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

Perth Air Emissions Study 2011–2012

Summary of emissions



Report

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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.

Disclaimer

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Summary

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

This report summarises the estimated emissions from five main emission groups:

- biogenic and geogenic;
- domestic;
- commercial and industrial;
- on-road vehicles; and
- off-road mobile emissions.

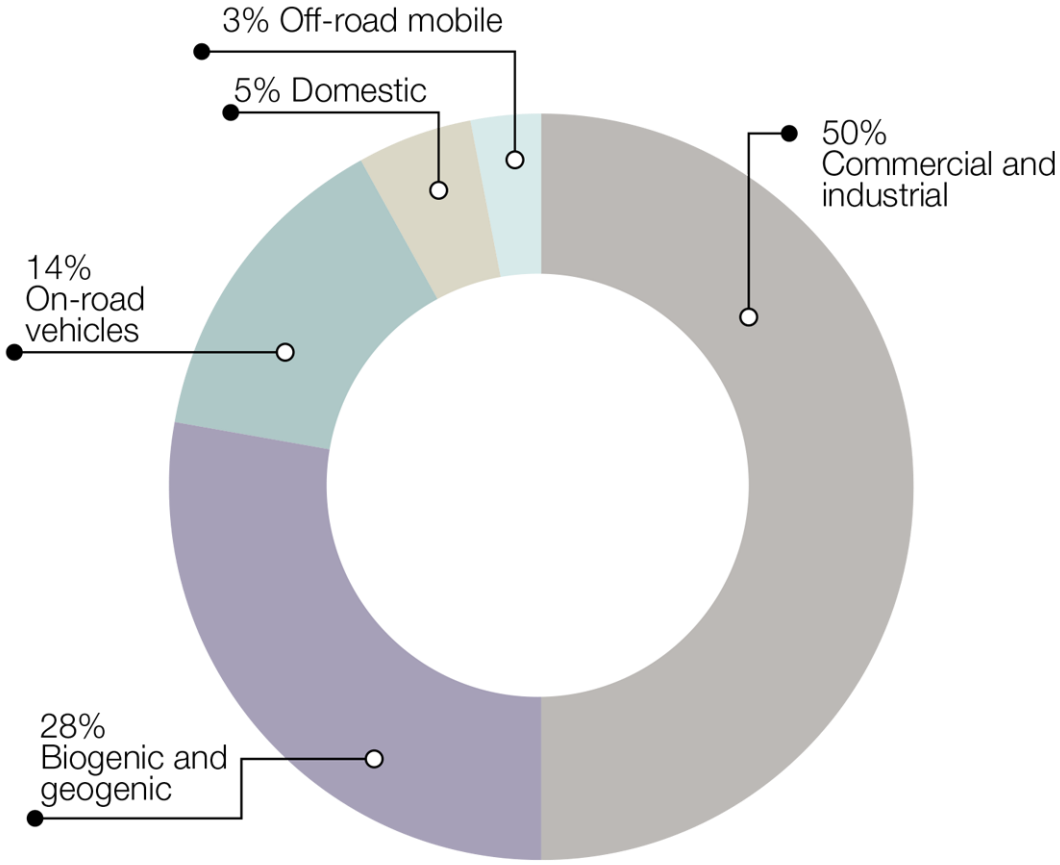
Emissions were estimated using the methodology published in the *2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in New South Wales* (NSW EPA 2012). Methodologies were adapted to address the availability of local data and, in some cases, were superseded by more relevant or recently developed methods. Emissions were spatially allocated based on the activity data available for each emission source.

The estimation methods and results for each emission group are summarised in individual technical reports, available on the DWER website <www.dwer.wa.gov.au>.

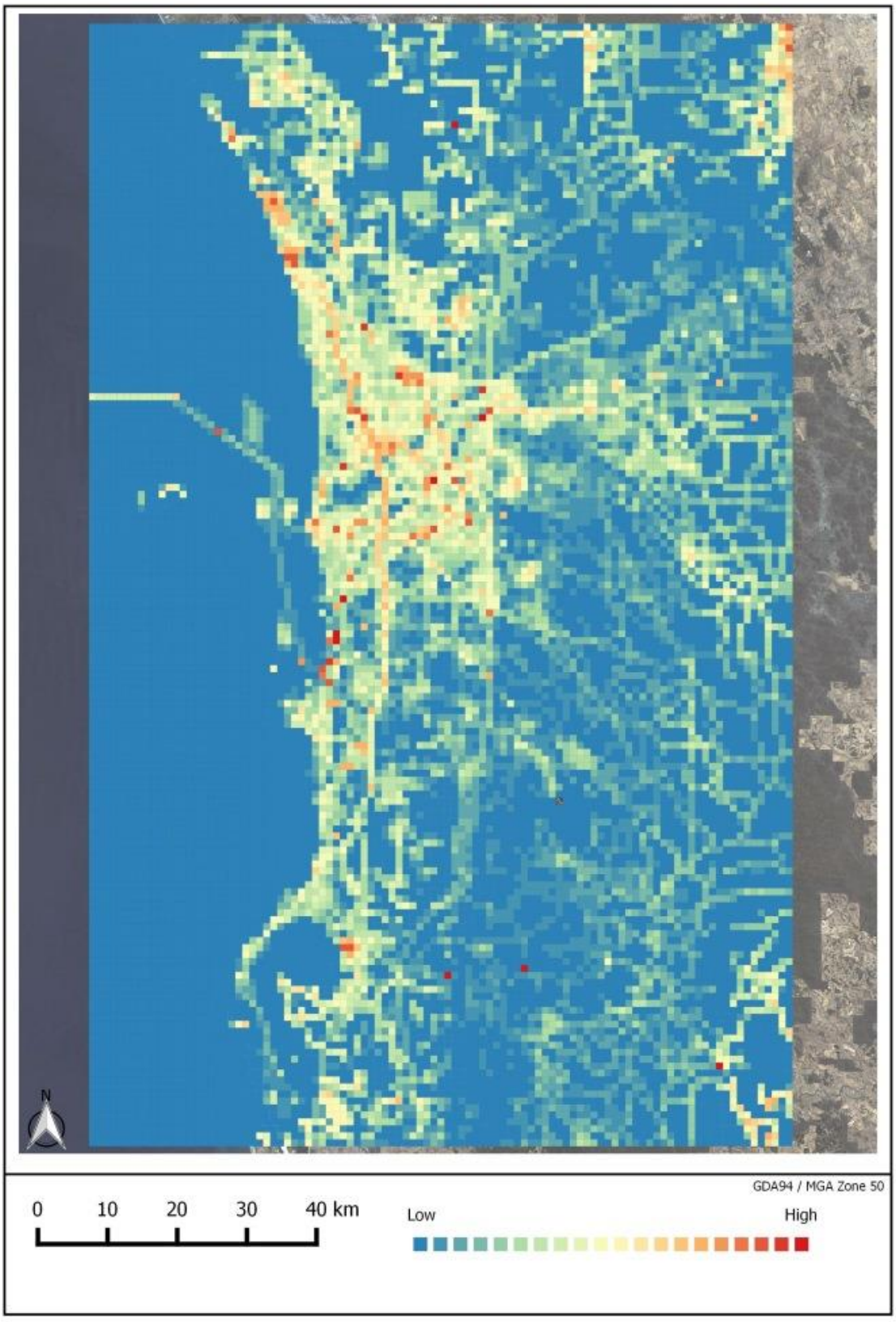
Based on a toxic equivalency potential (TEP) score, emission estimates from all sources for 2011–12 showed that particulate matter ≤ 2.5 µm ($PM_{2.5}$) emissions were the most significant of the pollutants listed in the National Environment Protection (Ambient Air Quality) Measure. Emission estimates of metals such as lead and mercury (speciated from particulate emissions) and polychlorinated dioxins and furans (TEQ) were comparatively small, but were the highest-risk pollutants due to their high toxicity.

Summary figures 1 and 2 show the relative contribution from all emission sources to the overall TEP score and the spatial allocation of the TEP score. Commercial and industrial sources made the largest contribution and represented 50 per cent of the emission risk.

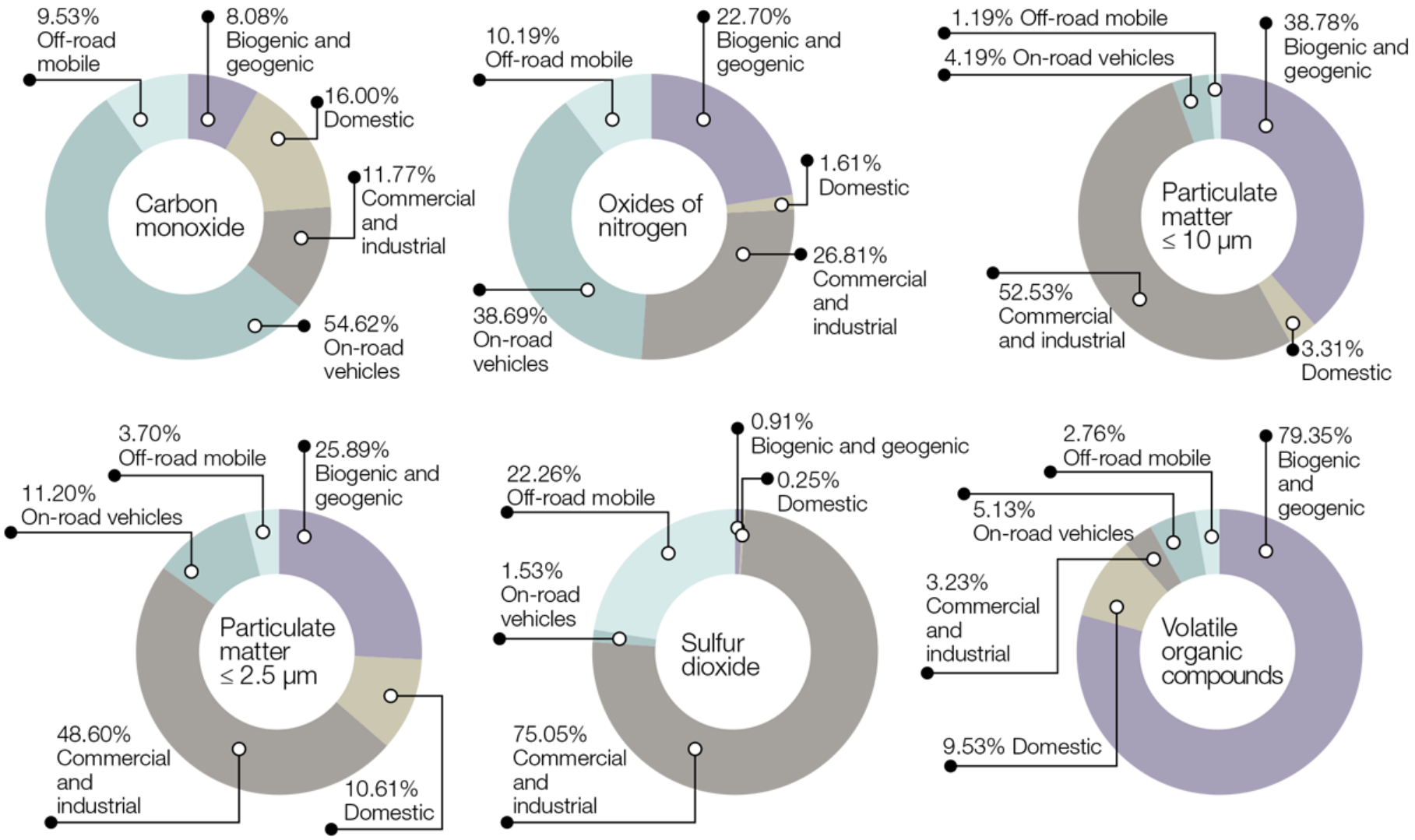
The relative contributions of all emission sources to key pollutants are presented in Summary figure 3. On-road vehicles were the main source of carbon monoxide (CO) and oxides of nitrogen (NO_x). Commercial and industrial activities were the main source of particulate matter ≤ 10 µm (PM_{10}) and $PM_{2.5}$ and sulfur dioxide (SO_2). Vegetation was the largest source of total volatile organic compounds (VOC).



Summary figure 1 – Relative TEP contributions from all sources



Summary figure 2 – Spatial allocation of TEP score



Summary figure 3 – Emission estimates: source contributions by mass

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 collated emission estimates for all sources, using information from the five technical reports listed below.

This technical report collates the emission estimates for all sources. It is one of six reports prepared for the Perth Air Emissions Study 2011–2012:

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 in 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 in Figure 2.

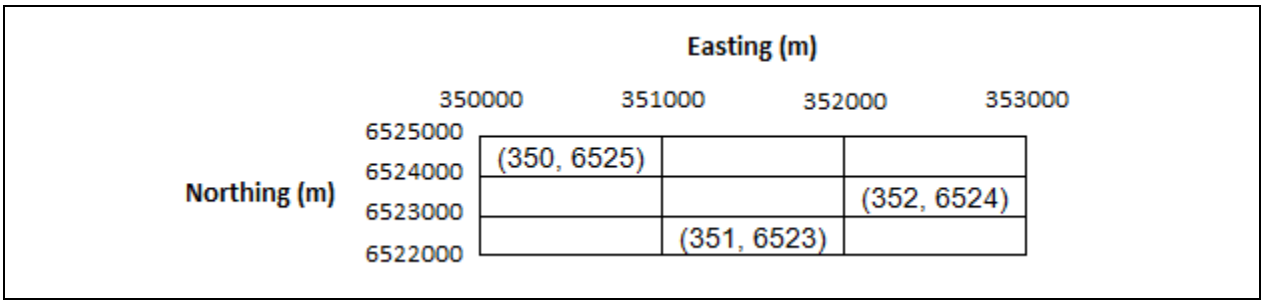


Figure 2 – Grid coordinate system

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 emissions inventory method had two discrete stages: the estimation of emissions, and the spatial allocation of those emissions. Activity and spatial data were sourced from government departments and industry organisations.

Most emission estimation techniques were based on methodologies published by the following agencies and programs:

- California Air Resources Board;
- European Environment Agency;
- National Pollutant Inventory (NPI);
- New South Wales Environment Protection Authority; and
- United States Environmental Protection Agency.

Other techniques included the use of modelling software packages, and recent academic studies for quantifying emissions from specific emission sources.

More detailed information about the specific methodology used for the biogenic and geogenic, domestic, commercial and industrial, on-road vehicles and off-road mobile sources can be found in the individual technical reports published on the DWER website <www.dwer.wa.gov.au>.

3 Results

Emission estimates and spatial allocation for key substances are presented for the following sources:

- biogenic and geogenic emissions, including vegetation, soils, fires, wind erosion and marine aerosol (i.e. natural emissions);
- domestic emissions, including residential lawn mowing, portable fuel containers and wood heaters;
- commercial and industrial emissions;
- on-road vehicle emissions, including registered buses, cars and trucks; and
- off-road mobile emissions, including shipping, boating, locomotives and aircraft.

3.1 Carbon monoxide

Total emissions

Total estimated annual emissions of CO by source type are presented in Table 2. On-road vehicles were the largest source of CO emissions. The relative contributions of emission sources for CO are summarised in Figure 4.

Table 2 – Total estimated CO emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
On-road vehicles	87,778	54.62
Domestic	25,707	16.00
Commercial and industrial	18,920	11.77
Off-road mobile	15,323	9.53
Biogenic and geogenic	12,986	8.08
Grand total	**160,714**	**100.00**

Activity emissions

A pareto[1] analysis identifying major CO emission sources is presented in Figure 3. A complete breakdown of CO emissions by activity is provided in Table 12.

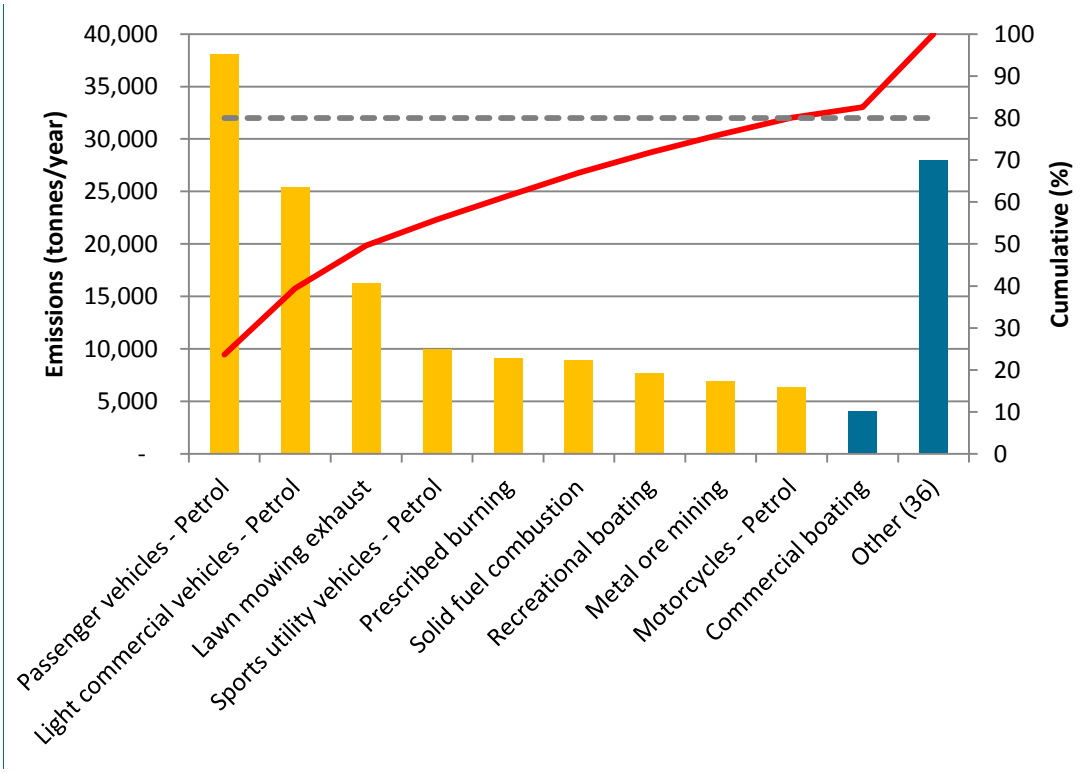


Figure 3 – Pareto analysis of CO emission sources

1 Pareto analysis is a prioritisation technique that identifies the most significant items among many. It employs the 80-20 rule that assumes 20 per cent of causes determine 80 per cent of problems.

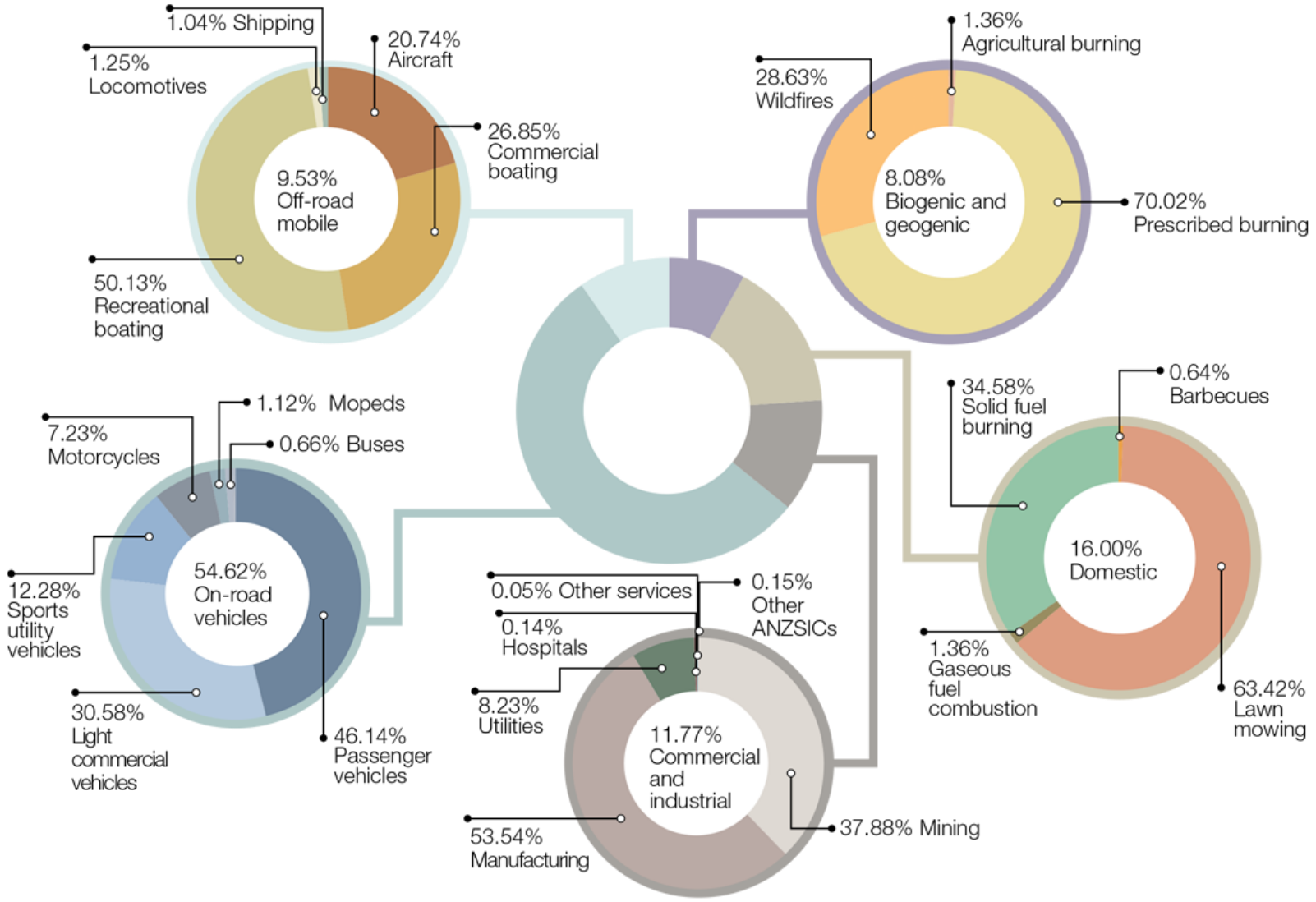


Figure 4 – Source contributions for CO

Spatial allocation

The spatial allocation of CO emissions is presented in Figure 5. CO emissions are concentrated along major roads, with the Mitchell and Kwinana freeways and Tonkin and Roe highways clearly visible. Concentrated emissions from industrial facilities in the Kwinana Industrial Area and mining operations in the south are also visible.

Key findings

- On-road vehicles were the largest source of CO emissions (55 per cent of total emissions). Petrol passenger and petrol light commercial vehicles produced more than 72 per cent of on-road vehicle CO emissions.
- Domestic emission sources produced more CO emissions than commercial and industrial sources. Lawn mowing was the most significant domestic source, with solid fuel burning from wood heaters also a significant source.
- Bushfires and prescribed burning produce CO emissions. While not as significant as other sources, when fires do occur, emissions are concentrated in relatively small areas and are produced rapidly.

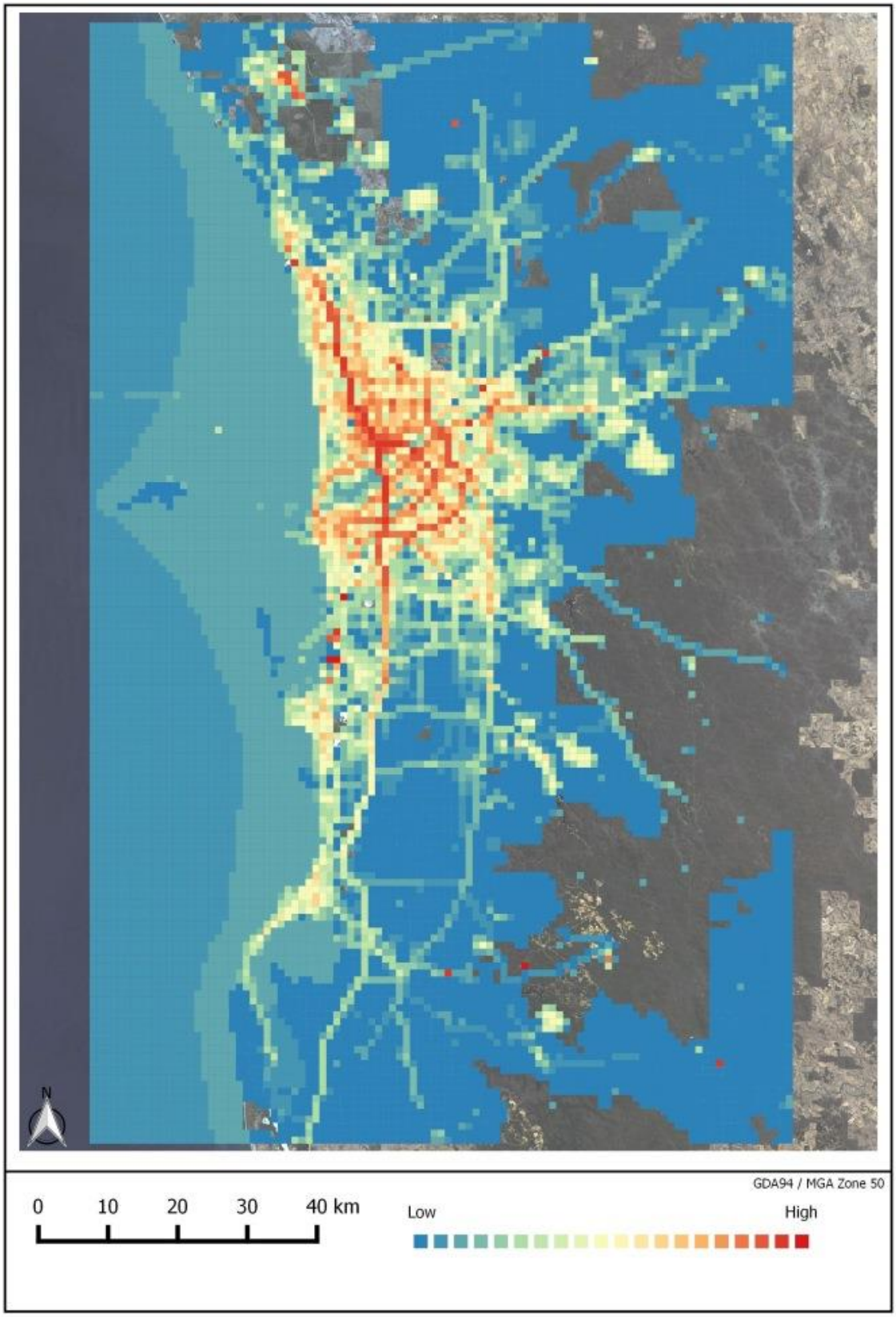


Figure 5 – Spatial allocation of CO emissions

3.2 Oxides of nitrogen

Total emissions

Total estimated annual emissions of NO_X by source type are presented in Table 3. On-road vehicles were the largest source of NO_X emissions. The relative contributions of emission sources for NO_X are summarised in Figure 7.

Table 3 – Total estimated NOx emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
On-road vehicles	25,919	38.69
Commercial and industrial	17,957	26.81
Biogenic and geogenic	15,208	22.70
Off-road mobile	6,826	10.19
Domestic	1,079	1.61
Grand total	**66,990**	**100.00**

Activity emissions

A pareto analysis identifying major NO_X emission sources is presented in Figure 6. A complete breakdown of NO_X emissions by activity is provided in Table 13.

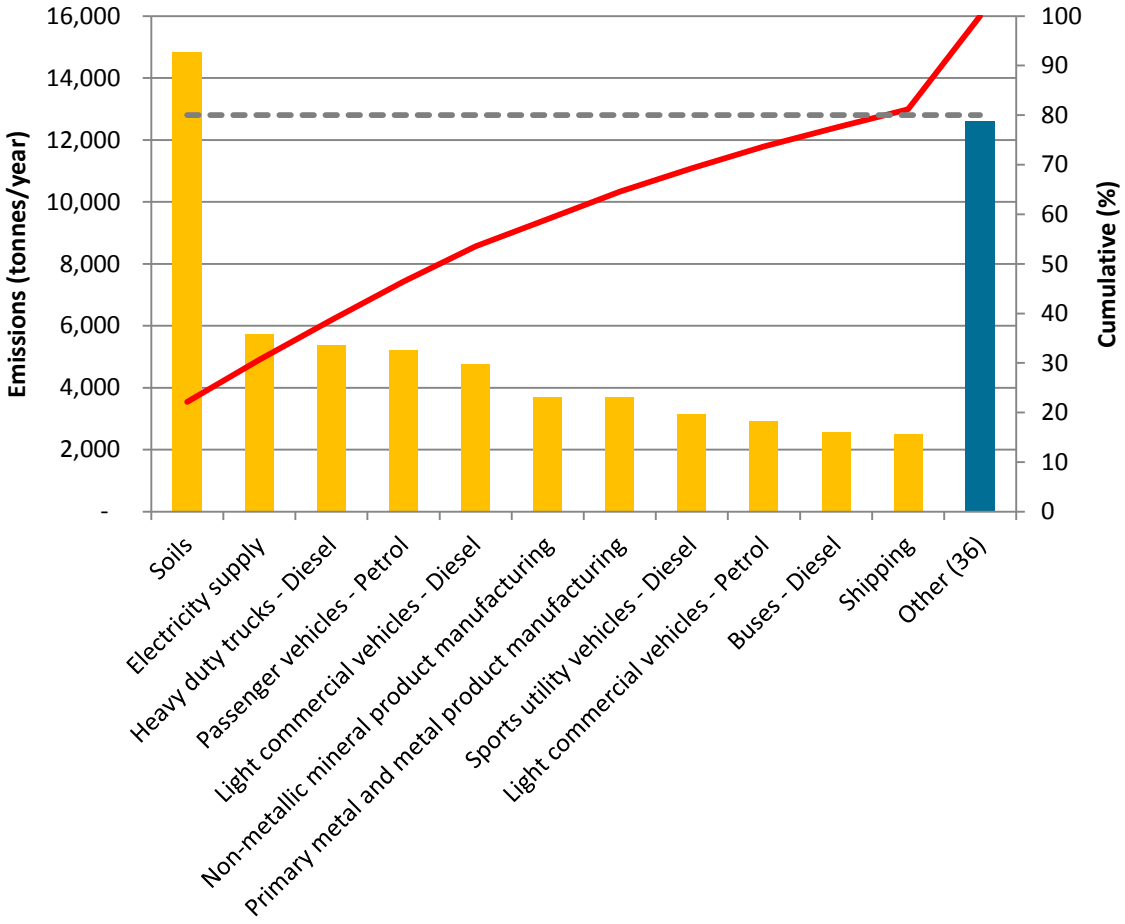


Figure 6 – Pareto analysis of NOx emission sources

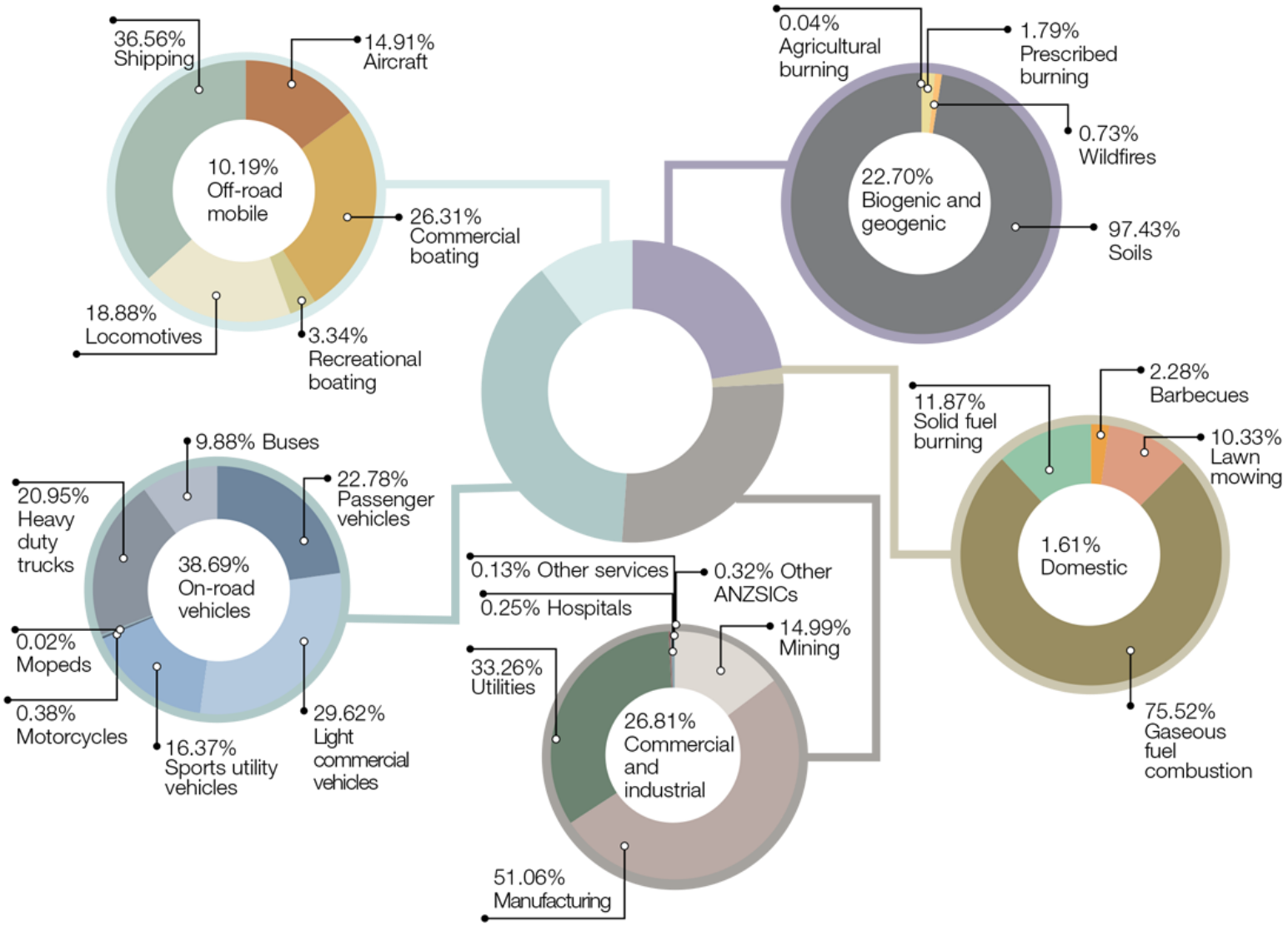


Figure 7 – Source contributions for NO_x

Spatial allocation

The spatial allocation of NO_X emissions is presented in Figure 8. NO_X emissions are concentrated in the Kwinana Industrial Area and mining operations in the south. Emissions are also concentrated along major roads and Fremantle port shipping lanes. Soil emissions can be seen stretching from the north and north-east through to the south.

Key findings

- On-road vehicles were the largest source of NO_X emissions. Diesel vehicles were the primary source of vehicle NO_X, with heavy duty and light commercial vehicles making the largest contribution. Because commercial traffic is more likely to use major transport routes, NO_X emissions from vehicles were more concentrated on major roads and less spread out over Perth compared with other vehicle emissions like carbon monoxide or particles.
- Commercial and industrial emissions of NO_X were entirely from fuel combustion. Power stations, metal manufacturing and non-metallic mineral processing industries were notable sources due to their large fuel consumption.
- Soils are the second-largest source (compared with total vehicle emissions) of NO_X in Perth. The level of NO_X emissions from soils depends mostly on land use, with grassland and agricultural soils producing substantially more NO_X than forest or urban soils.

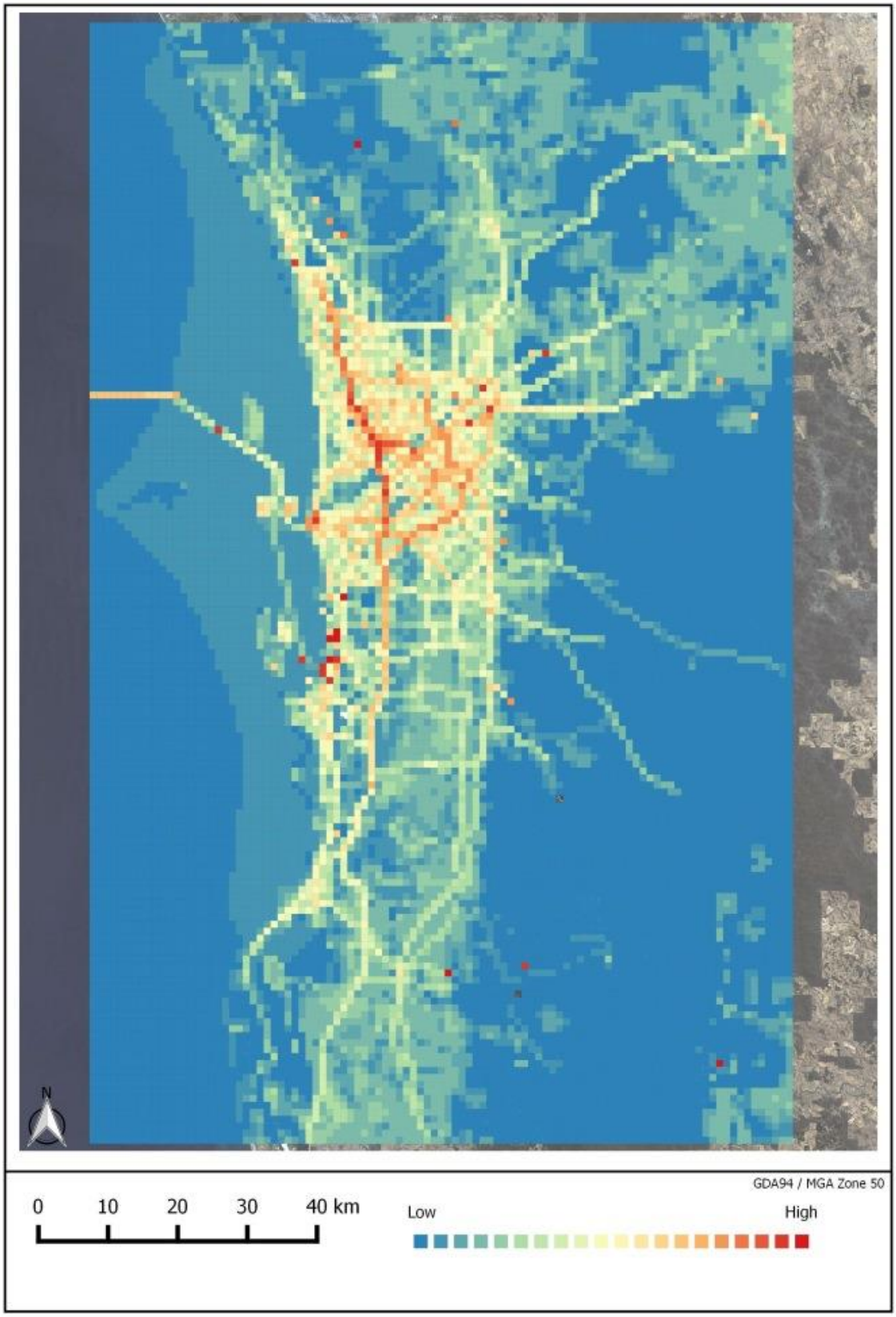


Figure 8 – Spatial allocation of NOx emissions

3.3 Particulate matter ≤ 10 µm

Total emissions

Total estimated annual emissions of PM_{10} by source type are presented in Table 4. Commercial and industrial facilities were the largest source of PM_{10} emissions. The relative contributions of emission sources for PM_{10} are summarised in Figure 10.

Table 4 – Total estimated PM_{10} emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
Commercial and industrial	22,140	52.53
Biogenic and geogenic	16,345	38.78
On-road vehicles	1,768	4.19
Domestic	1,395	3.31
Off-road mobile	502	1.19
Grand total	**42,150**	**100.00**

Activity emissions

A pareto analysis identifying major PM_{10} emission sources is presented in Figure 9. A complete breakdown of PM_{10} emissions by activity is provided in Table 14.

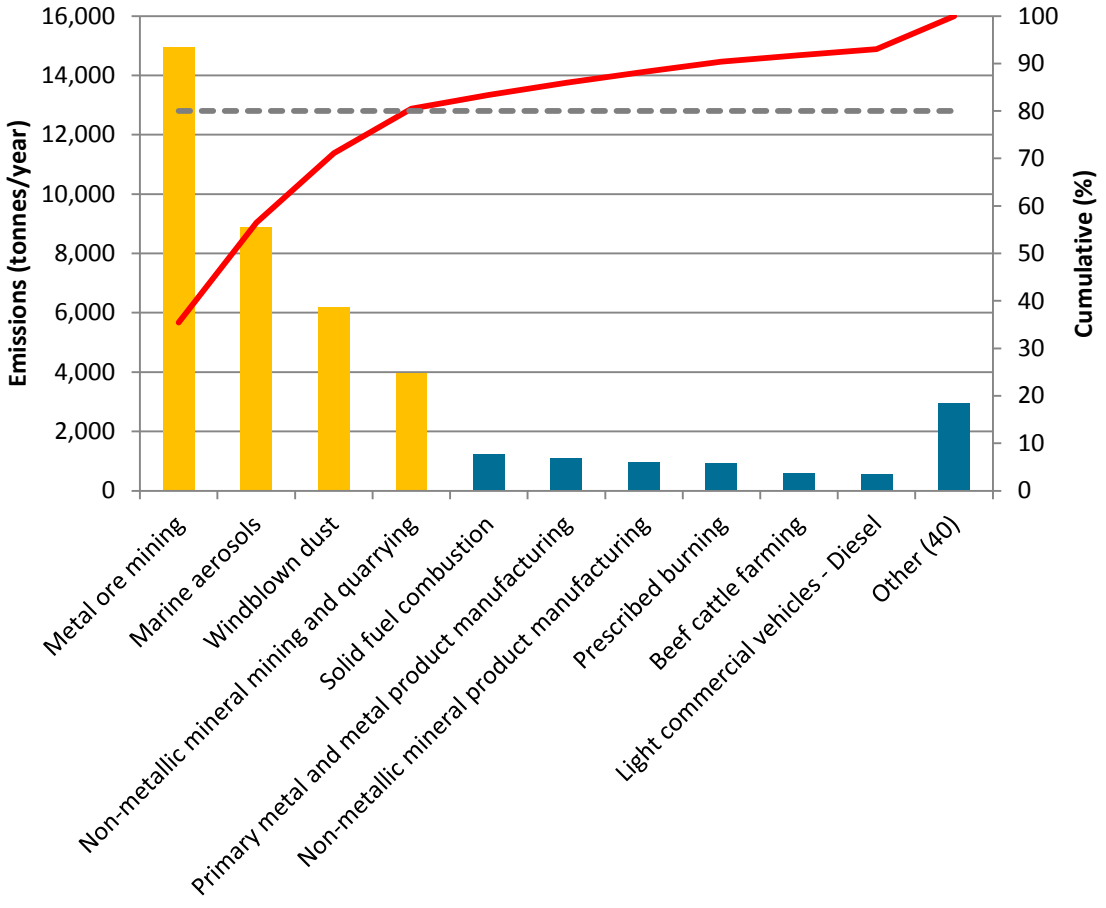


Figure 9 – Pareto analysis of PM_{10} emission sources

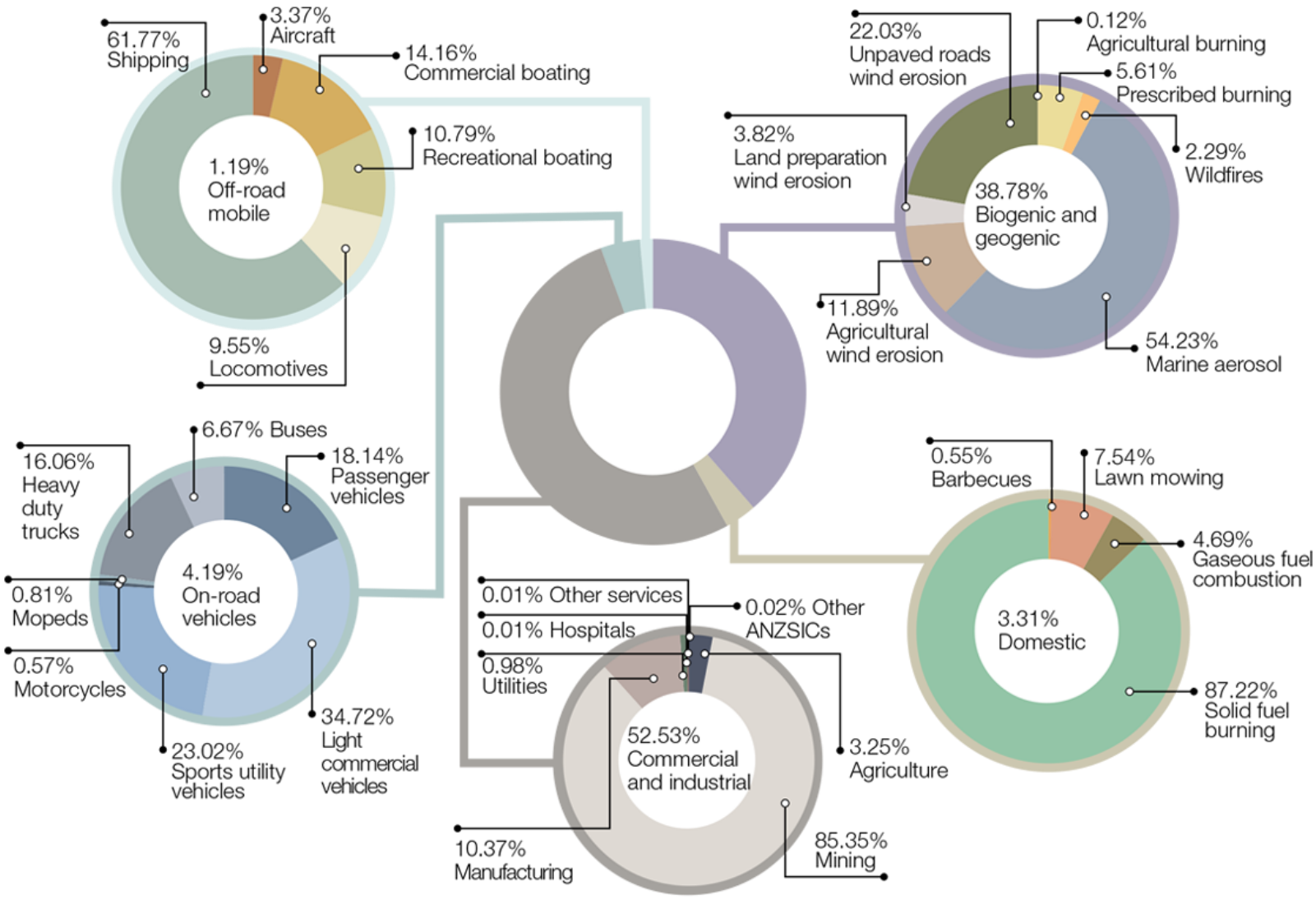


Figure 10 – Source contributions for PM_{10}

Spatial allocation

The spatial allocation of PM_{10} emissions is presented in Figure 11. PM_{10} emissions are concentrated in the Kwinana Industrial Area and mining operations in the south. Emissions from wind are also concentrated in agricultural areas and those cleared for urban development.

Key findings

- Commercial and industrial activities produce more PM_{10} than all other sources in Perth, though it is confined to bauxite mining and processing in the south and quarries on the edges of significant urban developments.
- Marine aerosol was the largest non-industrial source of PM_{10} for Perth. Marine aerosol is often described as the 'wind erosion of the sea'. Sea spray is picked up by wind, generating fine particles that are dispersed into the atmosphere. Marine aerosol mostly affects coastal areas.
- Wind erosion from unpaved roads and cleared areas were significant sources of PM_{10}. Unpaved roads exist all over Perth, producing low-level emissions. Cleared open areas, mostly associated with agricultural areas and land cleared for urban development, were major emission sources.

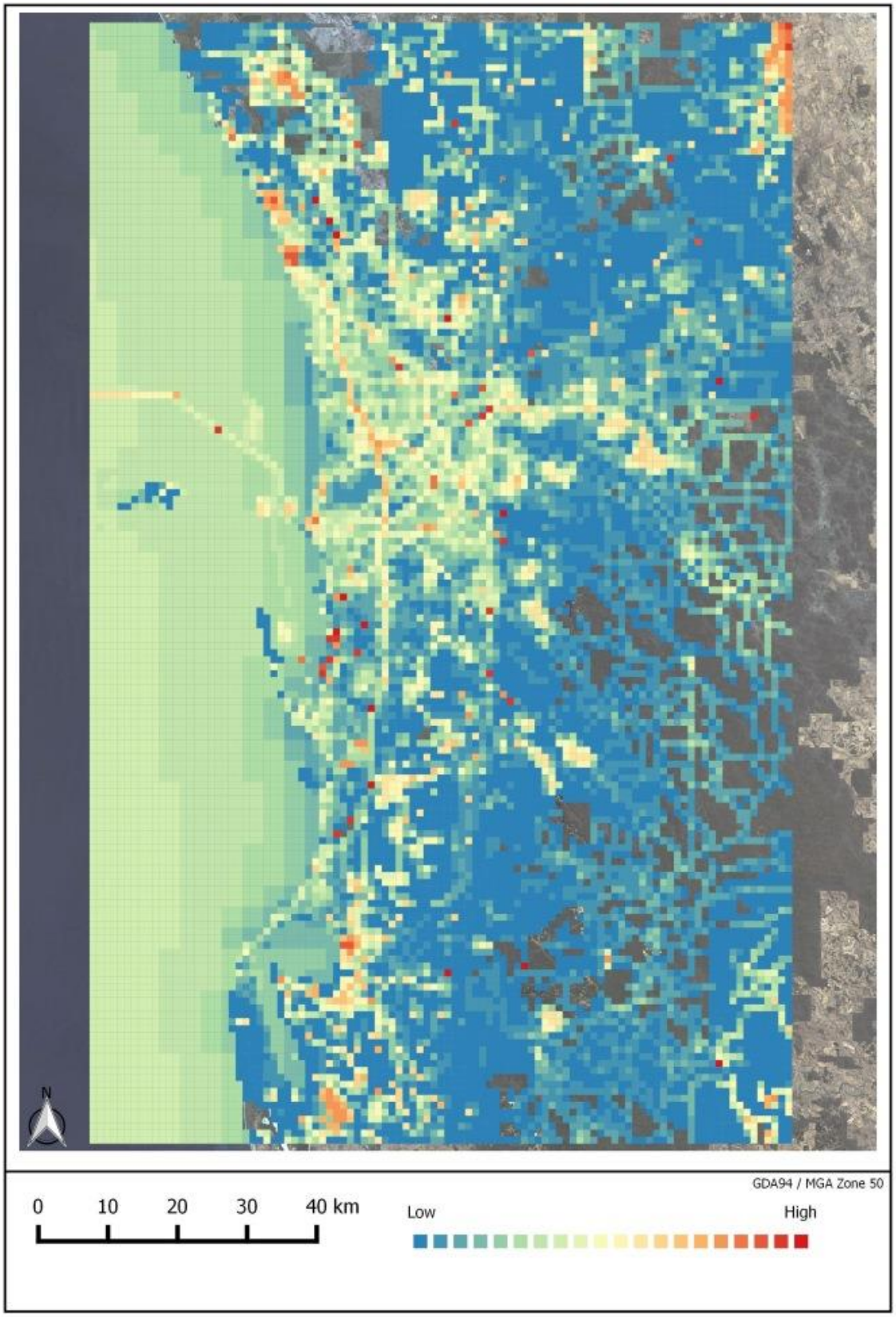


Figure 11 – Spatial allocation of PM_{10} emissions

3.4 Particulate matter ≤ 2.5 µm

Total emissions

Total estimated annual emissions of $PM_{2.5}$ by source type are presented in Table 5. Commercial and industrial facilities were the largest source of $PM_{2.5}$ emissions. The relative contributions of emission sources for $PM_{2.5}$ are summarised in Figure 13.

Table 5 – Total estimated $PM_{2.5}$ emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
Commercial and industrial	6,142	48.60
Biogenic and geogenic	3,271	25.89
On-road vehicles	1,416	11.20
Domestic	1,340	10.61
Off-road mobile	467	3.70
Grand total	**12,636**	**100.00**

Activity emissions

A pareto analysis identifying major $PM_{2.5}$ emission sources is presented in Figure 12. A complete breakdown of $PM_{2.5}$ emissions by activity is provided in Table 15.

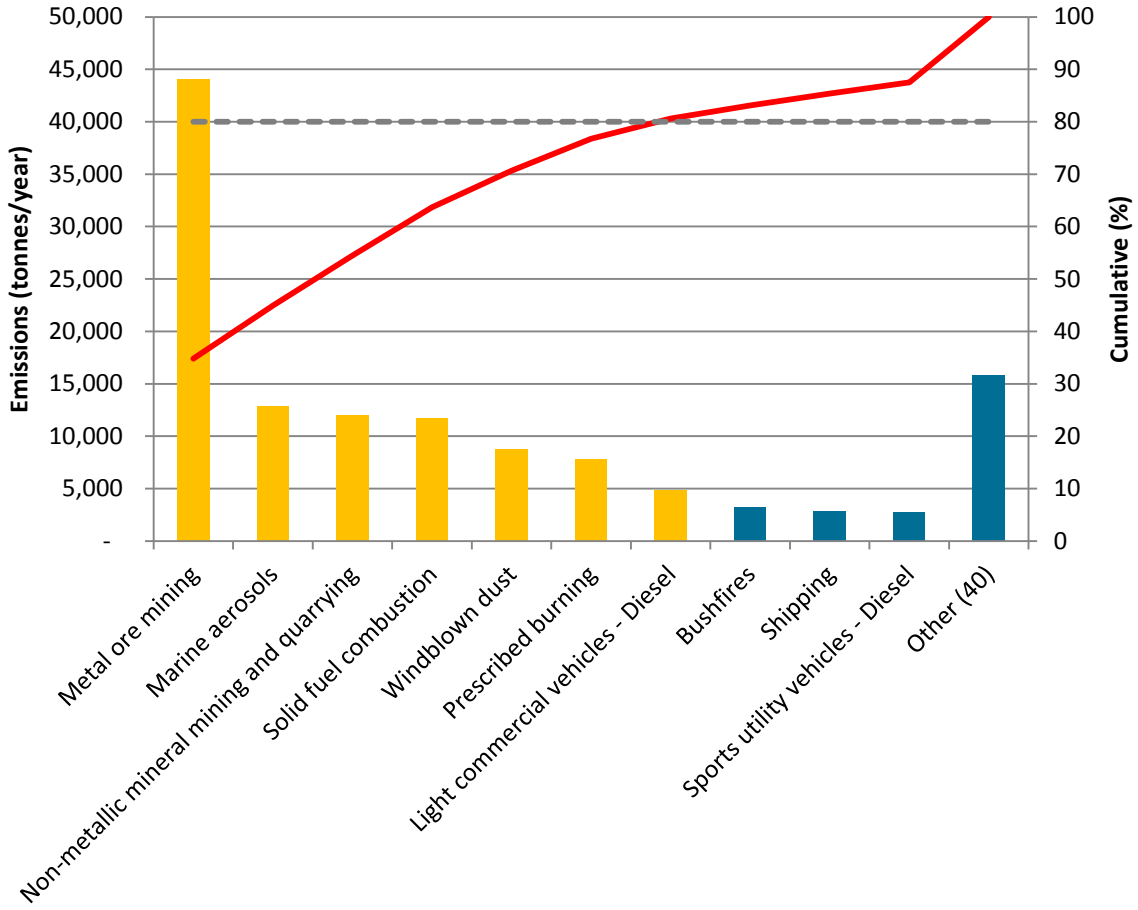


Figure 12 – Pareto analysis of $PM_{2.5}$ emission sources

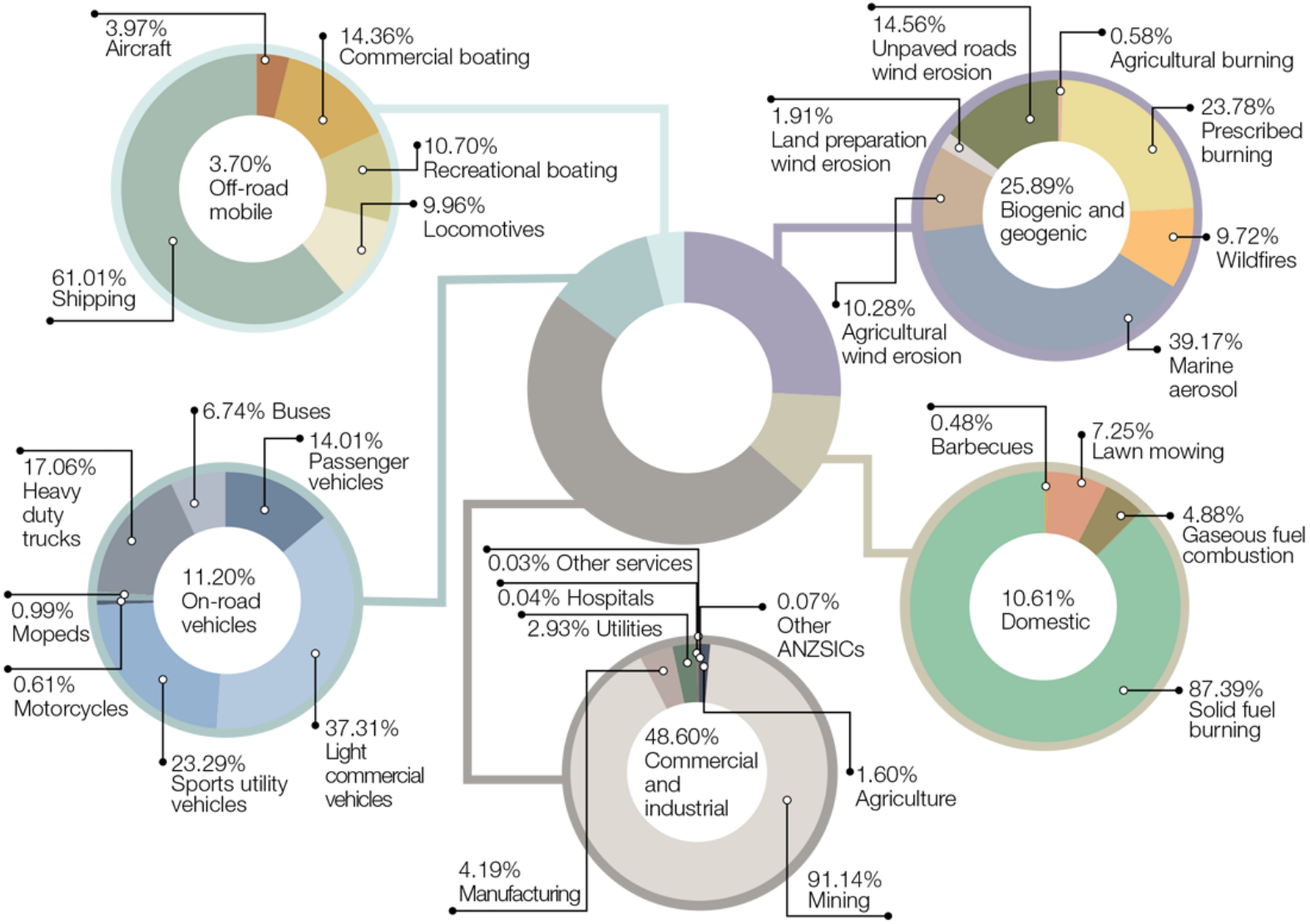


Figure 13 – Source contributions for $PM_{2.5}$

Spatial allocation

The spatial allocation of $PM_{2.5}$ emissions is presented in Figure 14. $PM_{2.5}$ emissions are concentrated in the Kwinana Industrial Area and mining operations in the south. Emissions are also concentrated along major roads and shipping lanes for Fremantle port. Bushfires and emissions from prescribed burning are also visible.

Key findings

- Commercial and industrial activities produced more $PM_{2.5}$ than all other sources in Perth, though it is confined to bauxite mining and processing in the south and quarries on the edges of significant urban developments.
- On-road vehicles were a major source of $PM_{2.5}$. Light commercial and heavy duty diesel vehicles produced more than half of all on-road vehicle $PM_{2.5}$ emissions.
- While still a significant source of particles, the marine aerosol contribution to total $PM_{2.5}$ was much less compared with total PM_{10}. This was also observed for wind erosion sources.
- Wood smoke from domestic wood heaters was a significant source. In the Perth Hills, where wood heater use is more common, it was the largest contributor of $PM_{2.5}$.
- Bushfires and prescribed burning produce $PM_{2.5}$ emissions. While not as significant as other sources, when fires do occur, the emissions are concentrated in relatively small areas and are produced rapidly.

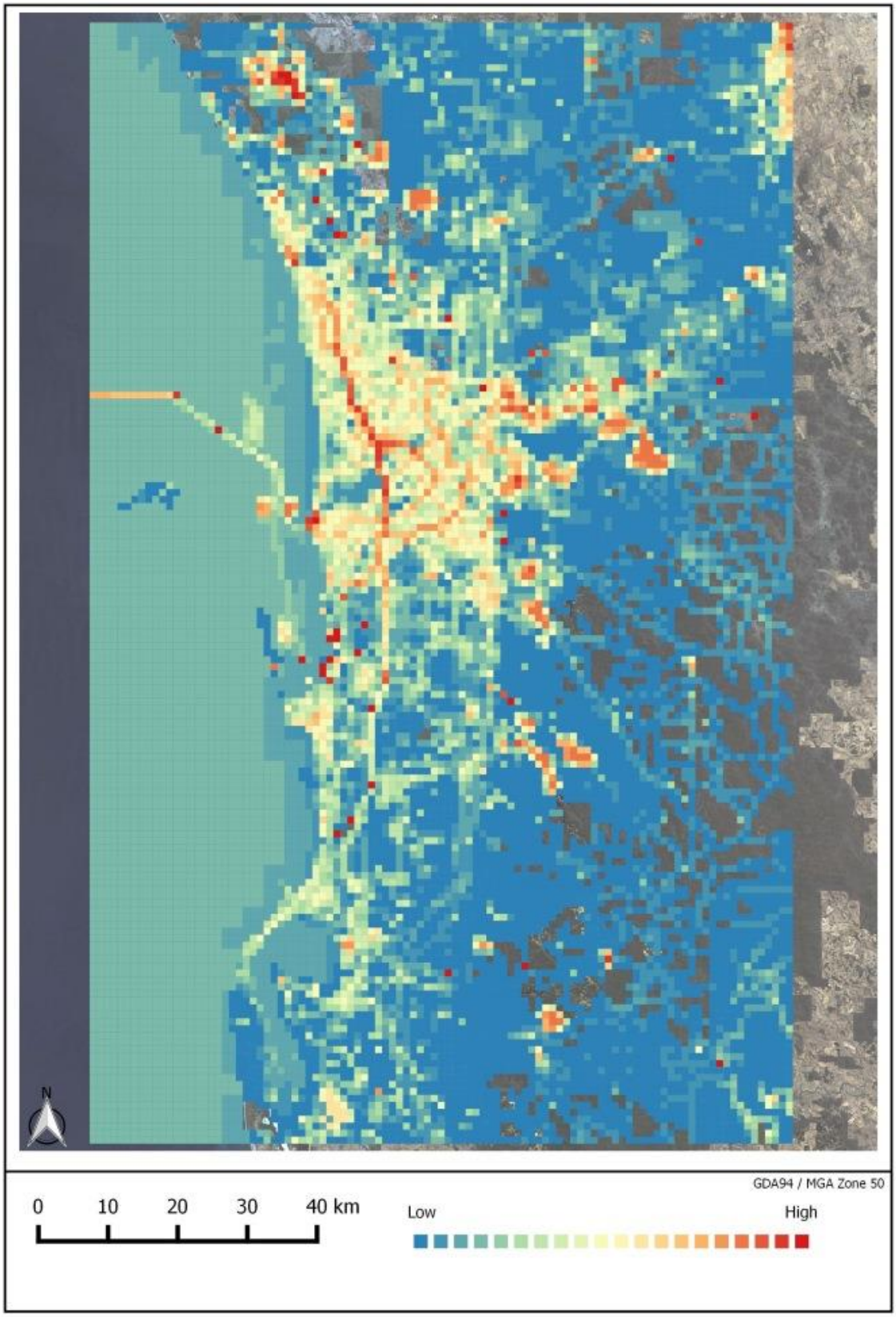


Figure 14 – Spatial allocation of $PM_{2.5}$ emissions

3.5 Sulfur dioxide

Total emissions

Total estimated annual emissions of SO_2 by source type are presented in Table 6. Commercial and industrial facilities were the largest source of SO_2 emissions. The relative contributions of emission sources for SO_2 are summarised in Figure 16.

Table 6 – Total estimated SO_2 emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
Commercial and industrial	9,948	75.05
Off-road mobile	2,950	22.26
On-road vehicles	203	1.53
Biogenic and geogenic	120	0.91
Domestic	34	0.25
Grand total	**13,255**	**100.00**

Activity emissions

A pareto analysis identifying major SO_2 emission sources is presented in Figure 15. A complete breakdown of SO_2 emissions by activity is provided in Table 16.

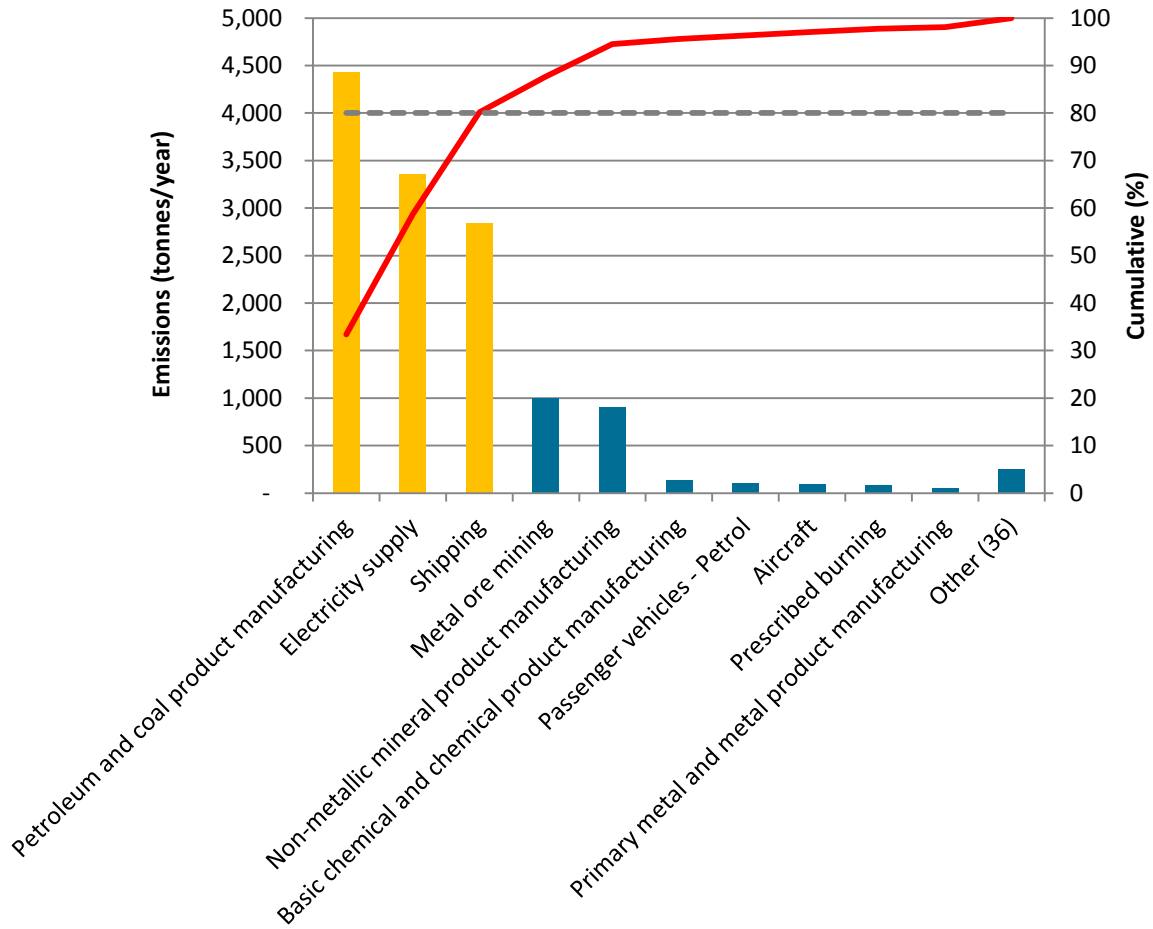


Figure 15 – Pareto analysis of SO_2 emission sources

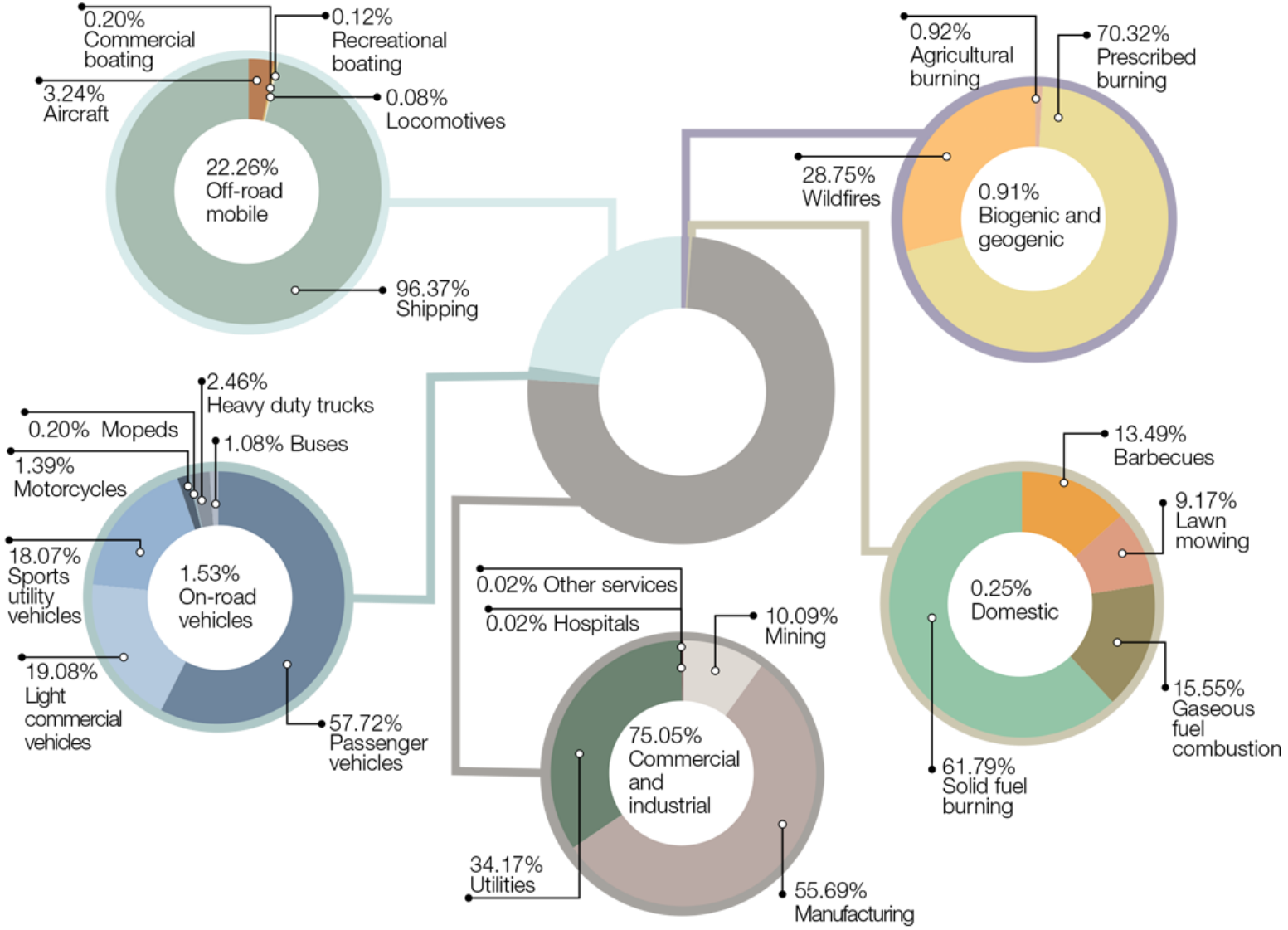


Figure 16 – Source contributions for SO_2

Spatial allocation

The spatial allocation of SO_2 emissions is presented in Figure 17. SO_2 emissions are concentrated around several industrial facilities in the Kwinana Industrial Area and along Fremantle port's shipping lanes. Aircraft take-off and landing routes are also visible.

Key findings

- Commercial and industrial facilities were the largest source of SO_2 emissions. Two industrial facilities, BP Refinery and Kwinana Power Station, contributed more than 50 per cent of total SO_2 emissions.
- Shipping was a significant source of SO_2 due to the use of high sulfur content fuel.
- Significant emissions of SO_2 were concentrated in heavy industrial areas and shipping operations. Vehicles produced much lower SO_2 emissions that were more dispersed throughout Perth.

Figure 17 – Spatial allocation of SO_2 emissions

3.6 Total volatile organic compounds

Total emissions

Total estimated annual emissions of VOC by source type are presented in Table 7. Vegetation was the largest source of VOC emissions. The relative contributions of emission sources for VOC are summarised in Figure 19.

Table 7 – Total estimated VOC emissions by source

Source	Emissions (tonnes/year)	Proportion (%)
Biogenic and geogenic	168,504	79.35
Domestic	20,238	9.53
On-road vehicles	10,897	5.13
Commercial and industrial	6,864	3.23
Off-road mobile	5,861	2.76
Grand total	**212,364**	**100.00**

Activity emissions

A pareto analysis identifying major VOC emission sources is presented in Figure 18. A complete breakdown of VOC emissions by activity is provided in Table 17.

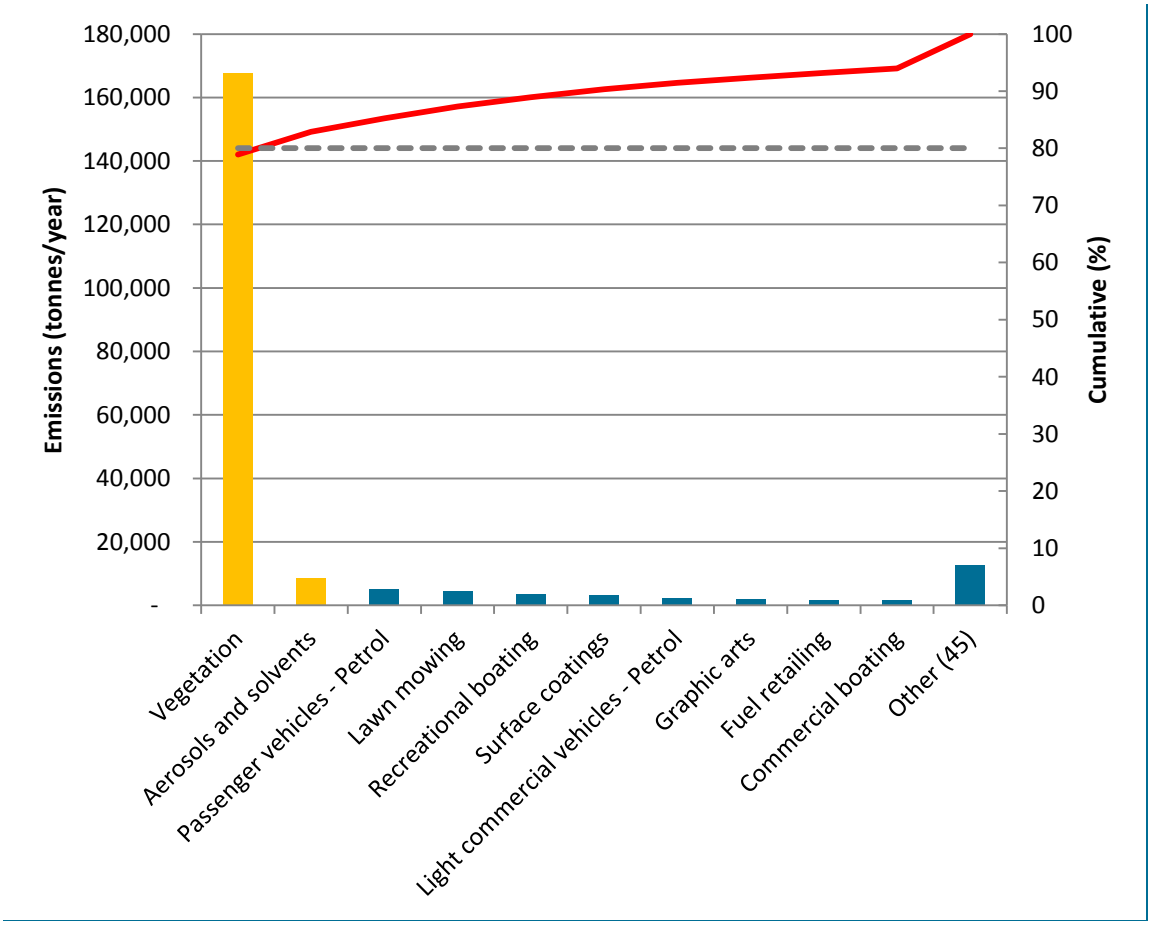


Figure 18 – Pareto analysis of VOC emission sources

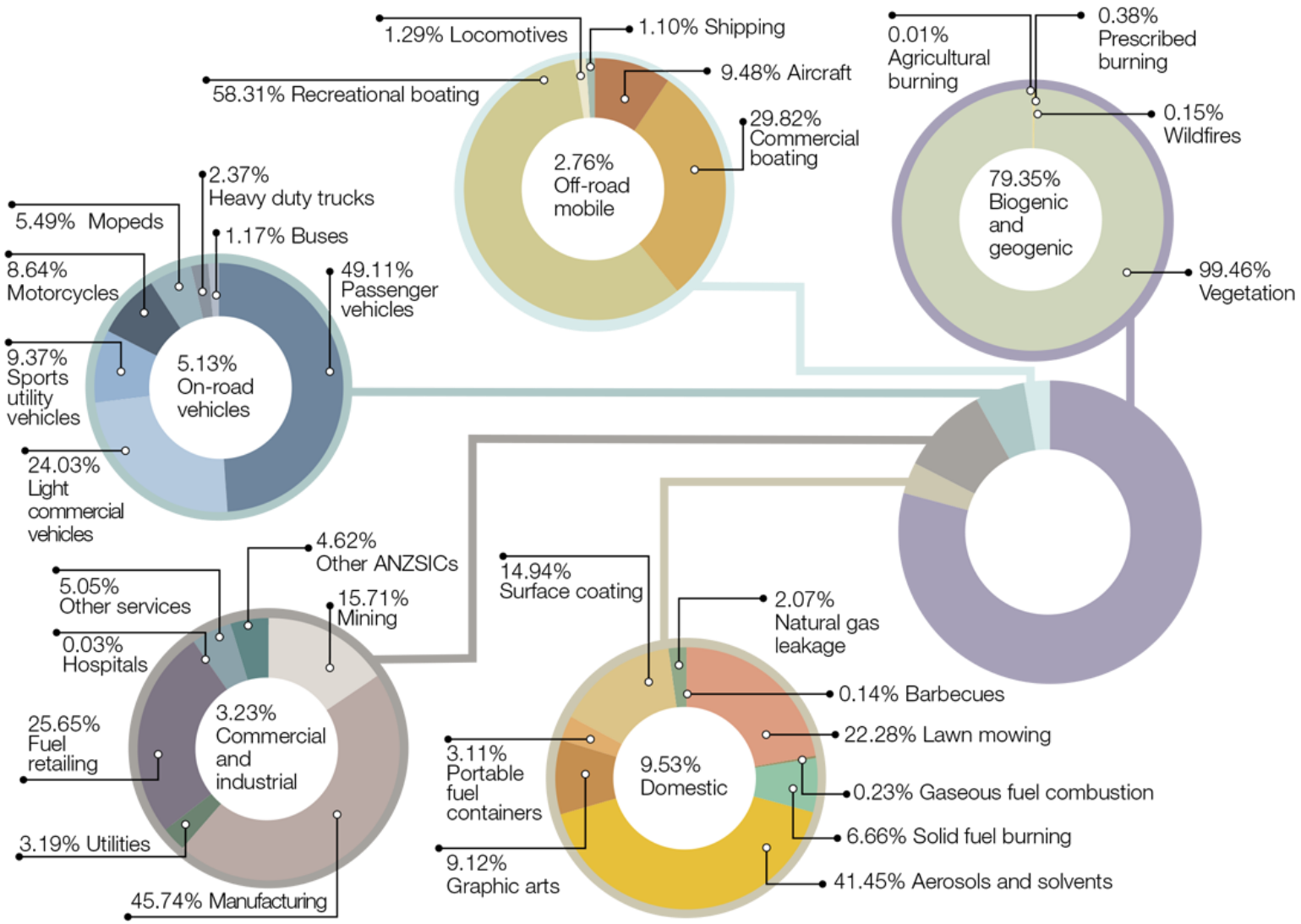


Figure 19 – Source contributions for VOC

Spatial allocation

The spatial allocation of VOC emissions is presented in Figure 20. VOC emissions are concentrated in urbanised areas of Perth and the Kwinana Industrial Area, which contains several industrial facilities that are major sources of VOC. Vegetation VOC emissions can be seen as the large areas to the north, north-east and east of Perth.

Key findings

- Vegetation was the largest source of VOC emissions. Most vegetation emissions occurred to the east and north of Perth away from heavily urbanised areas.
- Domestic use of aerosols and solvents was a major VOC source in Perth. While not as large as vegetation emissions, domestic VOC emissions were more concentrated in areas with greater population and dwelling density.
- On-road vehicles were also a significant source of VOC, with petrol vehicles producing significantly more than diesel vehicles. The largest source of VOCs from on-road vehicles were from petrol passenger cars, with evaporation of fuel from the tank and fuel lines making up nearly half the on-road vehicle VOCs emitted.

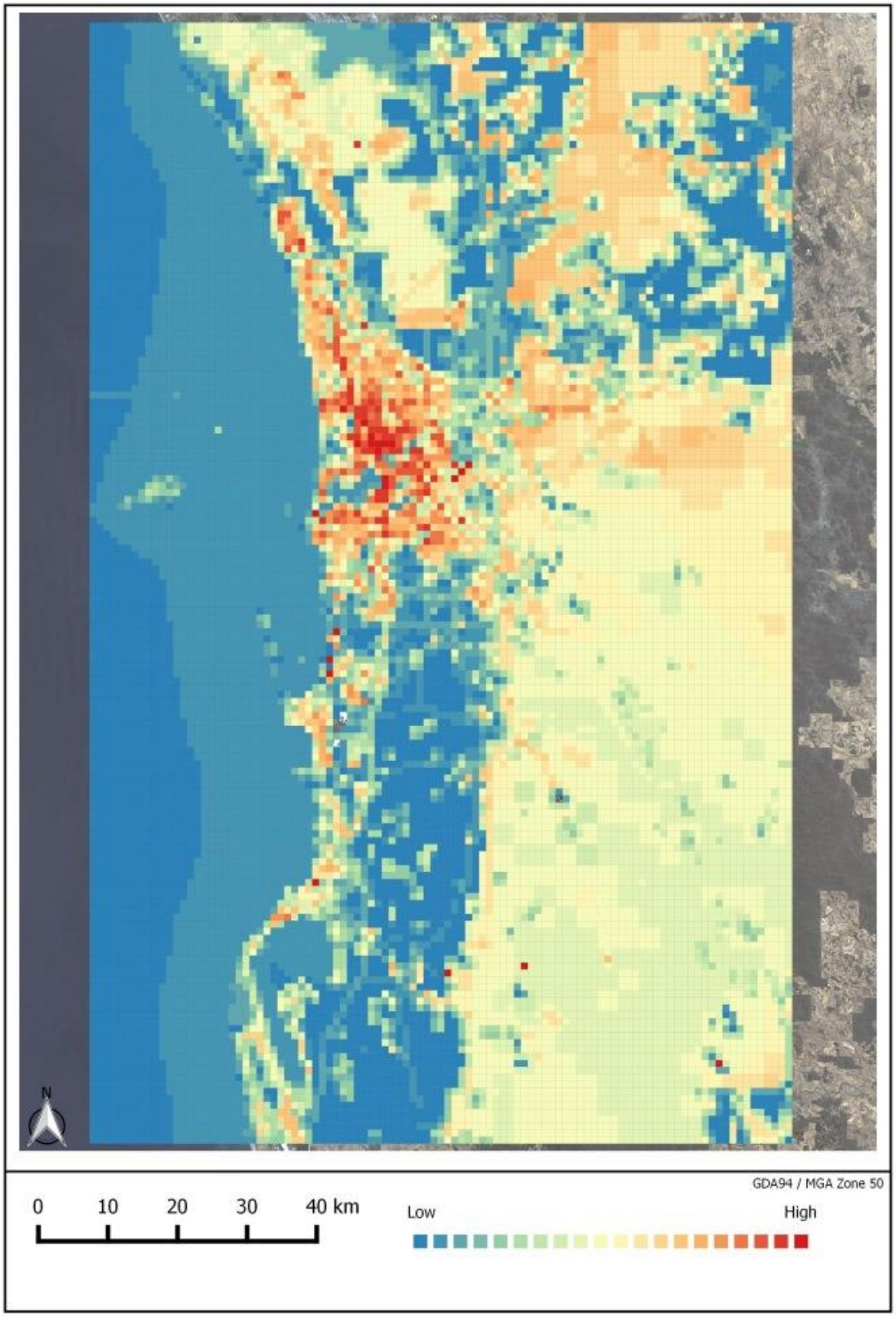


Figure 20 – Spatial allocation of VOC emissions

4 Total emissions risk

This section presents cumulative and comparative emission estimates for all sources.

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)[2].

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 is included in Table 11 in Appendix A.

4.1 Total emissions

Emission estimates and TEP scores for all sources are presented in Table 8. Total emissions from each source are presented in Table 9. TEP scores for each activity are presented in Table 10.

Table 8 – Total emission estimates and TEP score

Substance	Emissions (tonnes/year)	Toxic equivalency potential (TEP) score
Key pollutants		
Particulate matter ≤ 2.5 µm	12,634	214,787
Total volatile organic compounds	212,317	212,340
Oxides of nitrogen	66,987	147,373
Particulate matter ≤ 10 µm	42,150	63,226
Sulfur dioxide	13,254	41,089
Carbon monoxide	160,622	22,500
Other significant pollutants		
Lead and compounds	11.8	6,840,103
Mercury and compounds	1.23	6,129,013
Polychlorinated dioxins and furans (TEQ)	0.0000038	3,377,548
Cadmium and compounds	1.07	2,029,919
Copper and compounds	36.1	469,474

[2] 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

Substance	Emissions (tonnes/year)	Toxic equivalency potential (TEP) score
Arsenic and compounds	1.97	165,259
Chromium (total)	32.0	99,209
Acrolein	50.5	80,831
Cyanide (inorganic) compounds	134	77,461
Cobalt and compounds	2.41	74,805
Nickel and compounds	12.0	38,420
Manganese and compounds	43.8	34,132
Ammonia (total)	8,434	32,051
Total		
Substances not listed here		50,099
All substances		20,199,639

The relative contribution from emission sources to the overall TEP is presented in Figure 21.

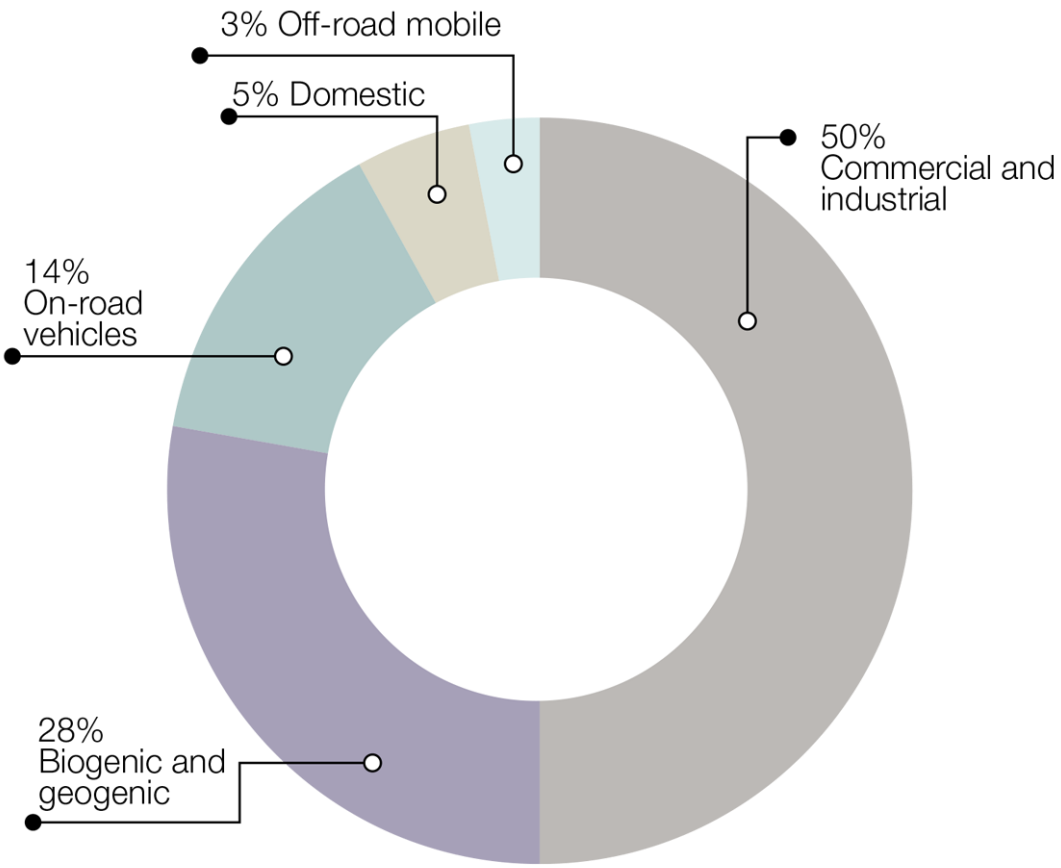


Figure 21 – TEP source contributions

Emissions of $PM_{2.5}$ and VOCs represented the highest risk from the key pollutants. Emissions of heavy metals including lead and mercury were substantially smaller

compared with key pollutant emissions, but represented a greater risk due to their high toxicity.

Commercial and industrial activities dominated the emissions risk profile – contributing 50 per cent of total emission risk. Primary metal and metal product manufacturing was the largest single-source contributor to emission risk due to large emissions of mercury and polychlorinated dioxins and furans (TEQ). Other high-risk sources included wind-blown dust, on-road vehicles and metal ore mining due to large emissions of lead (speciated from dust emissions) and solid fuel burning as a result of large emissions of cadmium.

Table 9 – Total emission estimates: source

Substance	Emissions (tonnes/year)					
	Biogenic and geogenic	Domestic	Commercial and industrial	On-Road vehicle	Off-Road mobile	Total
Key pollutants						
Carbon monoxide	12,986	25,706	18,920	87,778	15,323	160,622
Oxides of nitrogen	15,208	1,079	17,957	25,917	6,826	66,987
Particulate matter ≤ 10 µm	16,345	1,395	22,140	1,769	502	42,150
Particulate matter ≤ 2.5 µm	3,271	1,340	6,142	1,414	467	12,634
Sulfur dioxide	120	33.6	9,948	203	2,949	13,254
Total volatile organic compounds	168,504	20,214	6,864	10,897	5,861	212,317
Other NPI-listed pollutants						
Acetaldehyde	95.6	165	48.0	79.9	36.9	425
Acetic acid (ethanoic acid)		4.27	0.014			4.28
Acetone	35.0	468	118	33.4	2.39	657
Acetonitrile			0.017			0.017
Acrolein		7.14		29.4	13.9	50.5
Acrylamide			0.038			0.038
Acrylic acid			0.21			0.21
Acrylonitrile (2-propenenitrile)			0.17			0.17
Ammonia (total)	470	240	6,927	795	3.39	8,434
Aniline			0.15			0.15
Antimony and compounds	0.14	0.00021	0.10		0.0057	0.24
Arsenic and compounds	0.19	0.011	1.73		0.042	1.97
Benzene		158	31.0	412	134	734
Beryllium and compounds		9.79×10^{-06}	0.053		1.37×10^{-03}	0.054
Biphenyl (1,1-biphenyl)			2.10×10^{-04}			2.10×10^{-04}

Substance	Emissions (tonnes/year)					
	Biogenic and geogenic	Domestic	Commercial and industrial	On-Road vehicle	Off-Road mobile	Total
Boron and compounds			2.87			2.87
1,3-Butadiene (vinyl ethylene)	8.42	24.0	0.39	86.3	19.3	138
Cadmium and compounds	0.30	0.23	0.50	0.032	0.0046	1.07
Carbon disulfide		0.000061	33.7			33.7
Chlorine and compounds			7.69		6.93	14.6
Chloroethane (ethyl chloride)			0.13			0.13
Chloroform (trichloromethane)		3.53	0.0043			3.54
Chromium (total)	2.68	0.037	28.7	0.46	0.11	32.0
Cobalt and compounds	1.42	0.021	0.77		0.20	2.41
Copper and compounds	0.97	0.20	25.9	8.91	0.11	36.1
Cumene (1-methylethylbenzene)		0.0089	2.93		0.14	3.07
Cyanide (inorganic) compounds		0.0012	134			134
Cyclohexane		3.02	12.6		0.35	16.0
1,2-Dibromoethane			0.0029			0.0029
1,2-Dichloroethane			0.0057			0.0057
Dibutyl phthalate		0.036				0.036
Dichloromethane		4.07	12.2			16.2
Ethanol	13.8	2,199	108			2,320
2-Ethoxyethanol		3.33				3.33
2-Ethoxyethanol acetate		3.85				3.85
Ethyl acetate		90.6	6.04			96.7
Ethylbenzene		97.1	5.20	327	107	535
Ethylene glycol (1,2-ethanediol)		61.0	0.048			61.0
Ethylene oxide		15.6				15.6

Substance	Emissions (tonnes/year)					
	Biogenic and geogenic	Domestic	Commercial and industrial	On-Road vehicle	Off-Road mobile	Total
Fluoride compounds			132			132
Formaldehyde (methyl aldehyde)		133	111	185	89.0	518
Glutaraldehyde		4.78	0.00039			4.78
Hydrochloric acid			869			869
Hydrogen sulfide		0.050	23.9			23.9
Lead and compounds	6.57	0.12	1.94	3.16	0.013	11.8
Manganese and compounds	12.0	0.10	31.5		0.20	43.8
Mercury and compounds	0.17	0.015	1.04		0.0012	1.23
Methanol	363	476	11.2			850
2-Methoxyethanol		2.59				2.59
Methyl ethyl ketone		150	12.3	9.10		172
Methyl isobutyl ketone		114	3.35			118
Methyl methacrylate		0.14	1.40			1.54
n-Hexane		135	36.9	145	65.0	382
Nickel and compounds	0.68	0.20	9.43	0.093	1.61	12.0
Nickel subsulfide			0.41			0.41
Nitric acid			0.14			0.14
Phenol		0.0000075	1.67		3.51	5.18
Phosphoric acid			0.0049			0.0049
Polychlorinated dioxins and furans (TEQ)	8.78×10^{-08}	4.61×10^{-07}	2.08×10^{-06}	6.22×10^{-07}	5.88×10^{-07}	3.83×10^{-06}
Polycyclic aromatic hydrocarbons (B[a]Peq)	0.021	0.25	0.46	0.058	0.77	1.55
Selenium and compounds	0.023	0.0024	0.24	0.0082	0.0011	0.28
Styrene (ethenylbenzene)		5.47	154	46.3	7.20	213

Substance	Emissions (tonnes/year)					
	Biogenic and geogenic	Domestic	Commercial and industrial	On-Road vehicle	Off-Road mobile	Total
Sulfuric acid			8.84			8.84
Tetrachloroethylene		30.7	52.9			83.6
Toluene (methylbenzene)		1,020	186	840	447	2,490
Toluene-2,4-diisocyanate			6.00×10^{-04}			6.00×10^{-04}
1,1,2-Trichloroethane			0.011			0.011
Trichloroethylene		1.80	0.055			1.86
Vinyl chloride monomer			0.045			0.045
Xylenes (individual or mixed isomers)		963	76.8	845	476	2,359
Zinc and compounds	7.67	0.95	14.3	8.46	0.089	31.5

Table 10 – TEP by activity

Module	Activity	TEP score	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Primary metal and metal product manufacturing	6,211,442	30.24	30.24
Biogenic and geogenic	Windblown dust	5,127,243	24.96	55.20
On-road vehicles	On-road vehicles	2,724,316	13.26	68.47
Commercial and industrial	Metal ore mining	1,647,488	8.02	76.49
Domestic	Solid fuel combustion	1,005,429	4.90	81.38
Commercial and industrial	Non-metallic mineral product manufacturing	955,156	4.65	86.03
Commercial and industrial	Fabricated metal product manufacturing	627,321	3.05	89.09
Domestic	Lawn mowing	363,105	1.77	90.86
Off-road mobile	Shipping	245,840	1.20	92.05
Off-road mobile	Commercial boating	219,738	1.07	93.12
Commercial and industrial	Electricity supply	216,764	1.06	94.18
Biogenic and geogenic	Prescribed burning	211,426	1.03	95.21
Commercial and industrial	Funeral, crematorium and cemetery services	201,939	0.98	96.19
Biogenic and geogenic	Vegetation	168,518	0.82	97.01
Commercial and industrial	Non-metallic mineral mining and quarrying	121,821	0.59	97.60
Off-road mobile	Locomotive	117,016	0.57	98.17
Biogenic and geogenic	Bushfires	74,532	0.36	98.54
Commercial and industrial	Basic chemical and chemical product manufacturing	49,319	0.24	98.78
Commercial and industrial	Petroleum and coal product manufacturing	43,226	0.21	98.99
Biogenic and geogenic	Marine aerosols	35,079	0.17	99.16
Biogenic and geogenic	Soils	33,884	0.16	99.32

Module	Activity	TEP score	Proportion (%)	Cumulative proportion (%)
Domestic	Gaseous fuel combustion	29,796	0.15	99.47
Off-road mobile	Aircraft	24,763	0.12	99.59
Commercial and industrial	Beef cattle farming	15,140	0.07	99.66
Domestic	Aerosols and solvents	11,763	0.06	99.72
Off-road mobile	Recreational boating	10,763	0.05	99.77
Domestic	Barbecues	6,786	0.03	99.80
Commercial and industrial	Agricultural burning	6,188	0.03	99.84
Commercial and industrial	Poultry farming	5,776	0.03	99.86
Commercial and industrial	Food product manufacturing	5,002	0.02	99.89
Commercial and industrial	Laundry and dry-cleaning services	4,096	0.02	99.91
Domestic	Surface coatings	3,540	0.02	99.92
Commercial and industrial	Hospitals	2,681	0.01	99.94
Commercial and industrial	Fuel retailing	1,908	0.01	99.95
Domestic	Graphic arts	1,864	0.01	99.96
Commercial and industrial	Dairy cattle farming	1,796	0.01	99.96
Commercial and industrial	Waste collection, treatment and disposal services	1,646	0.01	99.97
Commercial and industrial	Water supply, sewerage and drainage services	1,405	0.01	99.98
Domestic	Portable fuel containers	706	0.003	99.98
Commercial and industrial	Beverage manufacturing	697	0.003	99.99
Commercial and industrial	Pig farming	607	0.003	99.99
Domestic	Natural gas leakage	421	0.002	99.99
Commercial and industrial	Polymer product manufacturing	420	0.002	99.99
Commercial and industrial	Automotive body, paint and interior repair	388	0.002	100.00

Module	Activity	TEP score	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Wholesale trade	329	0.002	100.00
Commercial and industrial	Transport, postal and warehousing	254	0.001	100.00
Commercial and industrial	Printing and printing support services	125	0.001	100.00
Commercial and industrial	Gas supply	106	0.001	100.00
Commercial and industrial	Pulp, paper and converted paper product manufacturing	94	0.0005	100.00
Commercial and industrial	Machinery and equipment manufacturing	12	0.0001	100.00
Commercial and industrial	Transport equipment manufacturing	7	0.00003	100.00
Commercial and industrial	Wood product manufacturing	0.03	0.0000001	100.00

4.2 Spatial allocation summary

Spatial distribution of TEP scores are presented in

Figure 22. TEP scores are concentrated in industrial zones in Perth, particularly in the Kwinana Industrial Area and mining operations in the south. Major roads such as the Mitchell and Kwinana freeways are clearly visible, as are the Fremantle port shipping lanes. Emissions from wind erosion are concentrated in agricultural areas, as well as those cleared for urban development.

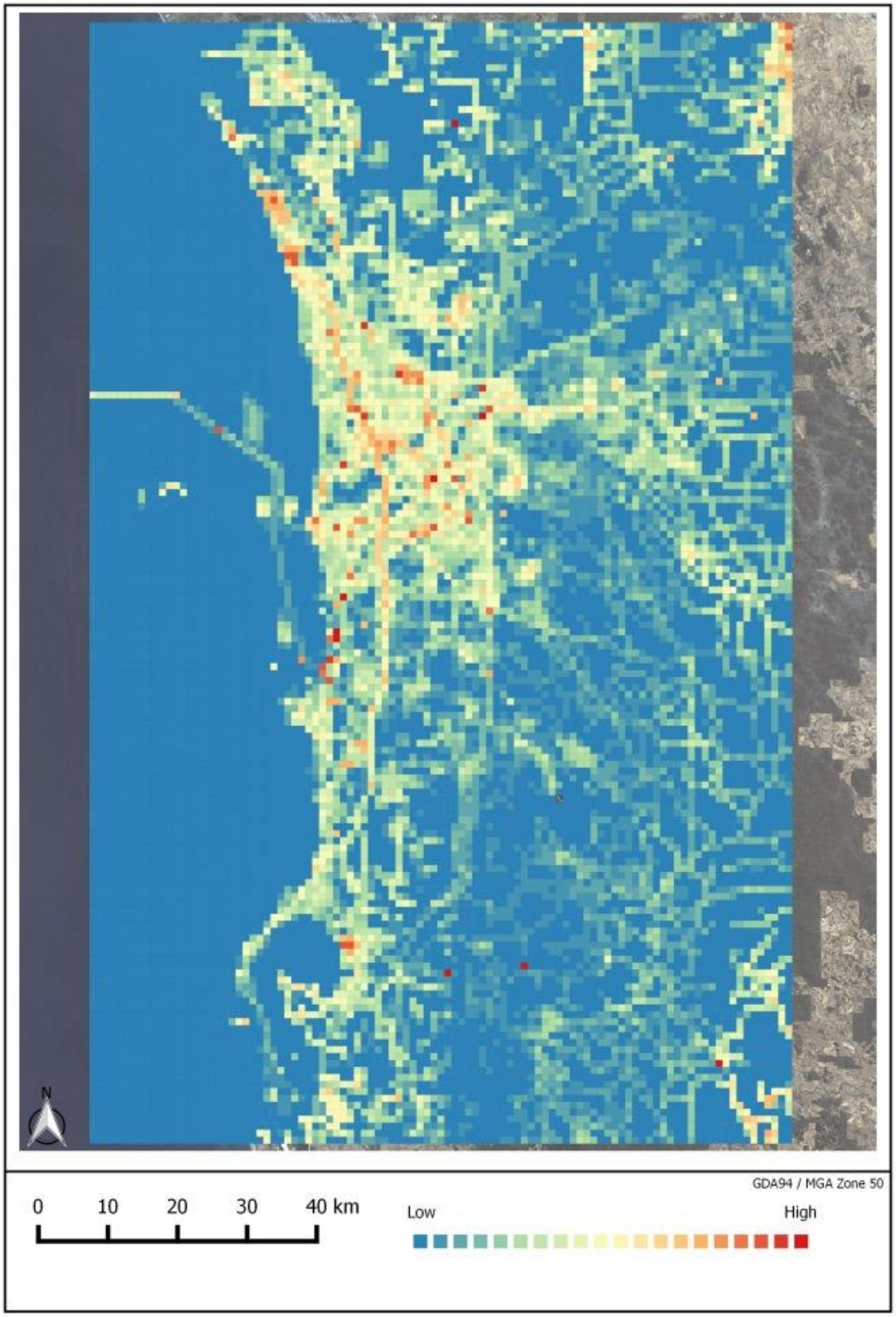


Figure 22 – Spatial allocation of TEP score

5 Key considerations

This study has found that:

- Emissions from manufacturing industries had the highest TEP score of all sources, and are concentrated in industrial zones.
- Of the key pollutants, $PM_{2.5}$ and VOCs had the highest TEP scores. $PM_{2.5}$ was mostly emitted from mining activities; other major sources included on-road vehicles, marine aerosol and wood heaters. Emissions from vegetation were the largest source of VOC.
- Lead, mercury and polychlorinated dioxins and furans (TEQ) had the highest TEP scores of all estimated pollutants. The main sources of lead emissions were wind-blown dust (46 per cent) and on-road vehicles (27 per cent). Primary metal and metal product manufacturing was the main source of mercury emissions (74 per cent) and polychlorinated dioxins and furans (TEQ) (35 per cent).
- On-road vehicles were the main source of CO and NO_X emissions. Petrol passenger and light commercial vehicles produced more than 72 per cent of on-road vehicle CO emissions. Diesel vehicles were the primary source of vehicle NO_X, with heavy duty and light commercial vehicles making the largest contribution.
- Commercial and industrial activities were the main source of particulate (PM_{10} and $PM_{2.5}$) and SO_2. Bauxite mining was the primary source of particulate emissions. Two industrial facilities in Kwinana were the major sources of SO_2 emissions, contributing more than 50 per cent of total SO_2 emissions.
- Commercial and industrial activities dominate the emissions risk profile – contributing 50 per cent of total emission risk. Primary metal and metal product manufacturing was the largest single-source contributor to emission risk due to large emissions of mercury and polychlorinated dioxins and furans (TEQ).

Appendices

Appendix A – Toxic equivalency potential score

Table 11 – 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

Substance	Non-cancer risk score (TEP)[1]
Copper and compounds	13,000
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

Substance	Non-cancer risk score (TEP)[1]
Methylene-bis(2-chloroaniline) (MOCA)	N/A
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

Appendix B – Emissions by activity

Table 12 – Emissions of CO by activity

Source	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
On-road vehicles	Passenger vehicles – petrol	38,050	23.68	23.68
On-road vehicles	Light commercial vehicles – petrol	25,389	15.80	39.47
Domestic	Lawn mowing exhaust	16,304	10.14	49.62
On-road vehicles	Sports utility vehicles – petrol	9,938	6.18	55.80
Biogenic and geogenic	Prescribed burning	9,093	5.66	61.46
Domestic	Solid fuel combustion	8,888	5.53	66.99
Off-road mobile	Recreational boating	7,681	4.78	71.77
Commercial and industrial	Metal ore mining	6,954	4.33	76.10
On-road vehicles	Motorcycles – petrol	6,349	3.95	80.05
Off-road mobile	Commercial boating	4,114	2.56	82.61
Biogenic and geogenic	Bushfires	3,717	2.31	84.92
Commercial and industrial	Non-metallic mineral product manufacturing	3,519	2.19	87.11
Off-road mobile	Aircraft	3,178	1.98	89.09
Commercial and industrial	Petroleum and coal product manufacturing	2,675	1.66	90.75
On-road vehicles	Passenger vehicles – autogas	2,400	1.49	92.24
Commercial and industrial	Primary metal and metal product manufacturing	2,180	1.36	93.60
On-road vehicles	Heavy duty trucks – diesel	1,689	1.05	94.65
Commercial and industrial	Basic chemical and chemical product manufacturing	1,670	1.04	95.69
On-road vehicles	Light commercial vehicles – diesel	1,456	0.91	96.60
Commercial and industrial	Electricity supply	1,239	0.77	97.37
On-road vehicles	Mopeds – petrol	979	0.61	97.98
On-road vehicles	Sports utility vehicles – diesel	845	0.53	98.50

Source	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
On-road vehicles	Buses – diesel	577	0.36	98.86
Domestic	Gaseous fuel combustion	349	0.22	99.08
Commercial and industrial	Non-metallic mineral mining and quarrying	214	0.13	99.21
Commercial and industrial	Water supply, sewerage and drainage services	212	0.13	99.34
Off-road mobile	Locomotive	192	0.12	99.46
Biogenic and geogenic	Agricultural burning	176	0.11	99.57
Domestic	Barbecues	166	0.10	99.67
Off-road mobile	Shipping	159	0.10	99.77
Commercial and industrial	Waste collection, treatment and disposal services	104	0.06	99.84
Commercial and industrial	Food product manufacturing	59	0.04	99.87
On-road vehicles	Passenger vehicles – diesel	52	0.03	99.91
On-road vehicles	Heavy duty trucks – petrol	42	0.03	99.93
Commercial and industrial	Transport, postal and warehousing	29	0.02	99.95
Commercial and industrial	Hospitals	26	0.02	99.97
On-road vehicles	Heavy duty trucks – autogas	13	0.01	99.98
Commercial and industrial	Fabricated metal product manufacturing	11	0.01	99.98
Commercial and industrial	Beverage manufacturing	7.8	0.005	99.99
Commercial and industrial	Laundry and dry-cleaning services	6.1	0.004	99.99
Commercial and industrial	Pulp, paper and converted paper product manufacturing	4.7	0.003	99.99
Commercial and industrial	Funeral, crematorium and cemetery services	3.0	0.002	100.00
Commercial and industrial	Gas supply	2.9	0.002	100.00
Commercial and industrial	Printing and printing support services	2.0	0.001	100.00
Commercial and	Transport equipment	1.1	0.001	100.00

Source	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
industrial	manufacturing			
Commercial and industrial	Polymer product manufacturing	0.9	0.001	100.00

Table 13 – Emissions NO_x by activity

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Biogenic and geogenic	Soils	14,817	22.12	22.12
Commercial and industrial	Electricity supply	5,716	8.53	30.65
On-road vehicles	Heavy duty trucks – diesel	5,365	8.01	38.66
On-road vehicles	Passenger vehicles – petrol	5,192	7.75	46.41
On-road vehicles	Light commercial vehicles – diesel	4,755	7.10	53.51
Commercial and industrial	Non-metallic mineral product manufacturing	3,713	5.54	59.05
Commercial and industrial	Primary metal and metal product manufacturing	3,707	5.53	64.59
On-road vehicles	Sports utility vehicles – diesel	3,152	4.71	69.29
On-road vehicles	Light commercial vehicles – petrol	2,922	4.36	73.65
On-road vehicles	Buses – diesel	2,560	3.82	77.47
Off-road mobile	Shipping	2,496	3.73	81.20
Commercial and industrial	Metal ore mining	2,101	3.14	84.34
Off-road mobile	Commercial boating	1,796	2.68	87.02
Off-road mobile	Locomotive	1,289	1.92	88.94
On-road vehicles	Sports utility vehicles – petrol	1,092	1.63	90.57
Off-road mobile	Aircraft	1,018	1.52	92.09
Commercial and industrial	Basic chemical and chemical product manufacturing	872	1.30	93.39
Domestic	Gaseous fuel combustion	815	1.22	94.61
Commercial and industrial	Petroleum and coal product manufacturing	775	1.16	95.77
Commercial and industrial	Non-metallic mineral mining and quarrying	590	0.88	96.65
On-road vehicles	Passenger vehicles – autogas	442	0.66	97.31
Biogenic and geogenic	Prescribed burning	273	0.41	97.71
On-road vehicles	Passenger vehicles – diesel	271	0.40	98.12

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Off-road mobile	Recreational boating	228	0.34	98.46
Commercial and industrial	Waste collection, treatment and disposal services	143	0.21	98.67
Domestic	Solid fuel combustion	128	0.19	98.86
Biogenic and geogenic	Bushfires	112	0.17	99.03
Domestic	Lawn mowing exhaust	111	0.17	99.20
Commercial and industrial	Water supply, sewerage and drainage services	102	0.15	99.35
On-road vehicles	Motorcycles – petrol	98	0.15	99.49
Commercial and industrial	Transport, postal and warehousing	58	0.09	99.58
Commercial and industrial	Food product manufacturing	52	0.08	99.66
On-road vehicles	Heavy duty trucks – petrol	51	0.08	99.73
Commercial and industrial	Hospitals	44	0.07	99.80
Commercial and industrial	Fabricated metal product manufacturing	29	0.04	99.84
Domestic	Barbecues	25	0.04	99.88
Commercial and industrial	Funeral, crematorium and cemetery services	16	0.02	99.90
On-road vehicles	Heavy duty trucks – autogas	15	0.02	99.93
Commercial and industrial	Gas supply	11	0.02	99.94
Commercial and industrial	Beverage manufacturing	8.4	0.01	99.96
Commercial and industrial	Laundry and dry-cleaning services	7.2	0.01	99.97
Commercial and industrial	Pulp, paper and converted paper product manufacturing	6.7	0.01	99.98
Biogenic and geogenic	Agricultural burning	6.5	0.01	99.99
On-road vehicles	Mopeds – petrol	3.9	0.01	99.99
Commercial and industrial	Printing and printing support services	2.8	0.004	100.00
Commercial and	Transport equipment	1.4	0.002	100.00

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
industrial	manufacturing			
Commercial and industrial	Polymer product manufacturing	1.1	0.002	100.00

Table 14 – Emissions PM_{10} by activity

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Metal ore mining	14,939	35.44	35.44
Biogenic and geogenic	Marine aerosols	8,864	21.03	56.47
Biogenic and geogenic	Windblown dust	6,169	14.64	71.11
Commercial and industrial	Non-metallic mineral mining and quarrying	3,958	9.39	80.50
Domestic	Solid fuel combustion	1,217	2.89	83.39
Commercial and industrial	Primary metal and metal product manufacturing	1,080	2.56	85.95
Commercial and industrial	Non-metallic mineral product manufacturing	956	2.27	88.22
Biogenic and geogenic	Prescribed burning	917	2.17	90.39
Commercial and industrial	Beef cattle farming	574	1.36	91.76
On-road vehicles	Light commercial vehicles – diesel	535	1.27	93.03
Biogenic and geogenic	Bushfires	375	0.89	93.91
Off-road mobile	Shipping	310	0.74	94.65
On-road vehicles	Sports utility vehicles – diesel	301	0.71	95.37
On-road vehicles	Heavy duty trucks – diesel	283	0.67	96.04
On-road vehicles	Passenger vehicles – petrol	265	0.63	96.67
Commercial and industrial	Electricity supply	211	0.50	97.17
Commercial and industrial	Petroleum and coal product manufacturing	123	0.29	97.46
On-road vehicles	Buses – diesel	118	0.28	97.74
On-road vehicles	Sports utility vehicles – petrol	106	0.25	97.99
Domestic	Lawn mowing exhaust	105	0.25	98.24
Commercial and industrial	Basic chemical and chemical product manufacturing	79	0.19	98.43
On-road vehicles	Light commercial vehicles –	79	0.19	98.61

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
	petrol			
Commercial and industrial	Poultry farming	78	0.18	98.80
Off-road mobile	Commercial boating	71	0.17	98.97
Commercial and industrial	Dairy cattle farming	68	0.16	99.13
Domestic	Gaseous fuel combustion	65	0.16	99.28
Off-road mobile	Recreational boating	54	0.13	99.41
Off-road mobile	Locomotive	48	0.11	99.53
Commercial and industrial	Food product manufacturing	43	0.10	99.63
On-road vehicles	Passenger vehicles – autogas	36	0.09	99.71
On-road vehicles	Passenger vehicles – diesel	20	0.05	99.76
Biogenic and geogenic	Agricultural burning	20	0.05	99.81
Off-road mobile	Aircraft	19	0.04	99.85
On-road vehicles	Mopeds – petrol	14	0.03	99.89
Commercial and industrial	Fabricated metal product manufacturing	13	0.03	99.92
On-road vehicles	Motorcycles – petrol	10	0.02	99.94
Domestic	Barbecues	7.7	0.02	99.96
Commercial and industrial	Waste collection, treatment and disposal services	5.9	0.01	99.97
Commercial and industrial	Transport, postal and warehousing	4.8	0.01	99.99
Commercial and industrial	Hospitals	2.5	0.01	99.99
Commercial and industrial	Funeral, crematorium and cemetery services	1.2	0.003	99.99
On-road vehicles	Heavy duty trucks – petrol	0.8	0.002	100.00
Commercial and industrial	Beverage manufacturing	0.6	0.001	100.00
Commercial and industrial	Laundry and dry-cleaning services	0.5	0.001	100.00
On-road vehicles	Heavy duty trucks – autogas	0.2	0.0005	100.00

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Pulp, paper and converted paper product manufacturing	0.2	0.0004	100.00
Commercial and industrial	Printing and printing support services	0.1	0.0003	100.00
Commercial and industrial	Transport equipment manufacturing	0.1	0.0002	100.00
Commercial and industrial	Polymer product manufacturing	0.1	0.0002	100.00
Commercial and industrial	Gas supply	0.1	0.0002	100.00

Table 15 – Emissions $PM_{2.5}$ by activity

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Metal ore mining	43,995	34.82	34.82
Biogenic and geogenic	Marine aerosols	12,813	10.14	44.96
Commercial and industrial	Non-metallic mineral mining and quarrying	11,981	9.48	54.44
Domestic	Solid fuel combustion	11,714	9.27	63.71
Biogenic and geogenic	Windblown dust	8,749	6.92	70.63
Biogenic and geogenic	Prescribed burning	7,779	6.16	76.79
On-road vehicles	Light commercial vehicles – diesel	4,820	3.81	80.60
Biogenic and geogenic	Bushfires	3,180	2.52	83.12
Off-road mobile	Shipping	2,849	2.25	85.38
On-road vehicles	Sports utility vehicles – diesel	2,700	2.14	87.51
On-road vehicles	Heavy duty trucks – diesel	2,410	1.91	89.42
Commercial and industrial	Electricity supply	1,744	1.38	90.80
Commercial and industrial	Primary metal and metal product manufacturing	1,575	1.25	92.05
On-road vehicles	Passenger vehicles – petrol	1,530	1.21	93.26
Domestic	Lawn mowing exhaust	972	0.77	94.03
On-road vehicles	Buses – diesel	954	0.75	94.78
Commercial and industrial	Beef cattle farming	718	0.57	95.35
Off-road mobile	Commercial boating	670	0.53	95.88
Domestic	Gaseous fuel combustion	654	0.52	96.40
On-road vehicles	Sports utility vehicles – petrol	598	0.47	96.87
Off-road mobile	Recreational boating	500	0.40	97.27
Off-road mobile	Locomotive	465	0.37	97.63
On-road vehicles	Light commercial vehicles – petrol	463	0.37	98.00

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Petroleum and coal product manufacturing	448	0.35	98.36
Commercial and industrial	Non-metallic mineral product manufacturing	329	0.26	98.62
On-road vehicles	Passenger vehicles – autogas	291	0.23	98.85
Biogenic and geogenic	Agricultural burning	189	0.15	99.00
Off-road mobile	Aircraft	185	0.15	99.14
Commercial and industrial	Poultry farming	178	0.14	99.28
On-road vehicles	Passenger vehicles – diesel	162	0.13	99.41
Commercial and industrial	Basic chemical and chemical product manufacturing	154	0.12	99.53
On-road vehicles	Mopeds – petrol	140	0.11	99.64
On-road vehicles	Motorcycles – petrol	86	0.07	99.71
Commercial and industrial	Dairy cattle farming	85	0.07	99.78
Domestic	Barbecues	64	0.05	99.83
Commercial and industrial	Waste collection, treatment and disposal services	55	0.04	99.87
Commercial and industrial	Food product manufacturing	47	0.04	99.91
Commercial and industrial	Transport, postal and warehousing	45	0.04	99.95
Commercial and industrial	Hospitals	25	0.02	99.97
Commercial and industrial	Fabricated metal product manufacturing	12	0.01	99.98
Commercial and industrial	Funeral, crematorium and cemetery services	10	0.01	99.98
Commercial and industrial	Beverage manufacturing	5.3	0.004	99.99
Commercial and industrial	Laundry and dry-cleaning services	5.3	0.004	99.99
On-road vehicles	Heavy duty trucks – petrol	3.8	0.003	99.99
Commercial and	Pulp, paper and converted	1.7	0.001	100.00

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
industrial	paper product manufacturing			
Commercial and industrial	Printing and printing support services	1.3	0.001	100.00
On-road vehicles	Heavy duty trucks – autogas	1.0	0.001	100.00
Commercial and industrial	Transport equipment manufacturing	0.9	0.001	100.00
Commercial and industrial	Polymer product manufacturing	0.7	0.001	100.00
Commercial and industrial	Gas supply	0.7	0.001	100.00

Table 16 – Emissions SO_2 by activity

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Petroleum and coal product manufacturing	4,427	33.40	33.40
Commercial and industrial	Electricity supply	3,355	25.31	58.70
Off-road mobile	Shipping	2,842	21.44	80.15
Commercial and industrial	Metal ore mining	1,000	7.54	87.69
Commercial and industrial	Non-metallic mineral product manufacturing	901	6.80	94.49
Commercial and industrial	Basic chemical and chemical product manufacturing	141	1.07	95.56
On-road vehicles	Passenger vehicles – petrol	106	0.80	96.36
Off-road mobile	Aircraft	95	0.72	97.08
Biogenic and geogenic	Prescribed burning	85	0.64	97.71
Commercial and industrial	Primary metal and metal product manufacturing	51	0.38	98.10
Commercial and industrial	Water supply, sewerage and drainage services	43	0.32	98.42
Biogenic and geogenic	Bushfires	35	0.26	98.68
On-road vehicles	Light commercial vehicles – petrol	33	0.25	98.93
On-road vehicles	Sports utility vehicles – petrol	33	0.25	99.18
Domestic	Solid fuel combustion	21	0.16	99.34
Commercial and industrial	Food product manufacturing	20	0.15	99.49
On-road vehicles	Passenger vehicles – autogas	11	0.08	99.57
Off-road mobile	Commercial boating	5.8	0.04	99.62
On-road vehicles	Light commercial vehicles – diesel	5.5	0.04	99.66
Domestic	Gaseous fuel combustion	5.2	0.04	99.70
Domestic	Barbecues	4.6	0.03	99.73
On-road vehicles	Heavy duty trucks – diesel	4.5	0.03	99.76

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Non-metallic mineral mining and quarrying	4.2	0.03	99.80
Off-road mobile	Recreational boating	4.0	0.03	99.83
On-road vehicles	Sports utility vehicles – diesel	3.7	0.03	99.85
Domestic	Lawn mowing exhaust	3.1	0.02	99.88
On-road vehicles	Motorcycles – petrol	2.8	0.02	99.90
Off-road mobile	Locomotive	2.2	0.02	99.92
Commercial and industrial	Funeral, crematorium and cemetery services	2.2	0.02	99.93
On-road vehicles	Buses – diesel	2.2	0.02	99.95
Commercial and industrial	Waste collection, treatment and disposal services	2.0	0.01	99.96
Commercial and industrial	Hospitals	1.9	0.01	99.98
Biogenic and geogenic	Agricultural burning	1.1	0.01	99.99
On-road vehicles	Heavy duty trucks – petrol	0.4	0.003	99.99
On-road vehicles	Mopeds – petrol	0.4	0.003	99.99
On-road vehicles	Passenger vehicles – diesel	0.4	0.003	100.00
On-road vehicles	Heavy duty trucks – autogas	0.1	0.001	100.00
Commercial and industrial	Beverage manufacturing	0.1	0.001	100.00
Commercial and industrial	Fabricated metal product manufacturing	0.1	0.001	100.00
Commercial and industrial	Laundry and dry-cleaning services	0.1	0.001	100.00
Commercial and industrial	Transport, postal and warehousing	0.05	0.0004	100.00
Commercial and industrial	Pulp, paper and converted paper product manufacturing	0.02	0.0002	100.00
Commercial and industrial	Printing and printing support services	0.02	0.0002	100.00
Commercial and industrial	Gas supply	0.02	0.0001	100.00
Commercial and industrial	Transport equipment manufacturing	0.01	0.0001	100.00

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Polymer product manufacturing	0.01	0.0001	100.00

Table 17 – Emissions VOC by activity

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Biogenic and geogenic	Vegetation	167,595	78.92	78.92
Domestic	Aerosols and solvents	8,378	3.95	82.86
On-road vehicles	Passenger vehicles – petrol	4,982	2.35	85.21
Domestic	Lawn mowing	4,503	2.12	87.33
Off-road mobile	Recreational boating	3,417	1.61	88.94
Domestic	Surface coatings	3,021	1.42	90.36
On-road vehicles	Light commercial vehicles – petrol	2,365	1.11	91.48
Domestic	Graphic arts	1,843	0.87	92.34
Commercial and industrial	Fuel retailing	1,761	0.83	93.17
Off-road mobile	Commercial boating	1,747	0.82	94.00
Commercial and industrial	Petroleum and coal product manufacturing	1,731	0.82	94.81
Domestic	Solid fuel combustion	1,346	0.63	95.44
Commercial and industrial	Metal ore mining	1,011	0.48	95.92
On-road vehicles	Sports utility vehicles – petrol	933	0.44	96.36
On-road vehicles	Motorcycles – petrol	922	0.43	96.79
Domestic	Portable fuel containers	651	0.31	97.10
Biogenic and geogenic	Prescribed burning	636	0.30	97.40
On-road vehicles	Mopeds – petrol	598	0.28	97.68
Off-road mobile	Aircraft	555	0.26	97.94
Domestic	Natural gas leakage	419	0.20	98.14
On-road vehicles	Passenger vehicles – autogas	360	0.17	98.31
Commercial and industrial	Basic chemical and chemical product manufacturing	353	0.17	98.48
Commercial and industrial	Primary metal and metal product manufacturing	324	0.15	98.63
Commercial and industrial	Polymer product manufacturing	316	0.15	98.78

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
Commercial and industrial	Wholesale trade	312	0.15	98.92
Commercial and industrial	Automotive body, paint and interior repair	287	0.13	99.06
Biogenic and geogenic	Bushfires	260	0.12	99.18
On-road vehicles	Light commercial vehicles – diesel	254	0.12	99.30
Commercial and industrial	Food product manufacturing	210	0.10	99.40
On-road vehicles	Heavy duty trucks – diesel	204	0.10	99.50
On-road vehicles	Buses – diesel	128	0.06	99.56
Commercial and industrial	Electricity supply	100	0.05	99.60
Commercial and industrial	Non-metallic mineral product manufacturing	91	0.04	99.65
Commercial and industrial	Printing and printing support services	90	0.04	99.69
On-road vehicles	Sports utility vehicles – diesel	88	0.04	99.73
Commercial and industrial	Gas supply	79	0.04	99.77
Off-road mobile	Locomotive	76	0.04	99.80
Commercial and industrial	Non-metallic mineral mining and quarrying	68	0.03	99.84
Off-road mobile	Shipping	65	0.03	99.87
Commercial and industrial	Laundry and dry-cleaning services	57	0.03	99.89
Domestic	Gaseous fuel combustion	47	0.02	99.92
On-road vehicles	Heavy duty trucks – petrol	41	0.02	99.93
Commercial and industrial	Waste collection, treatment and disposal services	40	0.02	99.95
Domestic	Barbecues	29	0.01	99.97
Biogenic and geogenic	Agricultural burning	14	0.01	99.97
On-road vehicles	Heavy duty trucks – autogas	13	0.01	99.98
Commercial and industrial	Beverage manufacturing	12	0.01	99.99

Module	Activity	Emissions (tonnes/ year)	Proportion (%)	Cumulative proportion (%)
On-road vehicles	Passenger vehicles – diesel	9.0	0.004	99.99
Commercial and industrial	Machinery and equipment manufacturing	8.6	0.004	99.99
Commercial and industrial	Transport, postal and warehousing	5.5	0.003	100.00
Commercial and industrial	Funeral, crematorium and cemetery services	3.1	0.001	100.00
Commercial and industrial	Hospitals	1.9	0.001	100.00
Commercial and industrial	Transport equipment manufacturing	1.6	0.001	100.00
Commercial and industrial	Fabricated metal product manufacturing	1.2	0.001	100.00
Commercial and industrial	Pulp, paper and converted paper product manufacturing	0.7	0.0003	100.00

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