Tracking sources of air pollution in NSW communities

Air emissions inventory for the Greater Metropolitan Region of NSW

Why do we need an air emissions inventory?

Air pollution comes from many sources, so to find the best ways to improve air quality we need to know the contribution made by each source. The last air emissions inventory for NSW was completed in 2007 and although that information has served us well until now, emissions have changed, making it necessary for a new inventory.

The major task of developing the new inventory started in 2009 and took over 2 years to complete. The results are now available and are being used to shape the way we improve air quality in NSW.

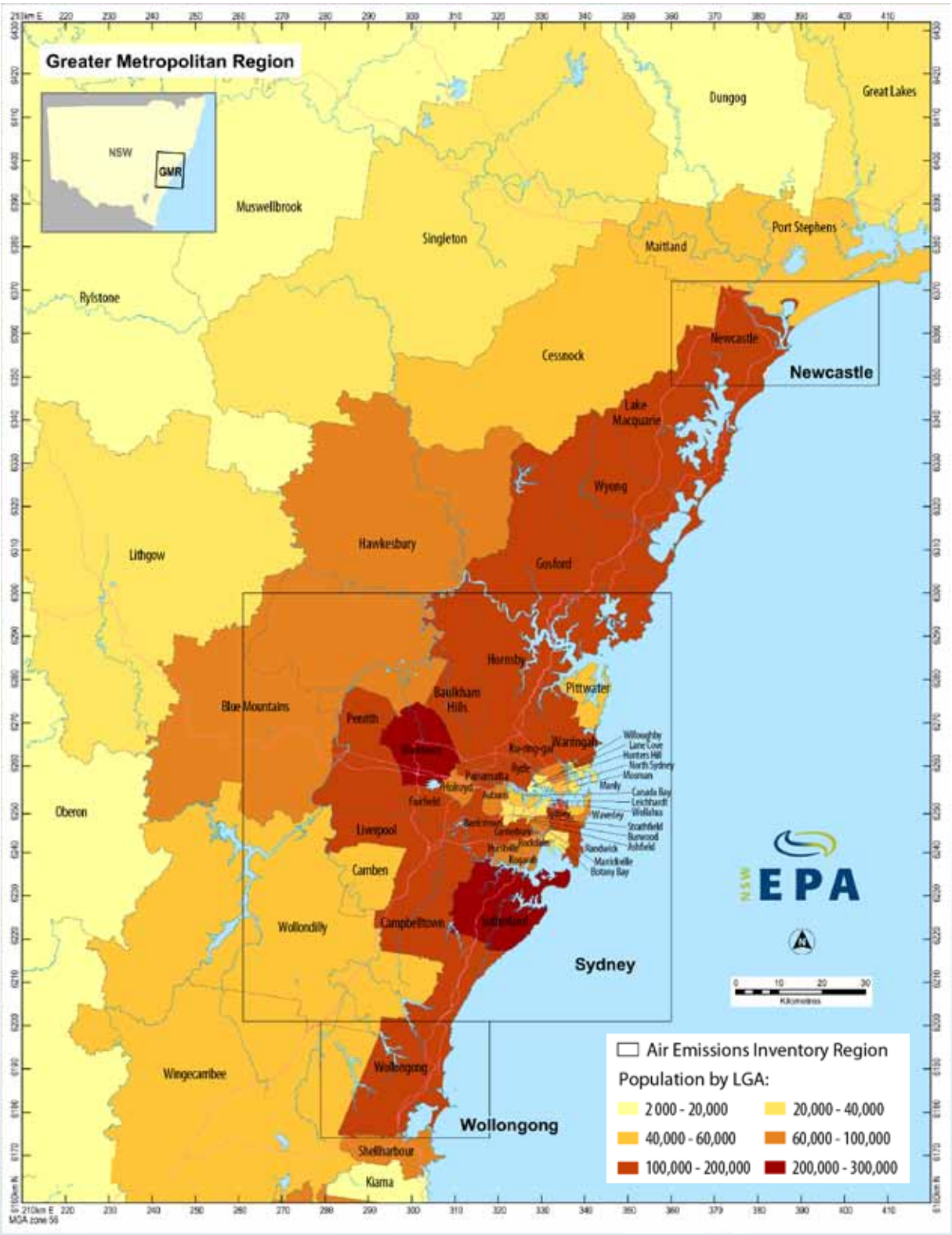


Figure 1: *Definition of GMR and the Sydney, Newcastle and Wollongong regions and population in each LGA*

What is the air emissions inventory?

The air emissions inventory is a detailed listing of pollutants discharged into the atmosphere by each source type during a given time period and at a specific location. The study area covers 57,330 km^2, which includes the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR). About 75% of the NSW population resides in the GMR. The GMR and the Sydney, Newcastle and Wollongong regions are shown in Figure 1, along with the population in each local government area (LGA).

The inventory includes emissions from biogenic (i.e. natural and living), geogenic (i.e. natural non-living) and anthropogenic (i.e. human-made) sources, as follows:

- natural (e.g. bushfires, marine aerosols and vegetation)
- commercial businesses (e.g. non-EPA licensed printers, quarries and service stations)
- domestic activities (e.g. residential lawn mowing, portable fuel containers and wood heaters)
- industrial premises (e.g. EPA licensed coal mines, oil refineries and power stations)
- off-road vehicles and equipment (e.g. dump trucks, bulldozers and marine vessels)
- on-road transport (e.g. registered buses, cars and trucks).

The inventory covers over 850 substances, including:

- common pollutants, such as ammonia, carbon monoxide (CO), lead, oxides of nitrogen (NO_x), particulate matter ≤ 10 µm (PM_{10}), particulate matter ≤ 2.5 µm ($PM_{2.5}$), sulfur dioxide (SO_2) and total volatile organic compounds (VOC)
- organic compounds, such as 1,3-butadiene, benzene and formaldehyde
- metals, such as cadmium, manganese and nickel
- PAH (polycyclic aromatic hydrocarbons), PCDD (polychlorinated dibenzo-p-dioxins) and PCDF (polychlorinated dibenzofurans)
- greenhouse gases (carbon dioxide, methane and nitrous oxide).

Air emissions data can be presented for the whole GMR, either of the Sydney, Newcastle or Wollongong regions, or each of the 64 LGA within the GMR. Emissions vary by month, day of week and hour of day so they can be presented on an annual, monthly, daily or hourly basis.

How was the air emissions inventory completed?

After 6 months of preparatory work and project planning, the air emissions inventory project formally started in August 2009. It has been a major air quality study that has taken over 2 years to complete.

Three highly skilled engineers with expertise in project management, emissions estimation methodology design, database design, activity data collection, emissions estimation and quality assurance/quality control have been responsible for completing the project.

How have air emissions been estimated?

Emission estimation techniques for all sources have been based on published state-of-the-art methodologies, such as those used by the California Air Resources Board (CARB), the European Environment Agency or the United States Environmental Protection Agency (USEPA).

All emissions have been calculated within six source-specific relational databases, which include all the data needed to estimate emissions to air from natural and human-made sources. These databases contain activity data; emission factors; particulate matter (PM) and VOC speciation profiles; spatial allocation data; hourly, daily and monthly temporal variation data; and emission projection factors.

Activity, spatial and temporal data have been acquired through a domestic survey of residential households and an industrial survey of EPA-licensed premises. They have also been supplied by a number of government departments and service providers.

Air emissions have been estimated by combining activity data with emission factors. Where available, source emission test data has been used in preference to emission factors for industrial and commercial sources.

The emissions have been assigned to map coordinates for industrial and commercial controlled point sources, or 1-km by 1-km grid cells for natural, domestic, off-road and on-road area sources and industrial and commercial uncontrolled fugitive sources. As an example, Figure 2 shows the spatial distribution of emissions from off-road vehicles and equipment.

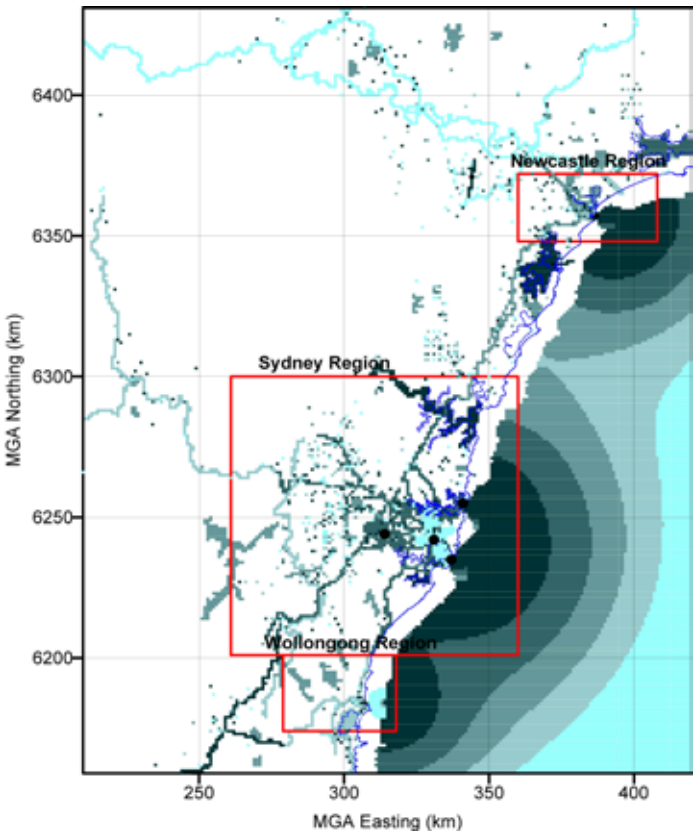


Figure 2: *Spatial distribution of off-road vehicles and equipment*

Emissions are then calculated for each month, day of week and hour of day by using factors derived from the activity data.

The base year of the inventory represents activities that took place in the 2008 calendar year. Emissions are projected from 2009 to 2036 by using Equation 1:

$$E_{i,j,n} = E_{i,j,2008} \times PF_{j,n}$$ **Equation 1**

where:

$E_{i,j,n}$ = emission of substance i from source type j for year n (tonne/year)

$E_{i,j,2008}$ = emission of substance i from source type j for the base year, 2008 (tonne/year)

$PF_{j,n}$ = emission projection factor for source type j for year n

Data from the following sources have been used to develop the emission projection factors:

- final energy consumption growth data published by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
- free-standing dwelling growth data published by the Australian Bureau of Statistics (ABS) and Bureau of Transport Statistics (BTS)
- population growth data published by ABS and BTS
- primary energy consumption growth data published by ABARES
- total dwelling growth data published by ABS and BTS
- vehicle kilometres travelled growth data published by BTS.

As an example of the information used to develop emission projection factors, Figure 3 shows total NSW primary energy consumption projections by fuel type.

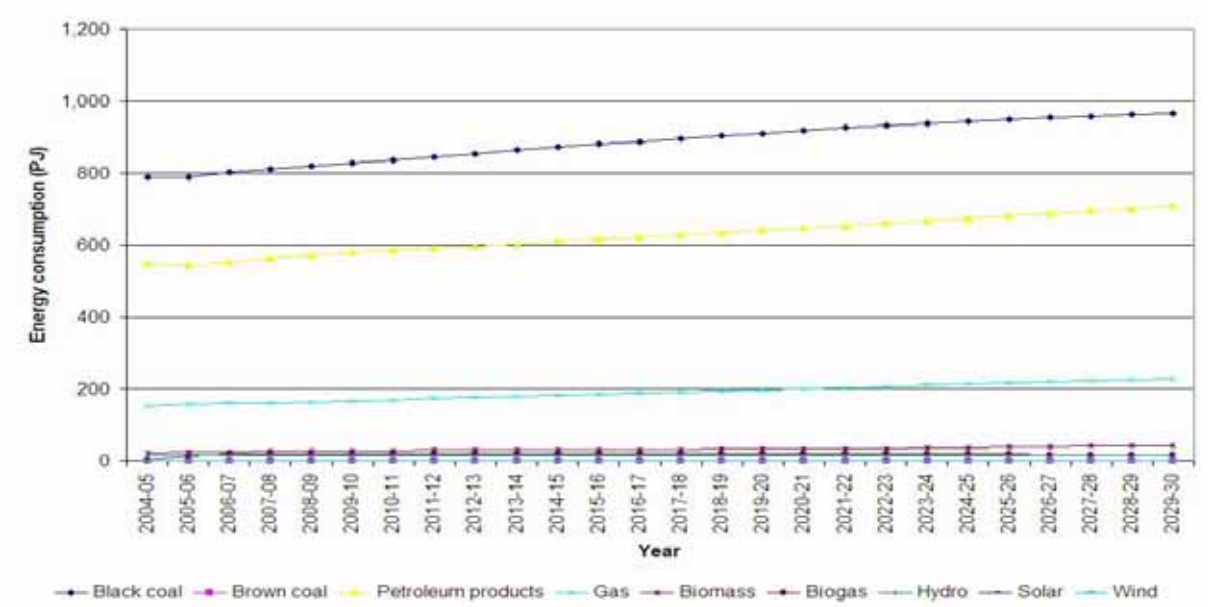


Figure 3: *Total NSW primary energy consumption projections by fuel type*

Where are the air emissions data stored?

The air emissions inventory data are stored in a Microsoft® SQL Server™ 2000 relational database. Figure 4 shows the Emissions Data Management System (EDMS) v2.0 start-up page. EDMS v2.0 includes a number of features, such as:

- air pollution modelling using models developed by the California Institute of Technology, CSIRO and USEPA
- emissions charting by air pollutant, source, LGA and region
- emissions data visualisation using geographical information systems
- emissions forecasting up to 2036
- emissions modelling to test out policy scenarios
- environmental reporting by air pollutant, source, LGA and region
- source and pollutant prioritisation using CARB facility prioritisation guidelines and the USEPA RSEI (risk screening environmental indicators) methodology
- VOC prioritisation based on photochemical smog forming potential, using the CARB MIR (maximum incremental reactivity) methodology.

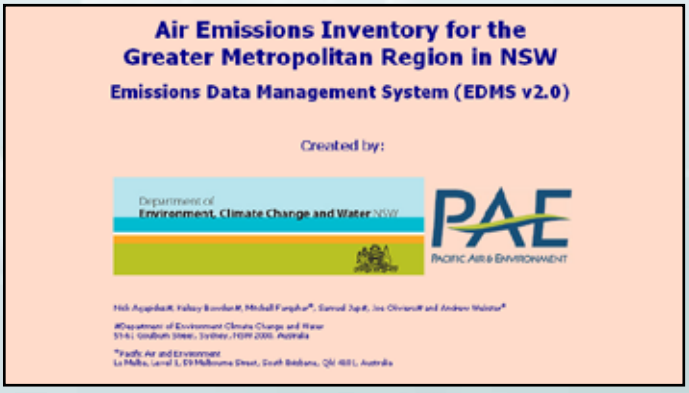


Figure 4: *EDMS v2.0 start-up page*

Ambient air monitoring determines compliance with Ambient Air Quality NEPM (National Environment Protection (Ambient Air Quality) Measure) standards. The air emissions inventory is then used to identify priority sources of key air pollutants. Modelling identifies the amount of air pollutant reductions required and cost effective emissions reduction strategies are then developed to improve air quality. Figure 5 shows the role of the air emissions inventory within the air quality management cycle.

Figure 5: *Air emissions inventory role in air quality management*

What are the priority air pollutants?

Air quality in the GMR has been steadily improving since the 1980s. In 1998, ambient air quality standards and goals for six common pollutants (i.e. CO, lead, nitrogen dioxide (NO_2), ozone (O_3), PM_{10} and SO_2) were included in the Ambient Air Quality NEPM. Ambient concentrations of CO, lead, NO_2 and SO_2 are all consistently below the respective national standards. However, concentrations of O_3, and sometimes PM_{10}, can exceed national standards. NO_x, PM_{10}, $PM_{2.5}$ and VOC are the air pollutants of primary concern in the GMR and the Sydney region.

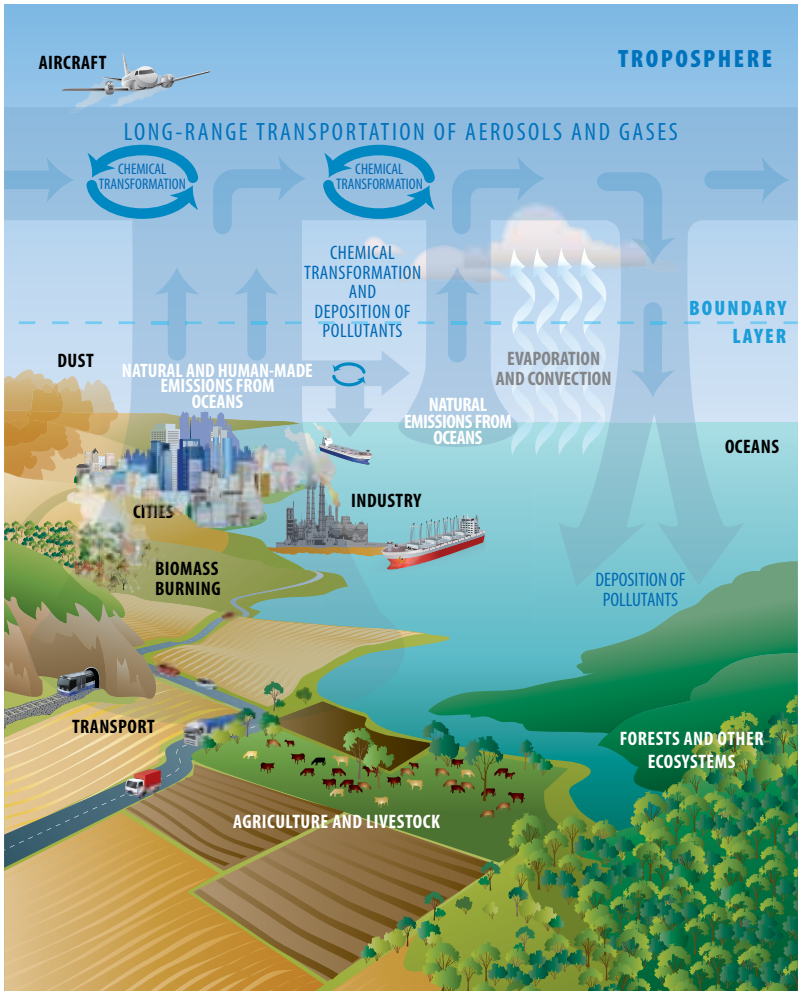
NO_x and VOC are photochemical smog precursors and when emitted in the presence of sunlight they undergo a series of complex reactions that cause photochemical smog to form. Ground-level ozone is an indicator of photochemical smog, which is characterised by a white atmospheric haze during the warmer months of the year.

PM_{10} and $PM_{2.5}$ emissions are responsible for primary particulate matter pollution, which is characterised by a brown atmospheric haze during the cooler months of the year.

NO_x, VOC, SO_2 and ammonia react in the atmosphere to form secondary organic aerosols, nitrate and sulfate compounds, which are collectively known as secondary particulate matter pollution.

Fine particulate matter pollution is made up of both primary emissions and secondary organic and inorganic aerosols, which are formed through atmospheric reactions.

Figure 6 illustrates air pollution sources, their transport and transformation, and the parts of the environment that are affected by air pollution.



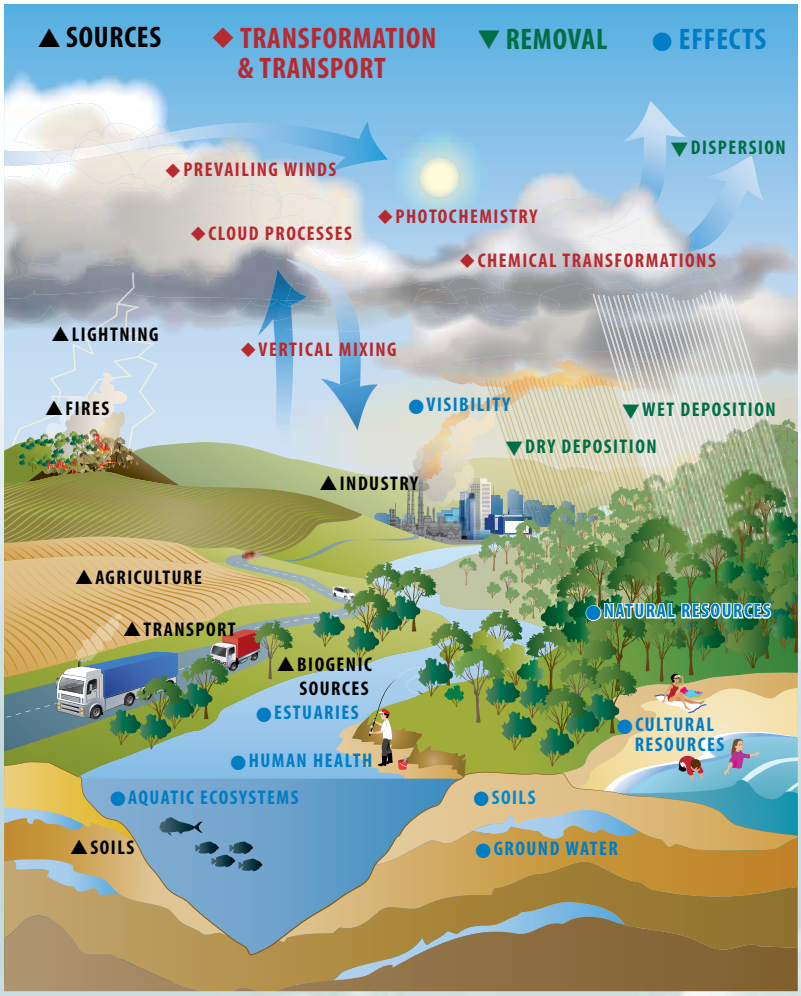


Figure 6: *Sources of air pollution and their impacts on the environment*

What are the major natural and human-made sources in the GMR?

Table 1 presents annual emissions of common pollutants from natural and human-made sources in the GMR. Human-made sources are the major contributors to CO (96.4%), NO_x (96.9%), PM_{10} (72.8%), $PM_{2.5}$ (81.2%) and SO_2 (99.9%) emissions, while VOC emissions from natural (55.3%) and human-made (44.7%) sources are similar.

Table 1: *Total estimated annual emissions from natural and human-made sources in the GMR*

Substance	Emissions (tonne/year)						
	Biogenic–geogenic	Commercial	Domestic–commercial	Industrial	Off-road mobile	On-road mobile	Grand total
CO	34,934	389	109,377	613,365	53,817	153,812	965,693
NO_x	9,811	501	3,290	191,411	53,210	60,932	319,156
PM_{10}	33,635	2,020	8,189	73,213	3,607	2,793	123,458
$PM_{2.5}$	7,338	695	7,873	17,672	3,433	2,071	39,083
SO_2	317	180	175	280,472	7,824	269	289,237
VOC	169,637	9,176	68,809	11,519	17,950	29,504	306,595

Using the data from Table 1, Figures 7 to 10 show the proportions of annual emissions for the priority pollutants NO_x, VOC, PM_{10} and $PM_{2.5}$ from natural and human-made sources in the GMR.

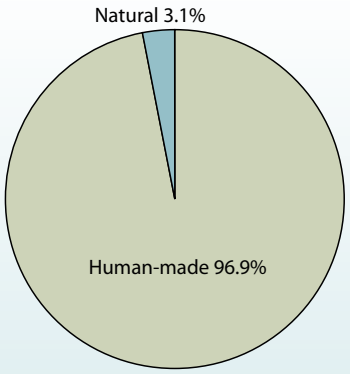


Figure 7: *Natural and human-made NO_x in the GMR*

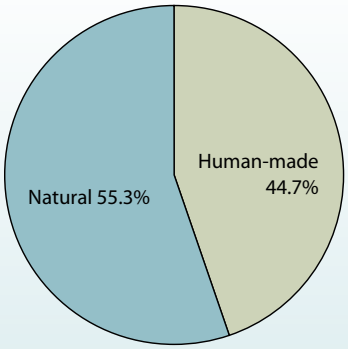


Figure 8: *Natural and human-made VOC in the GMR*

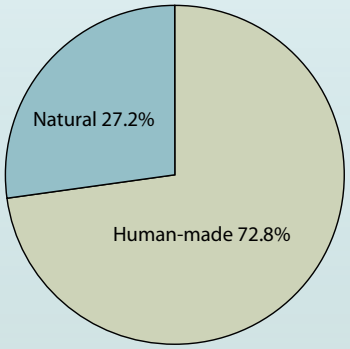


Figure 9: *Natural and human-made PM_{10} in the GMR*

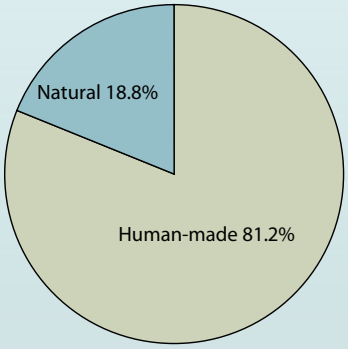


Figure 10: *Natural and human-made $PM_{2.5}$ in the GMR*

Using the data from Table 1, Figures 11 to 14 show the proportions of annual emissions for the priority pollutants NO_x, VOC, PM_{10} and $PM_{2.5}$, from each type of human-made source in the GMR. NO_x emissions from industrial (61.9%), on-road mobile (19.7%) and off-road mobile (17.2%) sources are the most significant and together make up nearly 99% of human-made emissions. For VOC emissions, domestic-commercial (50.2%), on-road mobile (21.5%) and off-road mobile (13.1%) sources are the most significant and together make up nearly 85% of human-made emissions. PM_{10} emissions are dominated by industrial sources (81.5%), while domestic-commercial sources (9.1%) are also significant. Over 91% of human-made $PM_{2.5}$ emissions are made up of industrial (55.7%), domestic-commercial (24.8%) and off-road mobile (10.8%) sources.

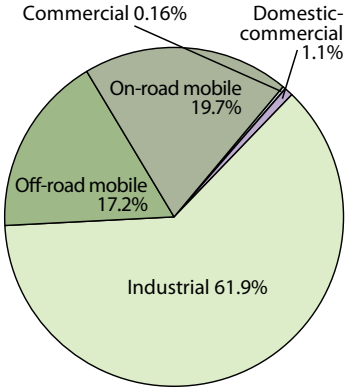


Figure 11: *Human-made NO_x in the GMR*

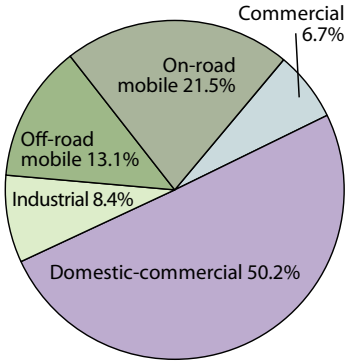


Figure 12: *Human-made VOC in the GMR*

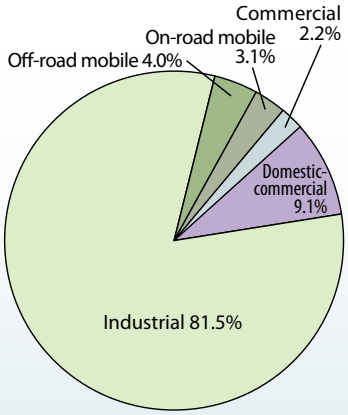


Figure 13: *Human-made PM_{10} in the GMR*

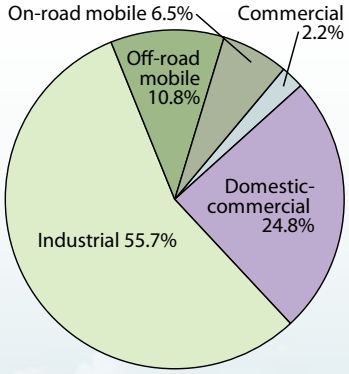


Figure 14: *Human-made $PM_{2.5}$ in the GMR*

What are the major natural and human-made sources in the Sydney region?

Table 2 presents annual emissions of common pollutants from natural and human-made sources in the Sydney region. Human-made sources are the major contributors to CO (97.8%), NO_x (98.3%), PM_{10} (80.9%), $PM_{2.5}$ (91.9%), SO_2 (99.5%) and VOC (75.3%) emissions.

Table 2: *Total estimated annual emissions from natural and human-made sources in the Sydney region*

Substance	Emissions (tonne/year)						
	Biogenic–geogenic	Commercial	Domestic–commercial	Industrial	Off-road mobile	On-road mobile	Grand total
CO	5,484	335	82,186	14,173	20,801	123,712	246,692
NO_x	1,296	344	2,531	8,921	16,238	45,392	74,722
PM_{10}	3,901	1,111	6,088	6,215	1,019	2,110	20,443
$PM_{2.5}$	951	485	5,853	1,935	952	1,553	11,728
SO_2	50	108	131	5,574	4,725	210	10,798
VOC	32,468	6,652	53,178	8,205	7,341	23,512	131,356

Using the data from Table 2, Figures 15 to 18 show the proportions of annual emissions for the priority pollutants NO_x, VOC, PM_{10} and $PM_{2.5}$ from natural and human-made sources in the Sydney region.

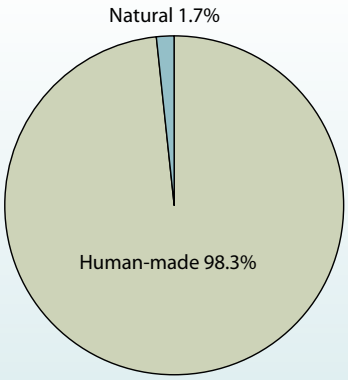


Figure 15: *Natural and human-made NO_x in the Sydney region*

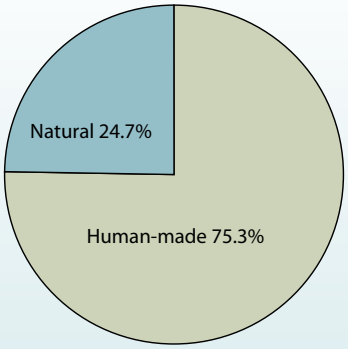


Figure 16: *Natural and human-made VOC in the Sydney region*

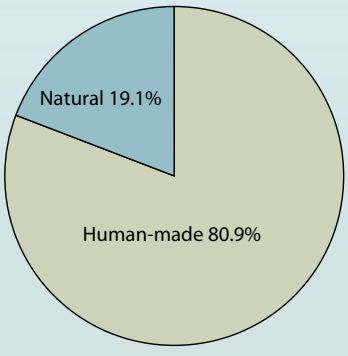


Figure 17: *Natural and human-made PM_{10} in the Sydney region*

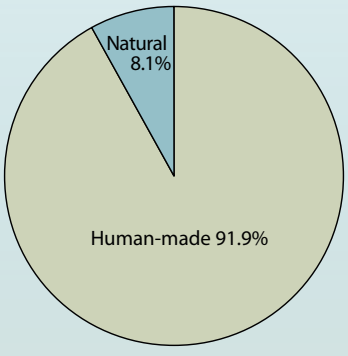


Figure 18: *Natural and human-made $PM_{2.5}$ in the Sydney region*

Using the data from Table 2, Figures 19 to 22 show the proportions of annual emissions for the priority pollutants NO_x, VOC, PM_{10} and $PM_{2.5}$, from each type of human-made source in the Sydney region. NO_x emissions from on-road mobile (61.8%), off-road mobile (22.1%) and industrial (12.1%) sources are the most significant and together make up over 96% of human-made emissions. For VOC emissions, domestic-commercial (53.8%) and on-road mobile (23.8%) sources are the most significant and together make up nearly 78% of human-made emissions. PM_{10} emissions from industrial (37.6%) and domestic-commercial (36.8%) sources are similar, while on-road mobile sources (12.8%) are also significant. Nearly 87% of human-made $PM_{2.5}$ emissions are made up of domestic-commercial (54.3%), industrial (18.0%) and on-road mobile (14.4%) sources.

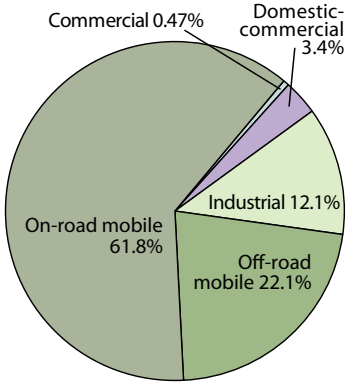


Figure 19: *Human-made NO_x in the Sydney region*

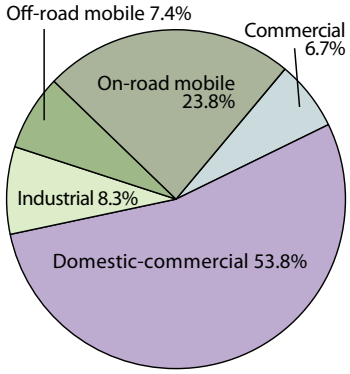


Figure 20: *Human-made VOC in the Sydney region*

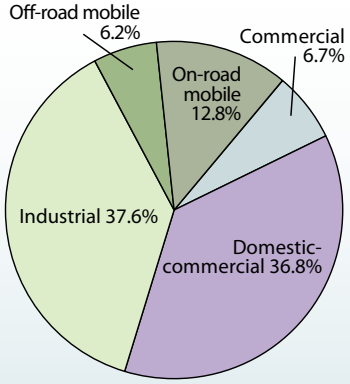


Figure 21: *Human-made PM_{10} in the Sydney region*

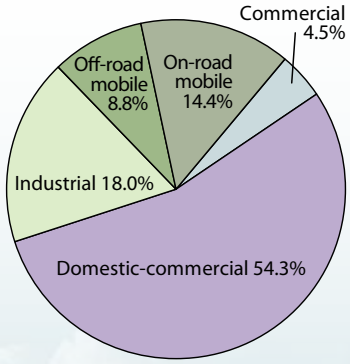


Figure 22: *Human-made $PM_{2.5}$ in the Sydney region*

Where can I obtain additional information?

If you need more detailed information about activity data, emission estimation methodologies, sources, or emissions of other air pollutants included in the air emissions inventory you can visit the EPA website at www.epa.nsw.gov.au and download the following documents:

- *Technical Report No. 1. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Consolidated Natural and Human-Made Emissions: Results*
- *Technical Report No. 2. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Biogenic and Geogenic Emissions: Results*
- *Technical Report No. 3. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Commercial Emissions: Results*
- *Technical Report No. 4. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Domestic-Commercial Emissions: Results*
- *Technical Report No. 5. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Industrial Emissions: Results*
- *Technical Report No. 6. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. Off-Road Mobile Emissions: Results*
- *Technical Report No. 7. Air Emissions Inventory for the Greater Metropolitan Region in New South Wales. 2008 Calendar Year. On-Road Mobile Emissions: Results.*

The work of a number of individuals is acknowledged, including Mr Nick Agapides, Manager Major Air Projects, Mr Kelsey Bawden, Senior Technical Policy Advisor and Mr Gareth Jones, Senior Atmospheric Scientist, for their efforts in project scoping and management, developing emission estimation methodologies, collecting activity data, developing databases, estimating emissions and preparing this brochure.

Published by:
Environment Protection Authority
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: (02) 9995 5000 (switchboard)
Phone: 131 555 (environment information and publications requests)
Phone: 1300 361 967 (national parks, climate change and energy efficiency information, and publications requests)
Fax: (02) 9995 5999
TTY users: phone 133 677 then ask for 131 555
Speak and listen users: phone 1300 555 727 then ask for 131 555
Email: info@environment.nsw.gov.au
Website: www.epa.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.epa.nsw.gov.au

ISBN 978 1 74293 642 0
EPA 2012/0404
August 2012
Printed on environmentally sustainable paper