	1.70%
4	2.22%	1.93%	1.56%	2.35%	2.01%	1.64%
5	2.45%	1.94%	1.51%	2.56%	2.02%	1.58%
6	3.35%	2.51%	1.48%	3.41%	2.57%	1.55%
7	4.45%	3.80%	2.12%	4.43%	3.81%	2.23%
8	5.39%	5.19%	4.33%	5.30%	5.16%	4.36%
9	6.01%	6.27%	6.58%	5.89%	6.20%	6.48%
10	6.38%	6.87%	8.20%	6.23%	6.78%	8.02%
11	6.57%	7.19%	9.05%	6.41%	7.08%	8.82%
12	6.59%	7.34%	9.29%	6.43%	7.23%	9.05%
13	6.50%	7.29%	9.11%	6.34%	7.18%	8.88%
14	6.27%	7.01%	8.56%	6.13%	6.91%	8.36%
15	5.90%	6.52%	7.60%	5.78%	6.44%	7.46%
16	5.41%	5.77%	6.00%	5.32%	5.71%	5.94%
17	4.77%	4.72%	4.03%	4.73%	4.70%	4.07%
18	3.99%	3.72%	3.01%	4.00%	3.73%	3.11%
19	3.31%	3.12%	2.47%	3.37%	3.16%	2.60%
20	2.97%	2.81%	2.22%	3.05%	2.86%	2.34%
21	2.79%	2.63%	2.08%	2.88%	2.68%	2.19%
22	2.67%	2.49%	1.98%	2.77%	2.55%	2.08%
23	2.57%	2.37%	1.89%	2.67%	2.44%	1.99%

4.6.3.4 Running Loss Emissions

The average daily running loss emission factors for the 2008 vehicle fleet by year of manufacture are given in Table 4-117 to Table 4-121 for the vehicle fleet operating on ethanol free fuel, and in Table 4-122 to Table 4-124 for vehicles operating on E10 fuel. For each of the road types the emission factors given are at the 24 hour VKT weighted average speed as given in Table 3-10. Note it is assumed that no pre-1986 vehicles operate on E10 fuel, and it is also assumed that no motorcycles or heavy duty commercial petrol vehicles operate on E10. The emission factors given are calculated according to the methodology given in Section 3.11, and are fleet aggregate emission factors including vehicles classified as both failed and passing for each age class.

The running loss hourly fleet composite emissions factors for the five inventory road types, at the road type hourly average speed as given in Table 4-3, are given in Table 4-125 to Table 4-129 for the ethanol free fuel fleet and in Table 4-130 to Table 4-134 for the E10 fleet.

Table 4-117: Running loss emission factors – ethanol free fuel fleet (E0) – residential roads 24.1 km/h

YOM	Running Losses (g/km) – Residential Roads 24.1 km/h											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.085	0.052	0.029	0.085	0.052	0.029	0.792	0.513	0.295	0.148	0.092	0.051
2007	0.085	0.053	0.030	0.085	0.053	0.030	0.792	0.513	0.295	0.156	0.096	0.054
2006	0.087	0.054	0.030	0.087	0.054	0.030	0.792	0.513	0.295	0.179	0.111	0.062
2005	0.089	0.055	0.031	0.089	0.055	0.031	0.792	0.513	0.295	0.265	0.164	0.092
2004	0.092	0.057	0.032	0.092	0.057	0.032	0.792	0.513	0.295	0.113	0.070	0.040
2003	0.240	0.151	0.085	0.516	0.331	0.189	0.792	0.513	0.295	1.066	0.683	0.390
2002	0.266	0.168	0.095	0.626	0.402	0.230	0.792	0.513	0.295	0.534	0.343	0.196
2001	0.300	0.190	0.108	0.752	0.484	0.277	0.792	0.513	0.295	1.097	0.706	0.405
2000	0.343	0.218	0.124	0.881	0.568	0.326	0.792	0.513	0.295	2.749	1.773	1.017
1999	0.395	0.252	0.143	0.996	0.643	0.369	0.792	0.513	0.295	2.697	1.741	0.999
1998	0.457	0.292	0.167	1.182	0.763	0.437	0.792	0.513	0.295	2.036	1.314	0.753
1997	0.529	0.339	0.194	1.231	0.795	0.456	0.792	0.513	0.295	2.084	1.345	0.772
1996	0.606	0.389	0.223	1.261	0.815	0.467	0.792	0.513	0.295	3.360	2.170	1.245
1995	0.684	0.440	0.252	1.278	0.826	0.474	0.792	0.513	0.295	2.976	1.922	1.103
1994	0.758	0.488	0.280	1.286	0.831	0.477	0.792	0.513	0.295	2.290	1.480	0.849
1993	0.969	0.623	0.357	1.290	0.834	0.478	0.792	0.513	0.295	2.779	1.795	1.030
1992	1.026	0.661	0.378	1.292	0.835	0.479	0.792	0.513	0.295	2.703	1.747	1.002
1991	1.069	0.689	0.395	1.293	0.835	0.479	0.792	0.513	0.295	2.383	1.540	0.884
1990	1.099	0.708	0.406	1.293	0.836	0.480	0.792	0.513	0.295	3.087	1.994	1.145
1989	1.119	0.721	0.413	1.293	0.836	0.480	0.792	0.513	0.295	1.799	1.163	0.667
1988	1.131	0.729	0.418	1.293	0.836	0.480	0.792	0.513	0.295	0.891	0.576	0.330
≤ 1987	1.293	0.836	0.480	1.584	1.026	0.589	0.792	0.513	0.295	1.413	0.915	0.526

Table 4-118: Running loss emission factors – ethanol free fuel fleet (E0) – arterial roads 38.0 km/h

YOM	Running Losses (g/km) – Arterial Roads 38.0 km/h											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.043	0.027	0.016	0.043	0.027	0.016	0.466	0.297	0.173	0.076	0.047	0.027
2007	0.044	0.027	0.016	0.044	0.027	0.016	0.466	0.297	0.173	0.080	0.050	0.029
2006	0.045	0.028	0.016	0.045	0.028	0.016	0.466	0.297	0.173	0.092	0.057	0.033
2005	0.046	0.029	0.017	0.046	0.029	0.017	0.466	0.297	0.173	0.137	0.085	0.049
2004	0.048	0.030	0.017	0.048	0.030	0.017	0.466	0.297	0.173	0.059	0.037	0.021
2003	0.129	0.081	0.047	0.295	0.187	0.109	0.466	0.297	0.173	0.608	0.385	0.224
2002	0.145	0.091	0.053	0.360	0.228	0.133	0.466	0.297	0.173	0.307	0.195	0.114
2001	0.165	0.104	0.060	0.435	0.277	0.161	0.466	0.297	0.173	0.635	0.404	0.235
2000	0.191	0.120	0.070	0.513	0.326	0.190	0.466	0.297	0.173	1.600	1.017	0.592
1999	0.222	0.140	0.082	0.581	0.370	0.215	0.466	0.297	0.173	1.574	1.001	0.583
1998	0.259	0.164	0.095	0.689	0.438	0.255	0.466	0.297	0.173	1.186	0.754	0.439
1997	0.302	0.191	0.111	0.719	0.457	0.266	0.466	0.297	0.173	1.216	0.773	0.451
1996	0.348	0.221	0.129	0.737	0.469	0.273	0.466	0.297	0.173	1.963	1.248	0.727
1995	0.395	0.251	0.146	0.747	0.475	0.277	0.466	0.297	0.173	1.740	1.106	0.645
1994	0.439	0.279	0.162	0.752	0.478	0.279	0.466	0.297	0.173	1.339	0.852	0.496
1993	0.559	0.355	0.207	0.755	0.480	0.280	0.466	0.297	0.173	1.625	1.033	0.602
1992	0.594	0.377	0.220	0.756	0.481	0.280	0.466	0.297	0.173	1.581	1.005	0.586
1991	0.620	0.394	0.229	0.756	0.481	0.280	0.466	0.297	0.173	1.394	0.886	0.517
1990	0.638	0.405	0.236	0.756	0.481	0.280	0.466	0.297	0.173	1.805	1.148	0.669
1989	0.650	0.413	0.241	0.756	0.481	0.280	0.466	0.297	0.173	1.052	0.669	0.390
1988	0.658	0.418	0.243	0.756	0.481	0.280	0.466	0.297	0.173	0.521	0.331	0.193
≤ 1987	0.756	0.481	0.280	0.933	0.594	0.346	0.466	0.297	0.173	0.832	0.530	0.309

Table 4-119: Running loss emission factors – ethanol free fuel fleet (E0) – commercial arterial roads 35.3 km/h

YOM	Running Losses (g/km) – Commercial Arterial Roads 35.3 km/h											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.045	0.028	0.016	0.045	0.028	0.016	0.484	0.308	0.180	0.079	0.049	0.028
2007	0.046	0.028	0.016	0.046	0.028	0.016	0.484	0.308	0.180	0.083	0.052	0.030
2006	0.047	0.029	0.017	0.047	0.029	0.017	0.484	0.308	0.180	0.096	0.060	0.034
2005	0.048	0.030	0.017	0.048	0.030	0.017	0.484	0.308	0.180	0.143	0.089	0.051
2004	0.050	0.031	0.018	0.050	0.031	0.018	0.484	0.308	0.180	0.061	0.038	0.022
2003	0.135	0.085	0.049	0.306	0.194	0.113	0.484	0.308	0.180	0.632	0.400	0.233
2002	0.151	0.095	0.055	0.374	0.237	0.138	0.484	0.308	0.180	0.319	0.203	0.118
2001	0.172	0.108	0.063	0.452	0.287	0.167	0.484	0.308	0.180	0.660	0.419	0.244
2000	0.198	0.125	0.073	0.532	0.339	0.197	0.484	0.308	0.180	1.661	1.056	0.615
1999	0.231	0.146	0.085	0.604	0.384	0.224	0.484	0.308	0.180	1.634	1.039	0.606
1998	0.269	0.171	0.099	0.715	0.455	0.265	0.484	0.308	0.180	1.231	0.783	0.456
1997	0.314	0.199	0.116	0.746	0.475	0.277	0.484	0.308	0.180	1.263	0.803	0.468
1996	0.362	0.230	0.134	0.765	0.487	0.284	0.484	0.308	0.180	2.038	1.296	0.755
1995	0.410	0.261	0.152	0.776	0.493	0.288	0.484	0.308	0.180	1.806	1.149	0.669
1994	0.456	0.290	0.169	0.781	0.497	0.289	0.484	0.308	0.180	1.390	0.884	0.515
1993	0.581	0.369	0.215	0.783	0.498	0.290	0.484	0.308	0.180	1.687	1.073	0.625
1992	0.617	0.392	0.228	0.784	0.499	0.291	0.484	0.308	0.180	1.641	1.044	0.609
1991	0.644	0.409	0.238	0.785	0.499	0.291	0.484	0.308	0.180	1.447	0.920	0.536
1990	0.663	0.421	0.245	0.785	0.499	0.291	0.484	0.308	0.180	1.874	1.192	0.695
1989	0.675	0.429	0.250	0.785	0.500	0.291	0.484	0.308	0.180	1.092	0.695	0.405
1988	0.683	0.434	0.253	0.785	0.500	0.291	0.484	0.308	0.180	0.541	0.344	0.201
≤ 1987	0.785	0.500	0.291	0.968	0.616	0.359	0.484	0.308	0.180	0.864	0.550	0.321

Table 4-120: Running loss emission factors – ethanol free fuel fleet (E0) – commercial highway roads 56.9 km/h

YOM	Running Losses (g/km) – Commercial Highway Roads 56.9 km/h											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.030	0.019	0.011	0.030	0.019	0.011	0.343	0.218	0.127	0.052	0.033	0.019
2007	0.030	0.019	0.011	0.030	0.019	0.011	0.343	0.218	0.127	0.055	0.034	0.020
2006	0.031	0.019	0.011	0.031	0.019	0.011	0.343	0.218	0.127	0.064	0.040	0.023
2005	0.032	0.020	0.011	0.032	0.020	0.011	0.343	0.218	0.127	0.095	0.059	0.034
2004	0.033	0.021	0.012	0.033	0.021	0.012	0.343	0.218	0.127	0.041	0.026	0.015
2003	0.091	0.057	0.033	0.214	0.135	0.079	0.343	0.218	0.127	0.441	0.279	0.162
2002	0.103	0.065	0.038	0.262	0.166	0.096	0.343	0.218	0.127	0.224	0.142	0.082
2001	0.118	0.074	0.043	0.318	0.201	0.117	0.343	0.218	0.127	0.464	0.294	0.171
2000	0.137	0.086	0.050	0.375	0.238	0.138	0.343	0.218	0.127	1.171	0.742	0.432
1999	0.160	0.101	0.059	0.426	0.270	0.157	0.343	0.218	0.127	1.154	0.731	0.426
1998	0.188	0.119	0.069	0.504	0.319	0.186	0.343	0.218	0.127	0.869	0.550	0.320
1997	0.219	0.139	0.081	0.527	0.334	0.194	0.343	0.218	0.127	0.891	0.565	0.329
1996	0.254	0.160	0.093	0.540	0.342	0.199	0.343	0.218	0.127	1.440	0.912	0.531
1995	0.288	0.182	0.106	0.548	0.347	0.202	0.343	0.218	0.127	1.276	0.808	0.471
1994	0.321	0.203	0.118	0.552	0.350	0.204	0.343	0.218	0.127	0.982	0.622	0.362
1993	0.408	0.258	0.150	0.554	0.351	0.204	0.343	0.218	0.127	1.192	0.755	0.440
1992	0.434	0.275	0.160	0.554	0.351	0.205	0.343	0.218	0.127	1.160	0.735	0.428
1991	0.453	0.287	0.167	0.555	0.351	0.205	0.343	0.218	0.127	1.022	0.648	0.377
1990	0.467	0.296	0.172	0.555	0.352	0.205	0.343	0.218	0.127	1.324	0.839	0.489
1989	0.476	0.301	0.175	0.555	0.352	0.205	0.343	0.218	0.127	0.772	0.489	0.285
1988	0.481	0.305	0.177	0.555	0.352	0.205	0.343	0.218	0.127	0.382	0.242	0.141
≤ 1987	0.555	0.352	0.205	0.686	0.435	0.253	0.343	0.218	0.127	0.612	0.388	0.226

Table 4-121: Running loss emission factors – ethanol free fuel fleet (E0) – freeway/highway roads 66.3 km/h

YOM	Running Losses (g/km) – Freeway/Highway Roads 66.3 km/h											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.023	0.014	0.008	0.023	0.014	0.008	0.282	0.178	0.104	0.041	0.025	0.015
2007	0.024	0.015	0.008	0.024	0.015	0.008	0.282	0.178	0.104	0.043	0.027	0.015
2006	0.024	0.015	0.009	0.024	0.015	0.009	0.282	0.178	0.104	0.049	0.031	0.018
2005	0.025	0.016	0.009	0.025	0.016	0.009	0.282	0.178	0.104	0.074	0.046	0.027
2004	0.026	0.016	0.009	0.026	0.016	0.009	0.282	0.178	0.104	0.032	0.020	0.012
2003	0.073	0.046	0.026	0.174	0.110	0.064	0.282	0.178	0.104	0.359	0.226	0.131
2002	0.082	0.052	0.030	0.214	0.135	0.078	0.282	0.178	0.104	0.182	0.115	0.067
2001	0.095	0.060	0.035	0.260	0.164	0.095	0.282	0.178	0.104	0.379	0.239	0.139
2000	0.110	0.069	0.040	0.307	0.194	0.113	0.282	0.178	0.104	0.958	0.605	0.352
1999	0.129	0.081	0.047	0.349	0.220	0.128	0.282	0.178	0.104	0.945	0.597	0.347
1998	0.152	0.096	0.056	0.413	0.261	0.152	0.282	0.178	0.104	0.711	0.449	0.261
1997	0.178	0.112	0.065	0.431	0.272	0.159	0.282	0.178	0.104	0.730	0.461	0.268
1996	0.207	0.130	0.076	0.443	0.280	0.163	0.282	0.178	0.104	1.179	0.745	0.433
1995	0.235	0.148	0.086	0.449	0.284	0.165	0.282	0.178	0.104	1.045	0.660	0.384
1994	0.262	0.165	0.096	0.452	0.286	0.166	0.282	0.178	0.104	0.805	0.508	0.296
1993	0.333	0.210	0.122	0.454	0.287	0.167	0.282	0.178	0.104	0.977	0.617	0.359
1992	0.354	0.224	0.130	0.454	0.287	0.167	0.282	0.178	0.104	0.950	0.600	0.349
1991	0.370	0.234	0.136	0.455	0.287	0.167	0.282	0.178	0.104	0.838	0.529	0.308
1990	0.382	0.241	0.140	0.455	0.287	0.167	0.282	0.178	0.104	1.085	0.685	0.399
1989	0.389	0.246	0.143	0.455	0.287	0.167	0.282	0.178	0.104	0.633	0.400	0.232
1988	0.394	0.249	0.145	0.455	0.287	0.167	0.282	0.178	0.104	0.313	0.198	0.115
≤ 1987	0.455	0.287	0.167	0.564	0.356	0.207	0.282	0.178	0.104	0.503	0.318	0.185

Table 4-122: Running loss emission factors – E10 fuel fleet – residential and arterial roads

YOM	Running Losses (g/km) – Residential Roads 24.1 km/h						Running Losses (g/km) – Arterial Roads 38.0 km/h					
	Petrol Passenger Vehicles			Petrol LCV			Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.112	0.069	0.039	0.112	0.069	0.039	0.057	0.036	0.020	0.057	0.036	0.020
2007	0.113	0.070	0.039	0.113	0.070	0.039	0.058	0.036	0.021	0.058	0.036	0.021
2006	0.115	0.071	0.040	0.115	0.071	0.040	0.059	0.037	0.021	0.059	0.037	0.021
2005	0.118	0.073	0.041	0.118	0.073	0.041	0.061	0.038	0.022	0.061	0.038	0.022
2004	0.122	0.075	0.042	0.122	0.075	0.042	0.063	0.039	0.023	0.063	0.039	0.023
2003	0.317	0.199	0.112	0.682	0.437	0.249	0.171	0.107	0.062	0.389	0.246	0.143
2002	0.351	0.222	0.126	0.826	0.531	0.304	0.191	0.120	0.070	0.475	0.301	0.175
2001	0.396	0.251	0.142	0.992	0.639	0.366	0.218	0.137	0.080	0.575	0.365	0.213
2000	0.452	0.287	0.163	1.163	0.750	0.430	0.252	0.159	0.092	0.677	0.430	0.251
1999	0.521	0.332	0.189	1.315	0.849	0.487	0.293	0.185	0.108	0.767	0.488	0.284
1998	0.604	0.386	0.220	1.550	1.007	0.577	0.342	0.217	0.126	0.896	0.578	0.337
1997	0.698	0.447	0.256	1.617	1.049	0.602	0.399	0.253	0.147	0.937	0.603	0.351
1996	0.800	0.514	0.294	1.657	1.075	0.617	0.460	0.292	0.170	0.962	0.619	0.360
1995	0.903	0.581	0.333	1.680	1.090	0.625	0.521	0.331	0.193	0.976	0.627	0.365
1994	1.001	0.644	0.369	1.691	1.097	0.630	0.580	0.368	0.214	0.983	0.631	0.368
1993	1.264	0.823	0.471	1.696	1.100	0.632	0.718	0.469	0.273	0.986	0.633	0.369
1992	1.341	0.872	0.500	1.699	1.102	0.632	0.766	0.498	0.290	0.988	0.634	0.370
1991	1.398	0.909	0.521	1.700	1.103	0.633	0.801	0.520	0.303	0.989	0.635	0.370
1990	1.439	0.935	0.536	1.700	1.103	0.633	0.826	0.535	0.312	0.989	0.635	0.370
1989	1.465	0.952	0.546	1.700	1.103	0.633	0.843	0.545	0.318	0.989	0.635	0.370
1988	1.482	0.963	0.552	1.700	1.103	0.633	0.853	0.552	0.321	0.989	0.635	0.370
1987	1.700	1.103	0.633	2.090	1.354	0.778	0.989	0.635	0.370	1.231	0.784	0.457
1986	1.700	1.103	0.633	2.090	1.354	0.778	0.989	0.635	0.370	1.231	0.784	0.457
≤ 1985	0	0	0	0	0	0	0	0	0	0	0	0

Table 4-123: Running loss emission factors – E10 fuel fleet – commercial arterial and commercial highway roads

YOM	Running Losses (g/km) – Commercial Arterial Roads 35.3 km/h						Running Losses (g/km) – Commercial Highway Roads 56.9 km/h					
	Petrol Passenger Vehicles			Petrol LCV			Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.060	0.037	0.021	0.060	0.037	0.021	0.039	0.025	0.014	0.039	0.025	0.014
2007	0.060	0.038	0.022	0.060	0.038	0.022	0.040	0.025	0.014	0.040	0.025	0.014
2006	0.062	0.038	0.022	0.062	0.038	0.022	0.041	0.025	0.015	0.041	0.025	0.015
2005	0.063	0.040	0.023	0.063	0.040	0.023	0.042	0.026	0.015	0.042	0.026	0.015
2004	0.066	0.041	0.024	0.066	0.041	0.024	0.044	0.027	0.016	0.044	0.027	0.016
2003	0.178	0.112	0.065	0.404	0.256	0.149	0.121	0.076	0.044	0.282	0.178	0.104
2002	0.199	0.125	0.073	0.493	0.313	0.182	0.136	0.086	0.050	0.346	0.219	0.127
2001	0.227	0.143	0.083	0.597	0.379	0.221	0.156	0.098	0.057	0.420	0.266	0.155
2000	0.262	0.165	0.096	0.703	0.447	0.260	0.181	0.114	0.066	0.496	0.314	0.183
1999	0.305	0.193	0.112	0.797	0.507	0.295	0.211	0.133	0.077	0.563	0.356	0.207
1998	0.356	0.225	0.131	0.929	0.600	0.350	0.248	0.157	0.091	0.659	0.422	0.245
1997	0.414	0.263	0.153	0.973	0.626	0.365	0.290	0.183	0.106	0.689	0.441	0.256
1996	0.477	0.303	0.176	0.999	0.642	0.374	0.335	0.212	0.123	0.708	0.452	0.263
1995	0.542	0.344	0.200	1.013	0.651	0.380	0.381	0.241	0.140	0.718	0.458	0.267
1994	0.602	0.382	0.223	1.020	0.656	0.382	0.424	0.268	0.156	0.723	0.461	0.269
1993	0.745	0.487	0.283	1.024	0.658	0.383	0.528	0.341	0.198	0.726	0.463	0.270
1992	0.795	0.517	0.301	1.025	0.659	0.384	0.563	0.363	0.211	0.727	0.464	0.270
1991	0.832	0.540	0.314	1.026	0.659	0.384	0.589	0.379	0.220	0.727	0.464	0.270
1990	0.857	0.556	0.324	1.026	0.659	0.384	0.608	0.390	0.227	0.727	0.464	0.270
1989	0.875	0.566	0.330	1.026	0.659	0.384	0.620	0.398	0.231	0.728	0.464	0.270
1988	0.885	0.573	0.334	1.026	0.659	0.384	0.628	0.402	0.234	0.728	0.464	0.270
1987	1.026	0.659	0.384	1.278	0.814	0.475	0.728	0.464	0.270	0.906	0.574	0.335
1986	1.026	0.659	0.384	1.278	0.814	0.475	0.728	0.464	0.270	0.906	0.574	0.335
≤ 1985	0	0	0	0	0	0	0	0	0	0	0	0

Table 4-124: Running loss emission factors – ethanol free fuel fleet (E0) – freeway/highway roads

YOM	Running Losses (g/km) – Freeway/Highway Roads 66.3 km/h					
	Petrol Passenger Vehicles			Petrol LCV		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
2008	0.031	0.019	0.011	0.031	0.019	0.011
2007	0.031	0.019	0.011	0.031	0.019	0.011
2006	0.032	0.020	0.011	0.032	0.020	0.011
2005	0.033	0.020	0.012	0.033	0.020	0.012
2004	0.034	0.021	0.012	0.034	0.021	0.012
2003	0.096	0.060	0.035	0.229	0.145	0.084
2002	0.109	0.068	0.040	0.282	0.178	0.103
2001	0.125	0.079	0.046	0.343	0.216	0.126
2000	0.146	0.092	0.053	0.405	0.256	0.149
1999	0.171	0.108	0.062	0.461	0.291	0.169
1998	0.201	0.127	0.074	0.541	0.344	0.200
1997	0.235	0.148	0.086	0.566	0.360	0.209
1996	0.273	0.172	0.100	0.581	0.369	0.215
1995	0.310	0.196	0.114	0.590	0.374	0.218
1994	0.346	0.218	0.127	0.594	0.377	0.219
1993	0.434	0.277	0.161	0.596	0.378	0.220
1992	0.463	0.295	0.172	0.597	0.379	0.220
1991	0.484	0.309	0.179	0.597	0.379	0.220
1990	0.499	0.318	0.185	0.597	0.379	0.221
1989	0.509	0.324	0.189	0.598	0.379	0.221
1988	0.516	0.328	0.191	0.598	0.379	0.221
1987	0.598	0.379	0.221	0.744	0.470	0.274
1986	0.598	0.379	0.221	0.744	0.470	0.274
≤ 1985	0	0	0	0	0	0

Table 4-125: Fleet composite hourly running loss emission factors – ethanol free fuel fleet (E0) – residential roads, 2008

Hour	Running Losses (g/km) – Residential Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.102	0.098	0.069	0.184	0.178	0.125	0.224	0.217	0.154	0.276	0.267	0.188
1	0.098	0.095	0.067	0.176	0.171	0.122	0.214	0.209	0.149	0.264	0.256	0.183
2	0.095	0.092	0.065	0.170	0.166	0.119	0.207	0.203	0.145	0.255	0.249	0.178
3	0.092	0.090	0.064	0.166	0.162	0.116	0.202	0.199	0.142	0.248	0.244	0.174
4	0.090	0.088	0.063	0.161	0.159	0.114	0.197	0.194	0.139	0.242	0.238	0.171
5	0.101	0.089	0.062	0.182	0.160	0.112	0.222	0.196	0.137	0.274	0.240	0.168
6	0.164	0.108	0.062	0.294	0.195	0.113	0.358	0.238	0.138	0.442	0.292	0.169
7	0.302	0.170	0.080	0.539	0.305	0.145	0.653	0.372	0.177	0.808	0.457	0.217
8	0.503	0.273	0.127	0.893	0.488	0.228	1.079	0.594	0.279	1.339	0.733	0.342
9	0.672	0.372	0.183	1.193	0.666	0.329	1.441	0.809	0.401	1.789	0.999	0.493
10	0.807	0.447	0.242	1.431	0.800	0.434	1.727	0.972	0.529	2.147	1.201	0.652
11	0.891	0.496	0.282	1.579	0.887	0.506	1.905	1.076	0.616	2.369	1.330	0.759
12	0.901	0.519	0.294	1.596	0.928	0.528	1.925	1.127	0.642	2.394	1.393	0.791
13	0.857	0.513	0.285	1.520	0.917	0.512	1.834	1.113	0.623	2.280	1.375	0.768
14	0.766	0.472	0.260	1.359	0.844	0.467	1.640	1.025	0.569	2.038	1.267	0.701
15	0.638	0.406	0.221	1.133	0.726	0.397	1.368	0.882	0.484	1.699	1.089	0.596
16	0.493	0.319	0.166	0.877	0.571	0.299	1.060	0.695	0.365	1.315	0.857	0.449
17	0.357	0.229	0.118	0.637	0.411	0.212	0.771	0.501	0.259	0.955	0.617	0.319
18	0.231	0.161	0.096	0.414	0.290	0.173	0.502	0.354	0.211	0.621	0.436	0.259
19	0.160	0.131	0.085	0.287	0.236	0.155	0.349	0.288	0.189	0.431	0.354	0.232
20	0.133	0.118	0.079	0.239	0.212	0.144	0.291	0.259	0.176	0.358	0.318	0.216
21	0.121	0.110	0.075	0.217	0.199	0.137	0.264	0.243	0.167	0.325	0.299	0.205
22	0.113	0.106	0.073	0.204	0.191	0.132	0.248	0.233	0.161	0.305	0.286	0.197
23	0.107	0.101	0.070	0.193	0.183	0.127	0.235	0.224	0.156	0.289	0.274	0.191

Table 4-126: Fleet composite hourly running loss emission factors – ethanol free fuel fleet (E0) – arterial roads, 2008

Hour	Running Losses (g/km) – Arterial Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.057	0.053	0.038	0.105	0.098	0.069	0.130	0.121	0.086	0.157	0.147	0.104
1	0.054	0.051	0.036	0.100	0.093	0.067	0.123	0.116	0.083	0.149	0.140	0.100
2	0.052	0.049	0.035	0.096	0.090	0.065	0.118	0.112	0.080	0.144	0.135	0.097
3	0.050	0.047	0.034	0.092	0.087	0.063	0.114	0.108	0.078	0.138	0.131	0.094
4	0.050	0.048	0.034	0.092	0.088	0.063	0.114	0.108	0.078	0.138	0.131	0.094
5	0.058	0.049	0.034	0.106	0.090	0.063	0.131	0.111	0.078	0.159	0.135	0.095
6	0.094	0.061	0.036	0.173	0.112	0.066	0.213	0.139	0.081	0.259	0.168	0.098
7	0.181	0.101	0.049	0.329	0.184	0.090	0.405	0.227	0.111	0.494	0.276	0.134
8	0.297	0.160	0.076	0.540	0.292	0.140	0.663	0.360	0.173	0.809	0.438	0.210
9	0.375	0.206	0.104	0.683	0.377	0.190	0.839	0.464	0.234	1.024	0.565	0.285
10	0.438	0.241	0.133	0.797	0.440	0.243	0.980	0.543	0.300	1.196	0.661	0.365
11	0.485	0.268	0.155	0.883	0.490	0.284	1.085	0.604	0.350	1.324	0.735	0.425
12	0.485	0.278	0.160	0.884	0.507	0.293	1.087	0.625	0.361	1.326	0.761	0.439
13	0.465	0.275	0.156	0.846	0.503	0.285	1.040	0.619	0.352	1.269	0.754	0.427
14	0.423	0.258	0.145	0.771	0.471	0.265	0.948	0.580	0.327	1.156	0.707	0.398
15	0.362	0.227	0.126	0.658	0.414	0.231	0.809	0.510	0.284	0.987	0.621	0.346
16	0.285	0.181	0.097	0.519	0.332	0.177	0.638	0.409	0.218	0.778	0.497	0.265
17	0.210	0.133	0.070	0.383	0.243	0.128	0.471	0.299	0.158	0.574	0.364	0.192
18	0.134	0.092	0.055	0.245	0.168	0.101	0.302	0.208	0.125	0.368	0.252	0.152
19	0.091	0.073	0.048	0.167	0.133	0.088	0.206	0.165	0.109	0.250	0.200	0.132
20	0.075	0.064	0.044	0.137	0.118	0.080	0.169	0.146	0.100	0.206	0.177	0.121
21	0.068	0.060	0.041	0.124	0.111	0.076	0.154	0.137	0.094	0.186	0.166	0.114
22	0.064	0.058	0.040	0.117	0.106	0.074	0.145	0.131	0.091	0.176	0.159	0.110
23	0.060	0.055	0.038	0.110	0.101	0.071	0.136	0.125	0.088	0.165	0.152	0.106

Table 4-127: Fleet composite hourly running loss emission factors – ethanol free fuel fleet (E0) – commercial arterial roads, 2008

Hour	Running Losses (g/km) – Commercial Arterial Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.057	0.054	0.038	0.106	0.099	0.070	0.130	0.122	0.087	0.158	0.148	0.105
1	0.055	0.051	0.037	0.100	0.094	0.067	0.124	0.117	0.083	0.151	0.141	0.101
2	0.053	0.050	0.035	0.097	0.091	0.065	0.120	0.113	0.081	0.145	0.137	0.098
3	0.051	0.048	0.035	0.094	0.088	0.064	0.116	0.110	0.079	0.140	0.133	0.095
4	0.051	0.048	0.034	0.093	0.088	0.063	0.115	0.109	0.079	0.139	0.132	0.095
5	0.058	0.049	0.035	0.107	0.091	0.064	0.132	0.112	0.079	0.160	0.136	0.096
6	0.098	0.063	0.037	0.179	0.116	0.068	0.220	0.143	0.084	0.268	0.174	0.102
7	0.192	0.107	0.052	0.349	0.195	0.095	0.429	0.240	0.117	0.523	0.293	0.142
8	0.314	0.170	0.081	0.571	0.309	0.148	0.701	0.380	0.183	0.856	0.464	0.222
9	0.387	0.213	0.107	0.704	0.389	0.196	0.866	0.479	0.242	1.057	0.583	0.294
10	0.454	0.250	0.138	0.825	0.456	0.252	1.015	0.562	0.311	1.238	0.684	0.378
11	0.502	0.277	0.160	0.913	0.507	0.293	1.122	0.624	0.362	1.369	0.760	0.440
12	0.503	0.288	0.166	0.916	0.526	0.303	1.125	0.647	0.374	1.373	0.788	0.455
13	0.481	0.285	0.161	0.876	0.520	0.295	1.076	0.641	0.364	1.314	0.781	0.443
14	0.437	0.266	0.150	0.796	0.486	0.274	0.977	0.599	0.337	1.193	0.729	0.410
15	0.382	0.240	0.133	0.695	0.438	0.244	0.853	0.539	0.300	1.042	0.656	0.365
16	0.301	0.192	0.102	0.547	0.350	0.187	0.672	0.431	0.230	0.820	0.525	0.280
17	0.222	0.140	0.074	0.403	0.256	0.135	0.496	0.315	0.166	0.605	0.384	0.202
18	0.139	0.095	0.057	0.254	0.175	0.105	0.313	0.215	0.130	0.381	0.262	0.158
19	0.092	0.073	0.048	0.168	0.135	0.089	0.208	0.166	0.110	0.253	0.202	0.133
20	0.075	0.065	0.044	0.138	0.119	0.081	0.171	0.147	0.100	0.207	0.178	0.122
21	0.068	0.061	0.042	0.125	0.111	0.077	0.155	0.138	0.095	0.188	0.167	0.115
22	0.064	0.058	0.040	0.118	0.107	0.074	0.146	0.132	0.092	0.177	0.160	0.111
23	0.060	0.055	0.039	0.111	0.102	0.071	0.137	0.126	0.088	0.166	0.153	0.107

Table 4-128: Fleet composite hourly running loss emission factors – ethanol free fuel fleet (E0) – commercial highway roads, 2008

Hour	Running Losses (g/km) – Commercial Highway Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.038	0.035	0.025	0.071	0.066	0.047	0.088	0.082	0.058	0.106	0.099	0.070
1	0.036	0.034	0.024	0.067	0.062	0.045	0.083	0.078	0.056	0.100	0.094	0.067
2	0.034	0.032	0.023	0.064	0.060	0.043	0.080	0.075	0.054	0.096	0.090	0.065
3	0.033	0.031	0.022	0.062	0.058	0.042	0.077	0.072	0.052	0.092	0.087	0.062
4	0.033	0.032	0.023	0.062	0.059	0.042	0.078	0.074	0.053	0.094	0.088	0.063
5	0.040	0.034	0.024	0.074	0.062	0.044	0.092	0.078	0.055	0.110	0.094	0.066
6	0.065	0.042	0.024	0.120	0.078	0.046	0.150	0.097	0.057	0.181	0.117	0.068
7	0.137	0.076	0.037	0.251	0.140	0.068	0.311	0.174	0.085	0.377	0.210	0.102
8	0.234	0.126	0.060	0.428	0.231	0.111	0.528	0.286	0.137	0.642	0.347	0.166
9	0.275	0.151	0.076	0.506	0.278	0.140	0.626	0.345	0.174	0.759	0.418	0.210
10	0.312	0.171	0.094	0.575	0.316	0.174	0.712	0.393	0.217	0.862	0.474	0.262
11	0.349	0.192	0.111	0.642	0.355	0.205	0.795	0.440	0.255	0.963	0.532	0.308
12	0.346	0.197	0.113	0.637	0.364	0.210	0.789	0.452	0.261	0.955	0.546	0.315
13	0.332	0.196	0.111	0.612	0.363	0.205	0.759	0.450	0.255	0.919	0.544	0.308
14	0.309	0.188	0.105	0.568	0.346	0.195	0.704	0.429	0.242	0.853	0.519	0.292
15	0.261	0.163	0.091	0.480	0.301	0.167	0.594	0.373	0.208	0.720	0.451	0.251
16	0.207	0.132	0.070	0.382	0.243	0.130	0.472	0.301	0.161	0.572	0.365	0.194
17	0.155	0.098	0.051	0.285	0.181	0.095	0.353	0.224	0.118	0.428	0.271	0.142
18	0.097	0.066	0.040	0.179	0.123	0.074	0.223	0.153	0.092	0.269	0.184	0.111
19	0.065	0.051	0.034	0.120	0.095	0.063	0.149	0.119	0.078	0.180	0.143	0.094
20	0.051	0.044	0.030	0.095	0.082	0.056	0.119	0.102	0.069	0.143	0.123	0.083
21	0.046	0.041	0.028	0.086	0.076	0.052	0.107	0.095	0.065	0.129	0.114	0.078
22	0.043	0.039	0.027	0.081	0.073	0.050	0.101	0.091	0.063	0.121	0.109	0.076
23	0.040	0.037	0.026	0.075	0.068	0.048	0.093	0.085	0.060	0.112	0.103	0.072

Table 4-129: Fleet composite hourly running loss emission factors – ethanol free fuel fleet (E0) – freeway/highway roads, 2008

Hour	Running Losses (g/km) – Freeway/Highway Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.027	0.025	0.017	0.051	0.047	0.033	0.064	0.059	0.042	0.076	0.070	0.050
1	0.024	0.023	0.016	0.046	0.043	0.031	0.059	0.054	0.039	0.070	0.065	0.046
2	0.023	0.021	0.015	0.044	0.041	0.029	0.055	0.052	0.037	0.066	0.061	0.044
3	0.022	0.020	0.014	0.041	0.038	0.027	0.052	0.049	0.035	0.062	0.057	0.041
4	0.023	0.022	0.016	0.044	0.041	0.029	0.055	0.052	0.037	0.066	0.062	0.044
5	0.028	0.024	0.017	0.053	0.045	0.031	0.067	0.056	0.040	0.080	0.067	0.047
6	0.050	0.032	0.019	0.094	0.061	0.035	0.118	0.076	0.044	0.141	0.091	0.053
7	0.118	0.066	0.032	0.218	0.121	0.059	0.271	0.151	0.073	0.327	0.182	0.088
8	0.203	0.109	0.052	0.373	0.201	0.096	0.462	0.250	0.120	0.560	0.302	0.145
9	0.215	0.118	0.059	0.399	0.219	0.110	0.498	0.273	0.138	0.599	0.328	0.165
10	0.241	0.132	0.073	0.449	0.246	0.136	0.561	0.308	0.170	0.673	0.369	0.204
11	0.271	0.149	0.086	0.504	0.278	0.161	0.629	0.347	0.201	0.756	0.416	0.241
12	0.267	0.152	0.087	0.498	0.284	0.163	0.622	0.355	0.204	0.747	0.426	0.245
13	0.257	0.152	0.086	0.480	0.283	0.160	0.599	0.354	0.200	0.719	0.424	0.240
14	0.241	0.146	0.082	0.449	0.272	0.153	0.560	0.340	0.191	0.673	0.409	0.230
15	0.221	0.138	0.077	0.410	0.257	0.143	0.510	0.319	0.178	0.615	0.385	0.214
16	0.177	0.112	0.060	0.327	0.208	0.111	0.406	0.259	0.138	0.490	0.312	0.166
17	0.133	0.084	0.044	0.245	0.155	0.081	0.305	0.193	0.101	0.368	0.232	0.122
18	0.076	0.052	0.031	0.142	0.097	0.058	0.177	0.121	0.073	0.213	0.145	0.087
19	0.047	0.037	0.025	0.089	0.070	0.046	0.111	0.088	0.058	0.133	0.105	0.069
20	0.037	0.032	0.021	0.070	0.060	0.041	0.088	0.075	0.051	0.105	0.089	0.061
21	0.033	0.029	0.020	0.063	0.055	0.038	0.079	0.069	0.048	0.094	0.083	0.057
22	0.031	0.028	0.019	0.059	0.053	0.037	0.074	0.067	0.046	0.089	0.080	0.055
23	0.029	0.026	0.018	0.054	0.049	0.034	0.068	0.062	0.043	0.081	0.074	0.051

Table 4-130: Fleet composite hourly running loss emission factors – E10 fuel fleet – residential roads, 2008

Hour	Running Losses (g/km) – Residential Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.105	0.101	0.071	0.192	0.186	0.132	0.295	0.287	0.203	0.276	0.267	0.188
1	0.100	0.097	0.069	0.184	0.179	0.128	0.283	0.276	0.197	0.264	0.256	0.183
2	0.097	0.094	0.067	0.178	0.174	0.124	0.274	0.268	0.192	0.255	0.249	0.178
3	0.094	0.092	0.066	0.173	0.170	0.122	0.266	0.262	0.188	0.248	0.244	0.174
4	0.092	0.090	0.064	0.169	0.167	0.119	0.259	0.256	0.184	0.242	0.238	0.171
5	0.104	0.091	0.063	0.191	0.168	0.118	0.293	0.259	0.181	0.274	0.240	0.168
6	0.169	0.111	0.064	0.309	0.205	0.118	0.472	0.314	0.182	0.442	0.292	0.169
7	0.311	0.174	0.082	0.565	0.320	0.152	0.861	0.491	0.234	0.808	0.457	0.217
8	0.518	0.280	0.130	0.938	0.513	0.240	1.424	0.784	0.368	1.339	0.733	0.342
9	0.693	0.383	0.188	1.253	0.700	0.345	1.901	1.068	0.529	1.789	0.999	0.493
10	0.833	0.461	0.248	1.504	0.842	0.456	2.280	1.283	0.699	2.147	1.201	0.652
11	0.919	0.511	0.290	1.660	0.932	0.532	2.514	1.421	0.813	2.369	1.330	0.759
12	0.929	0.535	0.302	1.677	0.976	0.554	2.541	1.488	0.848	2.394	1.393	0.791
13	0.885	0.528	0.293	1.597	0.964	0.538	2.420	1.469	0.823	2.280	1.375	0.768
14	0.790	0.486	0.267	1.428	0.888	0.491	2.165	1.353	0.752	2.038	1.267	0.701
15	0.658	0.418	0.227	1.190	0.763	0.417	1.806	1.164	0.639	1.699	1.089	0.596
16	0.508	0.328	0.171	0.921	0.601	0.314	1.400	0.917	0.482	1.315	0.857	0.449
17	0.368	0.236	0.121	0.668	0.432	0.223	1.017	0.661	0.342	0.955	0.617	0.319
18	0.238	0.166	0.098	0.434	0.305	0.181	0.663	0.468	0.279	0.621	0.436	0.259
19	0.165	0.134	0.088	0.301	0.248	0.162	0.461	0.380	0.250	0.431	0.354	0.232
20	0.137	0.121	0.081	0.250	0.223	0.151	0.384	0.342	0.232	0.358	0.318	0.216
21	0.124	0.113	0.077	0.227	0.209	0.143	0.348	0.321	0.221	0.325	0.299	0.205
22	0.116	0.108	0.075	0.213	0.200	0.138	0.327	0.308	0.213	0.305	0.286	0.197
23	0.110	0.104	0.072	0.202	0.192	0.133	0.310	0.295	0.206	0.289	0.274	0.191

Table 4-131: Fleet composite hourly running loss emission factors – E10 fuel fleet – arterial roads, 2008

Hour	Running Losses (g/km) – Arterial Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.058	0.054	0.038	0.109	0.102	0.073	0.171	0.160	0.114	0.157	0.147	0.104
1	0.055	0.052	0.037	0.104	0.098	0.070	0.163	0.153	0.109	0.149	0.140	0.100
2	0.053	0.050	0.036	0.100	0.094	0.068	0.156	0.147	0.106	0.144	0.135	0.097
3	0.051	0.048	0.035	0.096	0.091	0.066	0.151	0.143	0.103	0.138	0.131	0.094
4	0.051	0.048	0.035	0.096	0.092	0.066	0.150	0.143	0.103	0.138	0.131	0.094
5	0.058	0.050	0.035	0.110	0.094	0.066	0.172	0.147	0.104	0.159	0.135	0.095
6	0.096	0.062	0.036	0.180	0.117	0.069	0.281	0.183	0.107	0.259	0.168	0.098
7	0.184	0.103	0.050	0.343	0.193	0.094	0.535	0.300	0.146	0.494	0.276	0.134
8	0.302	0.163	0.078	0.562	0.306	0.146	0.875	0.475	0.228	0.809	0.438	0.210
9	0.381	0.210	0.106	0.711	0.394	0.199	1.108	0.613	0.309	1.024	0.565	0.285
10	0.445	0.246	0.135	0.830	0.461	0.254	1.294	0.717	0.396	1.196	0.661	0.365
11	0.493	0.273	0.158	0.920	0.513	0.297	1.433	0.797	0.462	1.324	0.735	0.425
12	0.494	0.283	0.163	0.921	0.531	0.306	1.435	0.825	0.477	1.326	0.761	0.439
13	0.473	0.281	0.159	0.881	0.526	0.298	1.373	0.818	0.464	1.269	0.754	0.427
14	0.431	0.263	0.148	0.803	0.493	0.277	1.251	0.766	0.432	1.156	0.707	0.398
15	0.368	0.231	0.128	0.686	0.434	0.241	1.068	0.674	0.376	0.987	0.621	0.346
16	0.290	0.185	0.098	0.540	0.347	0.185	0.842	0.539	0.288	0.778	0.497	0.265
17	0.214	0.135	0.071	0.399	0.254	0.134	0.621	0.395	0.208	0.574	0.364	0.192
18	0.136	0.094	0.056	0.255	0.176	0.106	0.399	0.274	0.165	0.368	0.252	0.152
19	0.093	0.074	0.049	0.174	0.139	0.092	0.272	0.217	0.144	0.250	0.200	0.132
20	0.076	0.065	0.044	0.143	0.123	0.084	0.224	0.193	0.131	0.206	0.177	0.121
21	0.069	0.061	0.042	0.129	0.116	0.080	0.203	0.181	0.125	0.186	0.166	0.114
22	0.065	0.059	0.041	0.122	0.111	0.077	0.191	0.173	0.120	0.176	0.159	0.110
23	0.061	0.056	0.039	0.115	0.106	0.074	0.180	0.165	0.116	0.165	0.152	0.106

Table 4-132: Fleet composite hourly running loss emission factors – E10 fuel fleet – commercial arterial roads, 2008

Hour	Running Losses (g/km) – Commercial Arterial Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.058	0.055	0.039	0.110	0.103	0.073	0.172	0.161	0.114	0.158	0.148	0.105
1	0.055	0.052	0.037	0.104	0.099	0.070	0.164	0.154	0.110	0.151	0.141	0.101
2	0.053	0.050	0.036	0.101	0.095	0.068	0.158	0.149	0.107	0.145	0.137	0.098
3	0.052	0.049	0.035	0.097	0.092	0.066	0.153	0.145	0.104	0.140	0.133	0.095
4	0.051	0.049	0.035	0.097	0.092	0.066	0.152	0.144	0.104	0.139	0.132	0.095
5	0.059	0.050	0.035	0.111	0.095	0.067	0.174	0.148	0.104	0.160	0.136	0.096
6	0.099	0.064	0.038	0.186	0.121	0.071	0.291	0.189	0.111	0.268	0.174	0.102
7	0.195	0.109	0.053	0.363	0.204	0.099	0.566	0.317	0.155	0.523	0.293	0.142
8	0.320	0.173	0.083	0.595	0.324	0.155	0.925	0.502	0.241	0.856	0.464	0.222
9	0.394	0.217	0.109	0.734	0.407	0.205	1.143	0.632	0.319	1.057	0.583	0.294
10	0.461	0.255	0.140	0.860	0.478	0.264	1.339	0.742	0.410	1.238	0.684	0.378
11	0.511	0.283	0.164	0.951	0.530	0.307	1.480	0.823	0.478	1.369	0.760	0.440
12	0.512	0.294	0.169	0.954	0.550	0.317	1.485	0.855	0.494	1.373	0.788	0.455
13	0.490	0.291	0.165	0.912	0.545	0.309	1.421	0.846	0.481	1.314	0.781	0.443
14	0.445	0.272	0.153	0.829	0.509	0.286	1.290	0.790	0.445	1.193	0.729	0.410
15	0.389	0.245	0.136	0.724	0.458	0.255	1.126	0.711	0.396	1.042	0.656	0.365
16	0.306	0.196	0.104	0.570	0.366	0.195	0.887	0.569	0.304	0.820	0.525	0.280
17	0.225	0.143	0.075	0.420	0.268	0.141	0.654	0.416	0.219	0.605	0.384	0.202
18	0.141	0.097	0.058	0.265	0.183	0.110	0.413	0.284	0.172	0.381	0.262	0.158
19	0.093	0.075	0.049	0.175	0.141	0.093	0.274	0.219	0.145	0.253	0.202	0.133
20	0.077	0.066	0.045	0.144	0.124	0.085	0.225	0.194	0.132	0.207	0.178	0.122
21	0.069	0.062	0.042	0.130	0.116	0.080	0.204	0.182	0.125	0.188	0.167	0.115
22	0.065	0.059	0.041	0.123	0.112	0.077	0.192	0.174	0.121	0.177	0.160	0.111
23	0.061	0.056	0.039	0.115	0.106	0.074	0.181	0.166	0.116	0.166	0.153	0.107

Table 4-133: Fleet composite hourly running loss emission factors – E10 fuel fleet – commercial highway roads, 2008

Hour	Running Losses (g/km) – Commercial Highway Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.038	0.036	0.025	0.074	0.069	0.049	0.117	0.109	0.077	0.106	0.099	0.070
1	0.036	0.034	0.024	0.070	0.065	0.046	0.110	0.103	0.074	0.100	0.094	0.067
2	0.035	0.033	0.023	0.067	0.063	0.045	0.106	0.099	0.071	0.096	0.090	0.065
3	0.033	0.031	0.022	0.064	0.060	0.043	0.102	0.096	0.069	0.092	0.087	0.062
4	0.034	0.032	0.023	0.065	0.061	0.044	0.103	0.097	0.070	0.094	0.088	0.063
5	0.040	0.034	0.024	0.077	0.065	0.046	0.121	0.103	0.072	0.110	0.094	0.066
6	0.066	0.043	0.025	0.125	0.081	0.047	0.198	0.128	0.075	0.181	0.117	0.068
7	0.139	0.077	0.038	0.262	0.146	0.071	0.410	0.229	0.112	0.377	0.210	0.102
8	0.237	0.128	0.061	0.446	0.242	0.116	0.697	0.377	0.181	0.642	0.347	0.166
9	0.279	0.153	0.077	0.527	0.291	0.146	0.827	0.456	0.230	0.759	0.418	0.210
10	0.316	0.174	0.096	0.598	0.330	0.182	0.940	0.519	0.286	0.862	0.474	0.262
11	0.353	0.195	0.113	0.668	0.371	0.214	1.050	0.581	0.337	0.963	0.532	0.308
12	0.350	0.200	0.115	0.663	0.380	0.219	1.042	0.597	0.344	0.955	0.546	0.315
13	0.337	0.199	0.113	0.638	0.379	0.214	1.002	0.594	0.337	0.919	0.544	0.308
14	0.313	0.191	0.107	0.592	0.362	0.203	0.929	0.567	0.319	0.853	0.519	0.292
15	0.264	0.166	0.092	0.499	0.314	0.175	0.784	0.493	0.274	0.720	0.451	0.251
16	0.210	0.134	0.071	0.397	0.254	0.135	0.623	0.398	0.212	0.572	0.365	0.194
17	0.157	0.100	0.052	0.297	0.189	0.099	0.466	0.295	0.156	0.428	0.271	0.142
18	0.098	0.067	0.040	0.187	0.128	0.077	0.294	0.201	0.121	0.269	0.184	0.111
19	0.065	0.052	0.034	0.125	0.099	0.066	0.197	0.157	0.103	0.180	0.143	0.094
20	0.052	0.045	0.030	0.099	0.085	0.058	0.157	0.134	0.092	0.143	0.123	0.083
21	0.047	0.041	0.028	0.089	0.079	0.054	0.141	0.125	0.086	0.129	0.114	0.078
22	0.044	0.040	0.027	0.084	0.076	0.053	0.133	0.120	0.083	0.121	0.109	0.076
23	0.041	0.037	0.026	0.078	0.071	0.050	0.123	0.113	0.079	0.112	0.103	0.072

Table 4-134: Fleet composite hourly running loss emission factors – E10 fuel fleet – freeway/highway roads, 2008

Hour	Running Losses (g/km) – Freeway/Highway Roads											
	Petrol Passenger Vehicles			Petrol LCV			Motorcycles			Heavy Duty Commercial Petrol		
	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter	Summer	Autumn-Spring	Winter
0	0.027	0.025	0.018	0.053	0.049	0.034	0.084	0.078	0.055	0.076	0.070	0.050
1	0.025	0.023	0.016	0.048	0.045	0.032	0.078	0.072	0.051	0.070	0.065	0.046
2	0.023	0.021	0.015	0.046	0.042	0.030	0.073	0.068	0.049	0.066	0.061	0.044
3	0.022	0.020	0.014	0.043	0.040	0.028	0.069	0.064	0.046	0.062	0.057	0.041
4	0.023	0.022	0.016	0.045	0.043	0.031	0.073	0.068	0.049	0.066	0.062	0.044
5	0.028	0.024	0.017	0.055	0.047	0.033	0.088	0.074	0.052	0.080	0.067	0.047
6	0.051	0.033	0.019	0.098	0.063	0.037	0.155	0.100	0.059	0.141	0.091	0.053
7	0.119	0.066	0.032	0.227	0.127	0.062	0.357	0.199	0.097	0.327	0.182	0.088
8	0.206	0.111	0.053	0.388	0.210	0.101	0.610	0.329	0.158	0.560	0.302	0.145
9	0.217	0.119	0.060	0.415	0.228	0.115	0.657	0.361	0.182	0.599	0.328	0.165
10	0.243	0.133	0.073	0.467	0.256	0.141	0.740	0.406	0.224	0.673	0.369	0.204
11	0.273	0.150	0.087	0.524	0.289	0.167	0.830	0.458	0.265	0.756	0.416	0.241
12	0.270	0.153	0.088	0.518	0.296	0.170	0.821	0.468	0.270	0.747	0.426	0.245
13	0.260	0.153	0.087	0.499	0.295	0.167	0.791	0.467	0.264	0.719	0.424	0.240
14	0.244	0.148	0.083	0.467	0.284	0.160	0.739	0.449	0.252	0.673	0.409	0.230
15	0.224	0.140	0.078	0.427	0.268	0.149	0.673	0.422	0.235	0.615	0.385	0.214
16	0.179	0.114	0.060	0.340	0.217	0.115	0.536	0.341	0.182	0.490	0.312	0.166
17	0.134	0.085	0.044	0.255	0.162	0.085	0.402	0.254	0.134	0.368	0.232	0.122
18	0.077	0.052	0.031	0.147	0.101	0.061	0.234	0.160	0.096	0.213	0.145	0.087
19	0.048	0.038	0.025	0.092	0.073	0.048	0.147	0.117	0.077	0.133	0.105	0.069
20	0.037	0.032	0.022	0.073	0.062	0.042	0.116	0.099	0.067	0.105	0.089	0.061
21	0.033	0.029	0.020	0.065	0.057	0.039	0.104	0.092	0.063	0.094	0.083	0.057
22	0.032	0.028	0.020	0.062	0.055	0.038	0.098	0.088	0.061	0.089	0.080	0.055
23	0.029	0.026	0.018	0.056	0.051	0.036	0.090	0.082	0.057	0.081	0.074	0.051

4.6.3.5 Speciation Profiles

The VOC speciation profile for evaporative is derived from data generated by the commonwealth ethanol health impacts study (CSIRO & Orbital, 2008). The speciation profile for the substances reported in this section is shown in Table 4-135, whilst the full speciation profile is given in APPENDIX D.

Table 4-135: Evaporative speciation data for selected compounds

Substance	Petrol E0 (% VOC)	Petrol E10 (% VOC)
1,3 butadiene	N/A	N/A
Acetaldehyde	N/A	N/A
Benzene	0.658176	0.538167
Formaldehyde	N/A	N/A
Isomers of xylene	1.321277	0.828436
Toluene	2.766556	1.988936

4.6.4 Emission Estimates

Estimated emissions from the source type *Evaporative Emissions* source type within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-136.

Table 4-136: Estimated emissions from source type evaporative emissions

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	0	0	0	0	0
ACETALDEHYDE	0	0	0	0	0
BENZENE	74.2	5.51	2.81	11.8	94.3
FORMALDEHYDE	0	0	0	0	0
ISOMERS OF XYLENE	146	10.8	5.52	23.1	185
TOLUENE	308	22.9	11.7	49.0	392
TOTAL VOLATILE ORGANIC COMPOUNDS	11,512	855	436	1,828	14,632

The monthly profile for the base emission species is given in Table 4-137, the weekly profile is given in Table 4-138, and the daily profile is shown in Table 4-139. The speciated compounds have the same profile as the base emission species; i.e. each speciated evaporative VOC have the same profile as the total VOC profile.

Table 4-137: Monthly profile for emissions from evaporative source type

Month	Proportion	Month	Proportion
1	0.11569	7	0.04509
2	0.11469	8	0.04565
3	0.10384	9	0.07600
4	0.07578	10	0.07877
5	0.08009	11	0.10044
6	0.04309	12	0.12088

Table 4-138: Weekly profile for emissions from evaporative source type

Days	Proportion
Weekdays	0.74034
Weekend days	0.25966

Table 4-139: Daily profile for emissions from evaporative source type

Hour	Proportion	Hour	Proportion
0	0.00278	12	0.09543
1	0.00183	13	0.08761
2	0.00160	14	0.08483
3	0.00145	15	0.07238
4	0.00239	16	0.05868
5	0.00579	17	0.04411
6	0.02036	18	0.02289
7	0.05605	19	0.01173
8	0.09465	20	0.00703
9	0.10451	21	0.00562
10	0.10173	22	0.00554
11	0.10751	23	0.00349

The total VOC contribution by the individual petrol vehicle types to the total evaporative emission source type are given in Table 4-140.

Table 4-140: Annual evaporative emissions by vehicle type

Vehicle Type	Total VOC	% of total evaporative
Petrol Passenger Vehicles	10,870	74.3%
Petrol LCV	3,282	22.4%
Motorcycles	434.0	3.0%
Heavy duty commercial petrol	46.1	0.3%
Total	14,632	100.0%

The contribution of the four evaporative emission mechanisms to the total evaporative emissions by season is presented in Figure 4-14.

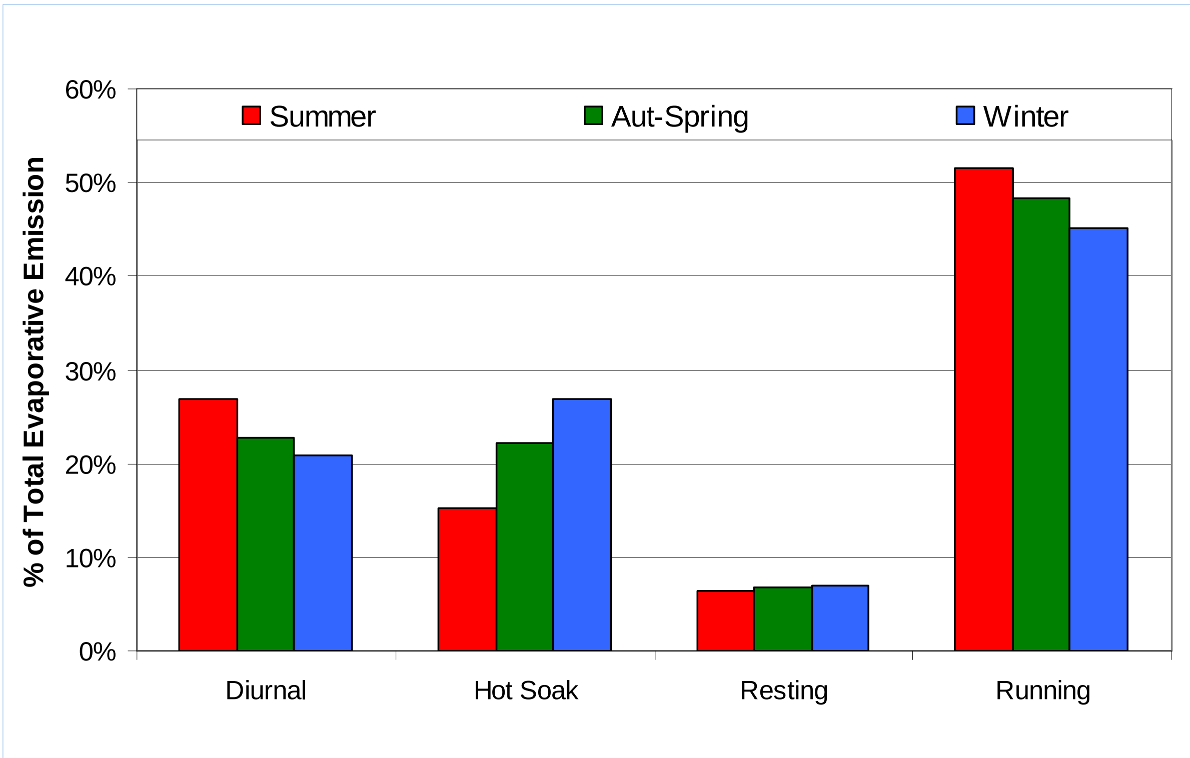

Figure 4-14: Contribution of evaporative mechanism to total evaporative emissions

4.7 Non-Exhaust Particulate Matter Emissions from All Vehicles

4.7.1 *Fleet Profile*

All vehicles are deemed to have the same non-exhaust PM emission rates, therefore an age profile is not relevant here.

4.7.2 *VKT Data*

Refer to the individual vehicle type VKT in the relevant exhaust emissions source type section.

4.7.3 *Emission Factors*

Non-exhaust PM emission factors are derived from the methodology of Ntziachristos & Boulter (2009) as outlined in Section 3.12. Emission factors for each vehicle type are determined for each road type at the 24 hour VKT weighted average speed. No speed correction is applied for hourly or spatial variation from this average speed. The emission factors are given in Table 4-141, Table 4-142 and Table 4-143 for tyre, brake, and road wear respectively. The combined total non-exhaust PM_{10} emission factors are given in Table 4-144. Size conversion from PM_{10} to TSP and $PM_{2.5}$ is given in Table 4-145.

Table 4-141: Tyre wear PM_{10} emission factors

Vehicle Type	Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
Petrol Passenger Vehicle	0.0089	0.0089	0.0089	0.0079	0.0073
Diesel Passenger Vehicle	0.0089	0.0089	0.0089	0.0079	0.0073
Petrol Light Commercial Vehicle	0.0141	0.0141	0.0141	0.0124	0.0115
Diesel Light Commercial Vehicle	0.0141	0.0141	0.0141	0.0124	0.0115
Heavy Duty Commercial Petrol	0.0176	0.0176	0.0176	0.0155	0.0144
Rigid Truck	0.0225	0.0225	0.0225	0.0199	0.0184
Articulated Truck	0.0639	0.0639	0.0639	0.0563	0.0521
Diesel Bus	0.0203	0.0203	0.0203	0.0179	0.0166
Motorcycle	0.0038	0.0038	0.0038	0.0034	0.0031

Table 4-142: Brake wear PM_{10} emission factors

Vehicle Type	Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
Petrol Passenger Vehicle	0.0123	0.0123	0.0123	0.0089	0.0071
Diesel Passenger Vehicle	0.0123	0.0123	0.0123	0.0089	0.0071
Petrol Light Commercial Vehicle	0.0191	0.0191	0.0191	0.0139	0.0110
Diesel Light Commercial Vehicle	0.0191	0.0191	0.0191	0.0139	0.0110
Heavy Duty Commercial Petrol	0.0239	0.0239	0.0239	0.0174	0.0138
Rigid Truck	0.0551	0.0551	0.0551	0.0401	0.0317
Articulated Truck	0.0551	0.0551	0.0551	0.0401	0.0317
Diesel Bus	0.0551	0.0551	0.0551	0.0401	0.0317
Motorcycle	0.0061	0.0061	0.0061	0.0044	0.0035

Table 4-143: Road wear PM_{10} emission factors

Vehicle Type	Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
Petrol Passenger Vehicle	0.0125	0.0125	0.0125	0.0091	0.0072
Diesel Passenger Vehicle	0.0125	0.0125	0.0125	0.0091	0.0072
Petrol Light Commercial Vehicle	0.0125	0.0125	0.0125	0.0091	0.0072
Diesel Light Commercial Vehicle	0.0125	0.0125	0.0125	0.0091	0.0072
Heavy Duty Commercial Petrol	0.0157	0.0157	0.0157	0.0114	0.0090
Rigid Truck	0.0635	0.0635	0.0635	0.0461	0.0365
Articulated Truck	0.0635	0.0635	0.0635	0.0461	0.0365
Diesel Bus	0.0635	0.0635	0.0635	0.0461	0.0365
Motorcycle	0.0050	0.0050	0.0050	0.0036	0.0029

Table 4-144: Combined tyre, brake and road wear PM_{10} emission factors

Vehicle Type	Residential/ Local	Arterial	Commercial Arterial	Commercial Highway	Freeway/ Motorway
Petrol Passenger Vehicle	0.0337	0.0337	0.0337	0.0259	0.0215
Diesel Passenger Vehicle	0.0337	0.0337	0.0337	0.0259	0.0215
Petrol Light Commercial Vehicle	0.0458	0.0458	0.0458	0.0354	0.0297
Diesel Light Commercial Vehicle	0.0458	0.0458	0.0458	0.0354	0.0297
Heavy Duty Commercial Petrol	0.0572	0.0572	0.0572	0.0443	0.0372
Rigid Truck	0.1411	0.1411	0.1411	0.1061	0.0866
Articulated Truck	0.1824	0.1824	0.1824	0.1425	0.1203
Diesel Bus	0.1389	0.1389	0.1389	0.1041	0.0848
Motorcycle	0.0149	0.0149	0.0149	0.0114	0.0095

Table 4-145: PM_{10} to TSP & $PM_{2.5}$ conversion factors for non-exhaust PM emissions

Emission Type	TSP Factor	$PM_{2.5}$ Factor
Tyre wear	1.67	0.70
Brake wear	1.02	0.40
Road wear	2.00	0.54
Combined Tyre, Brake and Road	1.551	0.532

4.7.4 *Emission Estimates*

Estimated emissions from the source type *non-exhaust PM* source type within the GMR, Sydney, Newcastle, Wollongong and Non Urban regions are provided in Table 4-146.

Table 4-146: Estimated emissions from source type non-exhaust PM

Substance	Estimated Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
LEAD & COMPOUNDS	2.62	0.209	0.102	0.451	3.38
PARTICULATE MATTER ≤ 10 µm	1,123	89.8	43.9	193	1,450
PARTICULATE MATTER ≤ 2.5 µm	597	47.7	23.3	103	771
TOTAL SUSPENDED PARTICULATE	1,742	139	68.0	300	2,249

The monthly profile for the base PM_{10} emission is given in Table 4-147, the weekly profile is given in Table 4-148, and the daily profile is shown in Table 4-149. The speciated compounds have the same profile as the base emission species; i.e. each of the speciated non-exhaust PM compounds have the same profile as the total PM_{10} profile.

Table 4-147: Monthly profile for emissions from source type non-exhaust PM

Month	Proportion	Month	Proportion
1	0.07948	7	0.08356
2	0.07879	8	0.08460
3	0.08810	9	0.08269
4	0.08245	10	0.08571
5	0.08715	11	0.08459
6	0.07985	12	0.08304

Table 4-148: Weekly profile for emissions from source type non-exhaust PM

Days	Proportion
Weekdays	0.78784
Weekend days	0.21216

Table 4-149: Daily profile for emissions from source type non-exhaust PM

Hour	Proportion	Hour	Proportion
0	0.00632	12	0.06295
1	0.00385	13	0.06353
2	0.00334	14	0.06943
3	0.00363	15	0.07022
4	0.00835	16	0.07141
5	0.02226	17	0.07105
6	0.04243	18	0.05049
7	0.07527	19	0.03084
8	0.08470	20	0.01934
9	0.07100	21	0.01534
10	0.06216	22	0.01545
11	0.06800	23	0.00865

5 RESULTS SUMMARY

Table 5-1 presents total estimated annual emissions (for selected substances) from all on-road mobile sources in the GMR, Sydney, Newcastle and Wollongong regions. Total estimated annual emissions are also presented for the region defined as Non Urban. This region is the area of the GMR minus the combined areas of the Sydney, Newcastle and Wollongong regions. The selected substances were chosen because they:

- Are the most common air pollutants found in airsheds according to the National Pollutant Inventory NEPM (NEPC, 2008);
- Are referred to in National Environment Protection Measures (NEPMs) for Ambient Air Quality (NEPC, 2003) and Air Toxics (NEPC, 2004); and
- Have been classified as priority air pollutants (NEPC, 2006).

Table 5-1: Total estimated annual emissions from on-road mobile sources in each region

Substance	Emissions (tonne/year)				
	Sydney	Newcastle	Wollongong	Non Urban	GMR
1,3 BUTADIENE	142	9.65	5.22	18.3	175
ACETALDEHYDE	101	7.30	3.79	16.1	128
BENZENE	624	42.7	23.0	82.3	772
CARBON MONOXIDE	123,712	8,369	4,786	16,944	153,812
FORMALDEHYDE	266	19.3	10.0	42.4	338
ISOMERS OF XYLENE	979	67.1	36.0	129	1,210
LEAD AND COMPOUNDS	2.82	0.227	0.112	0.495	3.65
OXIDES OF NITROGEN	45,392	3,902	2,184	9,453	60,932
PARTICULATE MATTER ≤ 10 µm	2,110	176	90.3	417	2,793
PARTICULATE MATTER ≤ 2.5 µm	1,553	131	68.2	319	2,071
POLYCYCLIC AROMATIC HYDROCARBONS	89.8	6.98	3.84	16.0	117
SULFUR DIOXIDE	210	15.1	8.13	35.0	269
TOLUENE	1,315	90.9	48.6	177	1,632
TSP	2,737	226	115	525	3,603
TOTAL VOLATILE ORGANIC COMPOUNDS	23,512	1,678	879	3,435	29,504

Figure 5-1 shows the proportion of total estimated GMR annual emissions (for selected substances) from on-road mobile, by Sydney, Newcastle, Wollongong and Non Urban regions.

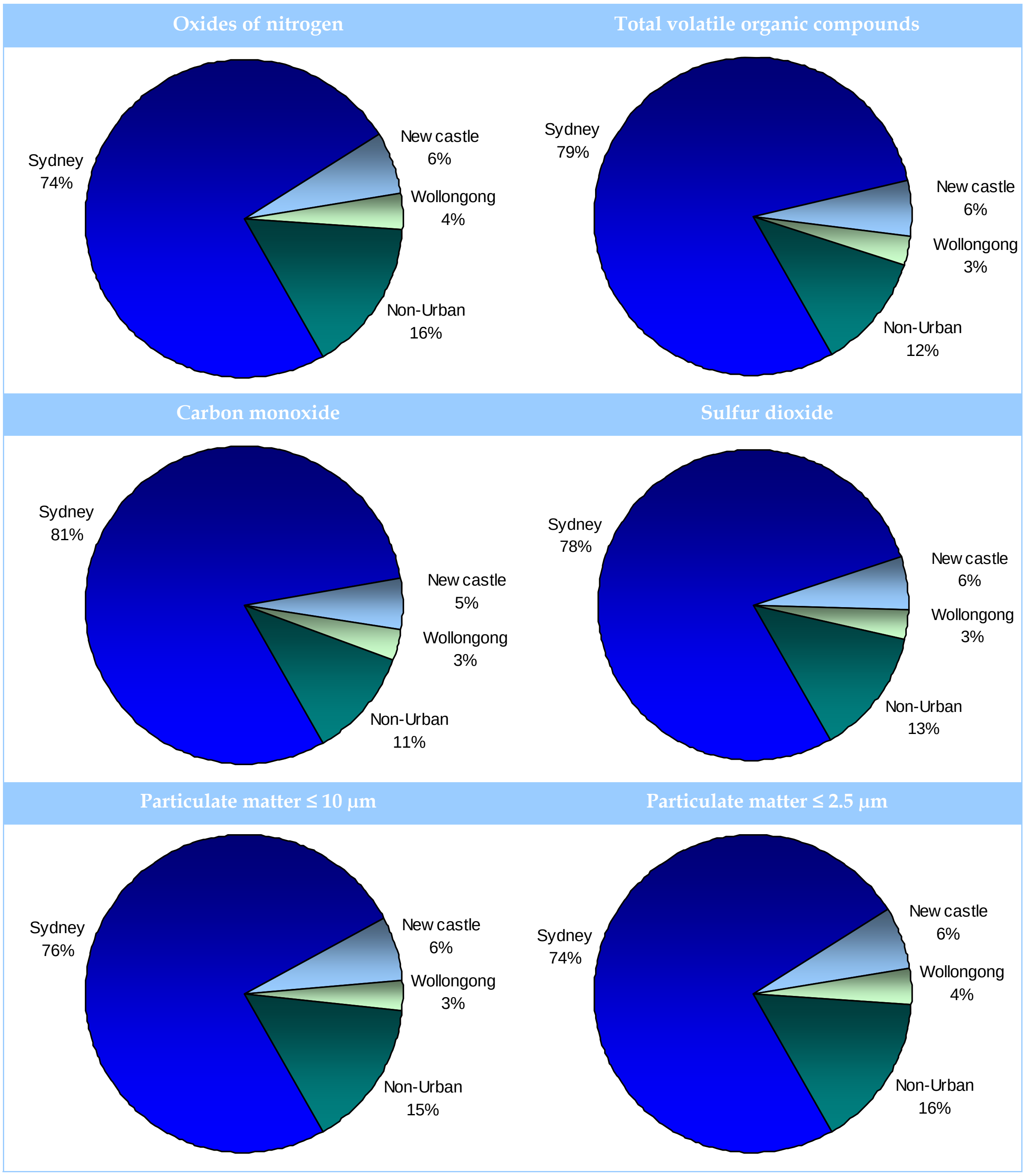

Figure 5-1: Proportion of total estimated GMR annual emissions from on-road mobile sources by region

Table 5-2, Table 5-3, Table 5-4, Table 5-5 and Table 5-6 present total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR, Sydney, Newcastle, Wollongong and Non Urban regions respectively.

Figure 5-2, Figure 5-3, Figure 5-4, Figure 5-5, and Figure 5-6 show the proportion of total estimated annual emissions (for selected substances) from each on-road mobile source type in the GMR, by Sydney, Newcastle, Wollongong and Non Urban regions respectively.

Table 5-2: Total estimated annual emissions by on-road mobile source type in the GMR

Substance	Emissions (tonne/year)							
	Exhaust Emissions - Petrol Passenger Vehicles	Exhaust Emissions - Light Duty Diesel Vehicles	Exhaust Emissions - Petrol Light Commercial Vehicles	Exhaust Emissions - Heavy Duty Diesel Vehicles	Exhaust Emissions - Other Vehicles	Evaporative Emissions - All Vehicles	Non-Exhaust Particulate Matter Emissions - All Vehicles	On-Road Mobile Total
1,3 BUTADIENE	121	0.819	41.9	4.72	6.55	0	0	175
ACETALDEHYDE	54.2	7.75	18.7	44.7	2.46	0	0	128
BENZENE	474	2.17	164	12.5	25.6	94.3	0	772
CARBON MONOXIDE	93,437	1,176	48,731	5,705	4,762	0	0	153,812
FORMALDEHYDE	145	20.0	50.0	116	7.58	0	0	338
ISOMERS OF XYLENE	729	0.780	252	4.50	39.3	185	0	1,210
LEAD & COMPOUNDS	0.043	0.055	0.023	0.150	0.0033	0	3.38	3.65
OXIDES OF NITROGEN	27,515	3,060	8,679	21,419	259	0	0	60,932
PARTICULATE MATTER ≤ 10 µm	121	308	63.7	841	9.39	0	1,450	2,793
PARTICULATE MATTER ≤ 2.5 µm	115	299	60.7	816	8.95	0	771	2,071
POLYCYCLIC AROMATIC HYDROCARBONS	49.5	10.1	21.2	32.6	3.20	0	0	117
SULFUR DIOXIDE	181	9.01	41.2	36.2	1.49	0	0	269
TOLUENE	881	0.954	304	5.50	47.5	392	0	1,632
TOTAL SUSPENDED PARTICULATE	121	311	63.7	850	9.39	0	2,249	3,603
TOTAL VOLATILE ORGANIC COMPOUNDS	9,647	203	3,331	1,173	518	14,632	0	29,504

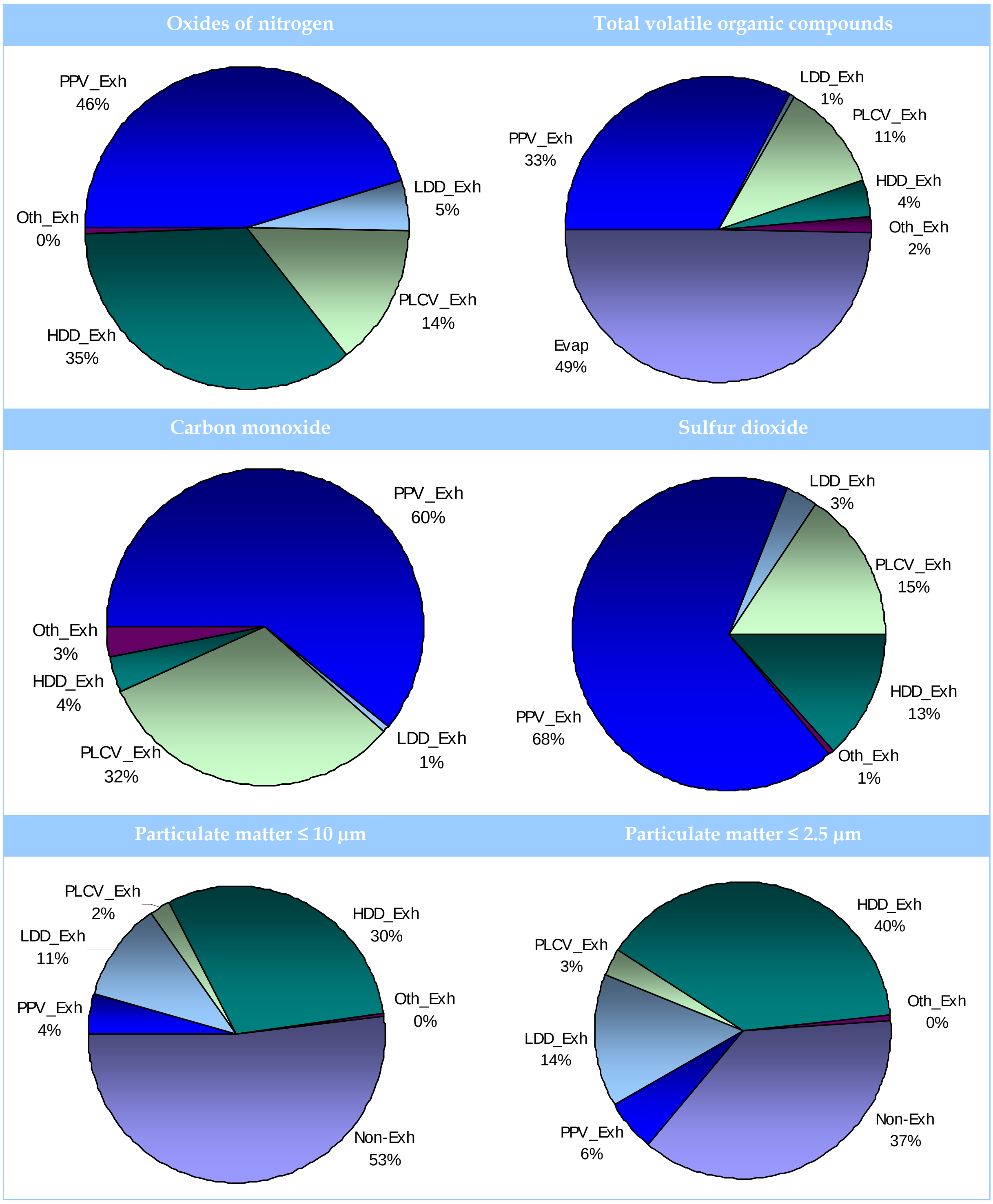

Figure 5-2: Proportion of total estimated annual emissions by on-road mobile source type† in the GMR

† PPV_Exh = Petrol passenger vehicle – exhaust, LDD_Exh = Light-duty diesel – exhaust, PLCV_Exh = Petrol light commercial vehicle – exhaust, HDD_Exh = Heavy-duty diesel – exhaust, Oth_Exh = Other vehicles – exhaust, Evap = Evaporative emissions all petrol vehicles, Non-Exh = Non-exhaust particulate matter – all vehicles

Table 5-3: Total estimated annual emissions by on-road mobile source type in the Sydney region

Substance	Emissions (tonne/year)							
	Exhaust Emissions - Petrol Passenger Vehicles	Exhaust Emissions - Light Duty Diesel Vehicles	Exhaust Emissions - Petrol Light Commercial Vehicles	Exhaust Emissions - Heavy Duty Diesel Vehicles	Exhaust Emissions - Other Vehicles	Evaporative Emissions - All Vehicles	Non-Exhaust Particulate Matter Emissions - All Vehicles	On-Road Mobile Total
1,3 BUTADIENE	98.0	0.677	34.8	3.49	5.18	0	0	142
ACETALDEHYDE	43.8	6.41	15.6	33.0	1.95	0	0	101
BENZENE	382	1.79	136	9.23	20.3	74.2	0	624
CARBON MONOXIDE	75,067	951	39,923	4,081	3,691	0	0	123,712
FORMALDEHYDE	117	16.6	41.6	85.3	5.99	0	0	266
ISOMERS OF XYLENE	589	0.645	209	3.32	31.1	146	0	979
LEAD & COMPOUNDS	0.033	0.044	0.018	0.106	0.0025	0	2.62	2.82
OXIDES OF NITROGEN	21,575	2,417	6,799	14,423	178	0	0	45,392
PARTICULATE MATTER ≤ 10 µm	92.3	247	49.5	592	6.99	0	1,123	2,110
PARTICULATE MATTER ≤ 2.5 µm	87.9	239	47.2	574	6.67	0	597	1,553
POLYCYCLIC AROMATIC HYDROCARBONS	39.0	8.12	17.0	23.3	2.45	0	0	89.8
SULFUR DIOXIDE	144	7.25	33.3	24.6	1.13	0	0	210
TOLUENE	712	0.788	253	4.06	37.6	308	0	1,315
TOTAL SUSPENDED PARTICULATE	92.3	249	49.5	598	6.99	0	1,742	2,737
TOTAL VOLATILE ORGANIC COMPOUNDS	7,789	168	2,768	866	409	11,512	0	23,512

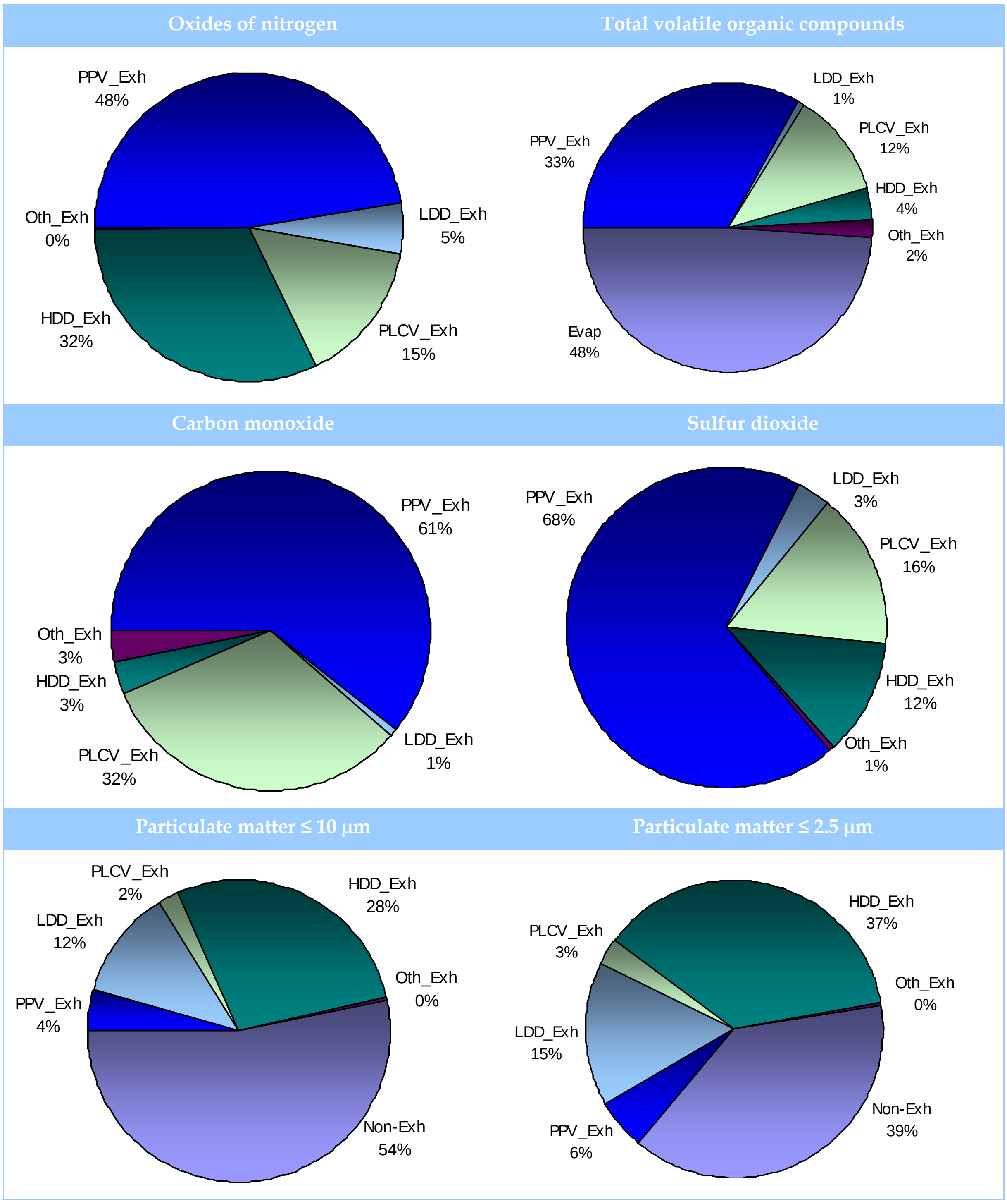

Figure 5-3: Proportion of total estimated annual emissions by on-road mobile source type in the Sydney region

Table 5-4: Total estimated annual emissions by on-road mobile source type in the Newcastle region

Substance	Emissions (tonne/year)							
	Exhaust Emissions - Petrol Passenger Vehicles	Exhaust Emissions - Light Duty Diesel Vehicles	Exhaust Emissions - Petrol Light Commercial Vehicles	Exhaust Emissions - Heavy Duty Diesel Vehicles	Exhaust Emissions - Other Vehicles	Evaporative Emissions - All Vehicles	Non-Exhaust Particulate Matter Emissions - All Vehicles	On-Road Mobile Total
1,3 BUTADIENE	6.75	0.042	2.18	0.293	0.377	0	0	9.65
ACETALDEHYDE	3.02	0.400	0.976	2.77	0.142	0	0	7.30
BENZENE	26.3	0.112	8.52	0.775	1.47	5.51	0	42.7
CARBON MONOXIDE	4,997	66.1	2,650	375	280	0	0	8,369
FORMALDEHYDE	8.06	1.03	2.61	7.16	0.436	0	0	19.3
ISOMERS OF XYLENE	40.5	0.040	13.1	0.279	2.26	10.8	0	67.1
LEAD & COMPOUNDS	0.0026	0.0031	0.0014	0.010	0.0002	0	0.209	0.227
OXIDES OF NITROGEN	1,666	177	530	1,511	18.2	0	0	3,902
PARTICULATE MATTER ≤ 10 µm	7.27	17.3	3.91	57.2	0.592	0	89.8	176
PARTICULATE MATTER ≤ 2.5 µm	6.93	16.8	3.72	55.5	0.564	0	47.7	131
POLYCYCLIC AROMATIC HYDROCARBONS	2.86	0.558	1.21	2.16	0.193	0	0	6.98
SULFUR DIOXIDE	9.73	0.505	2.27	2.53	0.091	0	0	15.1
TOLUENE	49.0	0.049	15.9	0.341	2.73	22.9	0	90.9
TOTAL SUSPENDED PARTICULATE	7.27	17.5	3.91	57.8	0.592	0	139	226
TOTAL VOLATILE ORGANIC COMPOUNDS	537	10.5	174	72.7	29.8	855	0	1,678

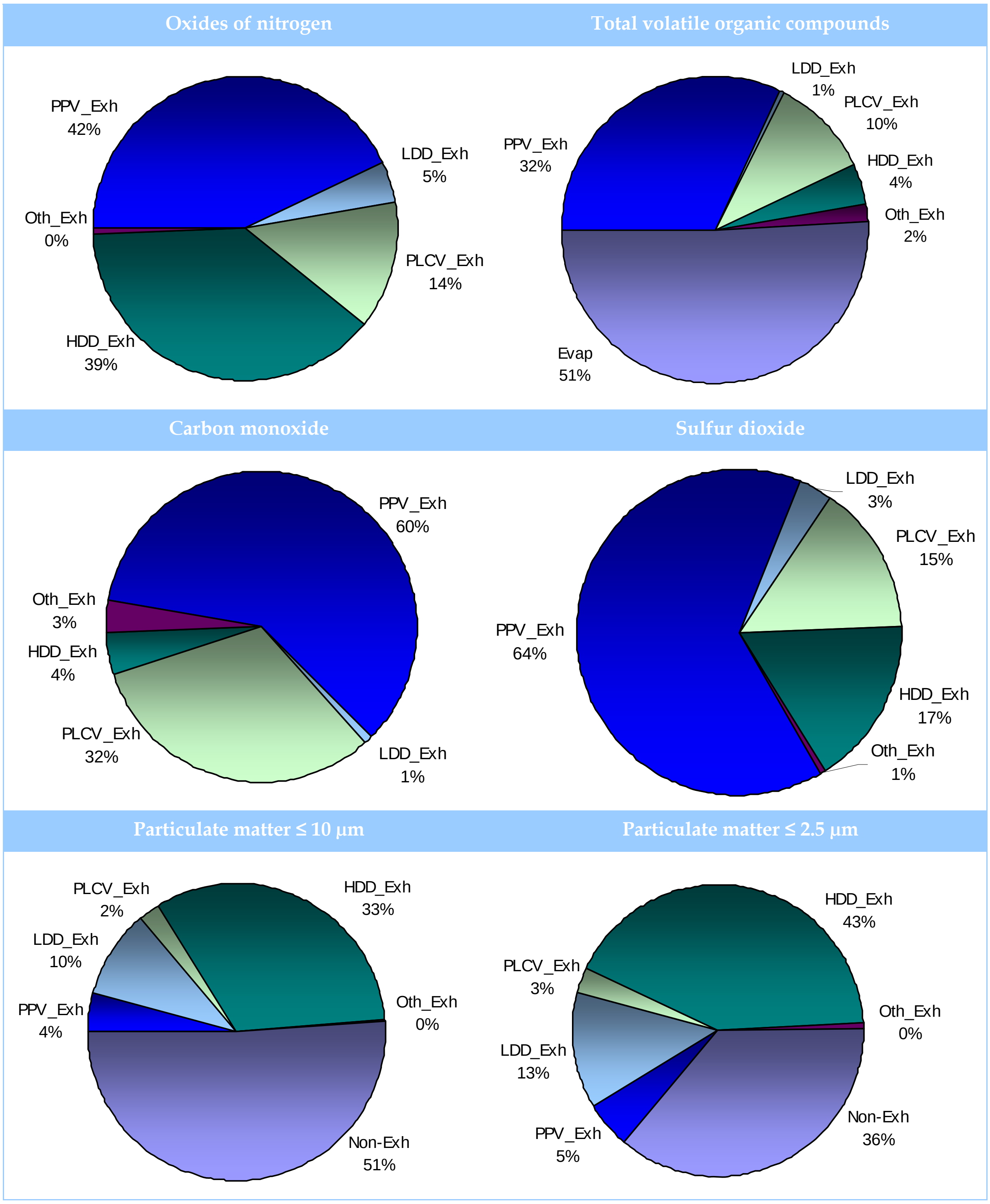

Figure 5-4: Proportion of total estimated annual emissions by on-road mobile source type in the Newcastle region

Table 5-5: Total estimated annual emissions by on-road mobile source type in the Wollongong region

Substance	Emissions (tonne/year)							
	Exhaust Emissions - Petrol Passenger Vehicles	Exhaust Emissions - Light Duty Diesel Vehicles	Exhaust Emissions - Petrol Light Commercial Vehicles	Exhaust Emissions - Heavy Duty Diesel Vehicles	Exhaust Emissions - Other Vehicles	Evaporative Emissions - All Vehicles	Non-Exhaust Particulate Matter Emissions - All Vehicles	On-Road Mobile Total
1,3 BUTADIENE	3.69	0.022	1.19	0.141	0.178	0	0	5.22
ACETALDEHYDE	1.65	0.210	0.531	1.33	0.067	0	0	3.79
BENZENE	14.4	0.059	4.63	0.373	0.696	2.81	0	23.0
CARBON MONOXIDE	2,861	38.2	1,564	184	140	0	0	4,786
FORMALDEHYDE	4.40	0.542	1.42	3.45	0.206	0	0	10.0
ISOMERS OF XYLENE	22.2	0.021	7.13	0.134	1.07	5.52	0	36.0
LEAD & COMPOUNDS	0.0015	0.0019	0.0009	0.0052	0.0001	0	0.102	0.112
OXIDES OF NITROGEN	938	107	346	783	9.92	0	0	2,184
PARTICULATE MATTER ≤ 10 µm	4.14	10.4	2.58	29.0	0.314	0	43.9	90.3
PARTICULATE MATTER ≤ 2.5 µm	3.95	10.1	2.46	28.1	0.300	0	23.3	68.2
POLYCYCLIC AROMATIC HYDROCARBONS	1.59	0.329	0.744	1.08	0.098	0	0	3.84
SULFUR DIOXIDE	5.15	0.281	1.36	1.30	0.046	0	0	8.13
TOLUENE	26.8	0.026	8.62	0.164	1.29	11.7	0	48.6
TOTAL SUSPENDED PARTICULATE	4.14	10.5	2.58	29.3	0.314	0	68.0	115
TOTAL VOLATILE ORGANIC COMPOUNDS	293	5.50	94.4	35.0	14.1	436	0	879

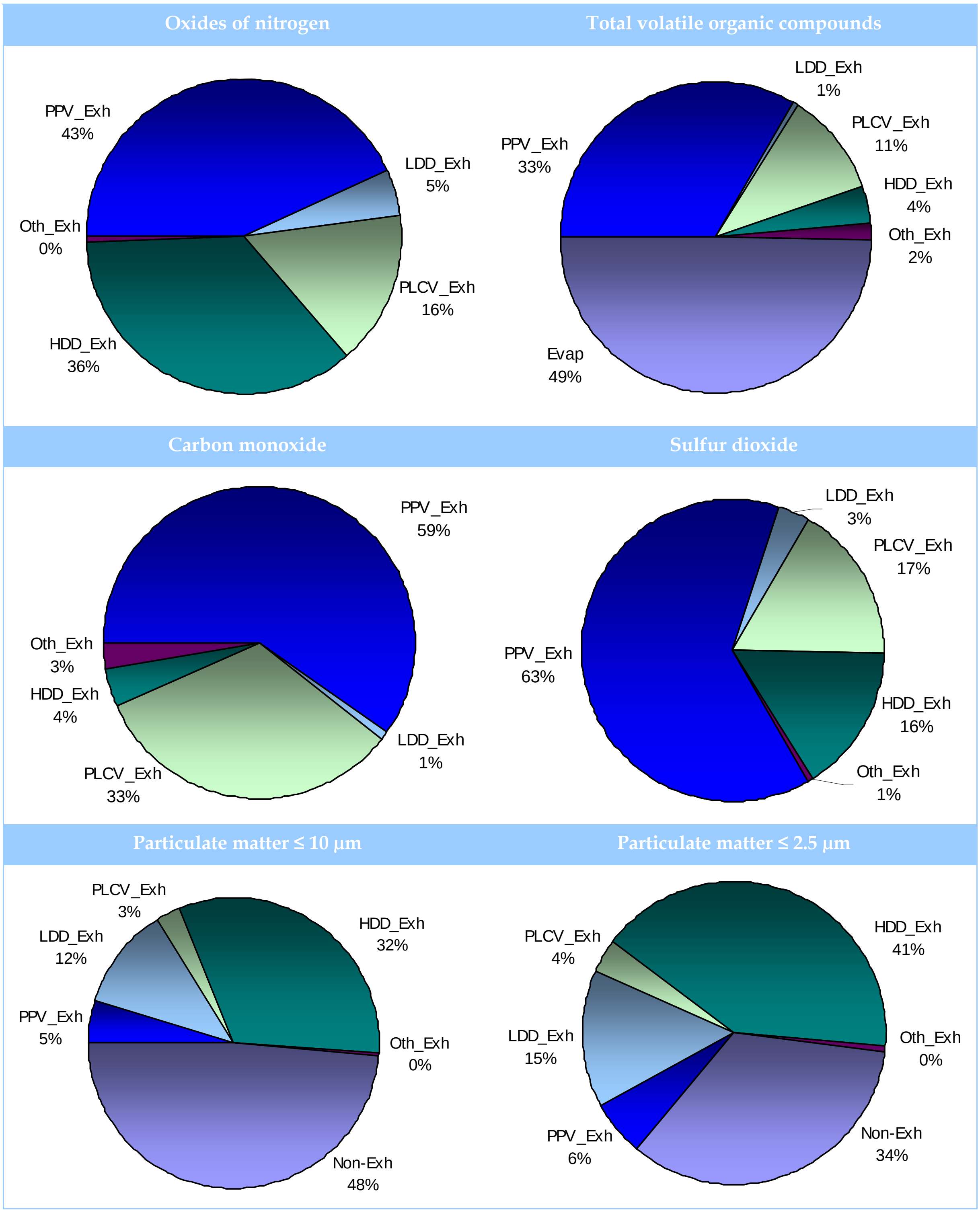

Figure 5-5: Proportion of total estimated annual emissions by on-road mobile source type in the Wollongong region

Table 5-6: Total estimated annual emissions by on-road mobile source type in the Non Urban region

Substance	Emissions (tonne/year)							
	Exhaust Emissions - Petrol Passenger Vehicles	Exhaust Emissions - Light Duty Diesel Vehicles	Exhaust Emissions - Petrol Light Commercial Vehicles	Exhaust Emissions - Heavy Duty Diesel Vehicles	Exhaust Emissions - Other Vehicles	Evaporative Emissions - All Vehicles	Non-Exhaust Particulate Matter Emissions - All Vehicles	On-Road Mobile Total
1,3 BUTADIENE	12.9	0.077	3.71	0.805	0.815	0	0	18.3
ACETALDEHYDE	5.78	0.733	1.66	7.62	0.307	0	0	16.1
BENZENE	50.5	0.205	14.5	2.13	3.19	11.8	0	82.3
CARBON MONOXIDE	10,512	121	4,595	1,065	651	0	0	16,944
FORMALDEHYDE	15.4	1.90	4.42	19.7	0.944	0	0	42.4
ISOMERS OF XYLENE	77.7	0.074	22.3	0.766	4.90	23.1	0	129
LEAD & COMPOUNDS	0.0061	0.0060	0.0027	0.029	0.0005	0	0.451	0.495
OXIDES OF NITROGEN	3,336	359	1,004	4,702	52.0	0	0	9,453
PARTICULATE MATTER ≤ 10 µm	17.2	33.5	7.73	163	1.49	0	193	417
PARTICULATE MATTER ≤ 2.5 µm	16.4	32.5	7.37	159	1.42	0	103	319
POLYCYCLIC AROMATIC HYDROCARBONS	6.08	1.07	2.26	6.11	0.459	0	0	16.0
SULFUR DIOXIDE	21.8	0.973	4.24	7.77	0.224	0	0	35.0
TOLUENE	94.0	0.090	26.9	0.937	5.92	49.0	0	177
TOTAL SUSPENDED PARTICULATE	17.2	33.9	7.73	165	1.49	0	300	525
TOTAL VOLATILE ORGANIC COMPOUNDS	1,029	19.2	295	200	64.5	1,828	0	3,435

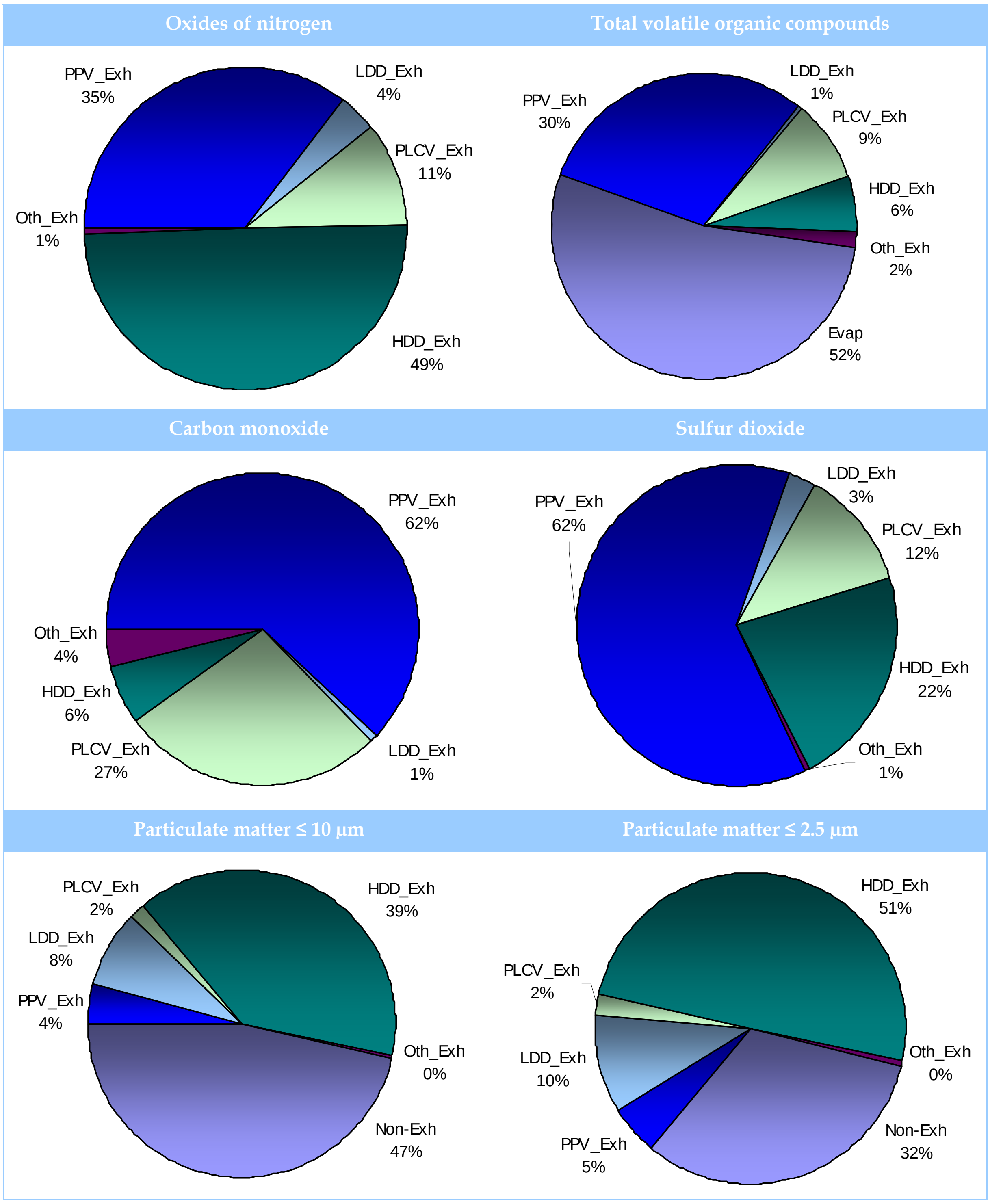

Figure 5-6: Proportion of total estimated annual emissions by on-road mobile source type in the Non Urban region

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