Government of **Western Australia**
Department of **Water and Environmental Regulation**

# Perth Air Emissions Study 2011–2012

## Technical report 4: On-Road Vehicle Emissions

Report

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June 2018



Temporal and spatially allocated emission estimates produced for this study can be made available on request. Please contact **npi@dwer.wa.gov.au** with queries and requests for information.

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# Summary

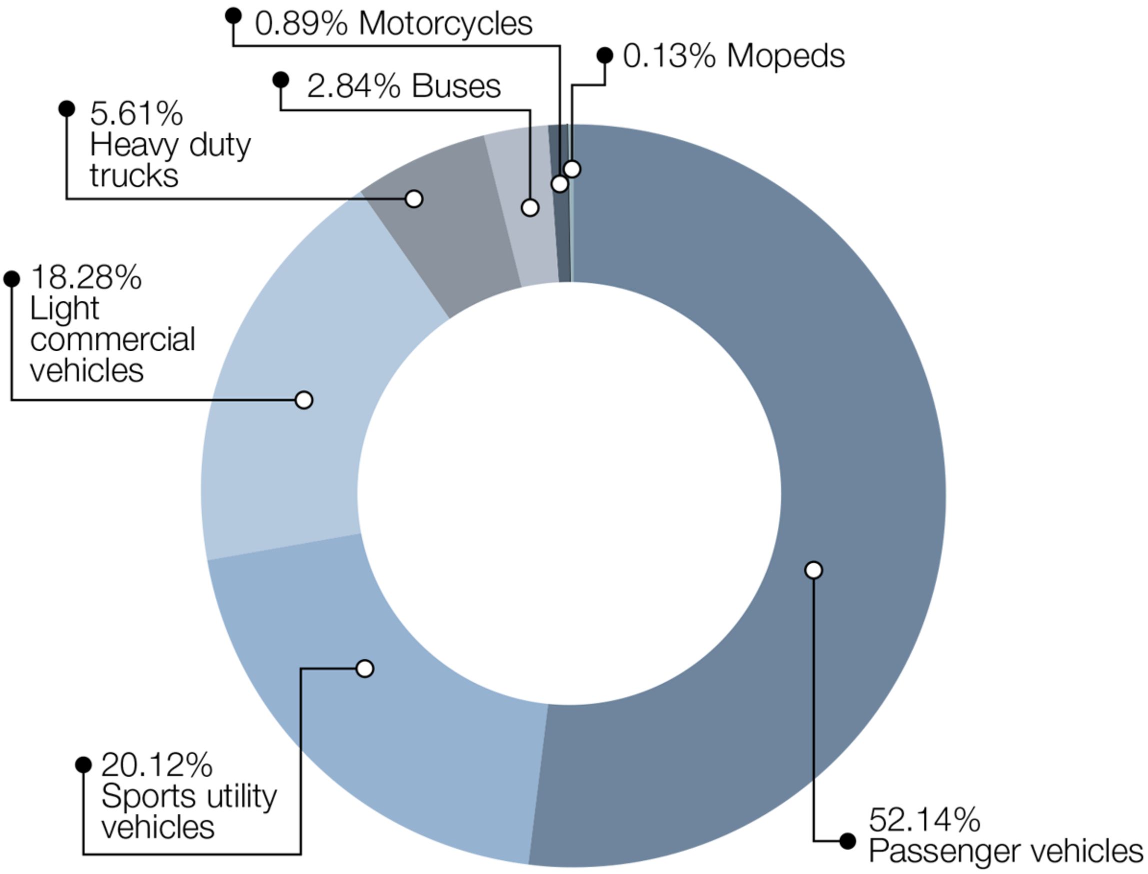
The Department of Water and Environmental Regulation (DWER) has completed an air emissions inventory of Perth for the 2011–12 financial year. The study area was generally consistent with the Australian Bureau of Statistics (ABS) Census Dataset: Greater Capital City Statistical Area – Greater Perth. The inventory estimated emissions for a variety of natural and anthropogenic emission sources.

This report summarises estimated emissions for on-road vehicle activity.

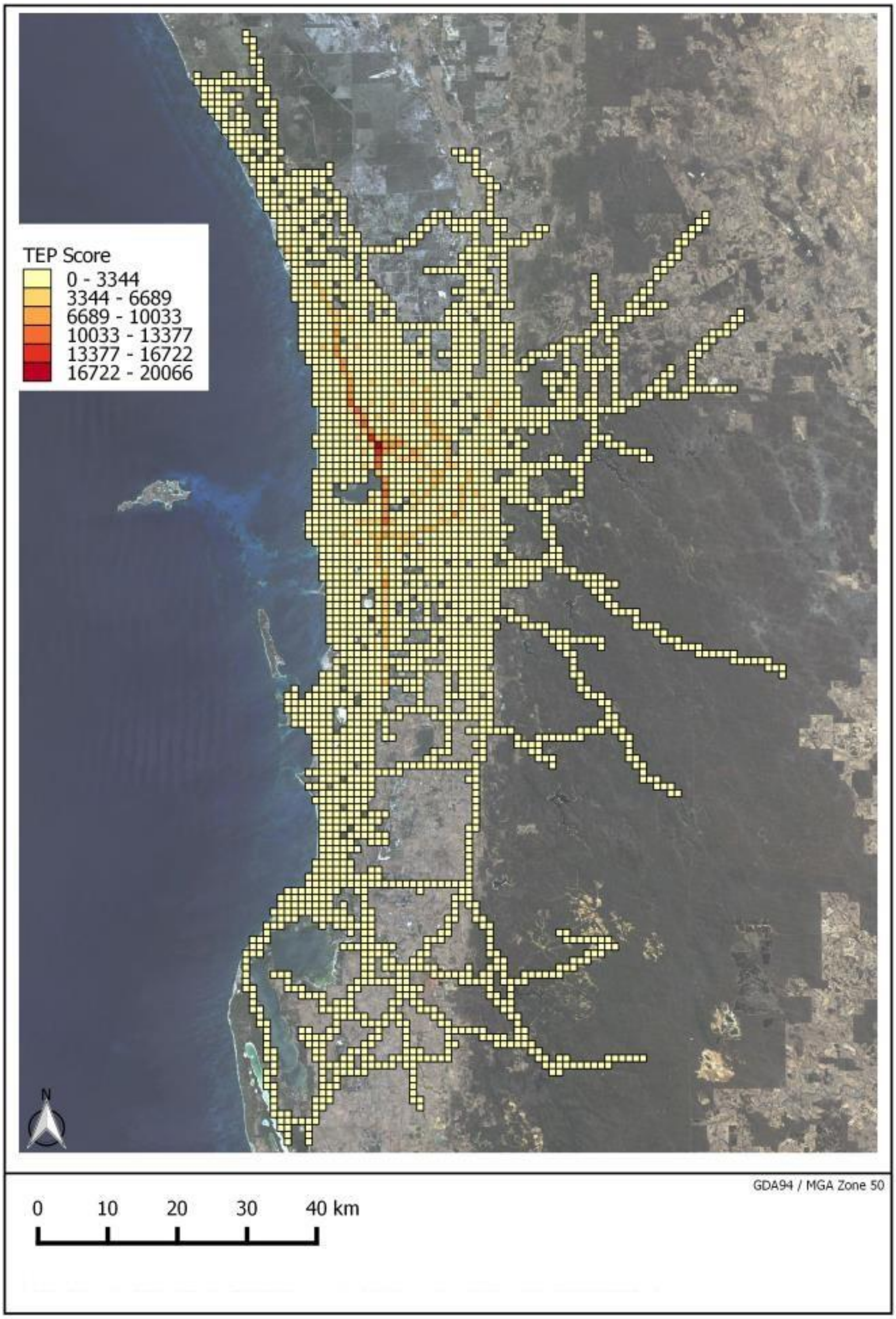
Emissions were estimated using the COPERT Australia (Version 1.2) software package, using input data from the 2010 Australian Motor Vehicle Emission Inventory published by the National Pollutant Inventory (NPI) and supplemented with data from the Australian Bureau of Statistics (ABS) and Western Australian Department of Transport (DoT). Spatial and temporal allocation of emissions was developed using the Main Roads WA ROM24 model.

Based on a toxic equivalency potential (TEP) scoring system, emission estimates from the operation of on-road vehicles for the 2011–12 financial year showed that fine particulate matter ($PM_{2.5}$) was the most significant of pollutants listed in the National Environment Protection (Ambient Air Quality) Measure. Emission estimates of metals such as lead, copper and cadmium were comparatively small, but were significant pollutants due to their high toxicity.

The summary figures show the relative contribution from individual vehicle groups to the overall TEP score for on-road vehicle emissions, and the spatial allocation of the TEP score. Passenger vehicles made the largest contribution for on-road vehicles due to their significantly larger population compared with other vehicle groups. Heavy vehicles, buses, mopeds and motorcycles contributed less than 10 per cent to on-road vehicle emissions TEP.




*Summary figure – relative TEP contributions from vehicle groups*




*Summary figure – spatial allocation of on-road vehicles TEP score*

# 1 Introduction

The Department of Water and Environmental Regulation (DWER) has completed an air emissions inventory of Perth for 2011–12.

This technical report presents the emission estimate methods, calculated emissions, and spatial allocation of emissions of on-road vehicle emission sources.

*This technical report focuses on emissions estimated as a result of vehicle activity on Perth's road network. It is one of the six reports prepared for the Perth Air Emissions Study 2011–12:*

1. *Perth Air Emissions Study 2011–2012: Summary of emissions*
2. *Technical report 1: Biogenic and geogenic emissions*
3. *Technical report 2: Domestic emissions*
4. *Technical report 3: Commercial and industrial emissions*
5. ***Technical report 4: On-road vehicle emissions***
6. *Technical report 5: Off-road mobile emissions*

## 1.1 Inventory scope

This module is defined by the following study parameters:

### Year

The data presented by this study represent emissions estimated for the 2011–12 financial year. This time period aligns with Australian Bureau of Statistics (ABS) census data and available datasets.

Where data are not available for 2011–12, data outside the study period have been used as being broadly representative of 2011–12.

### Boundaries

This study includes Local Government Areas (LGAs) in the ABS *Census Dataset: Greater Capital City Statistical Area – Greater Perth* (ABS 2012). The grid covers an area of 100 kilometres west to east (Rottnest Island to Toodyay) and 160 kilometres north to south (Two Rocks to Waroona). The corner coordinates are presented in Table 1, and the study area is shown on Figure 1.

*Table 1 – Study grid corner coordinates*

| | Easting* (m) | Northing* (m) |
|---|---|---|
| North-west | 350000 | 6525000 |
| North-east | 450000 | 6525000 |
| South-west | 350000 | 6365000 |
| South-east | 450000 | 6365000 |

* Geocentric Datum of Australia 1994 (GDA94 MGA Zone 50).


*Figure 1 – Perth Air Emissions Study 2011–2012 boundaries*

## Spatial allocation

The study used a one kilometre grid to spatially allocate emission estimates. This scale balances the resolution of fine data (roads, individual point sources etc.) and computationally demanding calculations.

Grid coordinates start at the upper left corner as illustrated on Figure 2.

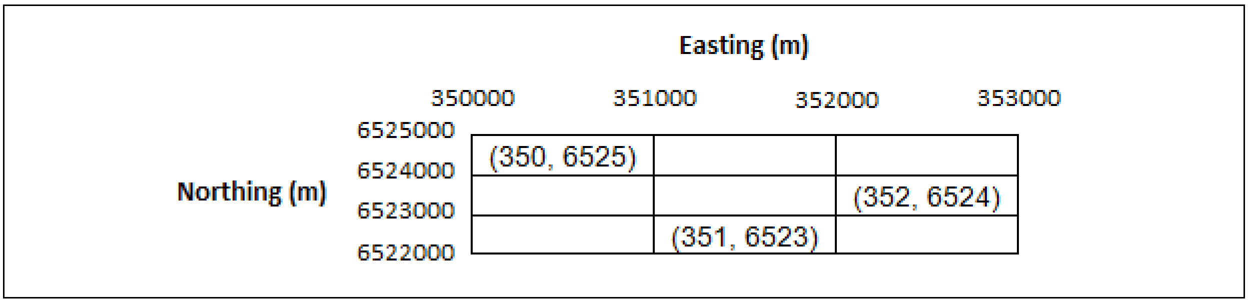



*Figure 2 – Grid coordinate system*

## Emission substances

The substances of interest in this study module are those in the *National Environment Protection (Ambient Air Quality) Measure*. These include:

- carbon monoxide (CO);
- nitrogen dioxide ($NO_2$), as a subset of oxides of nitrogen ($NO_X$);
- particulate matter ≤ 2.5 µm ($PM_{2.5}$);
- particulate matter ≤ 10 µm ($PM_{10}$); and
- sulfur dioxide ($SO_2$).

Ozone ($O_3$), as a proxy for photochemical smog, is a secondary pollutant resulting from the chemical transformation of pollutants in the atmosphere over time, and was not directly considered in this study. Instead, emissions of volatile organic compounds (VOCs) were estimated because these, along with oxides of nitrogen, are considered to be precursors to smog formation.

Other emissions estimated are included in the list of substances of interest to the National Pollutant Inventory (NPI):

- ammonia;
- heavy metals, including lead, cadmium, copper, chromium, nickel, selenium and zinc; and
- organic compounds, including speciated volatiles, polycyclic aromatic hydrocarbons (B[a]Peq), and polychlorinated dioxins and furans (TEQ).

# 2 Study methodology

The on-road vehicle emissions inventory method has two discrete stages: the estimation of total on-road vehicle emissions, and the spatial allocation of those emissions. The methods were developed to align with data readily available at the time. Several assumptions have been made to supplement data gaps and are documented in the relevant method sections.

## 2.1 Emission estimation

The COPERT Australia (Version 1.2) software package was used to estimate total emissions from on-road vehicle activity in Greater Perth. COPERT is an average speed model that is well-suited to calculating emissions at a national, regional and large-city level where vehicle population sizes are large enough for statistical-level data to produce representative results.

COPERT Australia is a localised adaptation of the European COPERT 4 model that has been calibrated to Australia's vehicle fleet and operating conditions. It can compile hot running, cold start, evaporative and non-exhaust emission estimates for 226 unique vehicle groupings based on vehicle type, fuel type and vehicle size.

To generate emission estimates, several data inputs are required. These include:

- Vehicle population
  - vehicle types (e.g. passenger, light commercial, buses)
  - vehicle fuel type (petrol, diesel, autogas)
  - vehicle size (engine size, gross vehicle mass)
- Average vehicle kilometres travelled (VKT) for each vehicle grouping by
  - vehicle age
  - base year being investigated
- Average speeds for each vehicle grouping on urban, highway and rural roads
- Average proportion of travel VKT spent on urban, highway and rural roads for each vehicle grouping
- Fuel tank size, fuel composition/quality data and engine technology
- Meteorological data (temperature and humidity)
- Annual fuel consumption for major fuels (petrol, diesel, autogas)

### Vehicle population

A representative vehicle population for Greater Perth was required to develop emission estimates and had a significant influence on estimated emissions. This study focused on building a representative vehicle fleet distribution for the study area for use in COPERT.

Whole-of-state vehicle population data is maintained by the Western Australian Department of Transport (DoT) and Australian Bureau of Statistics (ABS). Developing vehicle population data for the study area required downscaling of the data.

COPERT's vehicle classification system is different to those used by DoT and ABS. The COPERT Australia vehicle classification system is summarised in Table 2.

*Table 2 – COPERT Australia vehicle classification*

| Vehicle type | Size | Fuel type | Emission Standard[1] |
|---|---|---|---|
| Passenger cars | Small (<2.0 litres)<br>Medium (2.0–3.0 litres)<br>Large (≥3.0 litres) | Petrol, diesel, autogas, E10[2] | Uncontrolled, ADR27, ADR30, ADR37-00 & 01, ADR70-00, ADR79-00 through 05[3] |
| Sports utility vehicles (SUV) | Compact (≤4.0 litres)<br>Large (>4.0 litres) | Petrol, diesel, E10[2] | Uncontrolled, ADR30, ADR36, ADR37-00 & 01, ADR70-00, ADR79-00 through 05[3] |
| Light commercial vehicles (LCV) | ≤3.5 tonnes | Petrol, diesel | Uncontrolled, ADR30, ADR36, ADR37-00 & 01, ADR70-00, ADR79-00 through 05[3] |
| Heavy duty trucks | Medium[4] (3.5–12.0 tonnes)<br>Heavy[5] (12.0–25.0 tonnes)<br>Articulated (>25 tonnes) | Petrol, diesel, autogas | Uncontrolled, ADR30, ADR70-00, ADR80-00 through 05[6] |
| Buses | Light bus (≤8.5 tonnes)<br>Heavy bus (>8.5 tonnes) | Diesel | Uncontrolled, ADR30, ADR70-00, ADR80-00 through 05[6] |
| Mopeds | 2-stroke, 4-stroke | Petrol | Conventional, Euro 1-3 |
| Motorcycles | 2-stroke, 4-stroke(<250 $cm^3$)<br>4-stroke (250–750 $cm^3$)<br>4-stroke (≥750 $cm^3$) | Petrol | Conventional, Euro 1-3 |

1 ADR = Australian Design Rule
2 E10 fuel was not used in Western Australia before 2013 and was not included in this study
3 ADR79-03, 04 and 05 represent future ADRs and were not in effect as of 2012
4 'Medium' heavy duty trucks are referred to as MCVs throughout the report
5 'Heavy' heavy duty trucks are referred to as HCVs throughout the report
6 ADR80-04 and 05 are placeholders in COPERT Australia for future emission standards

Data were sourced from the following datasets:

- Vehicle registration extract from the DoT Transport Executive and Licensing Information System (TRELIS) database as of 30 June 2013
    - List of individual vehicles registered to a postcode in the study area, sorted by a variety of parameters (e.g. weight, body type, make/model)
- Australian Motor Vehicle Emission Inventory for the National Pollutant Inventory (UniQuest 2014)
    - Western Australia vehicle population for 2010 distributed across the 226 COPERT Australia vehicle fields

Vehicle population data sourced from DoT were taken from the state's vehicle registration database. The database was filtered by DoT to include vehicles registered to a postcode in the study area. Vehicles registered within the study area may not have operated in Perth. This was not considered to have a significant impact on emission estimates because these vehicles would have been offset by vehicles operating in Perth that were not registered to a postcode in the study area.

The DoT dataset includes all vehicles from June 2013. The point-in-time data for 2011–12 were available but did not include the data fields available for more recent data – which allow for better discrimination between vehicle groups. For the purpose of this study it was assumed that Perth's 2013 fleet composition was similar to that of 2012, as new vehicles would have been partially offset by the attrition of older vehicles. The vehicle fleet population used in this study may be slightly biased towards newer vehicles, though the likely impact on emission estimates is considered minor.

The dataset itself included more than 2.5 million individual vehicle registrations. The dataset fields listed below were used to sort the data into one of the 226 unique COPERT vehicle groupings.

- Heavy vehicle flag (NHV category)
- Vehicle weight
- Year of manufacture
- Primary motive power (fuel type)
- Vehicle insurance class
- Vehicle body type
- Make and model

The assumptions for refining the dataset can be broadly summarised as follows:

1. Removing vehicles that listed 'electric', 'solar', or 'towed' as the primary motive power. There would be some minor non-exhaust emissions from the operation of these vehicles, but COPERT cannot process these vehicles without creating custom vehicle classes. The removal of these vehicles did not significantly impact on emission estimates.
2. Removing vehicles (mostly mining and select industrial vehicle types) that were unlikely to operate on the road network, based on body type.
3. Separating the motorcycle and moped populations based on body type and vehicle insurance class.
4. Separating the bus population from main dataset based on body type and the NHV category for buses.
5. Separating heavy duty trucks and light commercial vehicles from main dataset based on vehicle body type. Vehicle weight data and NHV category were also used to differentiate within individual vehicle body types where necessary.
6. Separating SUVs from passenger vehicles. Individual vehicle models were

researched, and SUVs were separated and classified based on the engine size for the particular make and model. The COPERT model only has petrol and diesel fuel categories for SUVs, and therefore autogas SUVs (three per cent of the SUV population) were classified as petrol for the purposes of the study.

7. Passenger vehicles were classified by fuel type (petrol, diesel and autogas) using primary motive power data, and the ADR emission standard for year of manufacture. Engine size data were not available in the DoT dataset, so the WA passenger vehicle size distribution from the 2010 National Vehicle Emission Inventory (UniQuest 2014) was applied to classify the total passenger vehicle population into large, medium and small groupings.
8. LCV and heavy duty truck lists were reviewed and vehicles outside their respective weight range were reclassified.
9. LCVs were classified by fuel type (petrol and diesel) using primary motive power data, and the ADR emission standard for year of manufacture. The COPERT model only has petrol and diesel fuel categories for LCVs, and therefore autogas LCVs (four per cent of the total LCV population) were classified as petrol for this study.
10. Heavy duty trucks were classified by size (MCV, HCV, articulated trucks) using weight data, fuel type using primary motive power data, and ADR emission standard for year of manufacture.
11. Buses were classified by size (light and heavy) using weight data, and the ADR emission standard for year of manufacture. The COPERT model only has a diesel fuel category for buses, so petrol- and gas-fuelled buses (12 per cent of the total bus population) had to be classified as diesel for this study.

A summary of the ADR standard applied by year of manufacture for different vehicle types that was used in this study is provided in Appendix A.

The final vehicle population input to COPERT is presented in Appendix B. A breakdown of vehicle makes and models assigned to each vehicle group is too large to include in this report but is available on request.

### Vehicle kilometres travelled per year

The estimated kilometres travelled by an average vehicle for each of the 226 vehicle classifications had a significant influence on estimated emissions in the COPERT model.

Annual odometer data are not routinely collected in Western Australia. In the absence of state-specific data, the 2010 Australian Motor Vehicle Emission Inventory dataset was used (UniQuest 2014).

To scale the 2010 dataset to 2011–12, the total intrastate VKT for each vehicle type were extracted from the ABS Survey of Motor Vehicle Use (SMVU) 2011–12 dataset (ABS 2013) and compared with the equivalent total VKT calculated from the 2010 study. The scaling values used are summarised in Table 3.

*Table 3 – Vehicle activity scaling factors*

| Vehicle type | 2010 total VKT (UniQuest 2014) | 2011–12 total VKT (ABS 2013) | Scaling factor |
|---|---|---|---|
| Passenger cars | 18,395,557,337 | 18,540,000,000 | 1.008 |
| Light commercial vehicles | 5,361,467,321 | 5,299,000,000 | 0.988 |
| Heavy duty trucks | 2,613,832,216 | 2,225,000,000 | 0.851 |
| Buses | 185,097,234 | 319,000,000 | 1.723 |
| Motorcycles | 415,621,098 | 356,000,000 | 0.857 |

The data indicate broad consistency between the datasets, reflecting the small time gap and uncertainties in the data used to calculate total VKT.

The only major discrepancy is for buses. This is likely to be a result of how the two datasets allocate vehicles to different classification pools. While the bus population is a minor contributor to the total vehicle fleet, buses have high emissions for particulate matter and $NO_X$. Emission estimates for buses are likely to be conservative.

The average VKT per vehicle for each COPERT vehicle classification used in this study is presented in Appendix B.

### Accumulated vehicle mileage

COPERT takes vehicle ageing and mileage degradation into account in estimating emissions. This factor reflects deterioration of engine components and emission controls over time and usage. This is compounded for older cars as they have lower emission standards than newer cars.

The accumulated mileage per vehicle for the COPERT vehicle classification in this study was taken from the 2010 Australian Motor Vehicle Emission Inventory dataset (Appendix B).

No attempt was made to scale the 2010 mileage to 2011–12.

### Driving mode

Emissions from vehicles depend on driver operation as a function of the driving environment and road conditions. COPERT accounts for this by using three road types: urban, rural and highway. Each of the 226 vehicle classifications in COPERT is allocated an average speed (km/hr) and VKT share for each road type.

The values used in the 2010 Australian Motor Vehicle Emission Inventory for Western Australia were adapted as being representative of Greater Perth. The data were adjusted by increasing the VKT share for petrol and autogas vehicles on urban roads, and decreasing this for rural roads. These adjustments were developed iteratively during input data validation. Diesel vehicle driving mode data were not adjusted. The values used for the study are presented in Appendix C.

### Evaporative emission control

In addition to emissions from fuel combustion, evaporative emissions from petrol and ethanol vehicles can be significant. Temperature changes in the fuel tank and lines can cause evaporation of petrol and ethanol blends which can then leak from the vehicle. Emission control technology helps to mitigate these emissions.

COPERT estimates evaporative emissions having regard to car design. Factored into emission estimates for each vehicle classification are the average fuel tank size and carbon canister size; the proportion of cars with fuel injection technology; and the proportion of cars with evaporation control technology installed. COPERT also includes a factor for apportioning evaporative emissions based on road type (urban, rural, highway).

The 2010 Australian Motor Vehicle Emission Inventory engine technology input data for Western Australia were used (Appendix D).

### Meteorological data

Temperature and relative humidity are used by COPERT to calculate certain emission factors, including cold start emissions, evaporative emissions, and emissions resulting from air conditioner use.

The model requires monthly average minimum and maximum temperature (degrees celsius) and a monthly average relative humidity (per cent). Because COPERT uses a single value for the study area, the meteorological input needs to be representative of Greater Perth. Data from DWER's Caversham air quality monitoring station were selected as this site is relatively centrally located and is representative of where vehicle activity is occurring. The data used are summarised in Table 4.

*Table 4 – Study meteorological input*

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min temp. (°C) | 20.7 | 19.2 | 15.8 | 16.3 | 9.3 | 10.9 | 8.5 | 10.9 | 10.5 | 14.4 | 15.0 | 16.7 |
| Max temp. (°C) | 30.2 | 32.1 | 27.0 | 27.7 | 20.2 | 16.0 | 17.4 | 16.8 | 20.9 | 25.0 | 25.5 | 32.5 |
| Relative humidity (%) | 52.9 | 47.0 | 62.0 | 65.1 | 74.0 | 74.2 | 72.3 | 77.4 | 68.8 | 59.1 | 63.6 | 56.1 |

### Fuel quality

The properties of the fuel being burnt in the study area influence emission estimates. Concentrations of trace heavy metals and sulfur in fuel cause emissions of sulfur dioxide ($SO_2$) and metals, while the Reid vapour pressure (RVP) of fuel burnt is used to estimate cold start and evaporative emissions.

No fuel quality data were available from local fuel importers. The 2010 Australian Motor Vehicle Emission Inventory fuel quality inputs were used (UniQuest 2014).

- Heavy metal content of all fuels was based on COPERT 4 default values adjusted for Australian fuel density. Lead content was derived from the Australian Government's National Fuel Sampling Program, and was considered to be conservative (UniQuest 2014). Small changes in trace concentrations can significantly affect estimates derived from large volume fuel use.
- Sulfur content of all fuels was derived from the National Fuel Sampling Program. Sulfur content in fuel is regulated under statutory standards.
- RVP data were derived from sampling at local terminals.

Fuel quality input data are summarised in Appendix E other than RVP data, which were provided in confidence.

### COPERT Australia settings

In addition to the raw data inputs described above, a number of settings in the model influence emission estimates. The settings used in this study are summarised below:

- Average trip length of 11.4 km (default setting)
- Average trip time of 0.25 hours (default setting)
- Statistical fuel correction applied
- 2009 fuel effect year (this is the most modern fuel quality data in the model)
- Air conditioner usage calculation enabled

### Fuel use and input data validation

COPERT uses fuel consumption data to internally calibrate data inputs. The software uses vehicle population, activity and fuel data inputs to estimate the total fuel burned for the study area. By comparing the estimated fuel burned to actual fuel burned data in the area, it is possible to assess the consistency of input to the model.

Fuel use for Greater Perth was based on the ABS SMVU 2011–12 (ABS 2013). Cumulative fuel use data in this dataset are at a whole-of-state level. To establish a local consumption value, the fuel consumption rate (litres per 100 km) provided in the SMVU for each vehicle body type was applied to the population and annual mileage data for each COPERT vehicle grouping. This gave an estimate of annual fuel use for each fuel type. The relative standard error for the SMVU fuel consumption rate data was also used to calculate a plus/minus value.

Unleaded and premium unleaded petrol use was apportioned based on the Bureau of Resources and Energy Economics Australian Petroleum Statistics data (BREE 2012).

The fuel use calculated for the study area and COPERT calculated fuel use are presented in Table 5.

*Table 5 – Calculated vehicle fuel use for Perth 2011–12*

| Fuel | Study area calculated fuel use | | | COPERT calculated fuel use (tonnes) | Difference: tonnes and (%) |
|---|---|---|---|---|---|
| | Usage (ML) | Usage (tonnes) | +/- (tonnes) | | |
| Unleaded petrol | 1,606 | 1,180,053 | 29,536 (2.5%) | 1,474,708 | 29,806 (-2.0) |
| Premium unleaded petrol | 441 | 324,461 | 8,121 (2.5%) | | |
| Diesel | 1,350 | 1,128,884 | 74,029 (6.5%) | 1,123,382 | 5,502 (-0.5) |
| Autogas | 103 | 55,575 | 6,531 (12%) | 45,578 | 9,997 (-18.0) |

The results of the fuel balance, accounting for the error in study area calculated fuel use, show COPERT emission estimates for petrol and diesel are representative of the study area, but may underestimate autogas vehicle emissions.

Due to the method used to derive local autogas consumption data, it was not possible to adjust model settings to achieve a more accurate result for the fuel balance. It was not possible to determine whether the 18 per cent difference was a significant deviation. The ABS dataset shows LPG usage data has a higher uncertainty (12 per cent) compared with other fuel types. As autogas vehicle emissions are a small proportion of total vehicle emissions in the study area, this uncertainty is not expected to have a significant impact on total emission estimates.

## 2.2 Spatial and temporal distribution

The Main Roads WA Regional Operations Model (ROM24) was used to allocate the estimated emissions across the study grid. ROM24 is a strategic transport model to estimate vehicle flow for individual sections of road over a 24-hour ‘average weekday’ traffic cycle.

The vehicle flow data represent the number of vehicles using each modelled road segment every hour, with light commercial vehicle (LCV) and heavy commercial vehicle (HCV) activity also estimated as a subset of total activity. This study assumes that LCV and HCV subsets are representative of the COPERT light commercial vehicle and heavy duty truck classes. Bus and motorcycle activity is not simulated in the ROM24 model. For the purposes of this study, emissions from these vehicle types have been distributed using the non-commercial activity data.

Hourly VKT values for each road section were calculated using the road length and modelled number of cars travelling on it per hour. Calculated hourly VKT values were extrapolated to annual VKT values and summed for each study grid cell.

The hourly VKT distribution for each ROM24 modelled vehicle class is presented in Figure 3, which shows the dominance of non-commercial traffic on Perth’s road network. The relative level of activity for each ROM24 modelled vehicle class is presented in Figure 4. Passenger vehicles follow a dual peak pattern (8am and 5pm) while commercial vehicle activity maintains a consistent peak between 10am and 3pm before gradually tapering off in the evening. The vehicle activity profiles for passenger and commercial vehicles in the 2008 NSW EPA vehicle emissions inventory (NSW EPA 2012) for the Sydney greater metropolitan region are similar to the ROM24 model outputs. This increases confidence that the vehicle activity data used in this study are representative.

The 2008 NSW EPA vehicle emissions inventory shows different vehicle activity levels on weekends and weekdays (NSW EPA 2012). An 'average weekend' traffic cycle model was not available for Perth. While this did not affect the total emissions estimated for the study year, any temporal analysis of emissions in the study area should account for the different activity levels during the weekend.

The extent of the modelled road network is presented in Figure 5 overlain by population density. Less densely populated areas are shaded green, with more populated areas shaded yellow. The ROM24 model has good coverage for inner suburbs, coastal population hubs and major transport corridors where populations are concentrated.

The limitations of the ROM24 coverage are the low-density areas to the north and east of the study area and major road linkages at map edges, specifically the South West, Great Eastern and Great Northern highways. Vehicle emissions are poorly represented in these areas. The 'claw' features branching off from main roads in some low-density areas are not roads, but simulate the flow of traffic from a larger area to a main road section.

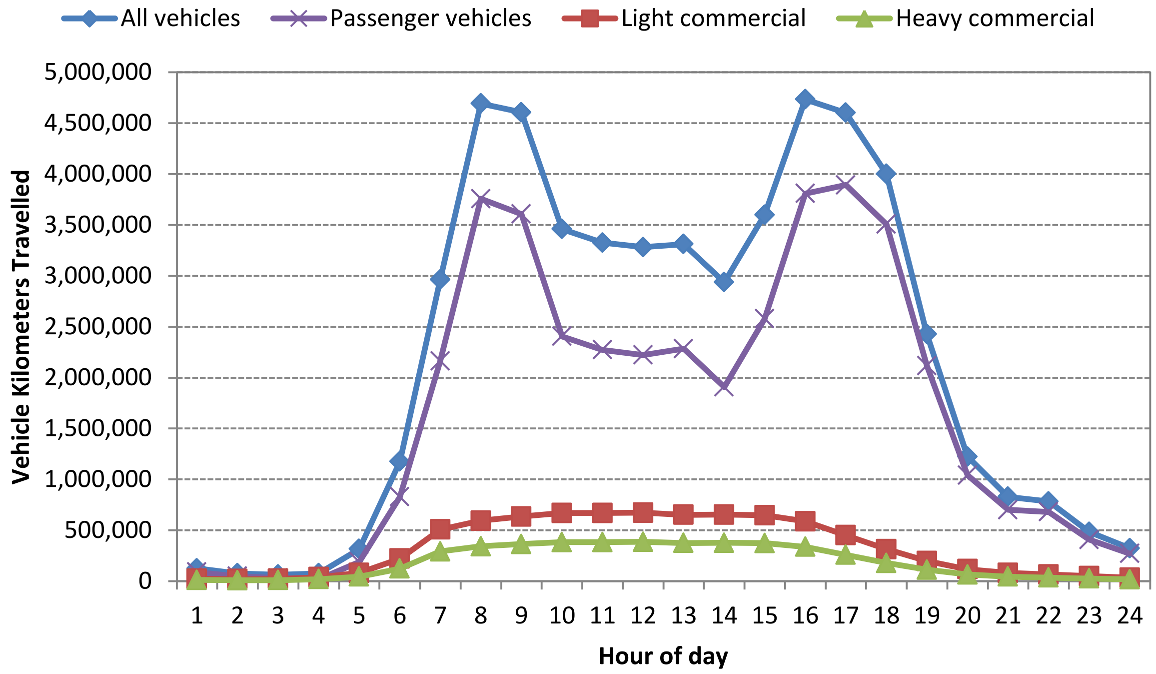



*Figure 3 – Hourly VKT distribution for ROM24 vehicle classes*

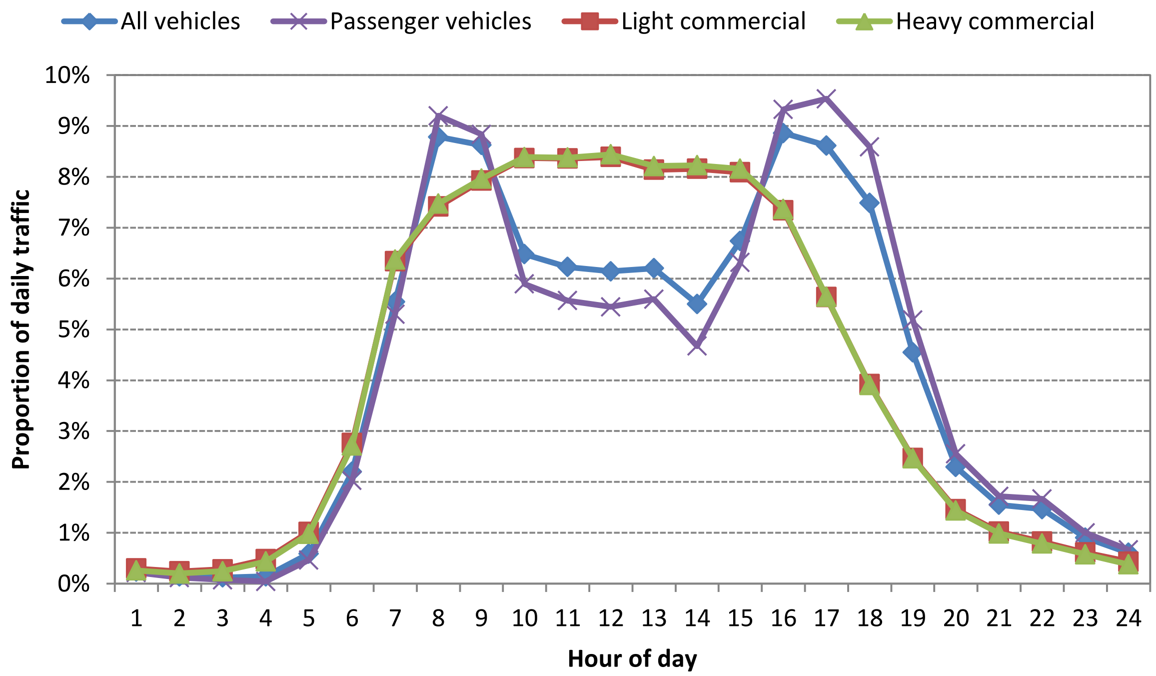



*Figure 4 – Hourly vehicle activity as a proportion of the day*

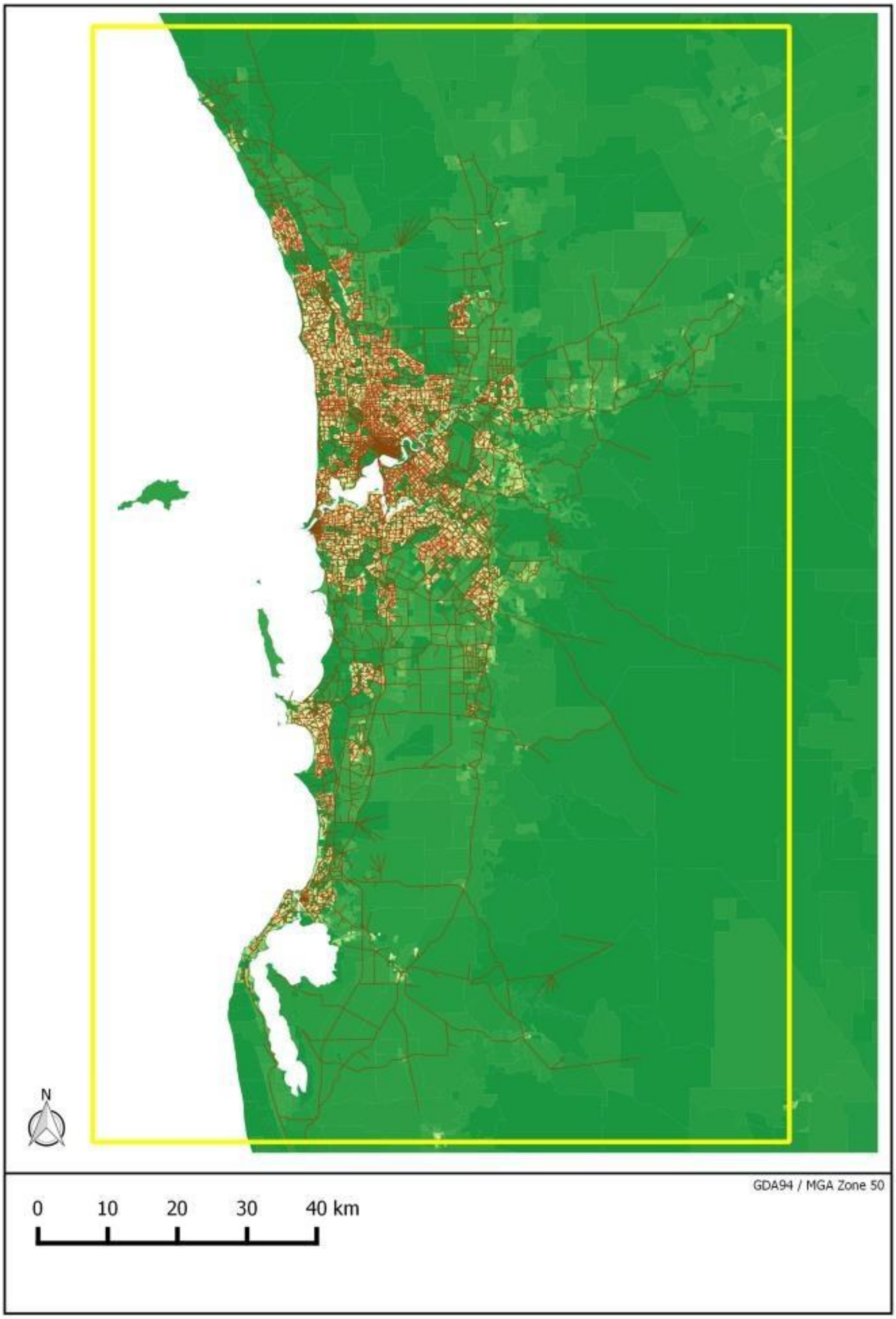



*Figure 5 – ROM24 modelled road network within study area*

# 3 Emission estimates

This section presents emissions estimates in cumulative and comparative contexts, including:

- total emissions;
- emissions by vehicle fuel group, and age of fleet;
- emissions from exhaust and non-exhaust sources; and
- emissions from cold and hot vehicle operation.

To assess the relative risk for all emission estimates, toxic equivalency potential (TEP) scores were calculated. TEP is a technique increasingly being used by Australian and international environment agencies for comparing substances that have varying toxicities. TEP provides a screening-level evaluation of substances according to their effect on human health, and can be calculated in two ways. The 'non-cancer risk' score converts emissions to toluene-equivalents and is an assessment of the potential impact of toxins on general human health. The 'cancer risk' score converts emissions to benzene-equivalents and is an assessment of the potential impact of carcinogenic toxins (Scorecard 2015)[1].

This study assessed TEP using the non-cancer risk score to indicate the more general health risk. TEP is calculated by multiplying the emission estimates for substances by their corresponding non-cancer risk score. A list of NPI substances and their associated risk scores are included in Appendix F.

## 3.1 Total on-road vehicle emissions

The total estimated emissions for on-road vehicle activity are presented in Table 6. The data show carbon monoxide to be the greatest substance emitted by mass. Lead, although only having an estimated emission of 3.16 tonnes, represents the largest risk from vehicle emissions primarily because of its high toxicity relative to other vehicle emissions.

COPERT estimates lead emissions mainly by using fuel concentration data (Section 2.1.7 and Appendix E). The lead concentration value used in this study was from the Australian Motor Vehicle Emission Inventory, derived from the National Fuel Sampling Program. The value used is significantly higher than that used in Europe. The Australian Motor Vehicle Emission Inventory included the recommendation that "further research is needed to determine a more accurate lead content values for Australian petrol fuels" (UniQuest 2014).

The NSW EPA's 2008 air emissions inventory used a $PM_{10}$ mass fraction to derive lead emissions from vehicle activity based on particulate speciation studies from the United States (NSW EPA 2012). The NSW approach would produce lower emission

[1] Further information on how TEP is calculated can be found on the Scorecard website at: http://scorecard.goodguide.com/env-releases/def/tep_caltox.html.

estimates for lead from petrol vehicles, but higher diesel and LPG vehicle lead emission estimates. The fuel lead concentration used and lead emissions estimated for this study are conservative.

*Table 6 – Total estimated annual emissions from on-road vehicles*

| Substance | Emissions (tonnes/year) | Toxic equivalency potential (TEP) score |
|---|---|---|
| Key pollutants | | |
| Oxides of nitrogen | 25,917 | 57,018 |
| Particulate matter ≤ 2.5 µm | 1,414 | 24,045 |
| Carbon monoxide | 87,778 | 12,289 |
| Total volatile organic compounds | 10,897 | 10,897 |
| Nitrogen dioxide | 3,894 | 8,566 |
| Particulate matter ≤ 10 µm | 1,769 | 2,653 |
| Sulfur dioxide | 203 | 629 |
| Other NPI-listed pollutants | | |
| Lead and compounds | 3.16 | 1,831,586 |
| Polychlorinated dioxins and furans (TEQ) | 0.00000062 | 546,922 |
| Copper and compounds | 8.91 | 115,842 |
| Cadmium and compounds | 0.032 | 59,905 |
| Acrolein | 29.4 | 47,100 |
| Benzene | 412 | 3,339 |
| Ammonia (total) | 795 | 3,023 |
| Formaldehyde (methyl aldehyde) | 185 | 2,963 |
| Zinc and compounds | 8.46 | 1,607 |
| Chromium (total) | 0.46 | 1,106 |
| Toluene (methylbenzene) | 840 | 840 |
| Acetaldehyde | 79.9 | 743 |
| Nickel and compounds | 0.093 | 297 |
| Xylenes (individual or mixed isomers) | 845 | 228 |
| 1,3-Butadiene (vinyl ethylene) | 86.3 | 190 |
| Ethylbenzene | 327 | 45.7 |
| Selenium and compounds | 0.0082 | 19.8 |
| n-Hexane | 145 | 4.35 |
| Styrene (ethenylbenzene) | 46.3 | 3.70 |
| Acetone | 33.4 | 1.67 |
| Methyl ethyl ketone | 9.10 | 0.45 |
| Polycyclic aromatic hydrocarbons ($B[a]P_{eq}$) | 0.058 | N/A[1] |

[1] ‘Polycyclic aromatic hydrocarbons’ include a range of organic compounds of varying toxicities. It does not have an assigned TEP score.

The relative contribution of individual vehicle groups to the overall TEP score for on-road vehicle emissions is shown in Figure 6.

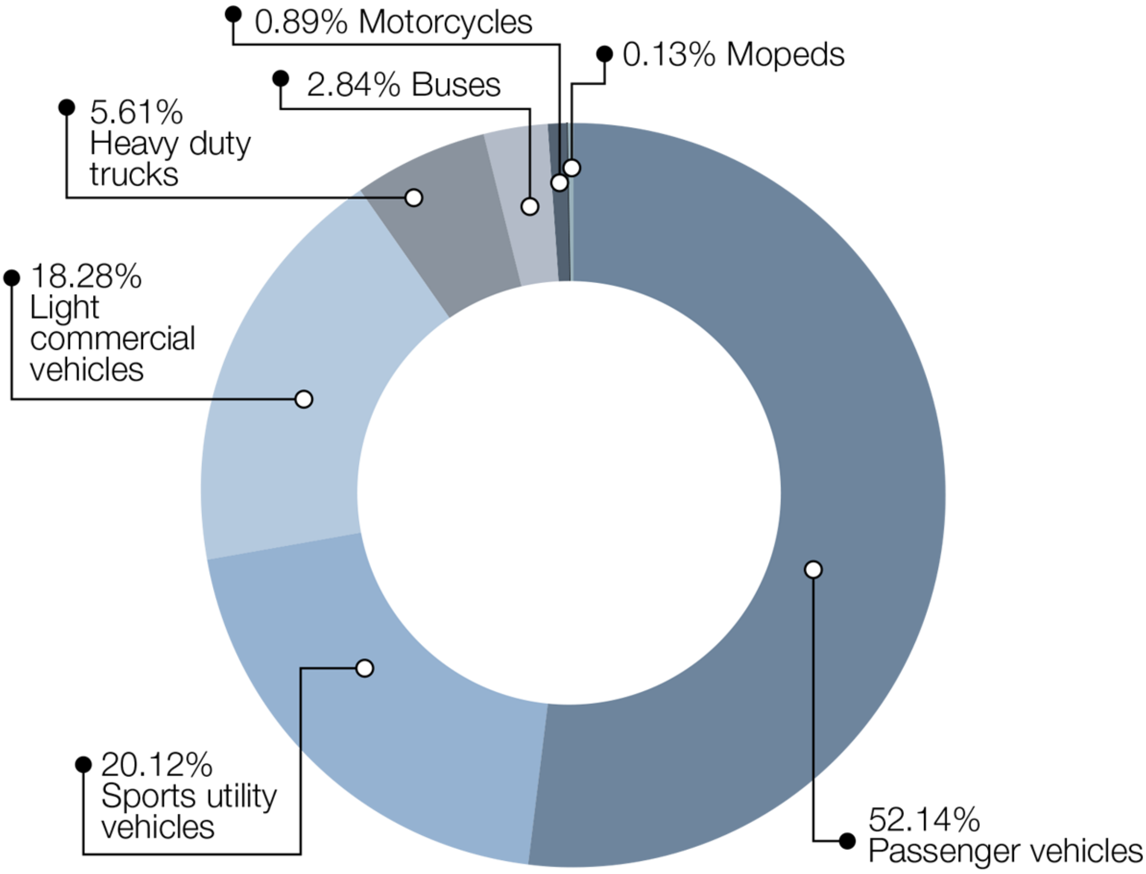



*Figure 6 – Relative TEP contributions from vehicle groups*

Passenger vehicles made the largest contribution to on-road vehicle emissions. This is because of their larger population compared with other vehicle groups. Heavy vehicles, buses, mopeds and motorcycles contributed less than 10 per cent of on-road vehicle emissions TEP.

Metals and polychlorinated dioxins and furans represented almost all of the TEP score for most vehicles classes (90 per cent on average). For passenger vehicles and SUVs this was almost 97 per cent. For light commercial vehicles, heavy duty trucks and buses this was modified by the TEP contribution from particles and oxides of nitrogen. For mopeds and motorcycles, the TEP contribution of carbon monoxide and VOC was slightly higher than for other vehicle groups. Emissions of polychlorinated dioxins and furans from vehicle exhausts are still poorly understood (DEH 2004), and emission estimates of these substances have a high degree of uncertainty.

Emissions for non-commercial, light commercial and heavy commercial vehicles have been spatially allocated according to the distributions presented in Figure 7, Figure 8 and Figure 9, derived from WA Main Roads ROM24 data (see Section 2.2). The colour scale in these figures is linear between yellow (low) and red (high).

The TEP score for all vehicles has been spatially allocated in Figure 11.

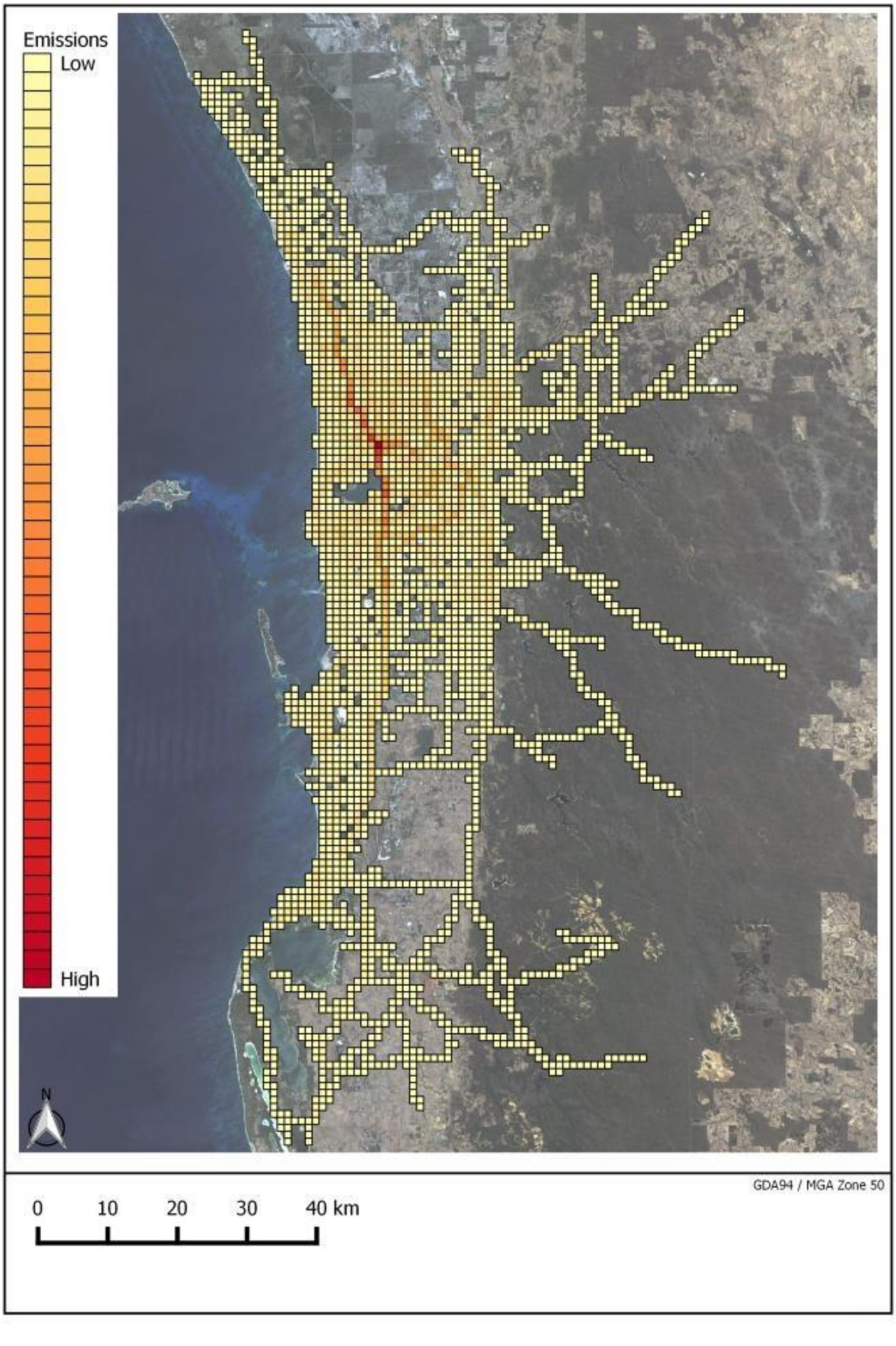



*Figure 7 – Emission distribution for non-commercial vehicles*

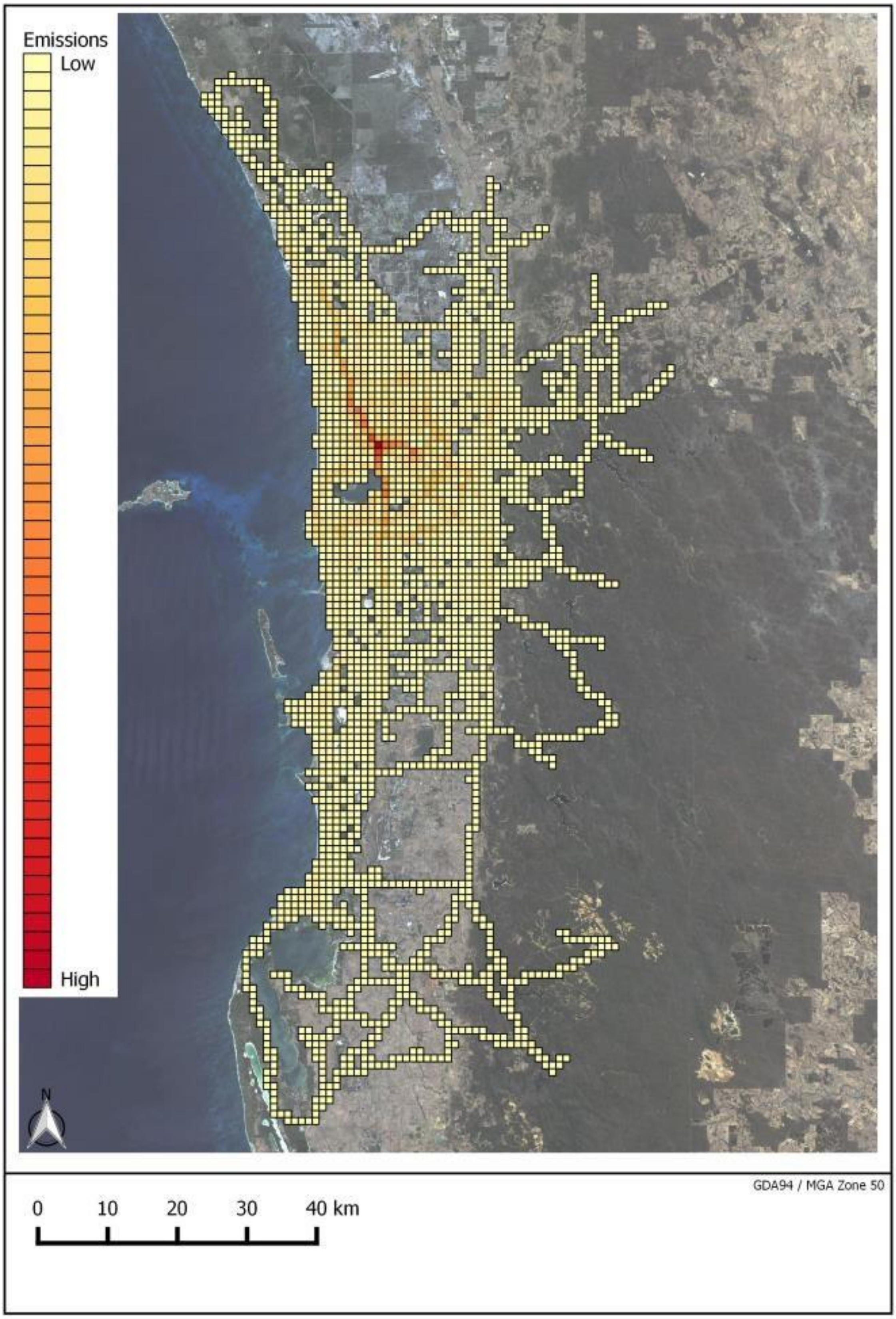



*Figure 8 – Emission distribution for light commercial vehicles*

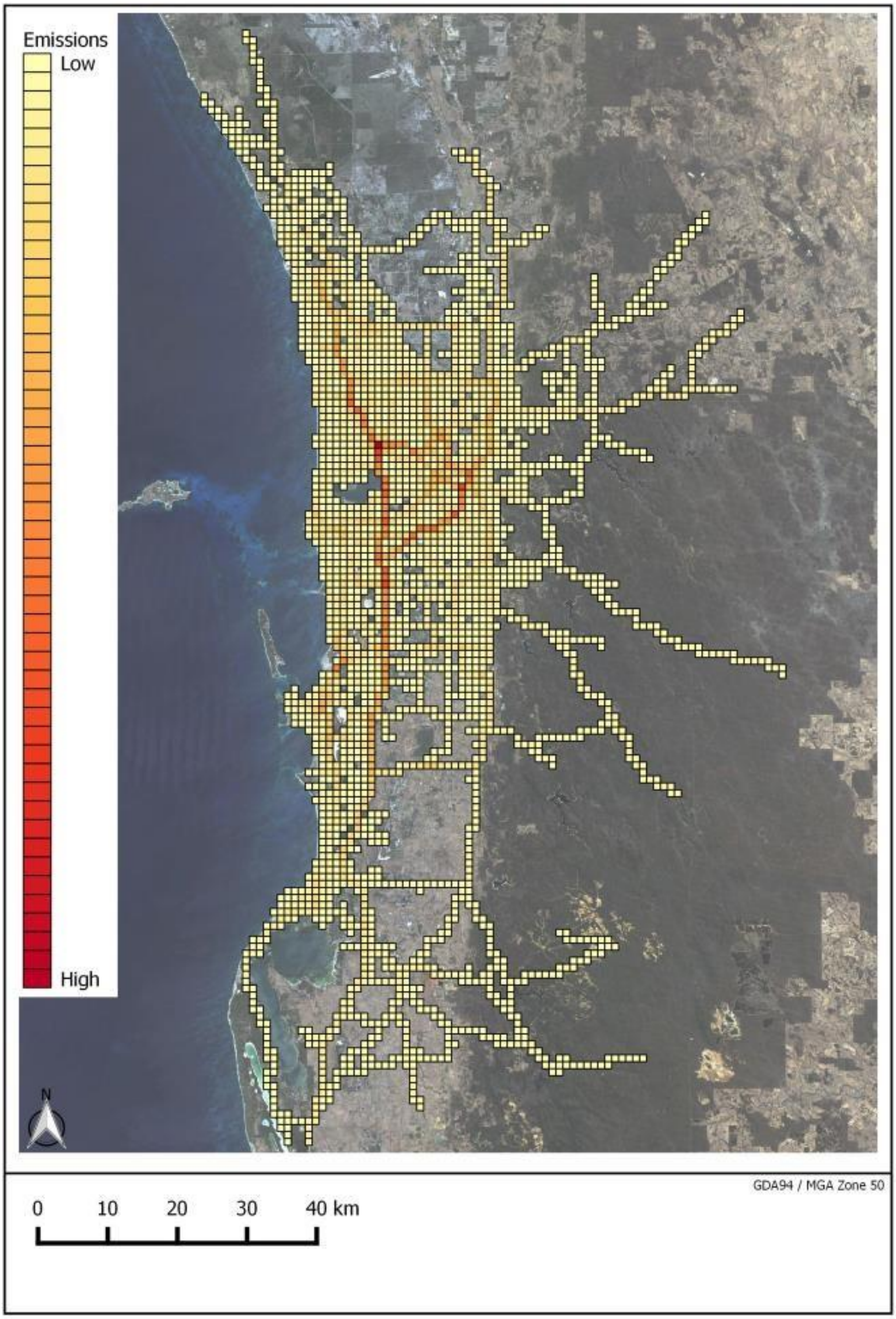



*Figure 9 – Emission distribution for heavy commercial vehicles*

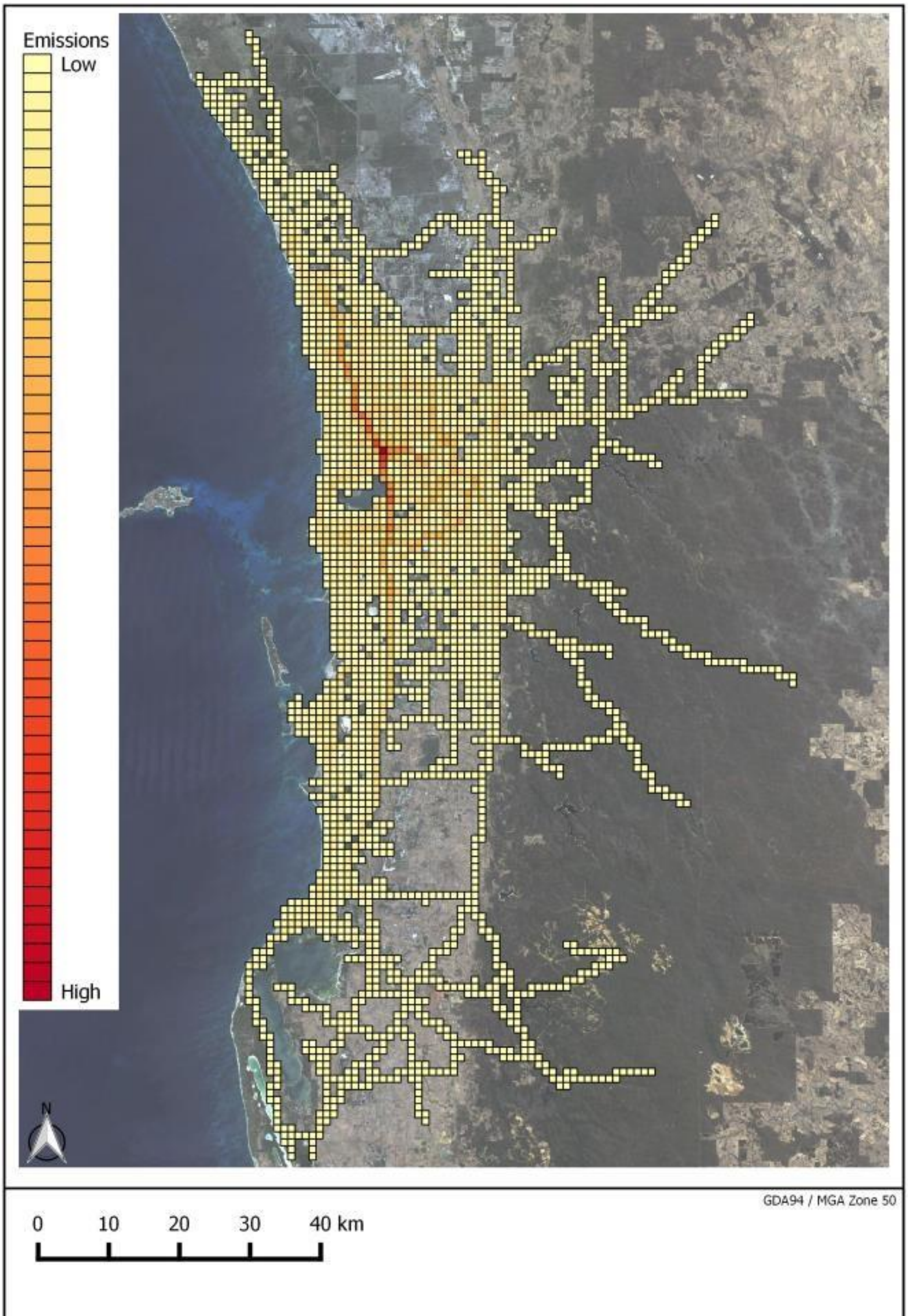



*Figure 10 – Emission distribution for all vehicles*

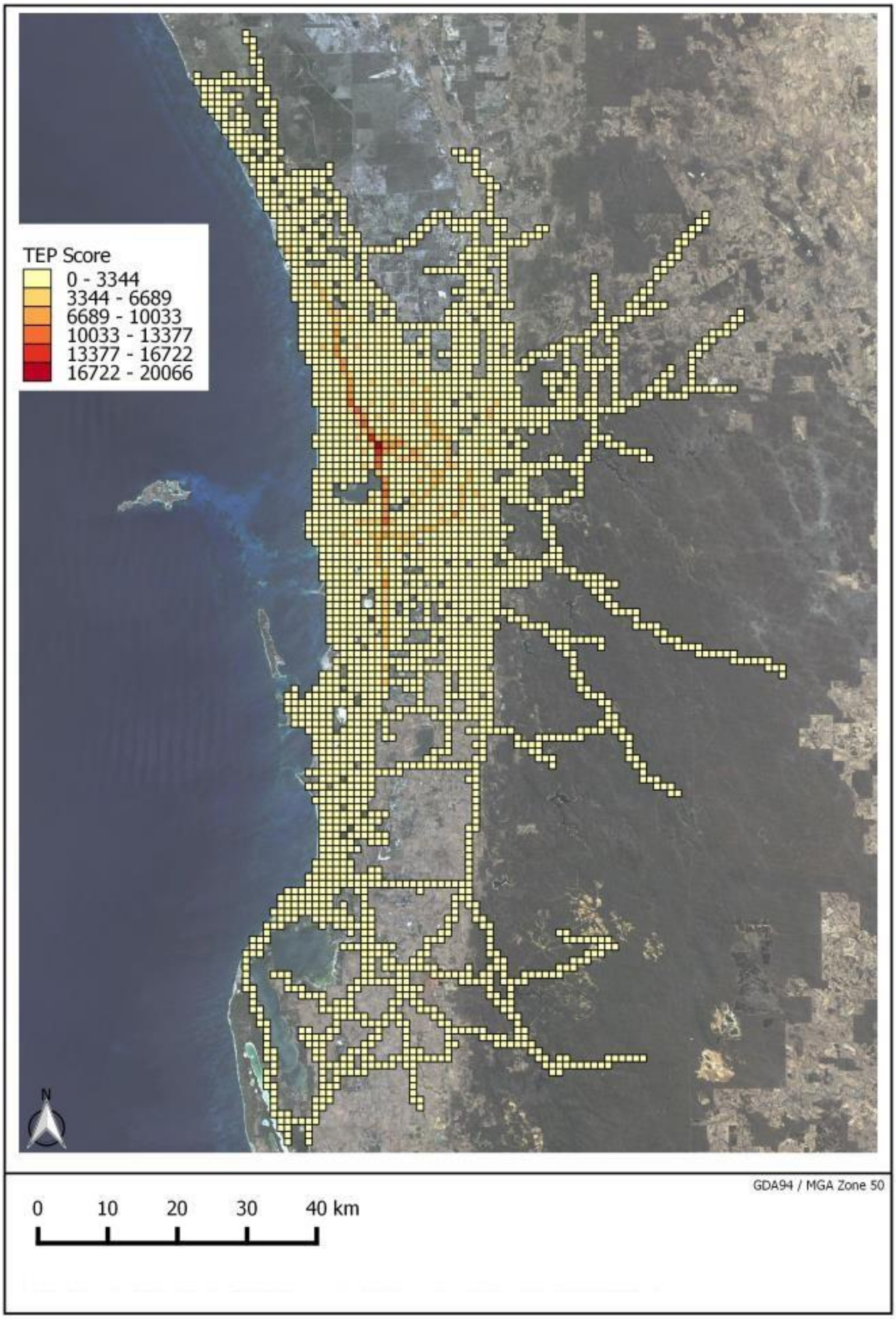



*Figure 11 – TEP score distribution for all vehicles*

The scale across all three images (Figure 7, Figure 8, Figure 9) is relative to the minimum and maximum cell values of each distribution. If an identical scale were used, it would not be possible to identify the unique emissions distribution for commercial traffic. This can be seen in Figure 10. The distribution for all vehicles is shown to be almost identical to the non-commercial vehicles in Figure 7. Figure 3 also shows the dominance of non-commercial vehicles in the study area.

Common to all three figures is the concentration of vehicle emissions along the Mitchell and Kwinana freeways running north and south. The influence of other major road arteries such as the Tonkin and Roe highways can also be seen, particularly for heavy commercial traffic.

Non-commercial vehicle activity is dispersed throughout the inner suburbs. Activity on freeways and major highways are clearly visible compared with other roads. Emission estimates from passenger vehicles, SUVs, buses, mopeds and motorcycles were allocated to this distribution.

Light commercial traffic has a smaller outer range than other vehicle activities. Most activity is concentrated along major roads. Emission estimates from light commercial vehicles were allocated to this distribution.

The heavy commercial traffic emissions distribution shows the major transport links in Perth. Activity is focused on the freeways, Tonkin and Roe highways, and in the Kwinana and Rockingham industrial areas. Emission estimates from heavy duty trucks were allocated to this distribution.

Emission estimates allocated to each distribution were summed to obtain total emissions for pollutants within each grid cell.

This study has not allocated emissions by vehicle operating mode. Vehicles on highways almost always operate hot (vehicles in suburban areas close to home operate cold). Evaporative emissions (diurnal, hot soak and resting) are more likely to be prevalent in areas where vehicles are parked and rather than on major road links. Particulate emissions from road/tyre/brake wear also vary based on the road type and average vehicle speeds. However, because the VKT model used to distribute emissions is not linked to COPERT model inputs, it is not feasible to link emission estimates for driving modes or sources to specific road types. Emission distribution error should be considered if individual areas or pollutants are further investigated.

## 3.2 Vehicle fuel type and age of fleet emissions

### Emissions by vehicle fuel type

The contribution of different vehicle fuel groups to emissions of key pollutants are summarised in Figure 12 and Table 7.

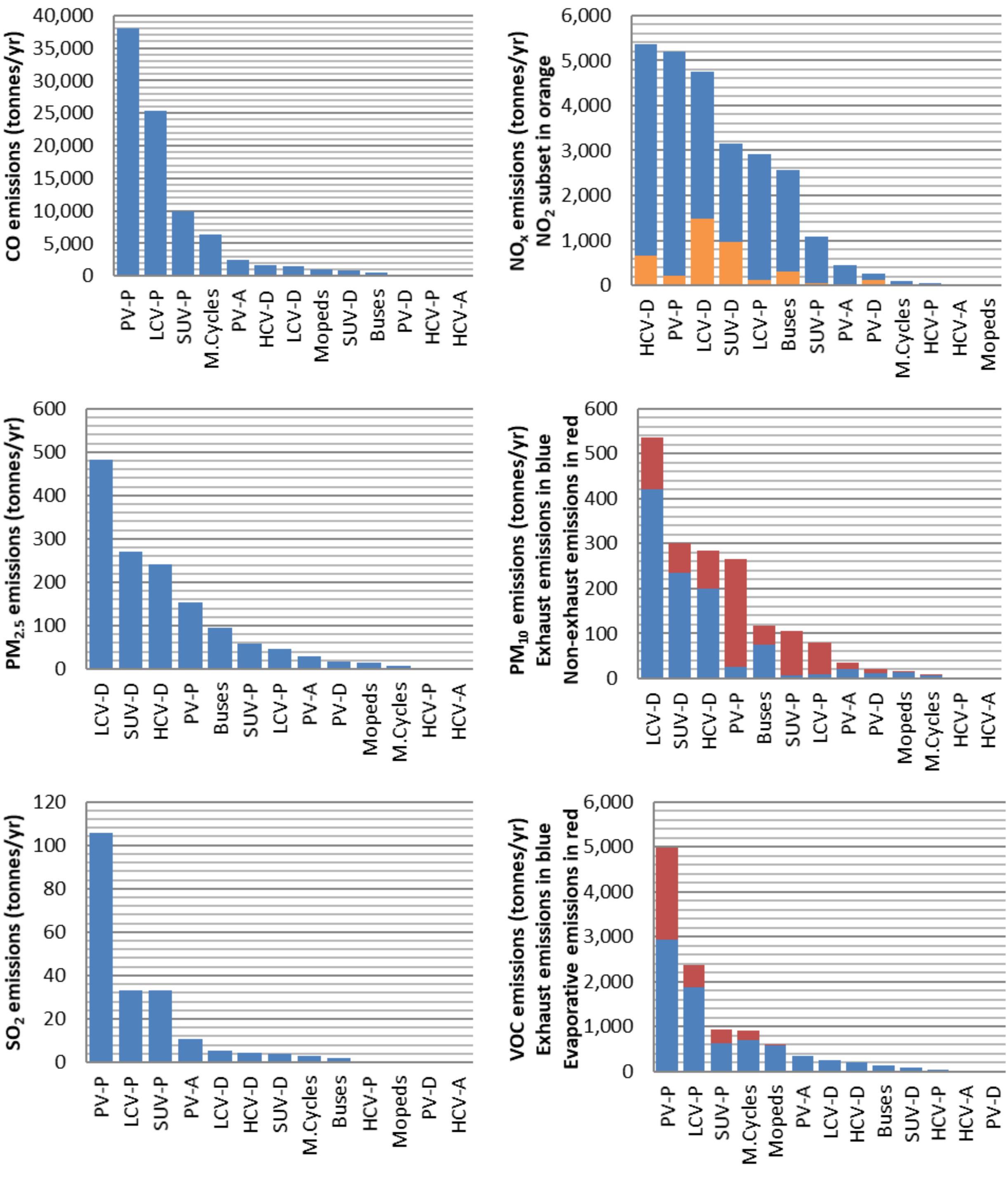



*Figure 12 – Ranked emissions for key pollutants by vehicle fuel groups*

*Table 7 – Estimated annual emissions – on-road vehicles by vehicle fuel group*

| Substance | Emissions (tonnes/year) | | |
|---|---|---|---|
| | Petrol (P) | Diesel (D) | Autogas (A) |
| **Passenger vehicles (PV)** | | | |
| Carbon monoxide | 38,050 | 51.5 | 2,400 |
| Nitrogen dioxide | 204 | 112 | 19.7 |
| Oxides of nitrogen | 5,192 | 271 | 442 |
| Particulate matter ≤ 2.5 µm | 153 | 16.2 | 29.1 |
| Particulate matter ≤ 10 µm | 265 | 19.9 | 35.9 |
| Sulfur dioxide | 106 | 0.39 | 10.8 |
| Total volatile organic compounds | 4,982 | 8.98 | 360 |
| **Sports utility vehicles (SUV)** | | | |
| Carbon monoxide | 9,938 | 845 | |
| Nitrogen dioxide | 42.3 | 964 | |
| Oxides of nitrogen | 1,092 | 3,152 | |
| Particulate matter ≤ 2.5 µm | 59.8 | 270 | |
| Particulate matter ≤ 10 µm | 106 | 301 | |
| Sulfur dioxide | 33.0 | 3.68 | |
| Total volatile organic compounds | 933 | 88.0 | |
| **Light commercial vehicles (LCV)** | | | |
| Carbon monoxide | 25,389 | 1,456 | |
| Nitrogen dioxide | 114 | 1,473 | |
| Oxides of nitrogen | 2,922 | 4,755 | |
| Particulate matter ≤ 2.5 µm | 46.3 | 482 | |
| Particulate matter ≤ 10 µm | 78.8 | 535 | |
| Sulfur dioxide | 33.2 | 5.54 | |
| Total volatile organic compounds | 2,365 | 254 | |
| **Heavy duty trucks** | | | |
| Carbon monoxide | 41.7 | 1,689 | 13.1 |
| Nitrogen dioxide | 2.02 | 661 | 0.61 |
| Oxides of nitrogen | 50.5 | 5,365 | 15.2 |
| Particulate matter ≤ 2.5 µm | 0.38 | 241 | 0.10 |
| Particulate matter ≤ 10 µm | 0.78 | 283 | 0.21 |
| Sulfur dioxide | 0.42 | 4.45 | 0.13 |
| Total volatile organic compounds | 41.3 | 204 | 12.6 |

| Substance | Emissions (tonnes/year) | | |
|---|---|---|---|
| | Petrol (P) | Diesel (D) | Autogas (A) |
| **Buses** | | | |
| Carbon monoxide | | 577 | |
| Nitrogen dioxide | | 297 | |
| Oxides of nitrogen | | 2,560 | |
| Particulate matter ≤ 2.5 µm | | 95.4 | |
| Particulate matter ≤ 10 µm | | 118 | |
| Sulfur dioxide | | 2.19 | |
| Total volatile organic compounds | | 128 | |
| **Mopeds** | | | |
| Carbon monoxide | 979 | | |
| Nitrogen dioxide | 0.16 | | |
| Oxides of nitrogen | 3.89 | | |
| Particulate matter ≤ 2.5 µm | 14.0 | | |
| Particulate matter ≤ 10 µm | 14.4 | | |
| Sulfur dioxide | 0.41 | | |
| Total volatile organic compounds | 598 | | |
| **Motorcycles (M.Cycles)** | | | |
| Carbon monoxide | 6,349 | | |
| Nitrogen dioxide | 3.94 | | |
| Oxides of nitrogen | 98.4 | | |
| Particulate matter ≤ 2.5 µm | 8.57 | | |
| Particulate matter ≤ 10 µm | 10.0 | | |
| Sulfur dioxide | 2.83 | | |
| Total volatile organic compounds | 922 | | |

Carbon monoxide (CO), sulfur dioxide ($SO_2$) and VOC emissions are dominated by petrol vehicles. For CO and $SO_2$, this is primarily a function of vehicle population and activity for each group rather than a feature of vehicle or fuel types. Petrol vehicles are highly represented in VOC emissions because higher fuel volatility results in greater evaporative emissions compared with diesel.

Oxides of nitrogen ($NO_X$) and particle emissions (as $PM_{2.5}$ and $PM_{10}$) are prevalent in diesel vehicles. Diesel vehicles also have a higher proportion of their $NO_X$ emitted as nitrogen dioxide ($NO_2$) compared with petrol and autogas vehicles. Petrol passenger vehicles rank highly for these pollutants mostly because of their large population.

The similar $PM_{2.5}$ and $PM_{10}$ emissions profile shows that most $PM_{10}$ emissions are within the $PM_{2.5}$ fraction. The increase in $PM_{10}$ emissions for petrol passenger and light commercials can be attributed to their large populations influencing non-exhaust emissions (i.e. road/tyre/brake wear) and lower particle exhaust emissions compared with diesel vehicles. This effect is discussed further in Section 3.3.

There are higher emissions of $PM_{2.5}$ and $PM_{10}$ from autogas passenger vehicles compared with diesel passenger vehicles. Both vehicle groups have similar populations, though autogas vehicles have a higher level of activity (Appendix A). The bulk of autogas particulate emissions is from a single grouping – ADR37-00 – for vehicles manufactured between 1986 and 1997. This group has a significantly higher activity level compared with diesel passenger vehicles of a comparable age. Only diesel passenger vehicles manufactured in 2007 or later have comparable activity levels, and the COPERT model estimates much lower emissions for these vehicles than for the autogas ADR37-00 grouping. This can be attributed to more advanced emission control technology in newer diesel vehicles.

### Emissions by vehicle age group

The contribution of vehicles built to varying emission standards (as a proxy for age) to emissions of key pollutants is summarised in Table 8 and presented in Figure 13, Figure 14, Figure 15 and Figure 16 for cumulative vehicle activity levels in each vehicle age group. The Australian Design Rule (ADR) alignment with manufacturing year used in this study is presented in Appendix A.

Mopeds and motorcycles have been excluded from this analysis as there is no separation by age or vehicle emission standard in COPERT.

*Passenger vehicles and compact SUVs – petrol/autogas*

This vehicle grouping represents the largest proportion of Perth's vehicle fleet for the ADR groupings used in this study.

Older vehicles in this grouping – ADR27 vehicles and earlier – contribute significantly fewer emissions overall than the newer vehicles. Individually, these vehicles will produce more emissions than newer cars, but as they have a lower population and activity level than the rest of the group, the potential for significant cumulative impact is reduced.

Vehicles built to ADR37-00 and ADR37-01 standards produce the most significant contributions to emissions for the group. Emissions from ADR37-01 vehicles are significantly lower relative to activity level when compared with ADR37-00 vehicles. ADR79 vehicles also show significantly improved emissions relative to activity, particularly for CO, $NO_X$ and VOCs, compared with older vehicles.

Emissions of $SO_2$ are lower in vehicles manufactured under ADR37-01 standards or later, but emissions are generally proportionate to vehicle activity levels. As $SO_2$ emission estimates are driven primarily by fuel quality, changes in emissions are likely to be a result of improving fuel efficiency and changes in vehicle sizes over time.

$PM_{10}$ and $PM_{2.5}$ emissions are proportionate to vehicle activity, with ADR37-00 vehicles and older showing higher emissions relative to level of activity. $PM_{10}$ emissions for post ADR37-00 vehicles are generally twice that of their $PM_{2.5}$ emissions, which is attributed to a lower particulate emission rate from exhaust (compared with older vehicles) and unchanged particulate emission rate from non-exhaust sources.

*Large SUVs and light commercial vehicles – petrol/autogas*

This group shows similar emission trends to petrol/autogas passenger and compact SUVs: slightly lower $SO_2$ emissions as vehicles get newer and more fuel efficient, and particulates from exhaust sources decrease, increasing the $PM_{10}$ and $PM_{2.5}$ ratio.

It is more difficult to discern trends over vehicle ages with the long timeframe for ADR36, ADR37-00 and ADR37-01 (1988 to 2003). The most significant feature of this vehicle group is the lower emissions of post ADR37 vehicles compared with older ADR vehicles. With the exception of particulates and $SO_2$, ADR36 and older vehicles produce more emissions as a group than all the vehicles built to ADR37 standards or better.

*Passenger vehicles, SUVs and light commercial vehicles – diesel*

This vehicle grouping shows a strong relationship between activity and emission levels compared with petrol vehicles. CO and $NO_X$ emissions are shown to increase consistently with activity levels until ADR79-01, where emissions are lower compared with previous groups despite activity levels being higher. $SO_2$ emissions are strongly correlated to activity with little evidence of changes in vehicle technology affecting emissions.

$NO_2$ emissions have increased within recent ADR groups relative to activity. This trend declines again in vehicles built to ADR79-02 standards. While appearing counter-intuitive – emissions should reduce in newer ADR vehicles relative to activity – evidence from the UK indicates that $NO_2$ emissions as a proportion of $NO_X$ have been increasing over time for diesel vehicles (Carslaw 2005; AQEG 2007). This has been attributed to the application of particulate emission controls (Liu et al. 2011). The lower emissions contributed by vehicles built to ADR79-02 standards are likely to be the result of better overall emissions control technology.

Particulate emissions from this group show a different distribution to petrol vehicles, with $PM_{10}$ emissions being comparable to $PM_{2.5}$ emissions. Exhaust emissions are the dominant source of particles from this vehicle group and non-exhaust sources are less significant than for petrol vehicles.

VOC emissions are primarily from vehicles manufactured under ADR70-00 and ADR79-00 standards, with these two groups accounting for 53 per cent of VOC emissions. VOC emissions relative to activity drop significantly for vehicles manufactured under ADR79-01 and newer standards.

*Medium and heavy duty trucks, buses*

This vehicle grouping is the smallest proportion of Perth's vehicle fleet for the ADR groupings in this study. Trucks and buses exhibit similar emission trends to those described for diesel passenger, SUVs and light commercial vehicles. $NO_2$ emissions do not, however, follow a similar trend – decreasing relative to activity over newer

ADR vehicles. Particle emissions show $PM_{2.5}$ represents slightly less of total $PM_{10}$ load than for lighter diesel vehicles.

VOC emissions of vehicles that were manufactured before ADRs came into effect (ADR-UNC) are significant for this group. This is attributed to petrol medium commercial vehicles, which have a single vehicle grouping in COPERT, and make up 32 per cent of the VOC emissions reported in this ADR group.

*Table 8 – Estimated annual emissions – on-road vehicles by vehicle emission standards (age) groups*

| Substance | Emissions (tonnes/year) | | | | | | |
|---|---|---|---|---|---|---|---|
| Passenger vehicles and compact SUVs – petrol/autogas | | | | | | | |
| | ADR 00-UNC | ADR27 | ADR 37-00 | ADR 37-01 | ADR 79-00 | ADR 79-01 | ADR 79-02 |
| Carbon monoxide | 3,493 | 1,245 | 14,218 | 16,853 | 4,877 | 4,858 | 966 |
| Nitrogen dioxide | 16.7 | 9.82 | 96.8 | 92.5 | 12.9 | 10.6 | 4.70 |
| Oxides of nitrogen | 418 | 245 | 2,421 | 2,270 | 315 | 342 | 156 |
| Particulate matter ≤ 2.5 µm | 3.88 | 3.35 | 50.8 | 54.5 | 28.9 | 62.6 | 27.3 |
| Particulate matter ≤ 10 µm | 5.60 | 4.43 | 69.3 | 96.8 | 52.0 | 113 | 49.1 |
| Sulfur dioxide | 3.04 | 1.86 | 31.8 | 34.1 | 17.5 | 37.9 | 15.7 |
| Total volatile organic compounds | 665 | 288 | 1,820 | 1,634 | 467 | 675 | 324 |
| Large SUVs and light commercial vehicles – petrol/autogas | | | | | | | |
| | ADR 00-UNC | ADR36 | ADR 37-00 | ADR 37-01 | ADR 79-00 | ADR 79-01 | ADR 79-02 |
| Carbon monoxide | 2,318 | 12,934 | 4,187 | 2,008 | 2,527 | 5,204 | 91.1 |
| Nitrogen dioxide | 14.0 | 79.8 | 13.1 | 13.3 | 8.20 | 7.59 | 0.48 |
| Oxides of nitrogen | 349 | 1,996 | 328 | 332 | 205 | 253 | 16.0 |
| Particulate matter ≤ 2.5 µm | 2.40 | 15.8 | 6.09 | 5.55 | 8.02 | 14.5 | 3.92 |
| Particulate matter ≤ 10 µm | 4.17 | 25.6 | 9.26 | 9.52 | 14.4 | 25.6 | 7.10 |
| Sulfur dioxide | 2.33 | 15.7 | 5.09 | 3.08 | 4.75 | 7.85 | 2.27 |
| Total volatile organic compounds | 513 | 1,129 | 222 | 180 | 162 | 533 | 26.6 |

| Substance | Emissions (tonnes/year) | | | | | |
|---|---|---|---|---|---|---|
| Passenger vehicles, SUVs, and light commercial vehicles – diesel | | | | | | |
| | ADR 00-UNC | ADR30 | ADR 70-00 | ADR 79-00 | ADR 79-01 | ADR 79-02 |
| Carbon monoxide | 211 | 290 | 377 | 553 | 523 | 383 |
| Nitrogen dioxide | 23.6 | 84.6 | 166 | 575 | 1,231 | 418 |
| Oxides of nitrogen | 214 | 769 | 1,507 | 2,298 | 2,239 | 1,044 |
| Particulate matter ≤ 2.5 µm | 66.4 | 199 | 171 | 159 | 138 | 28.1 |
| Particulate matter ≤ 10 µm | 68.3 | 206 | 182 | 178 | 164 | 50.0 |
| Sulfur dioxide | 0.23 | 0.78 | 1.25 | 2.13 | 2.74 | 2.31 |
| Total volatile organic compounds | 20.4 | 52.3 | 95.3 | 90.9 | 48.1 | 42.2 |

| Substance | Emissions (tonnes/year) | | | | | |
|---|---|---|---|---|---|---|
| Medium and heavy duty trucks, buses | | | | | | |
| | ADR00-UNC | ADR30 | ADR70-00 | ADR80-00 | ADR80-02 | ADR80-03 |
| Carbon monoxide | 256 | 372 | 497 | 682 | 277 | 236 |
| Nitrogen dioxide | 48.6 | 64.1 | 152 | 440 | 224 | 32.0 |
| Oxides of nitrogen | 474 | 584 | 1,386 | 3,149 | 1,597 | 799 |
| Particulate matter ≤ 2.5 µm | 39.2 | 85.3 | 90.2 | 70.7 | 28.1 | 23.0 |
| Particulate matter ≤ 10 µm | 41.8 | 88.8 | 98.7 | 91.9 | 44.9 | 36.3 |
| Sulfur dioxide | 0.63 | 0.34 | 0.82 | 2.22 | 1.75 | 1.44 |
| Total volatile organic compounds | 128 | 34.4 | 55.2 | 135 | 18.4 | 15.0 |

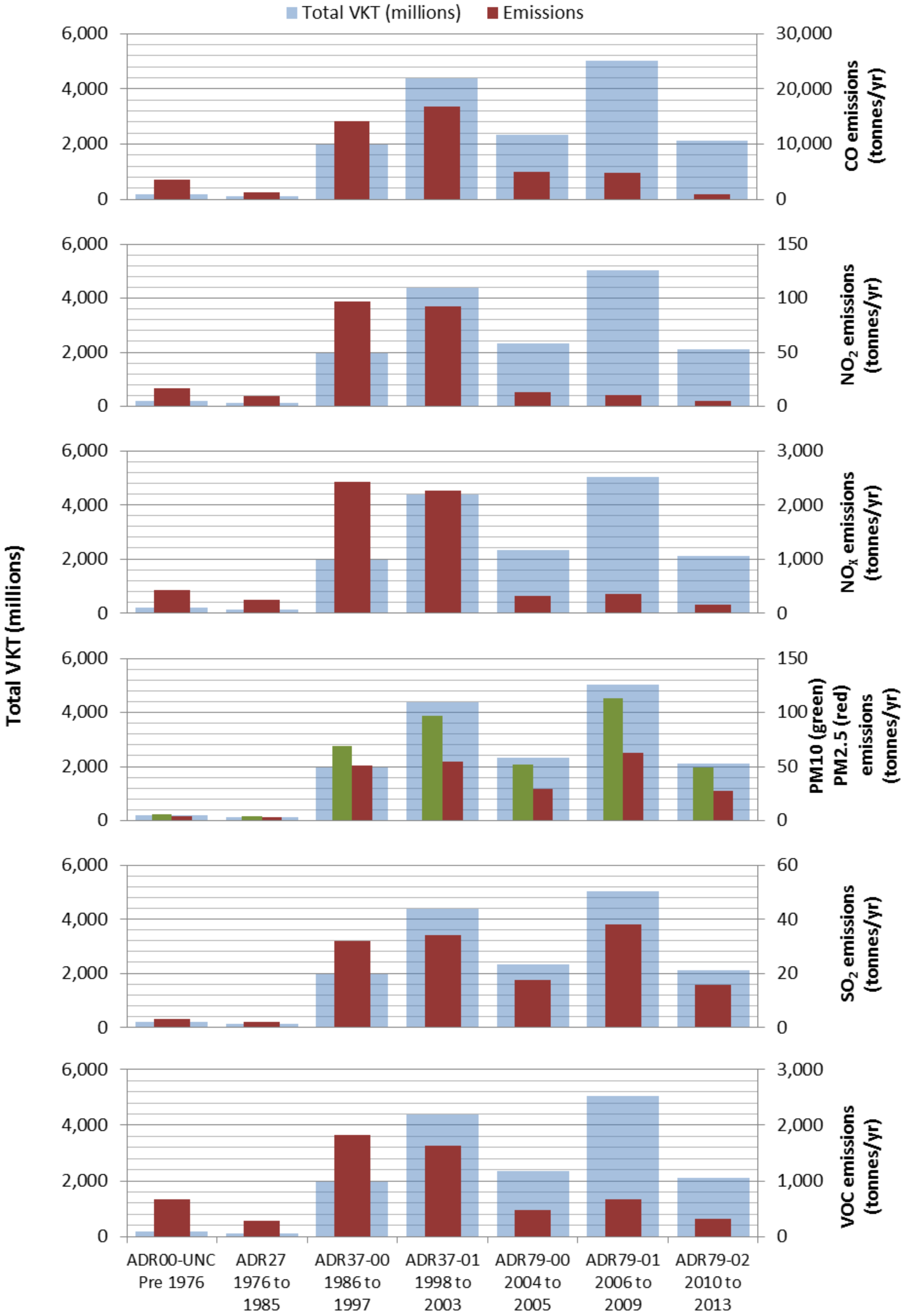



*Figure 13 – Emissions for passenger vehicles and compact SUVs – petrol/autogas*

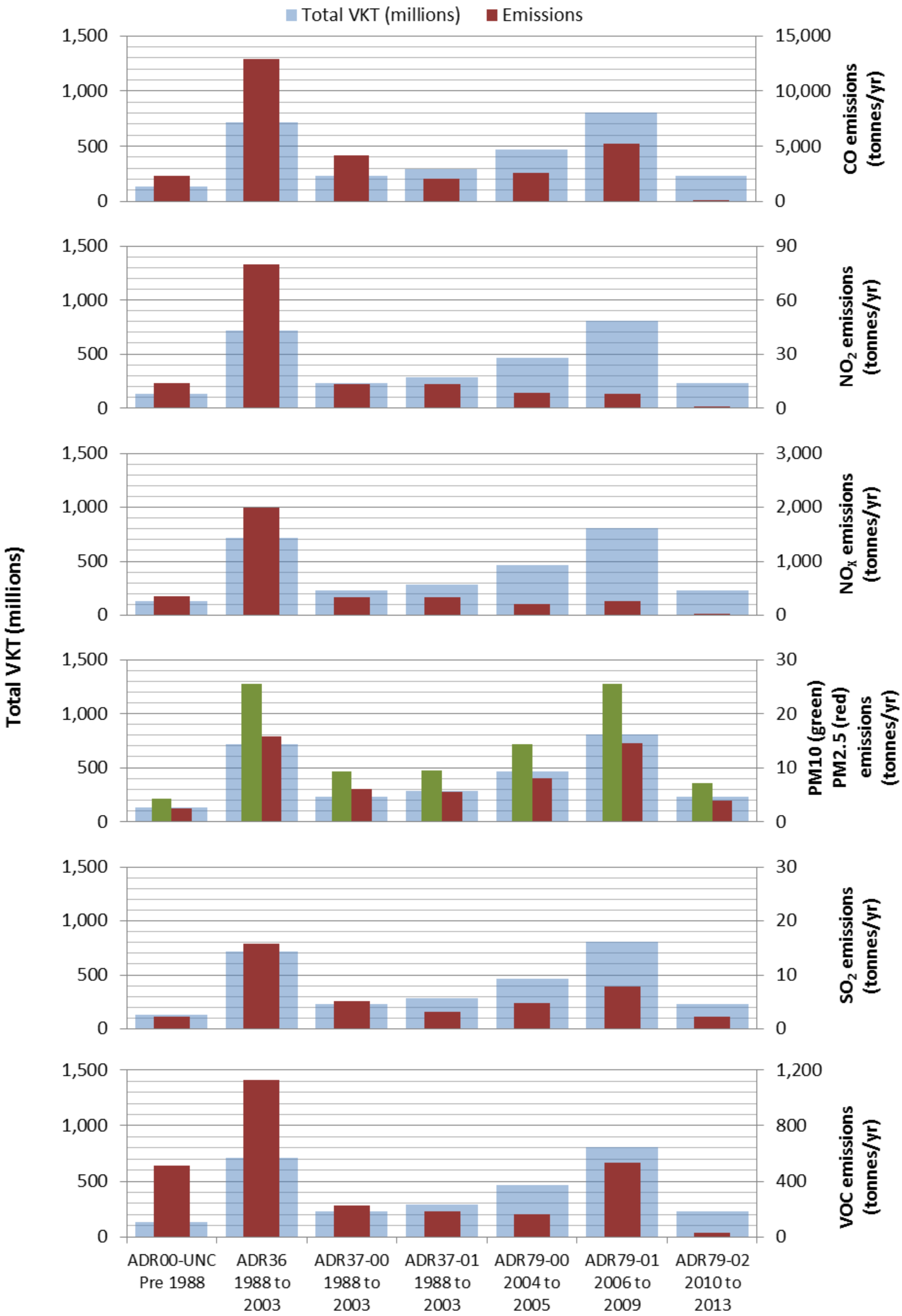



*Figure 14 – Emissions for large SUVs and light commercial vehicles – petrol/autogas*

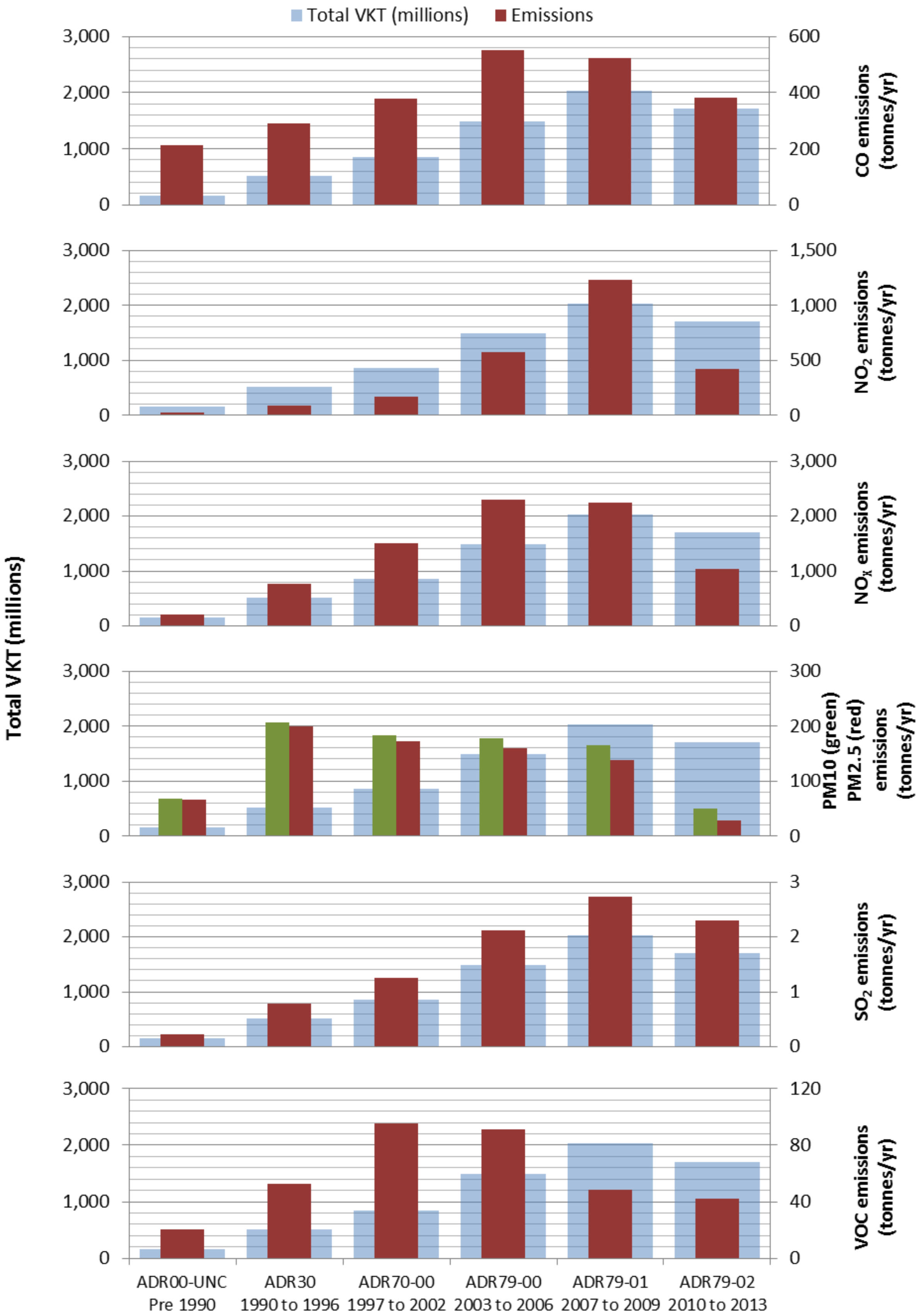
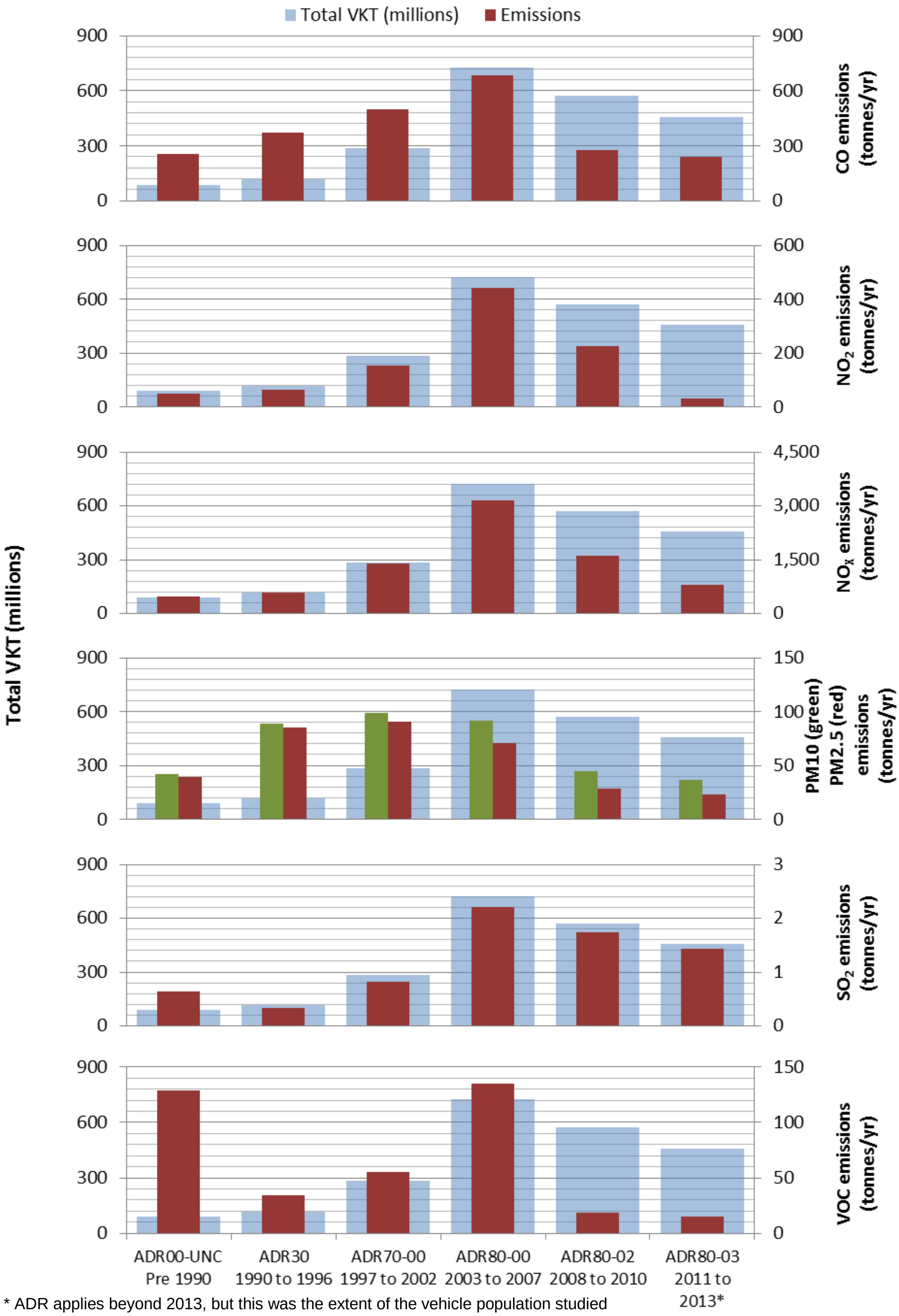



*Figure 15 – Emissions for passenger vehicles, SUVs, light commercial vehicles – diesel*




* ADR applies beyond 2013, but this was the extent of the vehicle population studied

*Figure 16 – Emissions for medium and heavy duty trucks, buses*

## 3.3 Exhaust and non-exhaust emissions

The two main emissions from non-exhaust sources are particulate matter from road/tyre interactions and brake wear, and volatile organic compounds from evaporation sources such as fuel tanks and fuel lines in petrol vehicles.

### Particulate matter

The contribution of different vehicle fuel groups to emissions of key pollutants are summarised on Figure 17 and Table 9 below.

*Table 9 – Estimated annual exhaust and non-exhaust particulate emissions for on-road vehicles*

| Emission source | Emissions (tonnes/year) | | |
|---|---|---|---|
| | Petrol (P) | Diesel (D) | Autogas (A) |
| **Passenger vehicles (PV)** | | | |
| Particulate matter ≤ 10 µm – exhaust | 25 | 12.0 | 21.4 |
| Particulate matter ≤ 10 µm – tyres-brakes | 240 | 7.9 | 14.5 |
| Particulate matter ≤ 10 µm – total | 265 | 19.9 | 35.9 |
| **Sports utility vehicles (SUV)** | | | |
| Particulate matter ≤ 10 µm – exhaust | 7 | 234 | |
| Particulate matter ≤ 10 µm – tyres-brakes | 100 | 67 | |
| Particulate matter ≤ 10 µm – total | 106 | 301 | |
| **Light commercial vehicles (LCV)** | | | |
| Particulate matter ≤ 10 µm – exhaust | 9.1 | 420 | |
| Particulate matter ≤ 10 µm – tyres-brakes | 69.6 | 115 | |
| Particulate matter ≤ 10 µm – total | 78.8 | 535 | |
| **Heavy duty trucks** | | | |
| Particulate matter ≤ 10 µm – exhaust | N/A* | 200 | N/A* |
| Particulate matter ≤ 10 µm – tyres-brakes | 0.78 | 83 | 0.21 |
| Particulate matter ≤ 10 µm – total | 0.78 | 283 | 0.21 |
| **Buses** | | | |
| Particulate matter ≤ 10 µm – exhaust | | 74 | |
| Particulate matter ≤ 10 µm – tyres-brakes | | 44 | |
| Particulate matter ≤ 10 µm – total | | 118 | |
| **Mopeds** | | | |
| Particulate matter ≤ 10 µm – exhaust | 13.7 | | |
| Particulate matter ≤ 10 µm – tyres-brakes | 0.7 | | |
| Particulate matter ≤ 10 µm – total | 14.4 | | |
| **Motorcycles (M.Cycles)** | | | |
| Particulate matter ≤ 10 µm – exhaust | 7.0 | | |
| Particulate matter ≤ 10 µm – tyres-brakes | 3.0 | | |
| Particulate matter ≤ 10 µm – total | 10.0 | | |

* Not estimated by COPERT

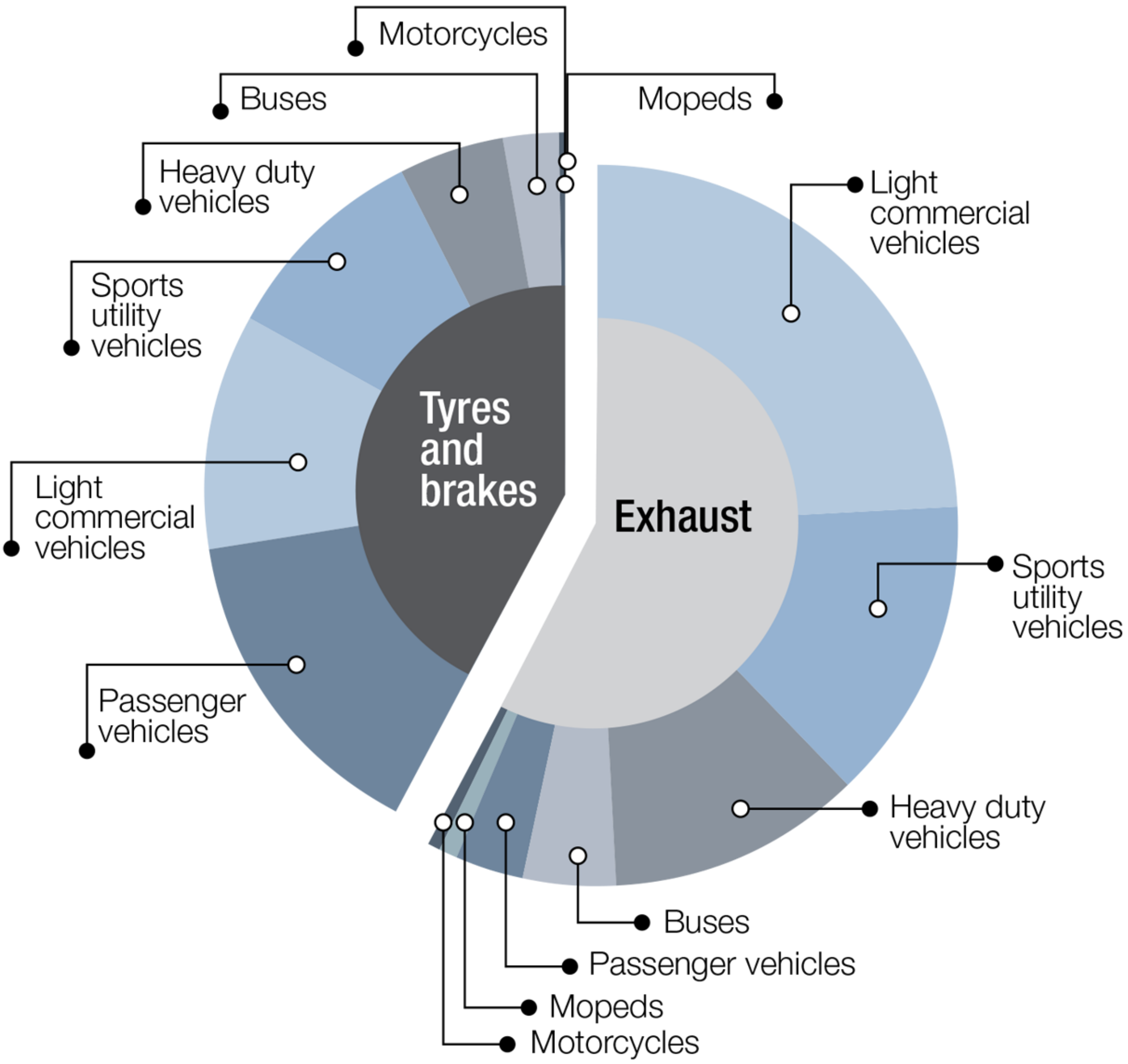



*Figure 17 – Particulate emissions from exhaust and non-exhaust sources*

Particulate emissions from exhaust make up 58 per cent of on-road particulate emissions, and are dominated by commercial and SUV diesel vehicles. Non-exhaust emissions are not clearly dominated by any particular fuel or vehicle type, with these emissions loosely correlated to the activity (total VKT) for the vehicle type in the study area.

Exhaust particulate emissions in COPERT Australia are assumed to comprise elemental and organic carbon. Heavy metal emissions are calculated as a function of trace concentrations in fuel, lubrication oil and engine wear (i.e. exhaust emissions). This means that any heavy metal emissions generated by non-exhaust particulate emissions are not accounted for in this study.

### Volatile organic compounds

The contribution of different vehicle fuel groups to emissions of key pollutants are summarised in Figure 18 and Table 10.

*Table 10 – Estimated annual VOC emissions for on-road vehicles – exhaust and non-exhaust sources*

| Vehicle type | Emissions (tonnes/year) | | | | |
|---|---|---|---|---|---|
| | Exhaust | | | Evaporative | Total |
| | Petrol | Diesel | Autogas | | |
| Passenger vehicles (PV) | 2,943 | 8.98 | 360 | 2,039 | 5,350 |
| Sports utility vehicles (SUV) | 622 | 88.0 | | 310 | 1,021 |
| Light commercial vehicles (LCV) | 1,872 | 254 | | 493 | 2,619 |
| Heavy duty trucks | 41.3 | 204 | 12.6 | N/A* | 258 |
| Buses (Bus) | | 128 | | N/A* | 128 |
| Mopeds | 579 | | | 19.7 | 598 |
| Motorcycles (M.Cycle) | 695 | | | 227 | 922 |

* Not estimated by COPERT

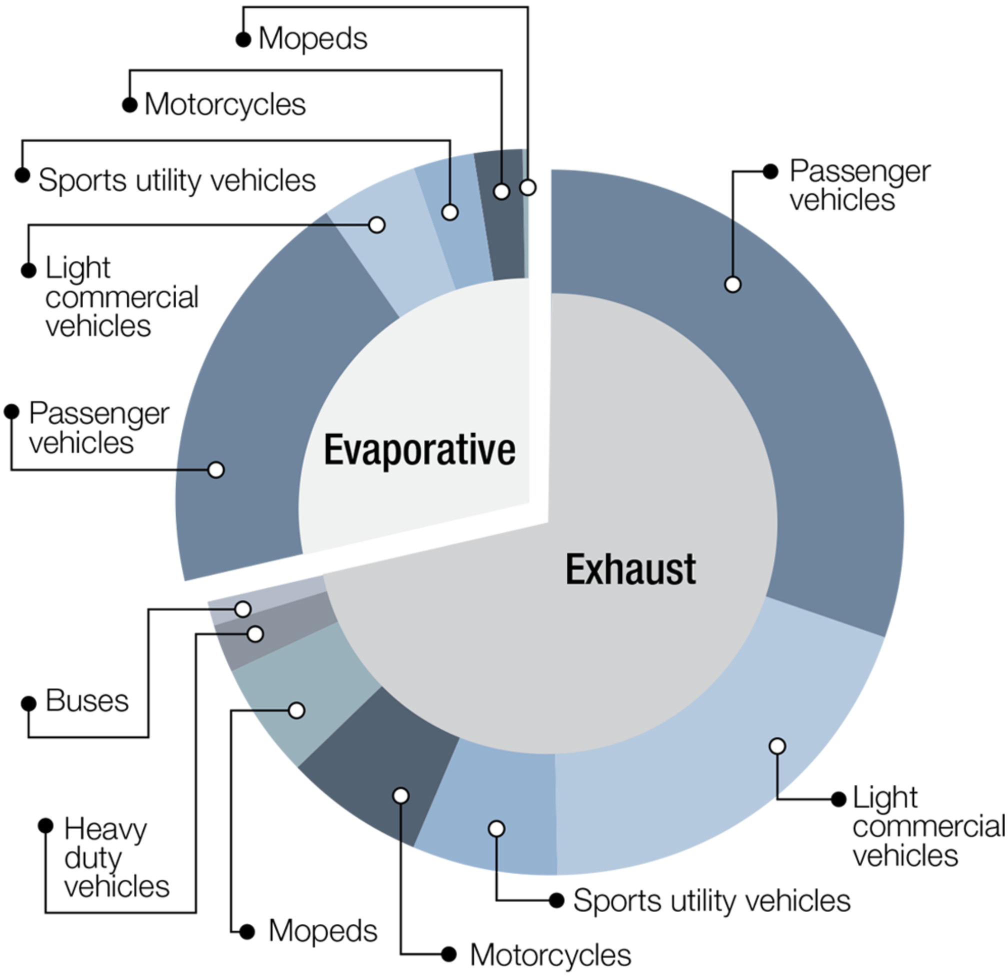



*Figure 18 – VOC emissions from exhaust and evaporative sources*

VOC emissions arise primarily from exhaust sources, with only 28 per cent of emissions arising from evaporative sources. Petrol vehicles are the dominant source of VOC exhaust emissions. The passenger vehicle fleet, given its large population, accounts for nearly half of all VOC emissions from on-road vehicles in the study area.

## 3.4 Cold and hot operating emissions

Operating temperature is an important factor in emissions from motor vehicles. When operating at optimal temperatures, a vehicle is said to be running 'hot'. During the time between when a vehicle is turned on and when it reaches its optimal operating temperature, a vehicle is said to be running 'cold'. Cold running produces significantly larger emissions than hot running as a result of inefficient engine operation.

COPERT factors cold running emissions into estimates for passenger, SUV and light commercial vehicle groups. Cold running emission factors exist in the model for most pollutants, though particulate matter estimates are limited to only diesel vehicles and have been excluded from this analysis. Hot and cold emission estimates are summarised in Table 11 and presented as proportions of total exhaust on Figure 19.

*Table 11 – Estimated annual hot and cold running on-road vehicle emissions*

| Vehicle type | Emissions (tonnes/year) | | |
|---|---|---|---|
| | Hot | Cold | Total |
| Passenger vehicles (PV) | | | |
| Carbon monoxide | 17,446 | 23,056 | 40,502 |
| Nitrogen dioxide | 284 | 52.2 | 336 |
| Oxides of nitrogen | 4,619 | 1,286 | 5,904 |
| Sulfur dioxide | 108 | 9.24 | 117 |
| Total volatile organic compounds | 1,359 | 1,953 | 3,312[1] |
| **TEP score** | **14,296** | **8,038** | **22,334** |
| Sports utility vehicles (SUV) | | | |
| Carbon monoxide | 6,080 | 4,703 | 10,783 |
| Nitrogen dioxide | 983 | 23.0 | 1,006 |
| Oxides of nitrogen | 3,981 | 263 | 4,244 |
| Sulfur dioxide | 34.3 | 2.46 | 36.7 |
| Total volatile organic compounds | 421 | 290 | 710[1] |
| **TEP score** | **10,137** | **1,534** | **11,670** |
| Light commercial vehicles (LCV) | | | |
| Carbon monoxide | 17,680 | 9,164 | 26,845 |
| Nitrogen dioxide | 1,539 | 48.2 | 1,587 |
| Oxides of nitrogen | 7,198 | 478 | 7,677 |
| Sulfur dioxide | 36.8 | 1.95 | 38.8 |
| Total volatile organic compounds | 1,277 | 849 | 2,126[1] |
| **TEP score** | **19,703** | **3,191** | **22,894** |

[1] Exhaust emissions total only (does not include evaporative emissions)

Cold running represents a significant portion of carbon monoxide and volatile organic compound total exhaust emissions for all vehicle classes, and is the dominant source of exhaust emissions from passenger vehicles. Cold running emissions of oxides of nitrogen are also notable for passenger vehicles.

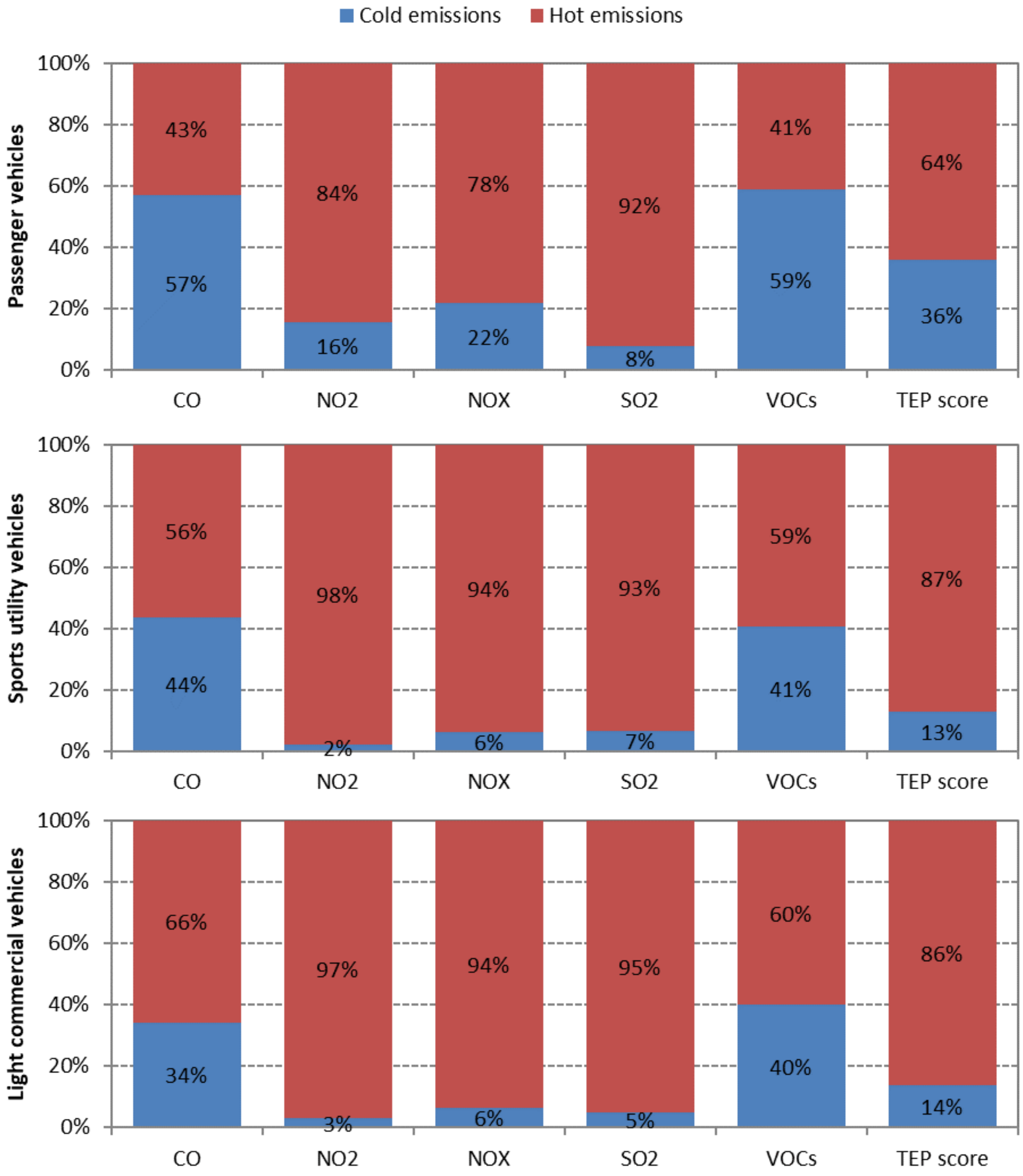



*Figure 19 – Proportion of cold and hot running emissions for key pollutants*

Different vehicles have different warm-up periods. The model has used a 25-minute average trip time for vehicles. On this basis, cold running emissions represent a disproportionate amount of pollution generated from vehicle exhausts, with the effect being a particular concern for passenger vehicles.

# 4 Key considerations

This study has found that:

- Emissions of heavy metals (such as lead) from trace concentrations in fuel and lube oil, as well as from general engine wear, may represent the most significant emission risk from vehicle operation – mostly due to the high toxicity of these substances relative to other more commonly emitted substances from combustion. However, heavy metal estimates in this study are very conservative and may be significantly overestimating emissions. It should be noted, however, that even an estimate an order of magnitude less would still present a significantly higher risk than all other pollutants except polychlorinated dioxins and furans. Improved fuel quality data (i.e. more sensitive analysis) are required to improve input data for the COPERT model.
- Very old passenger, SUV and light commercial vehicles (~20+ years) have significant emission levels on a grams-per-kilometre basis individually. Yet their lower activity levels make them of limited benefit for improvement programs to reduce emissions across the Perth area. DWER's CleanRun roadside monitoring has identified these vehicles as having much greater emissions than other vehicles and therefore a significant impact at a local level. It is recommended that they are targeted accordingly.
- Diesel vehicles are the primary source of exhaust particulate emissions in the study area. Encouraging regular servicing and replacement of diesel particulate filters might be the most effective way to reduce diesel vehicle particulate emissions.
- Emissions from road, tyre and brake wear are a significant particulate emission source (approximately 42 per cent of $PM_{10}$ emissions). Investigations into road-surface influence on particulate generation and tyre/brake technology are required to identify potential opportunities for mitigation.
- Sulfur dioxide emissions are driven primarily by sulfur content in the fuel and actual fuel use. Reducing emissions requires both improvements in overall fleet fuel efficiency and a lower sulfur content in fuel sold in the study area.
- Cold running vehicles produce significantly more emissions than those running at optimal temperatures, particularly for carbon monoxide and volatile organic compounds. Initiatives to discourage vehicle use for short trips would be an effective approach to reducing emissions.

This study's outcomes should be viewed in the wider context of other major emission sources (natural, domestic, commercial and industrial, off-road mobile sources) that were also part of the Perth Air Emissions Study 2011–2012.

# Appendices

## Appendix A — Emission standards by year of manufacture

The tables below show the alignment between year of vehicle manufacture and the relevant emission standard for use in COPERT Australia.

Mopeds and motorcycles have been lumped into one vehicle category (petrol motorcycle 4-stroke 250 to 750 $cm^3$) for this study and have not been separated by emission standard.

*Table 12 – Passenger vehicles and compact SUVs: petrol/autogas*

| Year of manufacture | Emission standard |
|---|---|
| 1975 and earlier | Uncontrolled |
| 1976 to 1985 | ADR27[1] |
| 1986 to 1997 | ADR37-00 |
| 1998 to 2003 | ADR37-01 |
| 2004 to 2005 | ADR79-00 |
| 2006 to 2009 | ADR79-01 |
| 2010 to 2013 | ADR79-02 |
| Not used | ADR79-03<br>ADR79-04<br>ADR79-05 |

[1] passenger vehicles only

*Table 13 – Passenger vehicles, SUVs, light commercial vehicles: diesel*

| Year of manufacture | Emission standard |
|---|---|
| 1989 and earlier | Uncontrolled |
| 1990 to 1996 | ADR30 |
| 1997 to 2002 | ADR70-00 |
| 2003 to 2006 | ADR79-00 |
| 2007 to 2009 | ADR79-01 |
| 2010 to 2013 | ADR79-02 |
| Not used | ADR79-03<br>ADR79-04<br>ADR79-05 |

*Table 14 – Large SUVs and light commercial vehicles: petrol/autogas*

| Year of manufacture | Emission standard |
|---|---|
| 1987 and earlier | Uncontrolled |
| 1988 to 2003 (large SUVs) | ADR36 (50%), ADR37-00 (19%), ADR37-01 (31%) |
| 1988 to 2003 (LCVs) | ADR36 (60%), ADR37-00 (23%), ADR37-01 (17%) |
| 2004 to 2005 | ADR79-00 |
| 2006 to 2009 | ADR79-01 |
| 2010 to 2013 | ADR79-02 |
| Not used | ADR79-03<br>ADR79-04<br>ADR79-05 |

*Table 15 – Medium and heavy duty trucks and buses*

| Year of manufacture | Emission standard |
|---|---|
| 1989 and earlier | Uncontrolled |
| 1990 to 1996 | ADR30 |
| 1997 to 2002 | ADR70-00 |
| 2003 to 2007 | ADR80-00 |
| 2008 to 2010 | ADR80-02 |
| 2011 and later | ADR80-03 |
| Not used | ADR80-04<br>ADR80-05 |

# Appendix B — COPERT Australia input fleet data

| Sector | Subsector | Technology | Population | Km/veh/yr | Accum. km |
|---|---|---|---|---|---|
| Passenger Cars | PC-S-petrol | ADR00-UNC | 7315 | 6279 | 290806 |
| Passenger Cars | PC-S-petrol | ADR27 | 4221 | 6279 | 290806 |
| Passenger Cars | PC-S-petrol | ADR37-00 | 63601 | 9876 | 189785 |
| Passenger Cars | PC-S-petrol | ADR37-01 | 121577 | 12262 | 122011 |
| Passenger Cars | PC-S-petrol | ADR79-00 | 63242 | 13020 | 79159 |
| Passenger Cars | PC-S-petrol | ADR79-01 | 154704 | 13529 | 41489 |
| Passenger Cars | PC-S-petrol | ADR79-02 | 132109 | 6722 | 6670 |
| Passenger Cars | PC-S-petrol | ADR79-03 | 0 | 6722 | N/A |
| Passenger Cars | PC-S-petrol | ADR79-04 | 0 | 6722 | N/A |
| Passenger Cars | PC-S-petrol | ADR79-05 | 0 | 6722 | N/A |
| Passenger Cars | PC-M-petrol | ADR00-UNC | 7864 | 6279 | 300000 |
| Passenger Cars | PC-M-petrol | ADR27 | 5909 | 6279 | 300000 |
| Passenger Cars | PC-M-petrol | ADR37-00 | 38815 | 9432 | 216262 |
| Passenger Cars | PC-M-petrol | ADR37-01 | 49157 | 12648 | 135866 |
| Passenger Cars | PC-M-petrol | ADR79-00 | 26002 | 14306 | 92855 |
| Passenger Cars | PC-M-petrol | ADR79-01 | 48329 | 15849 | 51292 |
| Passenger Cars | PC-M-petrol | ADR79-02 | 34891 | 8402 | 8337 |
| Passenger Cars | PC-M-petrol | ADR79-03 | 0 | 8402 | N/A |
| Passenger Cars | PC-M-petrol | ADR79-04 | 0 | 8402 | N/A |
| Passenger Cars | PC-M-petrol | ADR79-05 | 0 | 8402 | N/A |
| Passenger Cars | PC-L-petrol | ADR00-UNC | 12135 | 6279 | 300000 |
| Passenger Cars | PC-L-petrol | ADR27 | 6740 | 6279 | 300000 |
| Passenger Cars | PC-L-petrol | ADR37-00 | 71397 | 9749 | 219883 |
| Passenger Cars | PC-L-petrol | ADR37-01 | 107559 | 12836 | 148800 |
| Passenger Cars | PC-L-petrol | ADR79-00 | 39719 | 15240 | 103465 |
| Passenger Cars | PC-L-petrol | ADR79-01 | 52294 | 17574 | 58206 |
| Passenger Cars | PC-L-petrol | ADR79-02 | 35108 | 9663 | 9588 |
| Passenger Cars | PC-L-petrol | ADR79-03 | 0 | 9663 | N/A |
| Passenger Cars | PC-L-petrol | ADR79-04 | 0 | 9663 | N/A |
| Passenger Cars | PC-L-petrol | ADR79-05 | 0 | 9663 | N/A |
| Passenger Cars | PC-S-diesel | ADR00-UNC | 192 | 13613 | 238551 |
| Passenger Cars | PC-S-diesel | ADR30 | 192 | 13613 | 238551 |
| Passenger Cars | PC-S-diesel | ADR70-00 | 169 | 16099 | 168103 |
| Passenger Cars | PC-S-diesel | ADR79-00 | 1571 | 17493 | 88580 |
| Passenger Cars | PC-S-diesel | ADR79-01 | 5398 | 18070 | 43814 |
| Passenger Cars | PC-S-diesel | ADR79-02 | 8179 | 8909 | 8840 |
| Passenger Cars | PC-S-diesel | ADR79-03 | 0 | 8909 | N/A |
| Passenger Cars | PC-S-diesel | ADR79-04 | 0 | 8909 | N/A |
| Passenger Cars | PC-S-diesel | ADR79-05 | 0 | 8909 | N/A |
| Passenger Cars | PC-ML-diesel | ADR00-UNC | 717 | 12934 | 276978 |
| Passenger Cars | PC-ML-diesel | ADR30 | 1234 | 12934 | 276978 |
| Passenger Cars | PC-ML-diesel | ADR70-00 | 383 | 16223 | 198774 |
| Passenger Cars | PC-ML-diesel | ADR79-00 | 995 | 19919 | 107481 |
| Passenger Cars | PC-ML-diesel | ADR79-01 | 4933 | 21833 | 53356 |
| Passenger Cars | PC-ML-diesel | ADR79-02 | 6235 | 11326 | 11237 |
| Passenger Cars | PC-ML-diesel | ADR79-03 | 0 | 11326 | N/A |
| Passenger Cars | PC-ML-diesel | ADR79-04 | 0 | 11326 | N/A |
| Passenger Cars | PC-ML-diesel | ADR79-05 | 0 | 11326 | N/A |

| Sector | Subsector | Technology | Population | Km/veh/yr | Accum. km |
|---|---|---|---|---|---|
| Passenger Cars | PC-S-E10 | ADR00-UNC | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR27 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR37-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR37-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-02 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-03 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-04 | 0 | 0 | 300000 |
| Passenger Cars | PC-S-E10 | ADR79-05 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR00-UNC | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR27 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR37-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR37-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-02 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-03 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-04 | 0 | 0 | 300000 |
| Passenger Cars | PC-M-E10 | ADR79-05 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR00-UNC | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR27 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR37-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR37-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-00 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-01 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-02 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-03 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-04 | 0 | 0 | 300000 |
| Passenger Cars | PC-L-E10 | ADR79-05 | 0 | 0 | 300000 |
| Passenger Cars | PC-LPG | ADR00-UNC | 643 | 18343 | 292148 |
| Passenger Cars | PC-LPG | ADR27 | 818 | 18343 | 292148 |
| Passenger Cars | PC-LPG | ADR37-00 | 6599 | 21044 | 300000 |
| Passenger Cars | PC-LPG | ADR37-01 | 12801 | 25380 | 300000 |
| Passenger Cars | PC-LPG | ADR79-00 | 3589 | 29321 | 194621 |
| Passenger Cars | PC-LPG | ADR79-01 | 4435 | 33344 | 104369 |
| Passenger Cars | PC-LPG | ADR79-02 | 825 | 18058 | 17917 |
| Passenger Cars | PC-LPG | ADR79-03 | 0 | 18058 | N/A |
| Passenger Cars | PC-LPG | ADR79-04 | 0 | 18058 | N/A |
| Passenger Cars | PC-LPG | ADR79-05 | 0 | 18058 | N/A |
| SUV | SUV-C-petrol | ADR00-UNC | 796 | 6472 | 300000 |
| SUV | SUV-C-petrol | ADR37-00 | 14960 | 10030 | 212823 |
| SUV | SUV-C-petrol | ADR37-01 | 43731 | 13078 | 144188 |
| SUV | SUV-C-petrol | ADR79-00 | 28134 | 15279 | 102725 |
| SUV | SUV-C-petrol | ADR79-01 | 62557 | 17727 | 55198 |
| SUV | SUV-C-petrol | ADR79-02 | 59233 | 9663 | 9588 |
| SUV | SUV-C-petrol | ADR79-03 | 0 | 9663 | N/A |
| SUV | SUV-C-petrol | ADR79-04 | 0 | 9663 | N/A |
| SUV | SUV-C-petrol | ADR79-05 | 0 | 9663 | N/A |
| SUV | SUV-L-petrol | ADR00-UNC | 2723 | 6472 | 300000 |

| Sector | Subsector | Technology | Population | Km/veh/yr | Accum. km |
|---|---|---|---|---|---|
| SUV | SUV-L-petrol | ADR36 | 10816 | 11835 | 171421 |
| SUV | SUV-L-petrol | ADR37-00 | 4110 | 10243 | 207530 |
| SUV | SUV-L-petrol | ADR37-01 | 6706 | 12820 | 149080 |
| SUV | SUV-L-petrol | ADR79-00 | 3163 | 15295 | 102411 |
| SUV | SUV-L-petrol | ADR79-01 | 5931 | 17561 | 58457 |
| SUV | SUV-L-petrol | ADR79-02 | 5904 | 9663 | 9588 |
| SUV | SUV-L-petrol | ADR79-03 | 0 | 9663 | N/A |
| SUV | SUV-L-petrol | ADR79-04 | 0 | 9663 | N/A |
| SUV | SUV-L-petrol | ADR79-05 | 0 | 9663 | N/A |
| SUV | SUV-diesel | ADR00-UNC | 6139 | 9141 | 300000 |
| SUV | SUV-diesel | ADR30 | 17060 | 12544 | 300000 |
| SUV | SUV-diesel | ADR70-00 | 20953 | 16026 | 217864 |
| SUV | SUV-diesel | ADR79-00 | 25731 | 20428 | 132648 |
| SUV | SUV-diesel | ADR79-01 | 26073 | 24153 | 60214 |
| SUV | SUV-diesel | ADR79-02 | 44726 | 12808 | 12708 |
| SUV | SUV-diesel | ADR79-03 | 0 | 12808 | N/A |
| SUV | SUV-diesel | ADR79-04 | 0 | 12808 | N/A |
| SUV | SUV-diesel | ADR79-05 | 0 | 12808 | N/A |
| SUV | SUV-C-E10 | ADR00-UNC | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR37-00 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR37-01 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-00 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-01 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-02 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-03 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-04 | 0 | 0 | 300000 |
| SUV | SUV-C-E10 | ADR79-05 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR00-UNC | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR36 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR37-00 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR37-01 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-00 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-01 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-02 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-03 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-04 | 0 | 0 | 300000 |
| SUV | SUV-L-E10 | ADR79-05 | 0 | 0 | 300000 |
| Light Commercial Vehicles | LCV-petrol | ADR00-UNC | 19446 | 5735 | 300000 |
| Light Commercial Vehicles | LCV-petrol | ADR36 | 45431 | 12881 | 235830 |
| Light Commercial Vehicles | LCV-petrol | ADR37-00 | 17415 | 10829 | 275481 |
| Light Commercial Vehicles | LCV-petrol | ADR37-01 | 12872 | 15693 | 181472 |
| Light Commercial Vehicles | LCV-petrol | ADR79-00 | 22489 | 18506 | 127095 |
| Light Commercial Vehicles | LCV-petrol | ADR79-01 | 32926 | 21249 | 74075 |
| Light Commercial Vehicles | LCV-petrol | ADR79-02 | 15023 | 11628 | 11765 |
| Light Commercial Vehicles | LCV-petrol | ADR79-03 | 0 | 11628 | N/A |
| Light Commercial Vehicles | LCV-petrol | ADR79-04 | 0 | 11628 | N/A |
| Light Commercial Vehicles | LCV-petrol | ADR79-05 | 0 | 11628 | N/A |
| Light Commercial Vehicles | LCV-diesel | ADR00-UNC | 10876 | 7947 | 300000 |
| Light Commercial Vehicles | LCV-diesel | ADR30 | 20794 | 13337 | 300000 |
| Light Commercial Vehicles | LCV-diesel | ADR70-00 | 27633 | 18215 | 258025 |

| Sector | Subsector | Technology | Population | Km/veh/yr | Accum. km |
|---|---|---|---|---|---|
| Light Commercial Vehicles | LCV-diesel | ADR79-00 | 38529 | 23608 | 153802 |
| Light Commercial Vehicles | LCV-diesel | ADR79-01 | 46793 | 27802 | 72719 |
| Light Commercial Vehicles | LCV-diesel | ADR79-02 | 72441 | 14633 | 14806 |
| Light Commercial Vehicles | LCV-diesel | ADR79-03 | 0 | 14633 | N/A |
| Light Commercial Vehicles | LCV-diesel | ADR79-04 | 0 | 14633 | N/A |
| Light Commercial Vehicles | LCV-diesel | ADR79-05 | 0 | 14633 | N/A |
| Heavy Duty Trucks | MCV-petrol | ADR00-UNC | 2258 | 5638 | 300000 |
| Heavy Duty Trucks | MCV-diesel | ADR00-UNC | 14322 | 3388 | 300000 |
| Heavy Duty Trucks | MCV-diesel | ADR30 | 7071 | 11247 | 300000 |
| Heavy Duty Trucks | MCV-diesel | ADR70-00 | 8263 | 23407 | 300000 |
| Heavy Duty Trucks | MCV-diesel | ADR80-00 | 13637 | 33882 | 217062 |
| Heavy Duty Trucks | MCV-diesel | ADR80-02 | 7821 | 31512 | 71234 |
| Heavy Duty Trucks | MCV-diesel | ADR80-03 | 5392 | 31512 | N/A |
| Heavy Duty Trucks | MCV-diesel | ADR80-04 | 0 | 31512 | N/A |
| Heavy Duty Trucks | MCV-diesel | ADR80-05 | 0 | 31512 | N/A |
| Heavy Duty Trucks | HCV-diesel | ADR00-UNC | 789 | 3399 | 300000 |
| Heavy Duty Trucks | HCV-diesel | ADR30 | 655 | 11165 | 300000 |
| Heavy Duty Trucks | HCV-diesel | ADR70-00 | 763 | 22937 | 300000 |
| Heavy Duty Trucks | HCV-diesel | ADR80-00 | 1685 | 34063 | 211556 |
| Heavy Duty Trucks | HCV-diesel | ADR80-02 | 1481 | 32272 | 73504 |
| Heavy Duty Trucks | HCV-diesel | ADR80-03 | 1441 | 32272 | N/A |
| Heavy Duty Trucks | HCV-diesel | ADR80-04 | 0 | 32272 | N/A |
| Heavy Duty Trucks | HCV-diesel | ADR80-05 | 0 | 32272 | N/A |
| Heavy Duty Trucks | AT-diesel | ADR00-UNC | 96 | 10851 | 300000 |
| Heavy Duty Trucks | AT-diesel | ADR30 | 63 | 31593 | 300000 |
| Heavy Duty Trucks | AT-diesel | ADR70-00 | 89 | 65770 | 300000 |
| Heavy Duty Trucks | AT-diesel | ADR80-00 | 240 | 111897 | 300000 |
| Heavy Duty Trucks | AT-diesel | ADR80-02 | 213 | 116909 | 260768 |
| Heavy Duty Trucks | AT-diesel | ADR80-03 | 203 | 116909 | N/A |
| Heavy Duty Trucks | AT-diesel | ADR80-04 | 0 | 116909 | N/A |
| Heavy Duty Trucks | AT-diesel | ADR80-05 | 0 | 116909 | N/A |
| Heavy Duty Trucks | Autogas Trucks | ADR30 | 90 | 8020 | 300000 |
| Heavy Duty Trucks | Autogas Trucks | ADR70-00 | 16 | 30099 | 300000 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-00 | 37 | 51252 | 272728 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-02 | 4 | 65537 | 98375 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-03 | 1 | 65537 | N/A |
| Heavy Duty Trucks | Autogas Trucks | ADR80-04 | 0 | 65537 | N/A |
| Heavy Duty Trucks | Autogas Trucks | ADR80-05 | 0 | 65537 | N/A |
| Buses | BUS-L-diesel | ADR00-UNC | 1842 | 6657 | 300000 |
| Buses | BUS-L-diesel | ADR30 | 1024 | 20446 | 300000 |
| Buses | BUS-L-diesel | ADR70-00 | 1014 | 41770 | 300000 |
| Buses | BUS-L-diesel | ADR80-00 | 1757 | 80093 | 300000 |
| Buses | BUS-L-diesel | ADR80-02 | 2063 | 97505 | 109279 |
| Buses | BUS-L-diesel | ADR80-03 | 1596 | 97505 | N/A |
| Buses | BUS-L-diesel | ADR80-04 | 0 | 97505 | N/A |
| Buses | BUS-L-diesel | ADR80-05 | 0 | 97505 | N/A |
| Buses | BUS-H-diesel | ADR00-UNC | 1229 | 8254 | 300000 |
| Buses | BUS-H-diesel | ADR30 | 319 | 20436 | 300000 |
| Buses | BUS-H-diesel | ADR70-00 | 630 | 41637 | 300000 |
| Buses | BUS-H-diesel | ADR80-00 | 439 | 80392 | 300000 |

| Sector | Subsector | Technology | Population | Km/veh/yr | Accum. km |
|---|---|---|---|---|---|
| Buses | BUS-H-diesel | ADR80-02 | 529 | 97296 | 108773 |
| Buses | BUS-H-diesel | ADR80-03 | 617 | 97296 | N/A |
| Buses | BUS-H-diesel | ADR80-04 | 0 | 97296 | N/A |
| Buses | BUS-H-diesel | ADR80-05 | 0 | 97296 | N/A |
| Mopeds | 2-stroke <50 $cm^3$ | Conventional | 0 | 3588 | 39302 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro I | 0 | 3588 | 39302 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro II | 0 | 3588 | 39302 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro III | 0 | 3588 | 39302 |
| Mopeds | 4-stroke <50 $cm^3$ | Conventional | 21696 | 3588 | 39302 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro I | 0 | 3588 | 39302 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro II | 0 | 3588 | 39302 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro III | 0 | 3588 | 39302 |
| Motorcycles | 2-stroke >50 $cm^3$ | Conventional | 0 | 3588 | 39302 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro I | 0 | 3588 | 39302 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro II | 0 | 3588 | 39302 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro III | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke <250 $cm^3$ | Conventional | 2380 | 3588 | 39302 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro I | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro II | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro III | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Conventional | 95306 | 3588 | 39302 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro I | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro II | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro III | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke >750 $cm^3$ | Conventional | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro I | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro II | 0 | 3588 | 39302 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro III | 0 | 3588 | 39302 |

# Appendix C — COPERT Australia input circulation data

| Sector | Subsector | Technology | Avg Speed (km/hr) | | | VKT Share (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Urb. | Rur. | Hwy | Urb. | Rur. | Hwy |
| Passenger Cars | PC-S-petrol | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR27 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-petrol | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR27 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-M-petrol | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR27 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-L-petrol | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-S-diesel | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR30 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR70-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-diesel | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR30 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR70-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-ML-diesel | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |

| Sector | Subsector | Technology | Avg Speed (km/hr) | | | VKT Share (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Urb. | Rur. | Hwy | Urb. | Rur. | Hwy |
| Passenger Cars | PC-ML-diesel | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR27 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR37-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR37-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-S-E10 | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR27 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR37-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR37-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-M-E10 | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR27 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR37-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR37-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-L-E10 | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Passenger Cars | PC-LPG | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR27 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |
| Passenger Cars | PC-LPG | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-C-petrol | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |

| Sector | Subsector | Technology | Avg Speed (km/hr) | | | VKT Share (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Urb. | Rur. | Hwy | Urb. | Rur. | Hwy |
| SUV | SUV-C-petrol | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR00-UNC | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR36 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR37-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR37-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-00 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-01 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-02 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-03 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-04 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-L-petrol | ADR79-05 | 35 | 75 | 100 | 80 | 15 | 5 |
| SUV | SUV-diesel | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR30 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR70-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-diesel | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR37-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR37-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-C-E10 | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR00-UNC | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR36 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR37-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR37-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-00 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-01 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-02 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-03 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-04 | 35 | 75 | 100 | 70 | 25 | 5 |
| SUV | SUV-L-E10 | ADR79-05 | 35 | 75 | 100 | 70 | 25 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR00-UNC | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR36 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR37-00 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR37-01 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-00 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-01 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-02 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-03 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-04 | 35 | 75 | 100 | 75 | 20 | 5 |
| Light Commercial Vehicles | LCV-petrol | ADR79-05 | 35 | 75 | 100 | 75 | 20 | 5 |

| Sector | Subsector | Technology | Avg Speed (km/hr) | | | VKT Share (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Urb. | Rur. | Hwy | Urb. | Rur. | Hwy |
| Light Commercial Vehicles | LCV-diesel | ADR00-UNC | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR30 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR70-00 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-00 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-01 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-02 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-03 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-04 | 35 | 75 | 100 | 65 | 30 | 5 |
| Light Commercial Vehicles | LCV-diesel | ADR79-05 | 35 | 75 | 100 | 65 | 30 | 5 |
| Heavy Duty Trucks | MCV-petrol | ADR00-UNC | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR00-UNC | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR30 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR70-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR80-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR80-02 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR80-03 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR80-04 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | MCV-diesel | ADR80-05 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR00-UNC | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR30 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR70-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR80-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR80-02 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR80-03 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR80-04 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | HCV-diesel | ADR80-05 | 35 | 75 | 90 | 60 | 35 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR00-UNC | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR30 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR70-00 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR80-00 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR80-02 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR80-03 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR80-04 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | AT-diesel | ADR80-05 | 35 | 75 | 90 | 25 | 70 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR30 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR70-00 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-00 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-02 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-03 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-04 | 35 | 75 | 90 | 70 | 25 | 5 |
| Heavy Duty Trucks | Autogas Trucks | ADR80-05 | 35 | 75 | 90 | 70 | 25 | 5 |
| Buses | BUS-L-diesel | ADR00-UNC | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR30 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR70-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR80-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR80-02 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR80-03 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR80-04 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-L-diesel | ADR80-05 | 35 | 75 | 90 | 60 | 35 | 5 |

| Sector | Subsector | Technology | Avg Speed (km/hr) | | | VKT Share (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Urb. | Rur. | Hwy | Urb. | Rur. | Hwy |
| Buses | BUS-H-diesel | ADR00-UNC | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR30 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR70-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR80-00 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR80-02 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR80-03 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR80-04 | 35 | 75 | 90 | 60 | 35 | 5 |
| Buses | BUS-H-diesel | ADR80-05 | 35 | 75 | 90 | 60 | 35 | 5 |
| Mopeds | 2-stroke <50 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 4-stroke <50 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 2-stroke >50 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke <250 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke >750 $cm^3$ | Conventional | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro I | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro II | 35 | 75 | 100 | 70 | 25 | 5 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro III | 35 | 75 | 100 | 70 | 25 | 5 |

# Appendix D — COPERT Australia input evaporation data

Note: The 'Evaporation Share (%)' field is not included on the table below as it is the same for all vehicle classifications – urban 90%, rural 10%, highway 0%.

| Sector | Subsector | Technology | Tank Size (L) | Can. Size (L) | Fuel Inj. (%) | Evap. Control (%) |
|---|---|---|---|---|---|---|
| Passenger Cars | PC-S-petrol | ADR00-UNC | 50 | N/A | 1 | 0 |
| Passenger Cars | PC-S-petrol | ADR27 | 50 | 0.38 | 6 | 97 |
| Passenger Cars | PC-S-petrol | ADR37-00 | 50 | 0.43 | 33 | 97 |
| Passenger Cars | PC-S-petrol | ADR37-01 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-00 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-01 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-02 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-03 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-04 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-petrol | ADR79-05 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR00-UNC | 65 | N/A | 1 | 0 |
| Passenger Cars | PC-M-petrol | ADR27 | 65 | 0.43 | 1 | 97 |
| Passenger Cars | PC-M-petrol | ADR37-00 | 65 | 0.43 | 81 | 97 |
| Passenger Cars | PC-M-petrol | ADR37-01 | 65 | 1.25 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-00 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-01 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-02 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-03 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-04 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-petrol | ADR79-05 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR00-UNC | 70 | N/A | 1 | 0 |
| Passenger Cars | PC-L-petrol | ADR27 | 70 | 0.5 | 8 | 97 |
| Passenger Cars | PC-L-petrol | ADR37-00 | 70 | 0.54 | 90 | 97 |
| Passenger Cars | PC-L-petrol | ADR37-01 | 70 | 1.25 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-00 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-01 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-02 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-03 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-04 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-petrol | ADR79-05 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR00-UNC | 50 | N/A | 1 | 0 |
| Passenger Cars | PC-S-E10 | ADR27 | 50 | 0.38 | 6 | 97 |
| Passenger Cars | PC-S-E10 | ADR37-00 | 50 | 0.43 | 33 | 97 |
| Passenger Cars | PC-S-E10 | ADR37-01 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-00 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-01 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-02 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-03 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-04 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-S-E10 | ADR79-05 | 50 | 1 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR00-UNC | 65 | N/A | 1 | 0 |
| Passenger Cars | PC-M-E10 | ADR27 | 65 | 0.43 | 1 | 97 |
| Passenger Cars | PC-M-E10 | ADR37-00 | 65 | 0.43 | 81 | 97 |
| Passenger Cars | PC-M-E10 | ADR37-01 | 65 | 1.25 | 100 | 97 |

| Sector | Subsector | Technology | Tank Size (L) | Can. Size (L) | Fuel Inj. (%) | Evap. Control (%) |
|---|---|---|---|---|---|---|
| Passenger Cars | PC-M-E10 | ADR79-00 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR79-01 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR79-02 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR79-03 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR79-04 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-M-E10 | ADR79-05 | 65 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR00-UNC | 70 | N/A | 1 | 0 |
| Passenger Cars | PC-L-E10 | ADR27 | 70 | 0.5 | 8 | 97 |
| Passenger Cars | PC-L-E10 | ADR37-00 | 70 | 0.54 | 90 | 97 |
| Passenger Cars | PC-L-E10 | ADR37-01 | 70 | 1.25 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-00 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-01 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-02 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-03 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-04 | 70 | 2 | 100 | 97 |
| Passenger Cars | PC-L-E10 | ADR79-05 | 70 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR00-UNC | 65 | N/A | 1 | 0 |
| SUV | SUV-C-petrol | ADR37-00 | 65 | 0.77 | 100 | 97 |
| SUV | SUV-C-petrol | ADR37-01 | 65 | 1.25 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-00 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-01 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-02 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-03 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-04 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-petrol | ADR79-05 | 65 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR00-UNC | 75 | N/A | 1 | 0 |
| SUV | SUV-L-petrol | ADR36 | 75 | 0.77 | 100 | 97 |
| SUV | SUV-L-petrol | ADR37-00 | 75 | 0.77 | 100 | 97 |
| SUV | SUV-L-petrol | ADR37-01 | 75 | 1.25 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-00 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-01 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-02 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-03 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-04 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-petrol | ADR79-05 | 75 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR00-UNC | 65 | N/A | 1 | 0 |
| SUV | SUV-C-E10 | ADR37-00 | 65 | 0.77 | 100 | 97 |
| SUV | SUV-C-E10 | ADR37-01 | 65 | 1.25 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-00 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-01 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-02 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-03 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-04 | 65 | 2 | 100 | 97 |
| SUV | SUV-C-E10 | ADR79-05 | 65 | 2 | 100 | 97 |
| SUV | SUV-L-E10 | ADR00-UNC | 75 | N/A | 1 | 0 |
| SUV | SUV-L-E10 | ADR36 | 75 | 0.77 | 100 | 97 |
| SUV | SUV-L-E10 | ADR37-00 | 75 | 0.77 | 100 | 97 |
| SUV | SUV-L-E10 | ADR37-01 | 75 | 1.25 | 100 | 97 |
| SUV | SUV-L-E10 | ADR79-00 | 75 | 2 | 100 | 97 |

| Sector | Subsector | Technology | Tank Size (L) | Can. Size (L) | Fuel Inj. (%) | Evap. Control (%) |
|---|---|---|---|---|---|---|
| SUV | SUV-L-E10 | ADR79-01 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-E10 | ADR79-02 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-E10 | ADR79-03 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-E10 | ADR79-04 | 75 | 2 | 100 | 97 |
| SUV | SUV-L-E10 | ADR79-05 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR00-UNC | 75 | N/A | 1 | 0 |
| Light Commercial Vehicles | LCV-petrol | ADR36 | 75 | 0.77 | 88 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR37-00 | 75 | 0.77 | 95 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR37-01 | 75 | 1.25 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-00 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-01 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-02 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-03 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-04 | 75 | 2 | 100 | 97 |
| Light Commercial Vehicles | LCV-petrol | ADR79-05 | 75 | 2 | 100 | 97 |
| Mopeds | 2-stroke <50 $cm^3$ | Conventional | 5 | N/A | 0 | 0 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro I | 5 | N/A | 0 | 0 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro II | 5 | N/A | 0 | 0 |
| Mopeds | 2-stroke <50 $cm^3$ | Mop - Euro III | 5 | N/A | 0 | 0 |
| Mopeds | 4-stroke <50 $cm^3$ | Conventional | 5 | N/A | 0 | 0 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro I | 5 | N/A | 0 | 0 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro II | 5 | N/A | 0 | 0 |
| Mopeds | 4-stroke <50 $cm^3$ | Mop - Euro III | 5 | N/A | 0 | 0 |
| Motorcycles | 2-stroke >50 $cm^3$ | Conventional | 8 | N/A | 0 | 0 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro I | 8 | N/A | 0 | 0 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro II | 8 | N/A | 80 | 0 |
| Motorcycles | 2-stroke >50 $cm^3$ | Mot - Euro III | 8 | 0.5 | 100 | 10 |
| Motorcycles | 4-stroke <250 $cm^3$ | Conventional | 10 | N/A | 0 | 0 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro I | 10 | N/A | 0 | 0 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro II | 10 | N/A | 80 | 0 |
| Motorcycles | 4-stroke <250 $cm^3$ | Mot - Euro III | 10 | 0.5 | 100 | 10 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Conventional | 18 | N/A | 0 | 0 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro I | 18 | N/A | 0 | 0 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro II | 18 | N/A | 80 | 0 |
| Motorcycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro III | 18 | 0.5 | 100 | 10 |
| Motorcycles | 4-stroke >750 $cm^3$ | Conventional | 20 | 0.5 | 0 | 0 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro I | 20 | 0.5 | 0 | 0 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro II | 20 | 0.5 | 80 | 0 |
| Motorcycles | 4-stroke >750 $cm^3$ | Mot - Euro III | 20 | 0.5 | 100 | 10 |

# Appendix E — COPERT Australia fuel quality parameters

*Table 16 – Fuel specifications*

| | ULP | PULP | Diesel | Autogas | CNG | Biodiesel | Bioethanol |
|---|---|---|---|---|---|---|---|
| Sulfur (%wt) | 0.00661 | 0.00305 | 0.00072 | 0.01 | 0.01 | 0.00072 | 0 |
| Lead (g/L) | 0.00125 | 0.00125 | $4.37 \times 10^{-5}$ | $1.71 \times 10^{-5}$ | $5.06 \times 10^{-6}$ | $4.58 \times 10^{-5}$ | $2.62 \times 10^{-5}$ |
| H:C ratio | 1.92 | 1.89 | 1.86 | 2.525 | 3.9 | 1.94 | 3 |
| O:C ratio | 0 | 0.016 | 0.005 | 0 | 0 | 0.11 | 0.5 |
| Cadmium (mg/kg) | 0.0108 | 0.0108 | 0.0087 | 0.0106 | 0.0106 | 0.0087 | 0.0108 |
| Copper (mg/kg) | 0.0418 | 0.0418 | 0.0212 | 0.0373 | 0.0373 | 0.0212 | 0.0418 |
| Chromium (mg/kg) | 0.0159 | 0.0159 | 0.03 | 0.0093 | 0.0093 | 0.03 | 0.0159 |
| Nickel (mg/kg) | 0.013 | 0.013 | 0.0088 | 0.0107 | 0.0107 | 0.0088 | 0.013 |
| Selenium (mg/kg) | 0.0002 | 0.0002 | 0.0001 | 0 | 0 | 0.0001 | 0.0002 |
| Zinc (mg/kg) | 2.164 | 2.164 | 1.738 | 2.13 | 2.13 | 1.738 | 2.164 |

Note that while CNG, Biodiesel and Bioethanol fuel quality data was input to the COPERT model, these fuels were not included in the study.

# Appendix F — Toxic equivalency potential score

*Table 17 – NPI substance TEP rating*

| Substance | Non-cancer risk score (TEP)[1] |
|---|---|
| Acetaldehyde | 9.3 |
| Acetic acid (ethanoic acid) | N/A |
| Acetone | 0.05 |
| Acetonitrile | 30 |
| Acrolein | 1,600 |
| Acrylamide | 2,000 |
| Acrylic acid | 62 |
| Acrylonitrile (2-propenenitrile) | 38 |
| Ammonia (total) | 3.8 |
| Aniline (benzenamine) | 91 |
| Antimony and compounds | 8,100 |
| Arsenic and compounds | 84,000 |
| Benzene | 8.1 |
| Benzene hexachloro- (HCB) | 21,000 |
| Beryllium and compounds | 24,000 |
| Biphenyl (1,1-biphenyl) | 0.98 |
| Boron and compounds | N/A |
| Butadiene (vinyl ethylene) | 2.2 |
| Cadmium and compounds | 1,900,000 |
| Carbon disulfide | 1.2 |
| Carbon monoxide | 0.14 |
| Chlorine and compounds | N/A |
| Chlorine dioxide | N/A |
| Chloroethane (ethyl chloride) | 0.02 |
| Chloroform (trichloromethane) | 14 |
| Chlorophenols (di, tri, tetra) | 51 |
| Chromium (III) compounds | N/A |
| Chromium (VI) compounds | 3,100 |
| Cobalt and compounds | 31,000 |
| Copper and compounds | 13,000 |

| Substance | Non-cancer risk score (TEP)[1] |
|---|---|
| Cumene (1-methylethylbenzene) | 0.41 |
| Cyanide (inorganic) compounds | 580 |
| Cyclohexane | 0.02 |
| Dibromoethane | 1,500 |
| Dibutyl phthalate | 11 |
| Dichloroethane | 4.2 |
| Dichloromethane | 7 |
| Ethanol | N/A |
| Ethoxyethanol | N/A |
| Ethoxyethanol acetate | N/A |
| Ethyl acetate | 0.09 |
| Ethyl butyl ketone | N/A |
| Ethylbenzene | 0.14 |
| Ethylene glycol (1,2-ethanediol) | 0.25 |
| Ethylene oxide | 56 |
| Di-(2-Ethylhexyl) phthalate (DEHP) | 33 |
| Fluoride compounds | 3.6 |
| Formaldehyde (methyl aldehyde) | 16 |
| Glutaraldehyde | N/A |
| Hexane | N/A |
| Hydrochloric acid | 12 |
| Hydrogen sulfide | 34 |
| Lead and compounds | 580,000 |
| Magnesium oxide fume | N/A |
| Manganese and compounds | 780 |
| Mercury and compounds | 5,000,000 |
| Methanol | 0.09 |
| Methoxyethanol | N/A |
| Methoxyethanol acetate | N/A |
| Methyl ethyl ketone | 0.05 |
| Methyl isobutyl ketone | 0.03 |
| Methyl methacrylate | 0.53 |
| Methylene-bis(2-chloroaniline) (MOCA) | N/A |

| Substance | Non-cancer risk score (TEP)[1] |
|---|---|
| Methylene bis (phenylisocyanate) | N/A |
| Nickel and compounds | 3,200 |
| Nickel carbonyl | N/A |
| Nickel subsulfide | N/A |
| Nitric acid | 2.1 |
| Organo-tin compounds | N/A |
| Oxides of nitrogen | 2.2 |
| Particulate matter ≤ 2.5 µm | 17 |
| Particulate matter ≤ 10 µm | 1.5 |
| Phenol | 0.38 |
| Phosphoric acid | 16 |
| Polychlorinated biphenyls | 2,000,000 |
| Polychlorinated dioxins and furans (TEQ) | 880,000,000,000 |
| Polycyclic aromatic hydrocarbons (B[a]Peq) | N/A |
| Selenium and compounds | 2,400 |
| Styrene (ethenylbenzene) | 0.08 |
| Sulfur dioxide | 3.1 |
| Sulfuric acid | N/A |
| Tetrachloroethane | 56 |
| Tetrachloroethylene | 65 |
| Toluene (methylbenzene) | 1 |
| Toluene-2,4-diisocyanate | N/A |
| Total nitrogen | N/A |
| Total phosphorus | N/A |
| Total volatile organic compounds | 1 |
| Trichloroethane | 4.9 |
| Trichloroethylene | 0.63 |
| Vinyl chloride monomer | 69 |
| Xylenes (individual or mixed isomers) | 0.27 |
| Zinc and compounds | 190 |

[1] based on toluene equivalent

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