Managing particles and improving air quality in NSW

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Introduction

In February 2012 the NSW Government re-established the Environment Protection Authority (EPA) as an independent, accountable and modern regulator to protect the environment and people of NSW.

The EPA's vision is for a 'healthy environment, healthy community, healthy business'. Protecting air quality and reducing the impacts of air pollution on NSW urban and regional communities are central to this vision.

The EPA is committed to working with the community and stakeholders to improve understanding about air quality issues. The EPA leads business and the community to improve their environmental performance and employs regulatory tools, education, partnerships and economic mechanisms to achieve environmental outcomes.

The EPA collaborates with other jurisdictions, other NSW Government agencies, local councils and stakeholder groups, to maximise the effectiveness of environment protection activities. The EPA leads development of the National Plan for Clean Air, as Chair of the national working group tasked with the Plan's development.

Reducing particle pollution is a priority for the EPA, based on evidence that:

- communities in urban and regional NSW are exposed to particle pollution which is harmful to health
- there are feasible, cost effective actions available to governments, industry and the community to reduce particle emissions
- reducing particle pollution will deliver substantial health and economic gains.

Managing Particles and Improving Air Quality in NSW presents:

- the principles the EPA has adopted for managing particles
- the evidence on which the EPA bases management of particles
- a fully funded set of actions to reduce particle emissions in urban and regional NSW, targeting priority locations and sources to achieve the greatest public health benefit.

The actions presented encompass both actions to improve the evidence and to reduce impacts from a range of particle sizes and total particle pollution. The priority for EPA action is to reduce long-term exposure to fine particles (less than 2.5 microns in diameter), as this carries the greatest risk of serious health impacts.

Snapshot of particle pollution in NSW

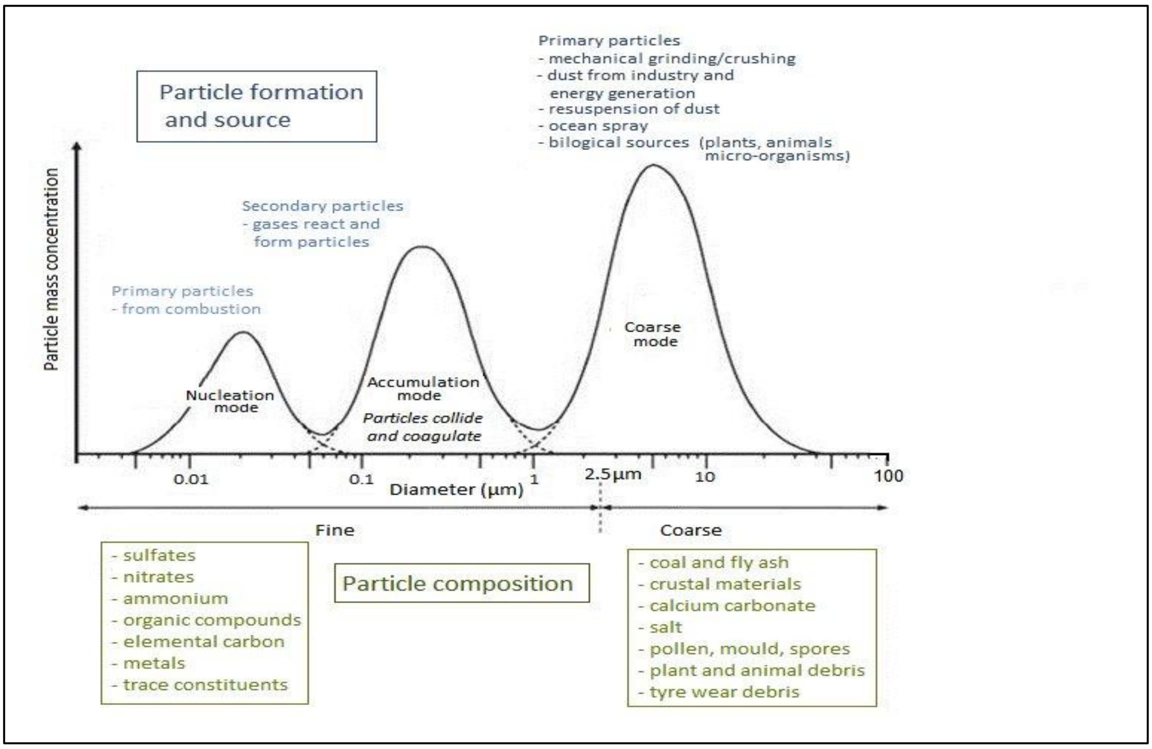
Particle pollution in the air can come directly from natural sources such as bushfires and dust storms, and also from human activities such as wood burning, mining, industrial processes and motor vehicle use. Particles are also produced by chemical reactions between gases or between gases and other particles in the air.

Particles in the atmosphere vary in size. The particles monitored in NSW are particles less than 10 microns in diameter (PM_{10}) and fine particles less than 2.5 microns in diameter ($PM_{2.5}$) (see Figure 1). The term total suspended particles (TSP) may be applied to the sum of all suspended particles less than 50 microns in diameter.

Figure 1 illustrates:

- the possible chemical composition of particles in different size ranges
- possible sources of different sizes and types of particles – with larger, coarser particles tending to come from dust and sea salt or mechanical processes such as grinding, whereas smaller, finer particles are more likely to result from chemical reactions and combustion processes
- modes and processes (mechanical and chemical) by which different particle types and sizes can be formed in the atmosphere.

Figure 1: Particulate matter size fractions and sources, formation and composition



While regulation of industry, vehicles and fuels has reduced emissions of many harmful pollutants in NSW in recent years, there is evidence that particle emissions are growing in the Greater Metropolitan Region (GMR) overall. This region includes Sydney, the Hunter, the Central Coast, the Illawarra and surrounding areas.

The rise in particle emissions in the GMR has occurred despite particle emissions falling in Sydney, and is due largely to increased coal mining activities in the Hunter. Other major sources of particles in the GMR include wood heaters and diesel vehicles and off-road diesel machines, such as those used in construction, mining and ports.

Primary and secondary particles

Primary particles are released directly into the atmosphere by mechanical or combustion activities e.g. from wind, erosion or combustion.

Secondary particles are formed in the atmosphere itself as a result of chemical reactions between gaseous pollutants (precursor pollutants) or gases and existing particles. Precursor pollutants include nitrogen oxides, sulfur oxides, volatile organic compounds and ammonia. Sometimes, there may be composite primary and secondary particles when primary particles react with atmospheric gases and acquire a coating.

Particle reduction measures outlined in *Managing Particles and Improving Air Quality in NSW* are targeted to primary particle emissions. Investigation is ongoing to improve our understanding and management of secondary particles and their impacts.

Health impacts and the benefits of reducing particles

According to the World Health Organisation (WHO), particles affect more people than any other air pollutant. Most urban and rural populations worldwide experience adverse health effects from inhaling particles. In NSW, particle levels occur at or above current national air quality standards in major cities and some regional centres.

The particles of most concern are fine particles less than 2.5 microns in diameter ($PM_{2.5}$). Unlike larger particles, these smaller particles invisible to the naked eye can be breathed deep into the lungs and even pass into the bloodstream. They also travel under the influence of wind and weather and can produce effects many kilometres from their source.

Long and short-term exposure to particles is linked to an increased risk of respiratory and cardiovascular disease and of death from those diseases. Long-term exposure is most harmful and those most affected by particle pollution are the elderly, children and people with existing cardiovascular and respiratory health conditions.

The evidence is clear that long-term exposure to $PM_{2.5}$ has a larger health effect than short-term exposure, indicating that strategies that provide long-term reductions in fine particle pollution are likely to produce the greatest health benefit.

On 17 October 2013, the International Agency for Research on Cancer (IARC) announced that it had classified outdoor air pollution and one of its major components, particulate matter, as carcinogenic to human beings, based on sufficient evidence that exposure to these causes lung cancer. The IARC had previously classified diesel exhausts as a human carcinogen (IARC 2012). Diesel exhausts are an important source of fine particles in ambient air.

There are substantial health and economic gains to be made by reducing particle pollution. The *Final Regulation Impact Statement for Review of Euro 5/6 Light Vehicle Emissions Standards* (Commonwealth Department of Infrastructure, November 2010) found that tightening Australian light vehicle emission standards to match European standards would yield up to $807 million worth of benefits nationally, primarily due to the reduction in mortality associated with reducing particles.

More information on health impacts is provided at Appendix 1.

Influencing particles management at national level: National Plan for Clean Air

The EPA is championing a new strategic national approach to air quality to be embodied in a National Plan for Clean Air.

In 2011 the Council of Australian Governments (COAG) identified air quality as a 'priority issue of national significance' and agreed that a National Plan for Clean Air would be developed by the end of 2014 (Standing Committee on Environment and Water 2012). The Plan responds to the review of the National Environment Protection (Ambient Air Quality) Measure (NEPC 2010, NEPC 2011) and seeks to maximise the benefits of improving air quality to the Australian community.

As promoted by NSW, particles are the priority for the Plan's first stage.

The Plan involves integrating a review of the particle standards in the National Environment Protection (Ambient Air Quality) Measure (Air NEPM) with new national and state-based measures to address particles.

As part of this process, the EPA is supporting:

- a mandatory standard for fine particles (as $PM_{2.5}$) and
- the introduction or tightening of national emission standards for wood heaters, non-road diesel engines and small spark ignition engines.

As demonstrated by the 2008 Air Emissions Inventory update, emissions from the product and equipment sectors have continued to climb as the population and the economy grow. Unregulated diesel and combustion sources, such as non-road diesel engines, two stroke engines and wood heaters, have become more significant emitters of particles and precursors of secondary particles and are an important target for new measures.

While NSW has introduced programs targeting these sources, gains can be eroded because national laws still allow products with high emissions to be imported and sold in Australia. Europe, North America, China, Japan and India have introduced or tightened relevant emission standards for a range of products and equipment.

A cost curve study undertaken for the EPA in 2010 confirmed that national actions to reduce emissions from these sources are priorities for any set of feasible, cost-effective actions to bring NSW into compliance with national air quality goals (DECCW 2010b). Studies and economic analyses for each sector have also demonstrated that substantial benefits can be achieved cost-effectively in Australia by bringing emission standards for these sectors into line with international best practice.

The first stage of the National Plan for Clean Air is considering new emission standards for non-road diesel engines, small spark ignition engines and wood heaters, as well as new frameworks and other actions to address particle pollution.

Subject to agreement among jurisdictions, the EPA has committed funding to the second stage of the National Plan for Clean Air. Potential future work may encompass investigating new standards for particle precursors, such as sulfur dioxide, and further national measures relating to particle and particle precursor source sectors, such as shipping, locomotives and aerosols.

How the EPA manages particles

EPA principles for managing particles

- ***Achieve national air quality goals and protect air quality for all communities***

  NSW has adopted particle standards to be achieved in population centres as set out in the National Environment Protection (Ambient Air Quality) Measure.

$PM_{2.5}$ advisory reporting standard

The advisory standard is that the maximum concentration, averaged over 24 hours, is 25 micrograms per cubic metre ($\mu g/m^3$), and the maximum concentration, when averaged over a year, is 8 $\mu g/m^3$. This Australian advisory standard is stricter than the World Health Organisation, European and United States standards for annual $PM_{2.5}$.

PM_{10} compliance standard

The maximum concentration allowed, when averaged over 24 hours, is 50 $\mu g/m^3$. This may be exceeded on up to five days a year, to take account of extreme events such as bushfires and dust storms.

  The Air NEPM is currently under review. The EPA's view is that the $PM_{2.5}$ NEPM reporting standard should be adopted as a compliance standard.

  For polluting activities wherever they occur in NSW, the EPA uses its regulatory powers to control industry emissions and protect air quality for local populations, and works in partnership with local councils and communities to reduce emissions from unregulated sources. The EPA pursues ongoing reductions in exposure to particles, to continue achieving health gains for the community as long as there is overall community benefit.

- ***Strengthen and act on evidence***

  To ensure a rigorous evidence base for its programs, NSW maintains and updates its air quality monitoring network and air emissions inventory and pursues a range of particles research programs.

- ***Use innovative and effective tools***

  The EPA manages particles through a combination of regulation and education, business and community partnerships and economic mechanisms. The EPA researches and implements best practice measures to continuously improve management of particles and ensure industry minimises emissions using all reasonable and practicable measures.

- ***Develop least cost pathways to improve air quality and maximise net benefits***

  The EPA applies economic analysis tools so that its management strategies and specific control measures deliver greatest benefit to the community while minimising costs to community and business.

- ***Engage and inform the community***

  The EPA and OEH use a range of communication and consultation techniques and technologies to make air quality data and information fully available to the public. An overview of air quality management in NSW and links to more detailed information are available at: www.epa.nsw.gov.au/air/index.htm. This includes a link to a short video about air quality in NSW and in particular the Hunter Valley region. It includes information on emissions and their sources, air quality monitoring, particulate matter and its effects on health and wellbeing. The EPA seeks stakeholder input on managing particle issues, via public forums on specific issues and projects and local community advisory committees. See www.epa.nsw.gov.au/MediaInformation/epacomcmtee.htm.

- ***Collaborate on cleaner air at all levels of government – NSW, local and national***

  The EPA works cooperatively with the Office of Environment and Heritage (OEH) on developing the evidence base for air quality management and collaborates with other NSW agencies including NSW Health, Transport for NSW, the Department of Planning and Infrastructure and the Department of Trade and Investment.

  The EPA supports local councils in their air quality management role with management frameworks and tools, information and guidance and funding for local initiatives.

  At national level, the EPA is championing a new strategic approach to air quality to be embodied in the National Plan for Clean Air. As advocated by the EPA, the first stage of developing the Plan focuses on particles as the pollutant of highest health impact.

How the EPA identifies and develops actions to manage particles

The EPA prioritises and targets particle control actions to areas where population health is most affected and to the most polluting activities impacting on public health in those areas. To develop the set of particle control actions that will maximise benefits to NSW communities, the EPA utilises:

- **Ambient air quality monitoring** to characterise regional air quality, show where national goals are and are not being met, and focus EPA attention where action is needed
- **The EPA air emissions inventory** to quantify particle emissions from all sources in the NSW GMR and identify the principal sources of particles impacting on air quality in a region
- **Particle characterisation studies** to further determine what particles sources are impacting on areas' ambient air quality and in what proportions
- **Particle modelling** to estimate future concentrations of particles under different scenarios and what emission reductions are required from different sources to achieve air quality targets
- **Research and economic analysis** to identify and develop best practice particle control measures that are feasible and cost-effective and will deliver the greatest overall gains for the community
- **Stakeholder communication and consultation** to increase community understanding of air quality issues and provide greater opportunity for stakeholders to provide input into EPA initiatives to improve air quality in NSW
- **Continued monitoring, modelling and evaluation** of specific strategies, including further consultation, to provide feedback to assess and continue improving EPA management of particles.

Reducing particle emissions across all sectors

Industry

The EPA licenses industry scheduled under the *Protection of the Environment Operations Act 1997* (POEO Act). The Act requires industry and business to operate in a way that avoids air pollution where possible and adopt all practicable means to prevent or minimise air pollution, and to comply with emission standards set under the Clean Air Regulation 2010.

The Department of Planning and Infrastructure (DP&I) also considers air quality impacts from developments and industry that will be subject to EPA licensing. The EPA provides expert technical advice to DP&I for development proposals referred to the EPA.

Statutory methods, *Approved methods for the modelling and assessment of air pollutants in NSW* (DEC 2005b), are specified for assessing each site so that appropriate emission limits can be set. Methods required to measure emissions of air pollutants from stationary sources in NSW, to determine compliance with emission limits, are specified in *Approved methods for the sampling and analysis of air pollutants in NSW* (DEC 2007).

Under the Clean Air Regulation, NSW industry is divided into groups, based on the date the industrial premises began operating. Over six years from 2005, emission limits were progressively tightened and a timetable imposed for upgrading older plant and equipment. This brought more polluting industrial premises, including some of NSW's oldest and largest industrial facilities such as refineries and steel mills, into compliance with modern standards. Upgraded plant is taken to belong to Group 6 and must comply with the most stringent limits. See Table 1.

Table 1: Progressive tightening of particle emission limits for new and existing industry

	Date of commencement of operations	**General standards of concentration for total solid particles ***
Group 1	Before January 1972	400 mg/m³
Group 2	On or after 1 January 1972 and before 1 July 1979	250 mg/m³
Group 3	On or after 1 July 1979 and before 1 July 1986	250 mg/m³
Group 4	On or after 1 July 1986 and before 1 August 1997	250 mg/m³
Group 5	On or after 1 August 1997 and before 1 September 2005	100 mg/m³
Group 6	On or after 1 September 2005	20 mg/m³ or 50 mg/m³ **

* There may be minor variation depending on activity
** Depending on activity

In the *Regulatory Impact Statement Proposed Protection of the Environment Operations (Clean Air) Regulation 2010* it was estimated that the health benefit from reduced PM_{10} emissions as a result of the Regulation is between $801 million and $3377 million over 20 years at 2010 values.

The EPA combines regulatory and economic tools in the form of load-based licensing (LBL). The LBL scheme sets limits on the pollutant loads emitted by holders of environment protection licences and links fees to pollutant emissions, thus encouraging industry to reduce and prevent emissions.

The EPA has consulted on a proposed new risk-based licensing framework. The aim is to ensure a level of regulation appropriate to the level of risk from all licensed premises; create stronger incentives to improve compliance and environmental performance; better equip the EPA to regulate facilities with a high pollution risk; and improve the information available to the community on EPA management and industry performance.

As well as implementing its broad regulatory approach, the EPA has commissioned scoping studies of priority industry sectors, such as coal mines, to identify international best practice approaches for the sector and bring NSW into line with these. To achieve this, the EPA attaches pollution reduction programs to the environment protection licences of premises in that sector (see coal mines dust and diesel emissions case study on page 30).

Commercial and domestic sources

Under the POEO Act, councils are the appropriate regulatory authority for air quality in relation to non-scheduled activities, usually medium-to-small industries, commercial businesses, domestic activities and rural and agricultural activities. Councils also have a major non-regulatory role in encouraging behaviours to reduce emissions, both to protect local air quality and improve outcomes for regional air quality.

An important component of the EPA's activities is supporting and mentoring local councils in discharging their responsibilities for managing air quality. The EPA supports local councils in their air quality management role with management frameworks and tools, information and guidance and funding for local initiatives. A comprehensive 'local government air quality toolkit' developed by the EPA is available to councils and supported by periodic training for council officers, in the form of highly interactive workshops. The toolkit is available on the EPA website at www.epa.nsw.gov.au/air/lgaqt.htm.

Part 3 of the Clean Air Regulation operates to effectively ban backyard burning in metropolitan areas and restricts it to varying levels in more rural areas. Councils may choose to be listed in Schedule 8 of the Clean Air Regulation which allows them to apply a level of control that is appropriate to local circumstances. This has been a major contributor to improvements in local air quality across urban and regional NSW. The EPA is now working closely with and providing financial and other support to assist councils in managing wood smoke (see wood smoke case study on page 34).

Vehicles, engines and fuels

The Clean Air Regulation, Part 4, deals with vehicle and fuel emissions, including excessive smoke from motor vehicles (enforced under the EPA's ongoing Smoky Vehicle Program), the fitting and maintenance of anti-pollution devices, limits on summertime petrol volatility and requirements for vapour recovery at petrol service stations. Reducing evaporative emissions from vehicles and fuels addresses atmospheric ozone pollution, which is an issue in Sydney, while also reducing precursors for secondary particles.

The EPA has also advocated successfully for progressive tightening of national vehicle and fuel standards, which have played and continue to play a major role in reducing vehicle emissions and improving urban air quality.

While standards have been effective in reducing emissions from new vehicles, a high proportion of emissions come from older vehicles within the existing fleet and have been addressed through such NSW initiatives as the diesel retrofit program. This involved the EPA and Roads and Maritime Services (RMS) working with local councils and private enterprise to retrofit fleet vehicles. At completion of the program in June 2011, over 520 vehicles from 71 fleets had been retrofitted. For the total program costs of $3.1 million, this delivers particle emission reductions of 4.7 tonnes per annum and will avoid approximately $1 million each year in health costs.

Following on from the diesel retrofit program, RMS is using camera technology to identify more polluting trucks which regularly use the M5 and providing incentives for owners to have them assessed, repaired and fitted with a particle trap on a 50:50 shared cost basis.

There are still significant public health gains available from reducing emissions in this sector, in particular from non-road engines which are not subject to national standards. The EPA is addressing these through its Clean Machine Program (see case study on page 33) and by supporting standards for new non-road equipment in line with world best practice.

Particle pollution in NSW

Outdoor particle pollution levels depend on the interactions of natural and human-made emissions and a number of other factors. These include:

- meteorology (wind speed and direction, temperature, sunlight and rainfall) – high wind speeds tend to disperse emissions, while wind direction dictates where they are transported. Local air quality may be impacted by large distant sources through medium or long-range transportation of emissions by wind
- topography (surrounding terrain) – this can trap emissions, influence how they disperse or determine the direction they are transported
- atmospheric reactions – in addition to primary particle emissions, secondary particulate matter (inorganic sulfates, nitrates and secondary organic aerosols (SOAs)) can form in the atmosphere
- source type (either point or area) – the influence of a particular emission source on local air quality tends to decrease with distance from the source. Substances may be emitted from a point source, such as a boiler chimney, or over a wider area such as diffuse motor vehicle emissions in an urban road network.

A range of tools is needed to understand how particle composition and concentrations vary over time and across regions, and what sources contribute to particles in the air. Emission inventories, ambient air quality monitoring, particle modelling and particle characterisation are important tools for air quality assessment and management, as shown in Figure 2. These tools are used to characterise particle pollution in NSW, with further analysis then undertaken to assess the effects of particle pollution on human health and the environment. Increasingly, these tools are improving our understanding of secondary particle pollution that is formed within the atmosphere, as well as the contribution of primary particles that are emitted directly.

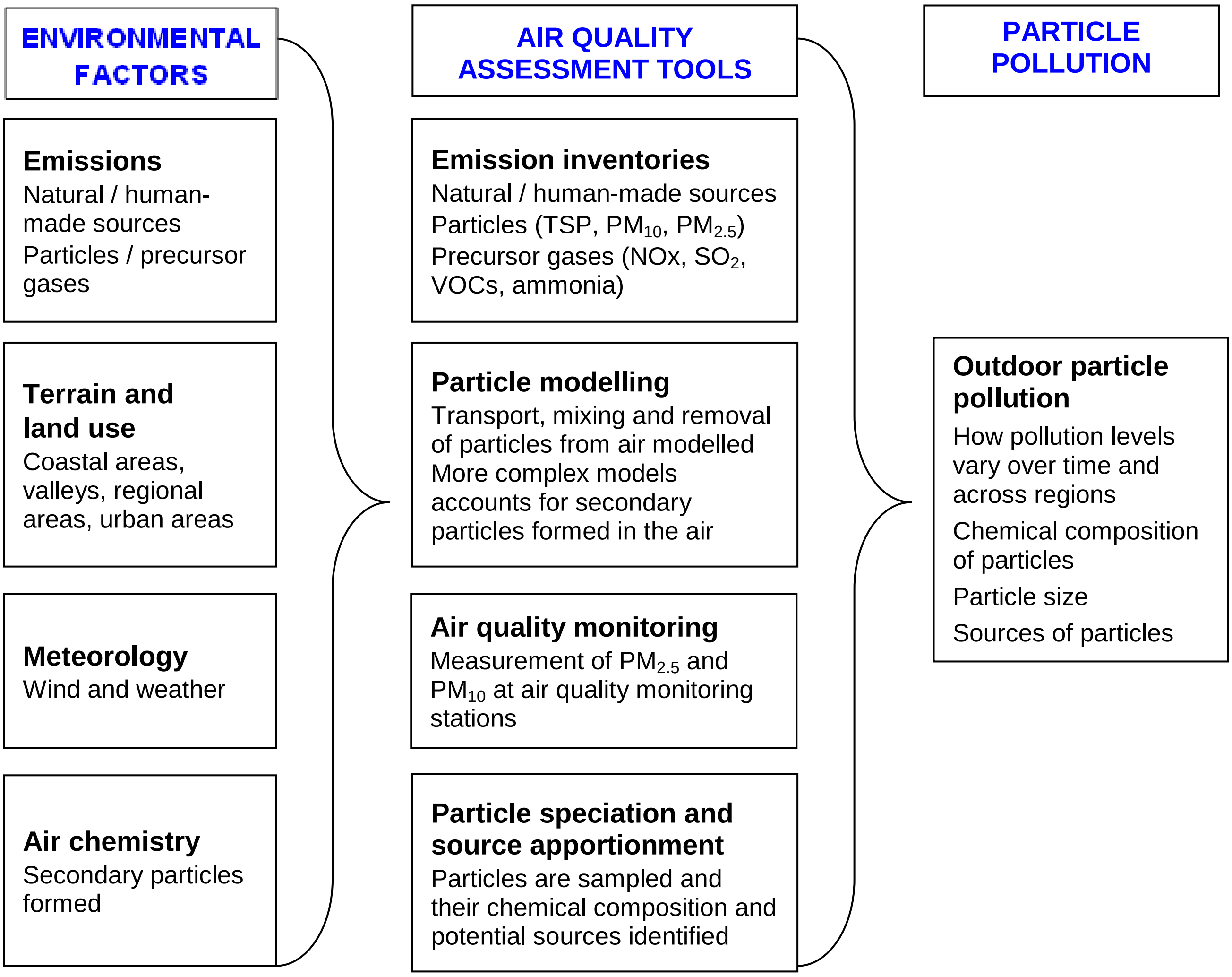
The NSW air emissions inventory provides information on natural and human-made sources of air emissions including primary particle emissions and precursor gas releases. Information from the emissions inventory is used together with meteorological and terrain data within air quality models, in order to predict outdoor particle concentrations.

The NSW air quality monitoring network provides continuous, high quality measurements of $PM_{2.5}$ and PM_{10} concentrations at a number of sites and makes this information available to government and communities in near real-time (i.e. within an hour of the measurement being made). Since it is not possible to measure particle pollution everywhere, air quality models are used to provide additional information on how outdoor particle pollution levels vary over a region. Models are also useful for helping assess the extent to which sources of air emissions affect particle concentrations, and allow us to project future changes in particle concentrations and evaluate the benefits of emission reduction measures.

Particles can be made up of a range of chemical species depending of the source of the particle or the precursor gases from which they form. So the chemical composition of particles in the air can in some cases indicate the source of the particles. In particle speciation studies, airborne particles are sampled and the chemical composition of the particles determined. Mathematical models, known as ‘receptor models’, are then used to estimate source contributions to the particles occurring at the measurement site.

Particle speciation and source apportionment studies have been commissioned by the NSW Government for Sydney and the Upper Hunter to determine the characteristics of $PM_{2.5}$ particles and identify the relative contribution of emission sources to airborne fine particles. Similar studies have been undertaken by the Australian Nuclear Science and Technology Organisation (ANSTO) for a number of Australian east coast sites including a site in the Lower Hunter.

Figure 2: Use of the emissions inventory, modelling and particle characterisation to characterise particle pollution



NSW air quality monitoring network

Sydney's air has been monitored since the 1960s and NSW currently has Australia's largest air quality monitoring program with the OEH operating a strategic network of 40 monitoring stations across the state. The data from this network enables NSW to deliver near real-time air quality information to the community, report against national air quality goals, and evaluate air quality management strategies.

The location of air quality monitoring stations is shown in Figure 3 and Figure 4. Air quality monitoring stations measuring particles are listed in Table 2. A total of 40 stations monitor PM_{10}, with 22 sites also monitoring visibility and 15 sites monitoring $PM_{2.5}$. There are 15 sites in Sydney, three in the Illawarra, three in the Lower Hunter, 14 sites in the Upper Hunter, one on the Central Coast and four sites in regional NSW. The NSW air quality monitoring program includes the industry-funded Upper Hunter Air Quality Monitoring Network (UHAQMN) which was completed in February 2012 and consists of 14 sites.

Public communication services from the NSW air quality monitoring network include:

- **hourly updates for local air quality levels on the air quality monitoring website www.environment.nsw.gov.au/AQMS/aboutaqi.htm**
- **an air pollution alert system, and SMS or email alerts on high pollution days**
- **links to NSW Health's website for information on air quality and health issues**
- **full public access to monitoring data and reports.**

Figure 3: Air quality monitoring in regional NSW and regions with monitoring networks

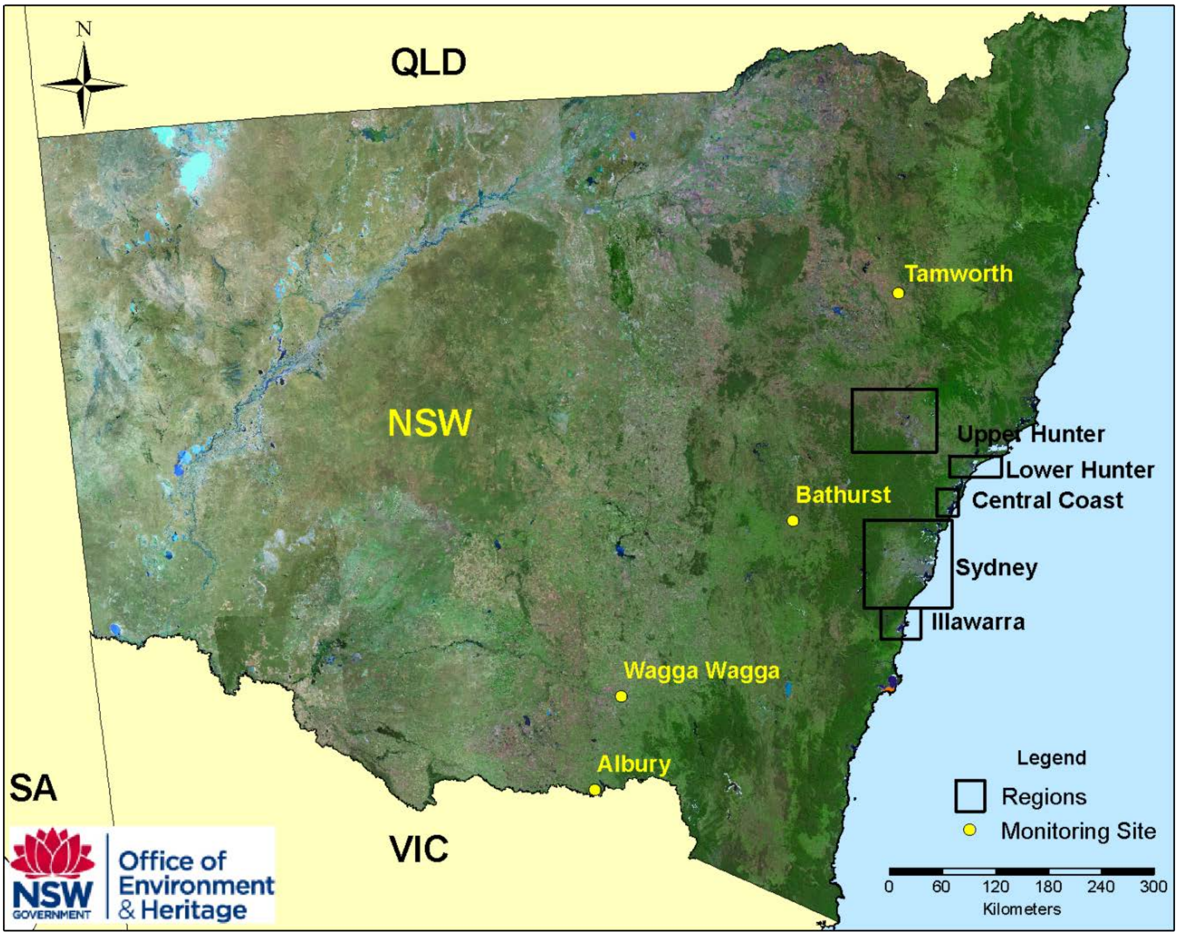


Figure 4: Air quality monitoring stations in the Sydney, Illawarra, Central Coast, Lower Hunter and Upper Hunter regions

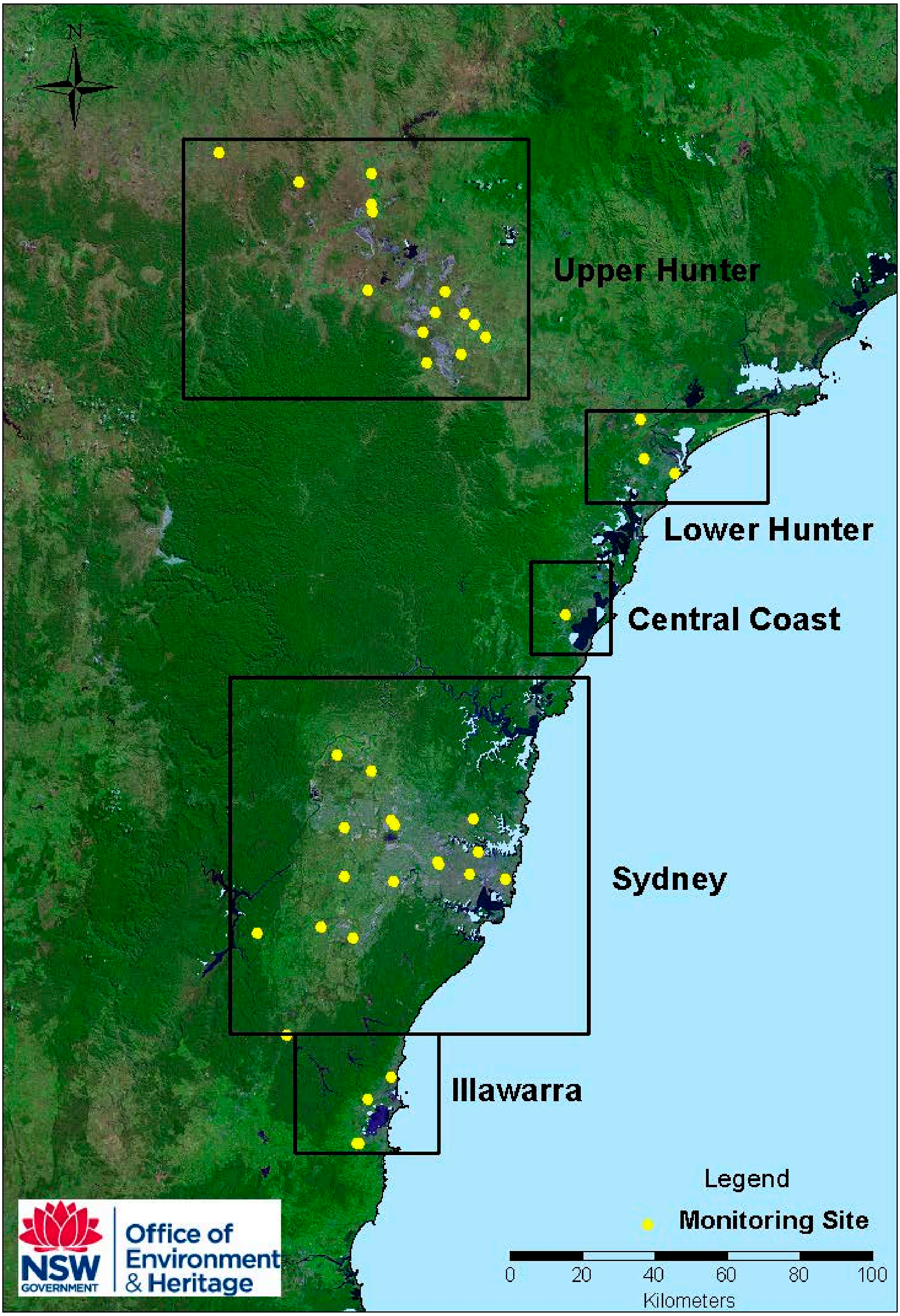


Table 2: NSW ambient air quality monitoring stations measuring particles

Station	Year established	Particles as $PM_{2.5}$	Particles as PM_{10}	Visibility
SYDNEY REGION				
Bargo (SW)	1996		✓	✓
Blacktown/ Prospect (NW)	1992/2007		✓	✓
Bringelly (SW)	1992		✓	✓
Camden (SW)	2012	✓	✓	✓
Earlwood (E)	1978	✓	✓	✓
Lidcombe/ Chullora (E)	1972/2003	✓	✓	✓
Chullora2 (E)	2009	✓		
Lindfield (E)	1994		✓	✓
Liverpool (SW)	1990	✓	✓	✓
Campbelltown West (SW)	2004/2012	✓	✓	✓
Oakdale (SW)	1996		✓	✓
Randwick (E)	1995		✓	✓
Richmond (NW)	1992	✓	✓	✓
Rozelle (E)	1976		✓	✓
St Marys (NW)	1992		✓	✓
Vineyard (NW)	1994		✓	✓
CENTRAL COAST				
Wyong	2012	✓	✓	✓
LOWER HUNTER REGION				
Beresfield	1993	✓	✓	✓
Newcastle	1992		✓	✓
Wallsend	1992	✓	✓	✓
ILLAWARRA REGION				
Albion Park South	1980 /2006		✓	✓
Kembla Grange	1994		✓	✓
Wollongong	1992	✓	✓	✓
RURAL NSW				
Albury	2000		✓	
Bathurst	2000		✓	
Tamworth	2000		✓	
Wagga Wagga	2001 to 2011		✓	
Wagga Wagga2	2011	✓	✓	
UPPER HUNTER				
Singleton Central	Dec 2010	✓	✓	
Muswellbrook Central	Dec 2010	✓	✓	
*Singleton NW (Rix's Creek)	Aug 2011		✓	
*Maison Dieu	May 2011		✓	
*Mount Thorley	Aug 2011		✓	
*Bulga	Aug 2011		✓	
*Camberwell	Aug 2011	✓	✓	
*Warkworth	Aug 2011		✓	
*Jerrys Plains	Dec 2011		✓	
*Singleton South	Dec 2011		✓	
*Muswellbrook NW	Dec 2011		✓	
*Aberdeen	Dec 2011		✓	
*Wybong	Dec 2011		✓	
*Merriwa	Feb 2012		✓	

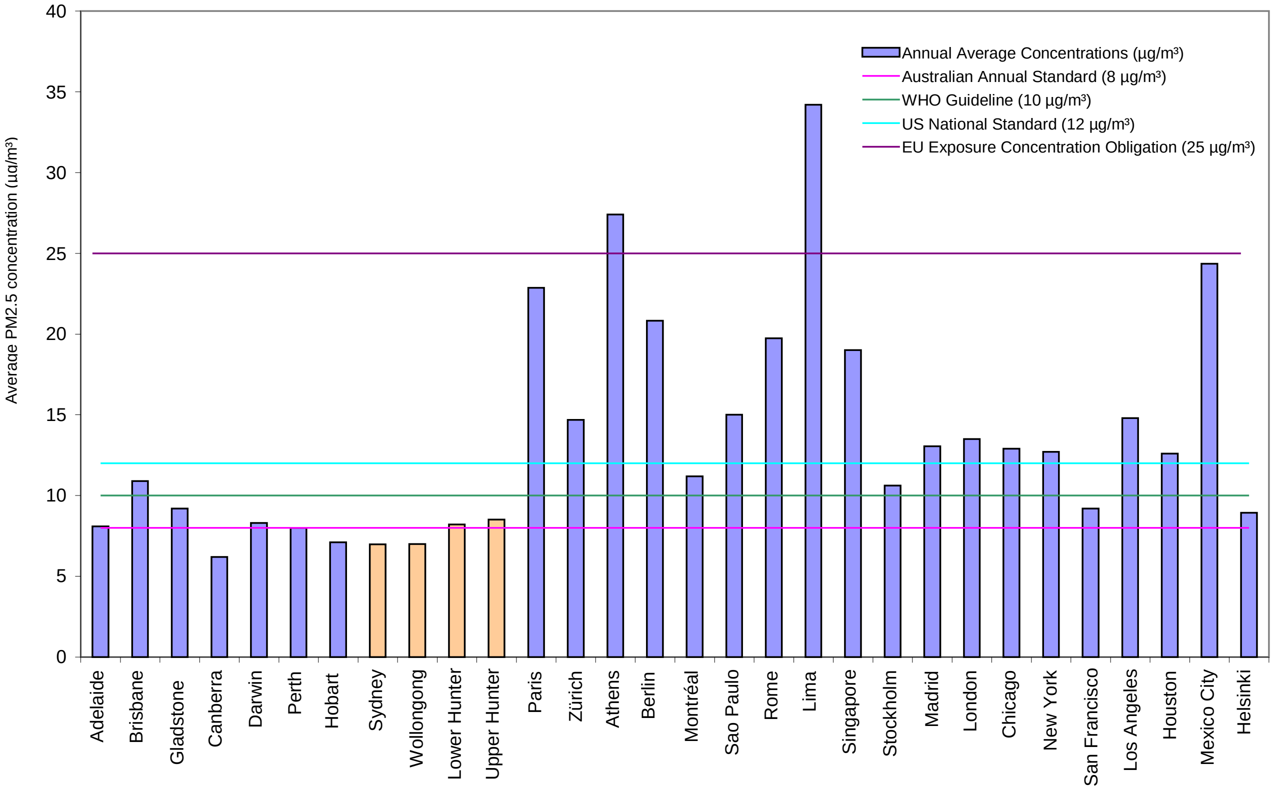
* Data from these stations is not used to characterise air pollution exposure for the general population in the region.

Particle levels measured in NSW

How NSW particle levels compare internationally and inter-state

Air quality in NSW is generally comparable with cities in other Australian jurisdictions and good by world standards, as illustrated in Figure 5, based on annual average $PM_{2.5}$ concentrations. The Australian annual average advisory reporting standard of 8 µg/m³ for $PM_{2.5}$ is more stringent than the air quality standards set internationally (European Union – 25 µg/m³, United States EPA – 12 µg/m³ and World Health Organisation – 10 µg/m³).

Figure 5: Comparison of annual average $PM_{2.5}$ data for several Australian and international cities for 2008-09 (WHO 2011), with annual average $PM_{2.5}$ concentrations shown for the Upper Hunter given for 2012



Note: Annual averages recorded at multiple stations are averaged for each city within the WHO database.

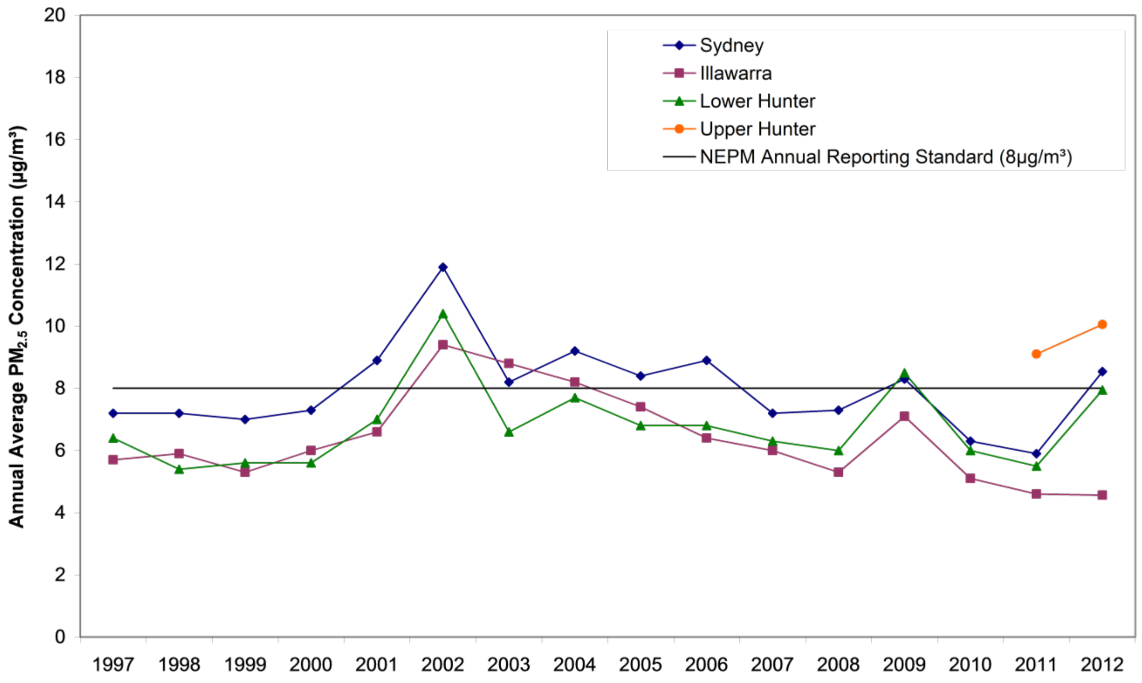
Trends in $PM_{2.5}$ concentration levels

Exceedances of the national advisory standard for $PM_{2.5}$ occur both in urban and regional areas of NSW.

$PM_{2.5}$ levels vary significantly from year to year, as shown by the annual and peak 24-hour average concentrations recorded in NSW over the 1997 to 2012 period (Figure 6, Figure 7) and the number of days each year on which exceedances of the national reporting standard were recorded (Table 3).

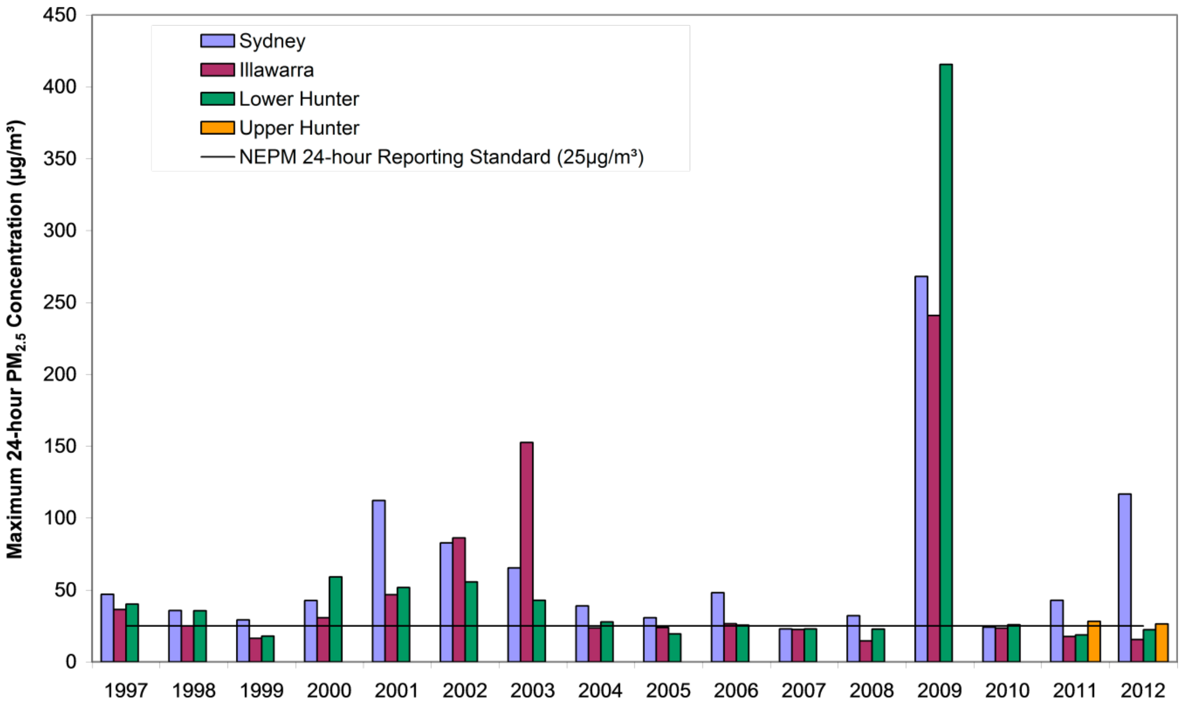
High $PM_{2.5}$ concentrations are typically recorded during years affected by large bushfires or dust storm events. Bushfires were major contributors to the extremely high concentrations of particle pollution recorded in the GMR during 2001–03, with the major state-wide dust storms in September 2009 accounting for widespread exceedances of the 24-hour reporting standard that year. Major bushfire events in spring 2013 have also resulted in very high $PM_{2.5}$ levels in parts of NSW. Local sources such as hazard reduction burns, construction and mining activity and wood heater emissions result in higher $PM_{2.5}$ levels occurring at some monitoring sites.

Figure 6: Annual average $PM_{2.5}$ concentrations recorded at NSW monitoring stations



Note: Maximum annual average across monitoring stations in a region is reported.

Figure 7: Maximum 24-hour average $PM_{2.5}$ concentrations recorded at NSW monitoring stations



Note: Maximum 24-hour average across monitoring stations in a region is reported.

Table 3: Number of days exceeding the national 24-hour average $PM_{2.5}$ reporting standard, as recorded at NSW monitoring stations

Year	Number of days exceeding the national $PM_{2.5}$ reporting standard			
	Sydney	**Illawarra**	**Lower Hunter**	**Upper Hunter**
1997	8	1	3	No data
1998	4	1	1	
1999	1	0	0	
2000	3	2	1	
2001	7	2	6	
2002	24	13	20	
2003	9	5	3	
2004	4	0	1	
2005	2	0	0	
2006	3	2	1	
2007	0	0	0	
2008	1	0	0	
2009	3	3	6	
2010	0	0	1	
2011	4	0	0	4
2012	2	0	0	3

Note: Maximum number of exceedance days across all stations within each region is given.

The distribution of days exceeding the national $PM_{2.5}$ reporting standard by month and region is shown in Figure 8 based on monitoring during the 1997 to 2012 period (the Upper Hunter is not included in this trend graph as monitoring is only available for 2011 and 2012 for this region). Exceedance days are most frequent during spring and summer months within Sydney, the Illawarra and the Lower Hunter, coinciding with periods of increased incidence of bushfires and dust storms. At least 60% of days where levels are above the national reporting standard show some influence from these natural events.

Whereas $PM_{2.5}$ levels are higher during warmer months in Sydney, the Illawarra and the Lower Hunter, more frequent exceedance days have been measured in the Upper Hunter during the winter, with wood heaters a key contributor to fine particle pollution at this time of the year (refer to the *Upper Hunter Fine Particle Characterisation Study* findings; Hibberd et al. 2013).

Trends in PM_{10} concentration levels

PM_{10} standards are met in most years in Sydney, the Illawarra and the Lower Hunter, with exceedances in other years generally attributable to bushfires or dust storms (Figure 9, Table 4). Exceedances of the NSW 24-hour average PM_{10} standard are frequently associated with such events, and therefore are more likely to occur during summer and spring (Figure 10).

Figure 8: Monthly distribution of exceedance days based on the national 24-hour $PM_{2.5}$ reporting standard, as recorded at NSW monitoring stations during 1997 to 2012

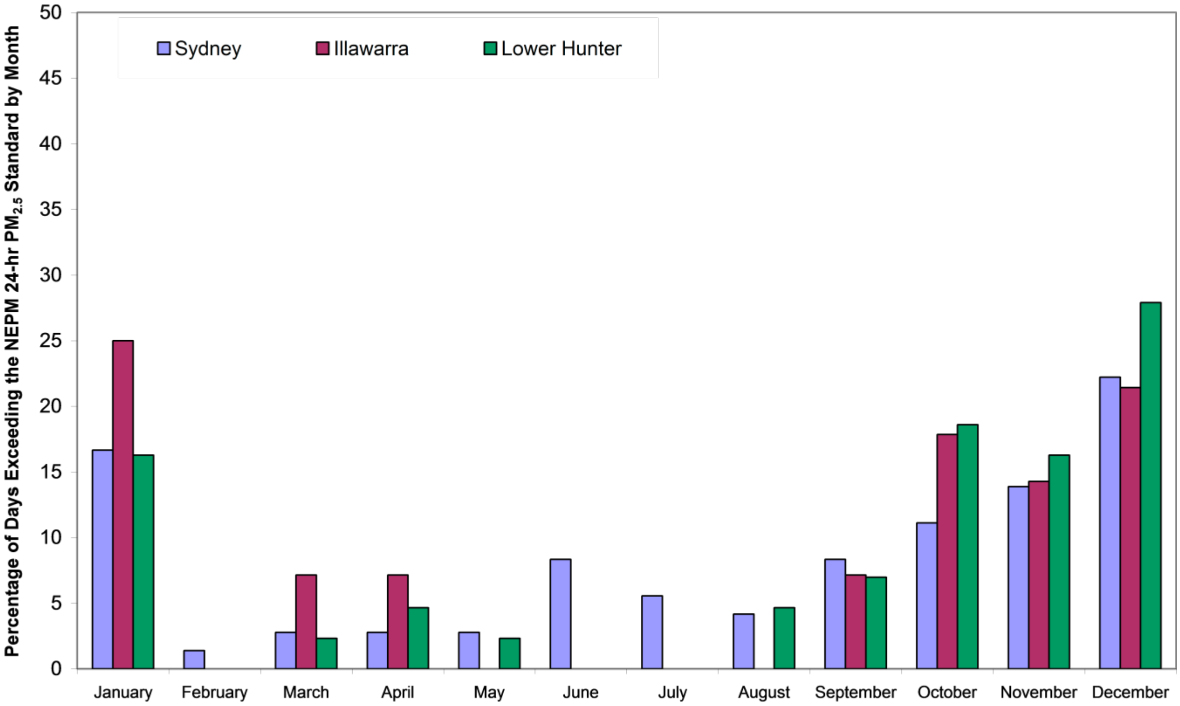
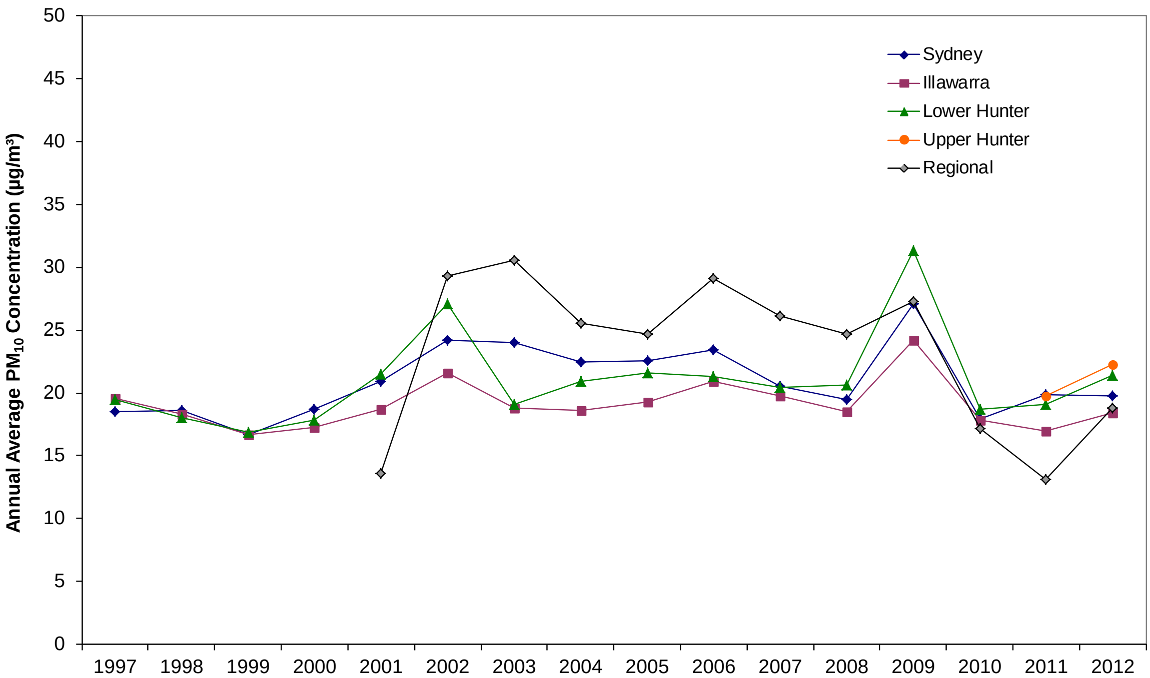


Figure 9: Annual average PM_{10} concentrations recorded at NSW monitoring stations



Note: Maximum annual average across monitoring stations in a region is reported. Upper Hunter data is from the Muswellbrook and Singleton stations as these stations are located to monitor the air quality experienced by the general population in the region.

The national 24-hour PM_{10} standard is sometimes exceeded in the regional centres of Albury (NSW–Victoria border), Bathurst (Central Tablelands), Tamworth (North-West Slopes) and Wagga Wagga (South-West Slopes) (Table 4). High exceedance years are due to factors such as dust storms, bushfires and other conditions associated with the prolonged drought, widespread agricultural stubble burning, and the use of wood heaters in the region. PM_{10} exceedances are most common in summer in Albury, Bathurst and Tamworth, and during autumn in Wagga Wagga.

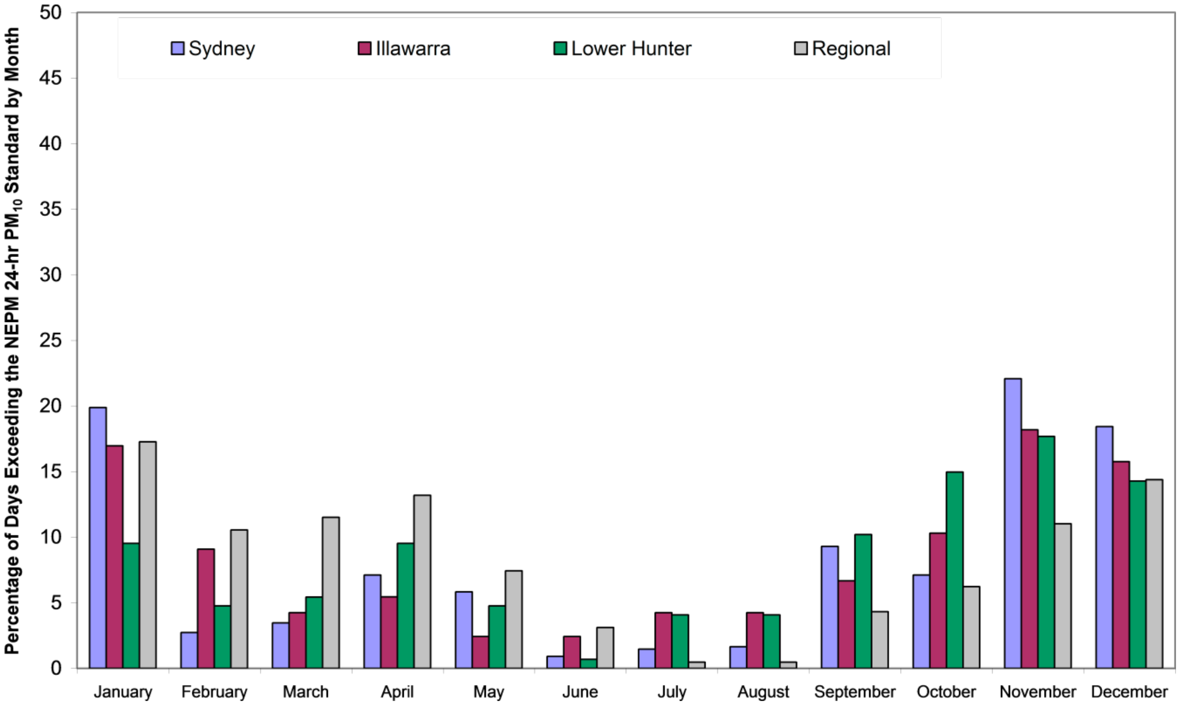
Table 4: Number of days exceeding the national 24-hour PM_{10} standard as recorded at NSW stations

Year	Number of days exceeding the national PM_{10} standard							
	Monitoring regions				Regional sites			
	Sydney	Illawarra	Lower Hunter	Upper Hunter	Tamworth	Albury	Wagga Wagga	Bathurst
1997	4	2	5	No data	No data	No data	No data	No data
1998	2	5	0					
1999	1	0	0					
2000	2	3	1					
2001	5	5	4					
2002	16	12	25		7	5	34	16
2003	11	8	5		7	29	21	12
2004	3	2	1		2	2	28	4
2005	3	5	1		2	3	27	0
2006	8	9	2		0	14	37	3
2007	3	5	5		0	11	34	2
2008	1	4	5		3	8	23	1
2009	11	14	15		17	15	21	12
2010	1	0	1		0	2	6	0
2011	7	1	0	2	1	0	0	0
2012	3	3	1	7	1	1	1	2

Notes: The national PM_{10} standard may be exceeded on up to five days a year to take account of extreme events such as bushfires and dust storms. Wagga Wagga station relocated in 2011. Upper Hunter data is from the Muswellbrook and Singleton stations as these stations are located to monitor the air quality experienced by the general population in the region.

Elevated PM_{10} concentrations are recorded at some sites within the Upper Hunter that are situated in close proximity to open cut mining operations. Due to the influence of such local sources the seasonal pattern of exceedance days is different from other regions, with the greatest number of high PM_{10} days being recorded during spring.

Figure 10: Monthly distribution of exceedance days based on the national 24-hour PM_{10} standard, as recorded at NSW monitoring stations during 1997 to 2012



Longer-term trends in particle concentrations

Particle pollution levels can vary significantly as a result of large-scale climate variations. The El Niño–La Niña climate cycle, which typically occurs between three and five years but can vary from two to seven years, affects the prevailing weather conditions. Dry El Niño years are associated with a greater frequency of bushfires and dust storms and therefore higher particle pollution levels. Lower particle pollution levels tend to occur during wetter La Niña years.

Statistical analysis of $PM_{2.5}$ concentration measurements was undertaken to remove seasonal variations in pollution levels so that longer-term trends could be considered. This was done by expressing each daily $PM_{2.5}$ concentration as a deviation from the mean for that day of the year based on the long-term record. The resulting trends are shown for Sydney in Figure 11 and for the Lower Hunter in Figure 12. While the data record is still limited, it appears that there are higher $PM_{2.5}$ levels during dry El Niño years (2002 to 2007) when compared to the wetter La Niña years (2010 to 2012).

Figure 11: Long-term trend of daily average $PM_{2.5}$ concentrations in the Sydney region, 1997–2012

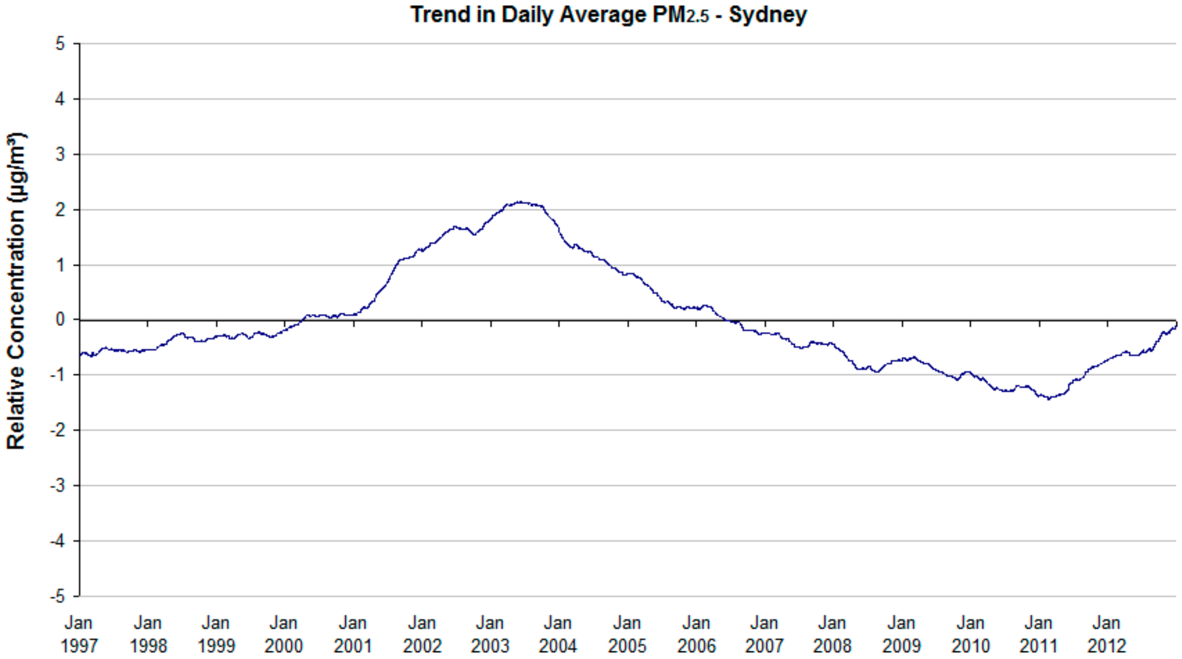
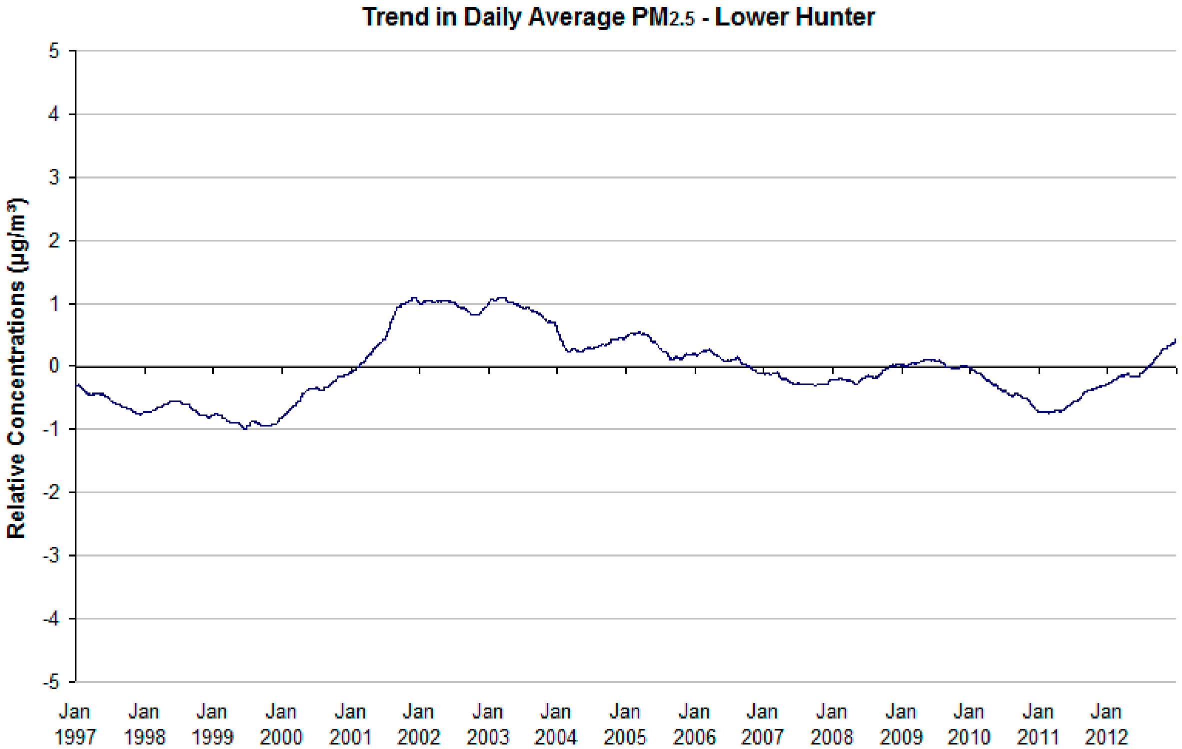


Figure 12: Long-term trend of daily average $PM_{2.5}$ concentrations in the Lower Hunter region, 1997–2012



NSW air emissions inventory

The NSW air emissions inventory is the most comprehensive study of air emissions in Australia. It is used for calculating emission levels, analysing air pollution issues and identifying major emission sources for action.

The EPA updates the inventory every five years, gathering data from a wide range of government and industry sources and by domestic surveys. The most recent update was published in 2012 (EPA 2012).

The inventory estimates emissions from biogenic (natural living), geogenic (natural non-living) and anthropogenic (human-made) sources:

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

The current inventory presents data for the 2008 calendar year, detailing estimated emissions and their sources for over 850 pollutants in the NSW GMR, where about 75% of the NSW population resides. Pollutants detailed in the inventory include primary emissions of PM_{10} and $PM_{2.5}$, and emissions of precursors of secondary particles, as well as other common pollutants, organic compounds, metals and greenhouse gases.

The full inventory reports are available on the EPA website at: www.epa.nsw.gov.au/air/airinventory.htm

Primary particle emissions in the Greater Metropolitan Region

According to estimates in the NSW air emissions inventory, from 1992 to 2008:

- PM_{10} emissions in the Sydney region fell (↓35%), despite growth in the population, the economy, vehicle kilometres travelled and energy consumption
- PM_{10} emissions in the GMR as a whole increased (↑20%).

The inventory estimates also show that other pollutants of concern – oxides of nitrogen and volatile organic compounds, which are precursors of ozone and particle pollution – fell in this period.

Overall the inventory findings confirm that regulation of industry and vehicle emissions is proving effective in driving down pollutants from those sources, but new action is needed to control particle pollution from coal mines and other sources such as wood heaters and non-road diesel engines. The inventory also highlights for future investigation significant particle sources such as shipping.

The main sources of fine particles in the GMR are coal mining and solid fuel heaters. Other significant sources are marine aerosols (sea salt), power generation and bushfires and prescribed burning (Figure 13).

In Sydney, the inventory shows that the foremost human-made source of primary $PM_{2.5}$ is domestic solid fuel heating. Wood heaters account for almost half of annual $PM_{2.5}$ emissions in Sydney (

Figure 14).

*Figure 13: Top 10 $PM_{2.5}$ sources in the GMR**

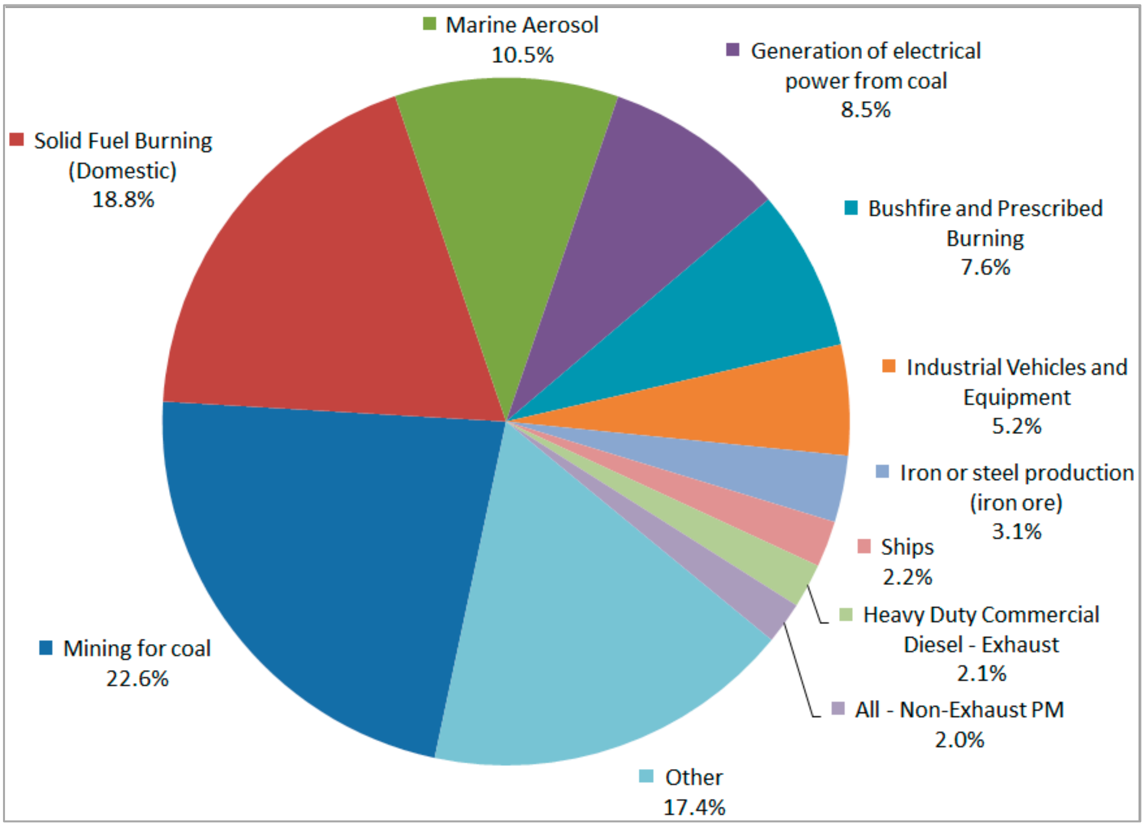
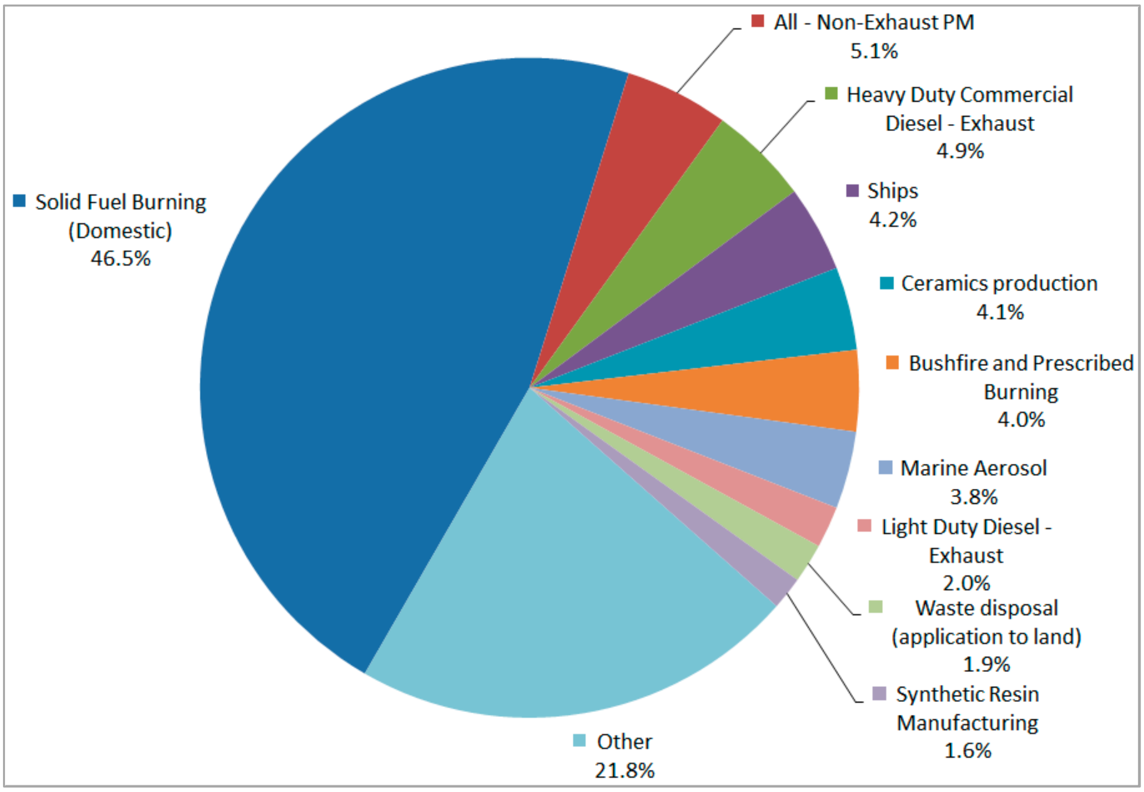


*Figure 14: Top 10 $PM_{2.5}$ sources in Sydney**

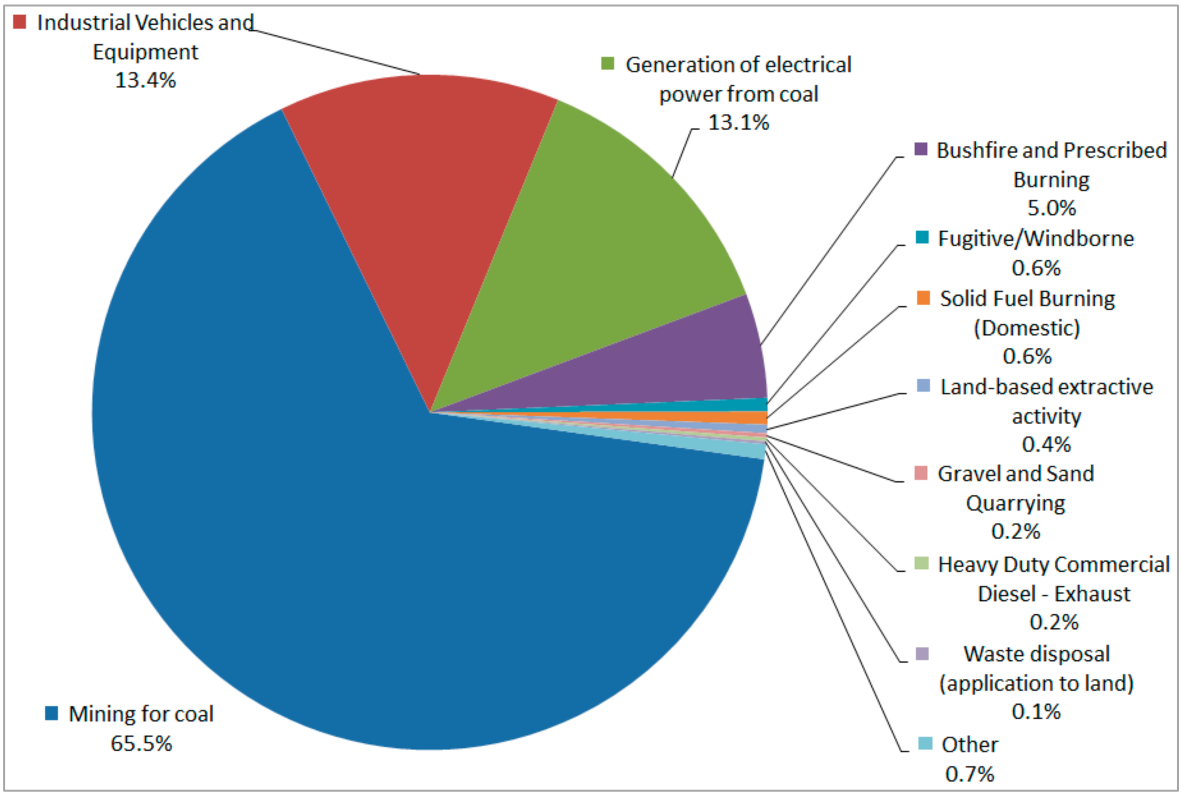


*Note that the colours in Figures 13 to 15 relate to the size of the source (deep blue for the largest, brown for the second largest, then olive green, purple, etc.), not to the type of source (except that light blue consistently refers to ‘other’ sources).

Primary particle emissions in the Upper Hunter

In the Upper Hunter, there has been an increase in estimated emissions of PM_{10} and $PM_{2.5}$ due to the expansion of coal mining. There has also been an increase in the proportion of particle emissions from other sources including home wood heaters and non-road diesel equipment used in mining and construction (Figure 15).

*Figure 15: Top 10 $PM_{2.5}$ sources in the Upper Hunter**



*Note that the colours in Figures 13 to 15 relate to the size of the source (deep blue for the largest, brown for the second largest, then olive green, purple and so on), and not to the type of source (except that light blue consistently refers to ‘other’ sources).

Particle characterisation and modelling studies

Particle characterisation and modelling studies provide us with additional information on the composition and likely sources of fine particles in regions investigated. Such studies include the Sydney Particle Study, Upper Hunter Fine Particle Characterisation Study (Hibberd et al. 2013), and ongoing fine particle characterisation work being carried out by ANSTO for a number of Australian east coast sites.

Sydney Particle Study

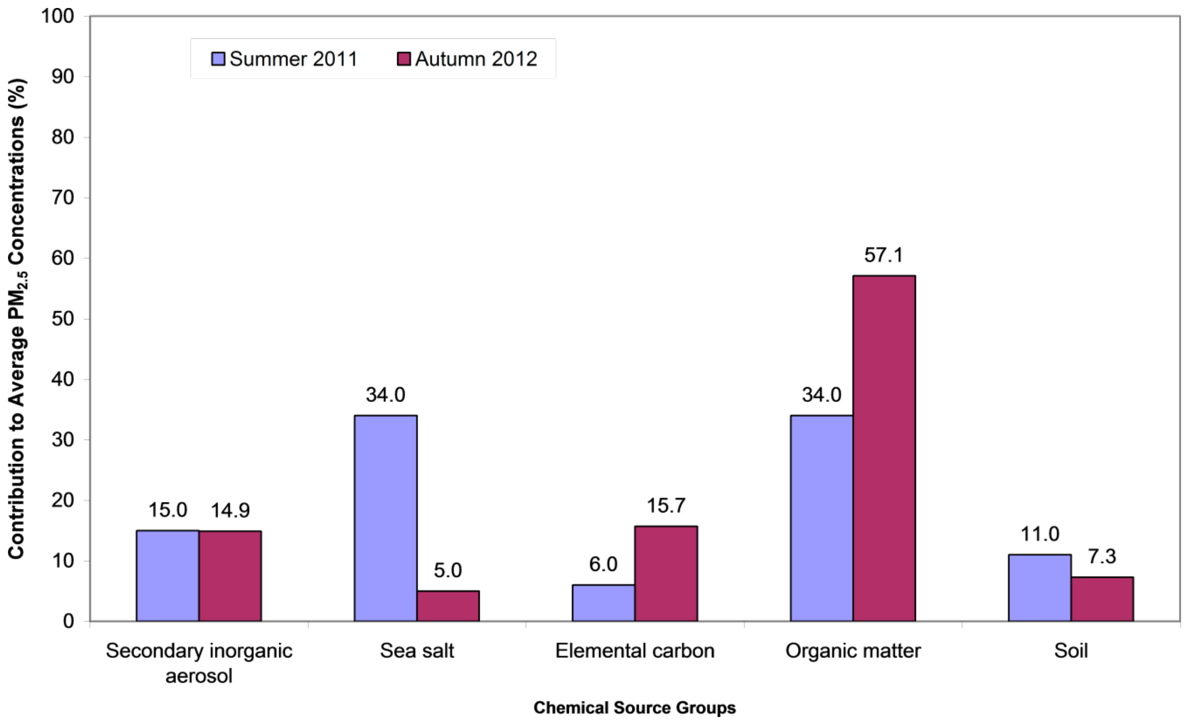
A Sydney Particle Study, commissioned by OEH and undertaken by CSIRO, established a modelling framework for investigating the characteristics of particles in Sydney. The study included two intensive sampling programs at Westmead located 26 kilometres west of the Sydney CBD, including a summer and an autumn observation program. The summer observation program identified sea salt and organic matter as being the major components of $PM_{2.5}$, with secondary inorganic particles, soil and elemental carbon also being present in significant amounts (Figure 16).

Sea salt emissions are due to waves breaking in the open ocean and from coastal surf breaks. Organic matter includes primary particles released from sources such as organic particles in car exhaust, and secondary organic particles formed in the atmosphere. Analysis indicated that up to 70% of the organic matter measured may be secondary organic particles formed in the atmosphere from gases released by biogenic sources. Secondary inorganic particles are sulfate, nitrate and ammonium fine particles produced by chemical reactions in the atmosphere from sulfur dioxide, oxides of nitrogen and ammonia emissions. Elemental carbon is emitted directly to the air from sources such as vehicles, wood heaters and bushfires.

The contribution of sea salt was much lower during the autumn with organic matter comprising a larger portion of the $PM_{2.5}$ measured. The contribution from elemental carbon was also larger compared to the summer, while the secondary inorganic aerosol contribution was about the same.

Chemical transport modelling indicated that the release of volatile organic compounds (VOCs) from vegetation is a major source of secondary organic particles during the summer, whereas wood heaters are a dominant source of such particles in the winter.

Figure 16: Percentage contribution of chemical source groups to summer 2011 and autumn 2012 sampling campaign average $PM_{2.5}$ concentrations measured at Westmead in Sydney



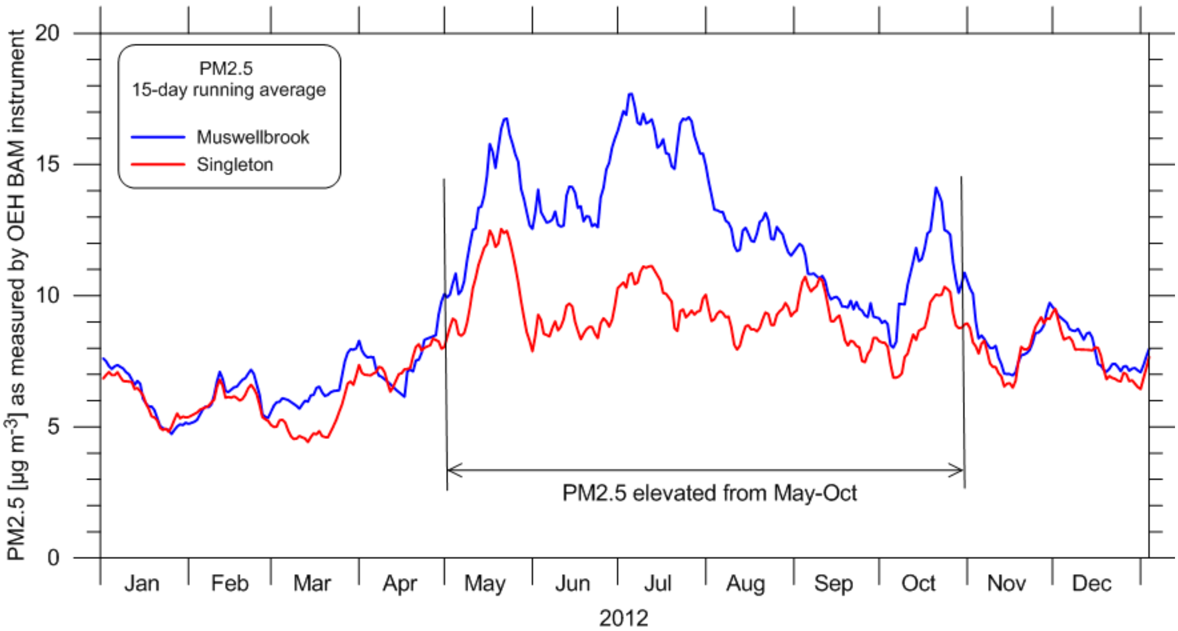
Monitoring and modelling undertaken during the Sydney Particle Study indicate that the composition of fine particles varies seasonally, with natural emissions such as sea salt and biogenic emissions (VOCs from vegetation and bushfires) contributing significantly to background $PM_{2.5}$ concentrations. Secondary particles formed in the atmosphere may account for about half of the $PM_{2.5}$ concentrations at some times of the year.

Data and modelling tools from the Sydney Particle Study are being used by OEH to develop particle modelling capability including accounting for chemical transformations and secondary particle formation. Such advanced particle modelling capabilities will significantly enhance the evidence base for NSW air quality management in future years.

Particle Characterisation Study in the Upper Hunter

Elevated $PM_{2.5}$ concentrations have been measured in Muswellbrook and Singleton during cooler months of the year, from May to October (Figure 17). As there are multiple sources of $PM_{2.5}$, NSW Health and OEH commissioned a research study to better understand the composition and sources of fine particles in the Upper Hunter. The objective of the study was to determine the major components and sources of $PM_{2.5}$ in Singleton and Muswellbrook as the two main population centres of the Upper Hunter. The study was undertaken by CSIRO and ANSTO (Hibberd et al. 2013).

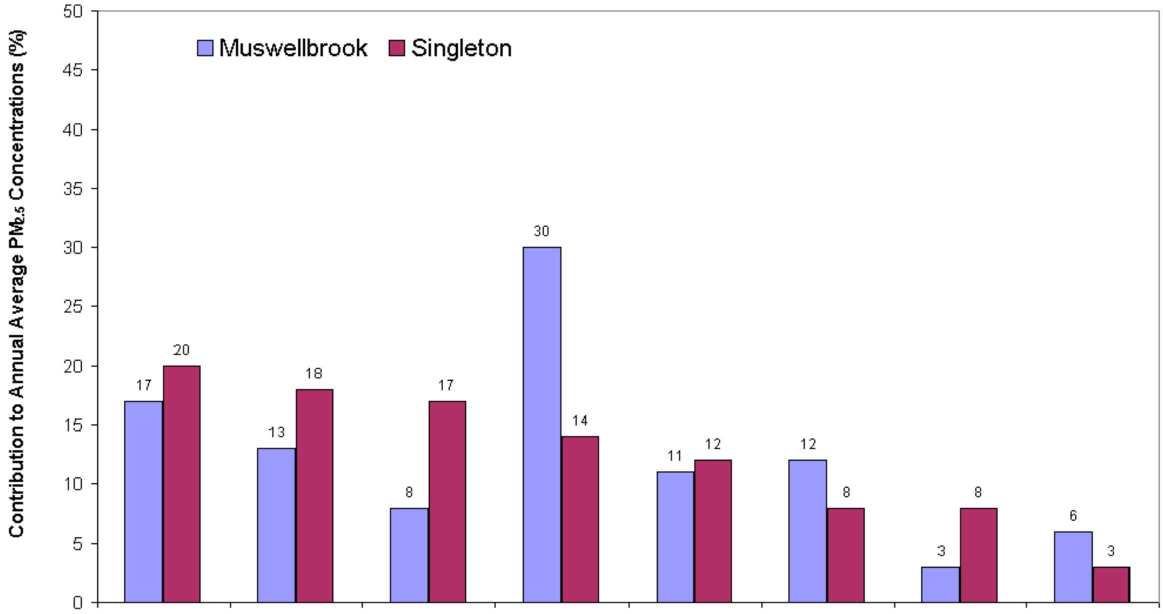
Figure 17: Running average $PM_{2.5}$ concentrations measured at OEH's Singleton and Muswellbrook monitoring stations to illustrate seasonal trends



Sampling was undertaken at Singleton and Muswellbrook on every third day during 2012, with samples subsequently analysed to determine the chemical composition of the particles collected. The chemical composition of all samples was analysed using a mathematical technique called Positive Matrix Factorisation (PMF) to identify factors and the contribution of each factor to the total $PM_{2.5}$ concentration. The key source of emissions in each factor was identified using a range of information including source characteristics, wind data and the pattern of seasonal variation in the factor.

The factors contributing to annual $PM_{2.5}$ concentrations were identified as including: wood smoke, secondary sulfate, industry aged sea salt, vehicles/industry, soil, biomass smoke, sea salt and secondary nitrate. Source contributions to $PM_{2.5}$ concentrations in Singleton and Muswellbrook over the year are shown in Figure 18.

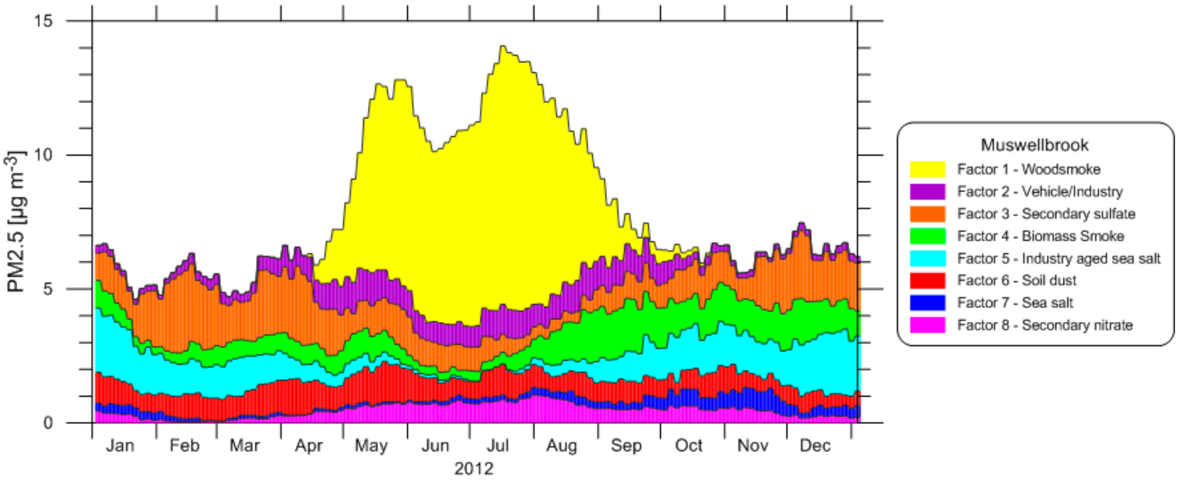
Figure 18: Annual contributions of the PMF factors and associated sources to $PM_{2.5}$ in Singleton and Muswellbrook for 2012



Factor:	Secondary Sulfate	Industry Aged Sea Salt	Vehicle/Industry	Wood smoke	Soil	Biomass Smoke	Sea Salt	Secondary Nitrate
Potential Sources:	Local and regional sources of SO_2 such as power stations	Sea salt, local and regional sources of SO_2 such as power stations	Vehicles, industry	Domestic wood heaters	Soil dust, fugitive coal dust	Wildfires, hazard reduction burns	Sea salt	Motor vehicle NO_2, power station NO_2

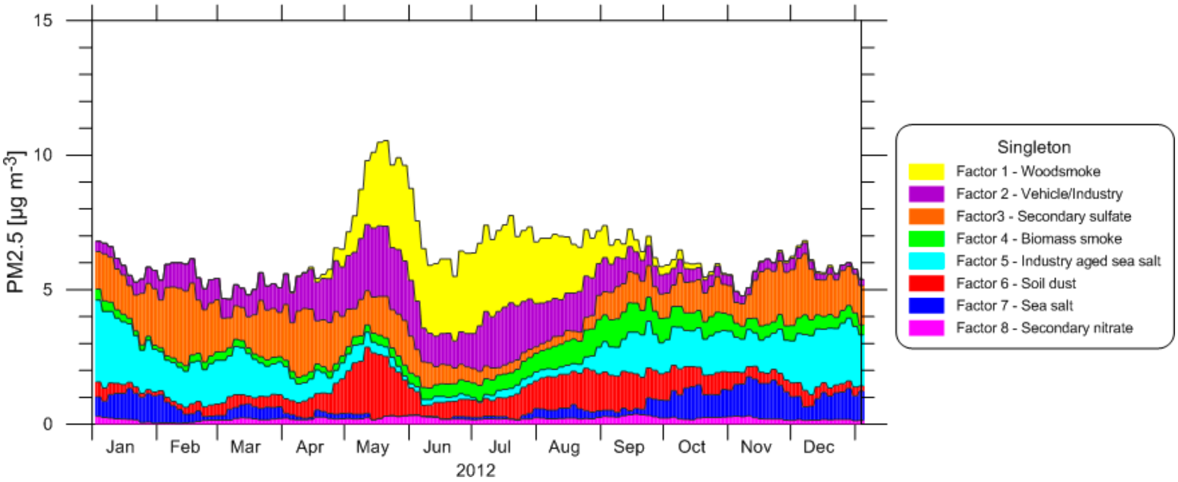
Monthly variations in the contributions from each factor to $PM_{2.5}$ concentrations measured at Muswellbrook and Singleton are shown in Figure 19 and Figure 20 respectively. The wood smoke factor dominates at both sites during the winter, while the secondary sulfate and industry aged sea salt factors make higher contributions during summer months.

Figure 19: Monthly variations in source contributions to $PM_{2.5}$ for Muswellbrook



Note: Time series (smoothed with 31-day running window) of the contribution of each factor to total $PM_{2.5}$

Figure 20: Monthly variations in source contributions to $PM_{2.5}$ for Singleton



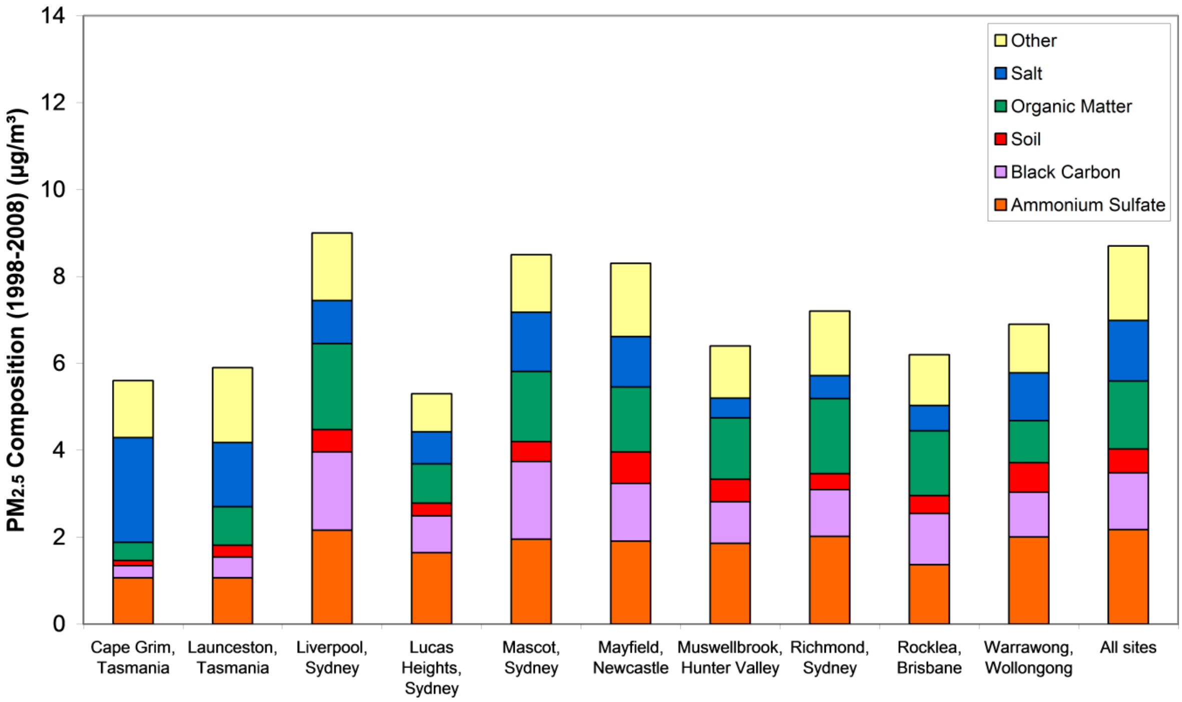
Note: Time series (smoothed with 31-day running window) of the contribution of each factor to total $PM_{2.5}$

A more detailed discussion of the methods and findings of the Upper Hunter Particle Characterisation Study is given in the study report (Hibberd et al. 2013).

Particle characterisation for Australian east coast sites by ANSTO

ANSTO has been conducting $PM_{2.5}$ characterisation at several east coast sites since 1998, including several sites within NSW and a background (pristine environment) site at Cape Grim in Tasmania. The long-term average (1998–2008) composition of $PM_{2.5}$ measured at these sites is shown in Figure 21. Particle composition was found to include ammonium sulfate, black carbon, organic matter, salt and soil components.

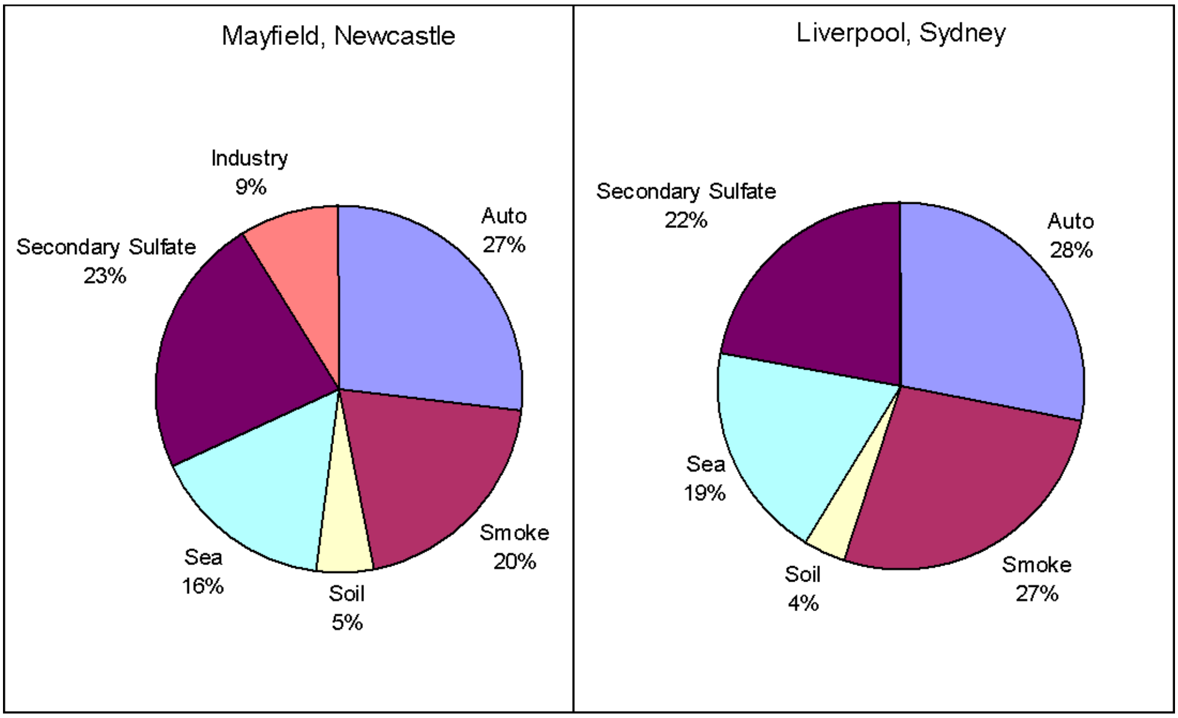
Figure 21: Average $PM_{2.5}$ mass and composition for Australian east coast sites, July 1998 to May 2008



Source: ANSTO 2008

Key sources of long-term average $PM_{2.5}$ concentrations determined by ANSTO are shown in Figure 22 for the Mayfield (Newcastle) and Liverpool (Sydney) sites. The following sources were identified: 'Secondary Sulfate' formed from reactions of sulfur dioxide with ammonium in the atmosphere, 'Auto' referring to motor vehicle emissions, 'Smoke' for smoke emissions, 'Sea' representing fresh sea salt, 'Soil' indicating soil dust, and 'Industry' emissions. Coal dust can only be present in either soil (5% of $PM_{2.5}$), or industry (9% of $PM_{2.5}$), meaning coal dust contributes to less than 14% of $PM_{2.5}$ at Mayfield. Sources of sulfur dioxide emissions in the region include coal-fired power generation, industry, vehicles and shipping.

Figure 22: Percentage source contribution to $PM_{2.5}$ concentrations recorded at Mayfield (1998–2009) and Liverpool (1998–2006)



Source: ANSTO 2010 and Stelcer et al. 2007

Summary of findings

While air quality to which NSW communities are exposed generally compares well with cities worldwide, elevated levels of particle pollution above national health-based standards are experienced in both urban and regional NSW.

Particle pollution levels can vary significantly from one year to the next with higher levels occurring during dry years when bushfires and dust storms are more frequent. Air quality in NSW is also subject to strong regional variation due to differences in air emission sources and weather patterns:

- In Sydney, the Illawarra and Lower Hunter, fine particle levels are driven by industry, vehicles, wood heaters in winter and by extreme events such as bushfires and dust storms in warmer months.
- In the Upper Hunter, coal mining activities contribute to elevated PM_{10} levels, particularly during the spring, with wood heaters a significant contributor to the high levels of $PM_{2.5}$ measured in winter.

The national standard is sometimes exceeded in the regional centres of Albury (NSW–Victoria border), Bathurst (Central Tablelands), Tamworth (North-West Slopes) and Wagga Wagga (South-West Slopes). This can be traced to a range of natural events and human activities, including bushfires, dust storms, construction and industrial activities, wood heaters and agricultural activities including stubble burning.

Information from the NSW air emissions inventory indicates that particle emissions have reduced in some regions such as Sydney, despite growth in the population, economy, vehicle activity and energy consumption, confirming that regulation of industry and vehicle emissions is proving effective.

Increasing particle emissions in regions such as the Upper Hunter and particle modelling projections for future years indicate that additional action is needed to control particle pollution from coal mines and other sources, such as wood heaters and non-road diesel engines.

Particle characterisation and modelling studies demonstrate the important contribution of secondary particles (and therefore sources of precursor gases) and regionally transported particles from distant sources (such as sea salt, bushfires, power stations) to $PM_{2.5}$ concentrations. Secondary particles formed in the atmosphere from natural and human-made emissions of gases may account for about half of the $PM_{2.5}$ concentrations at some times of the year, making these an important area for development of future strategies.

Analysis of NSW air emissions inventory information, measured regional and seasonal variations in particle pollution levels, and results from particle characterisation and modelling studies, help the EPA target actions effectively to reduce community exposure to particle pollution. Such studies have, for example, been used to trigger the development of targeted actions for Sydney, Wollongong and for regional centres in the Hunter and southern tablelands around Wagga Wagga.

The following section presents case studies of targeted plans and actions to reduce sources of primary particles.

Targeted plans and actions to reduce particles

The EPA develops initiatives targeting major sources of pollution across all sectors, as reflected by the plans and actions outlined below:

- industry – including the Dust Stop Program for coal mines (see page 30)
- vehicles, engines and fuels – including the Clean Machine Program (see page 33)
- commercial and domestic sources – including though the Wood Smoke Reduction Program for household wood heaters (see page 34).

Regional management case study: *Upper Hunter Air Particles Action Plan*

The EPA also develops targeted action plans for specific regions, such as the *Upper Hunter Air Particles Action Plan*, released in April 2013, which responds to particle issues and community concerns regarding particle pollution in that region (EPA 2013).

Given the rapid recent industrialisation and spread of coal mines in the Upper Hunter, air quality in the region is a priority for both the EPA and the Hunter community.

A high-level Interagency Taskforce on Air Quality in the Hunter, chaired by the EPA, collaborates to deliver actions to reduce emissions and address community concerns about air quality in the Upper Hunter. The taskforce, which draws its members from NSW Health, the Department of Planning and Infrastructure and the Department of Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy, sets a management framework and clear accountability for improving air quality in the Upper Hunter.

The taskforce's first priority is to reduce emissions from coal mining as the most significant source of particle pollution in the region. The *Upper Hunter Air Particles Action Plan* outlines a range of measures in place or being developed to improve air quality and better inform the public. See: www.epa.nsw.gov.au/aqms/130158uphuntap.htm

The actions included in the plan are designed to engage communities, improve planning decisions, reduce particle emissions from coal mines and other sources, and improve the evidence base for action through monitoring and research. The EPA has adopted the national annual average advisory standard for $PM_{2.5}$ of 8 µg/m³ as a firm target for major population centres (Muswellbrook and Singleton) in the *Upper Hunter Air Particles Action Plan.*

Industry management case study: Dust Stop and diesel programs for coal mining

The issue

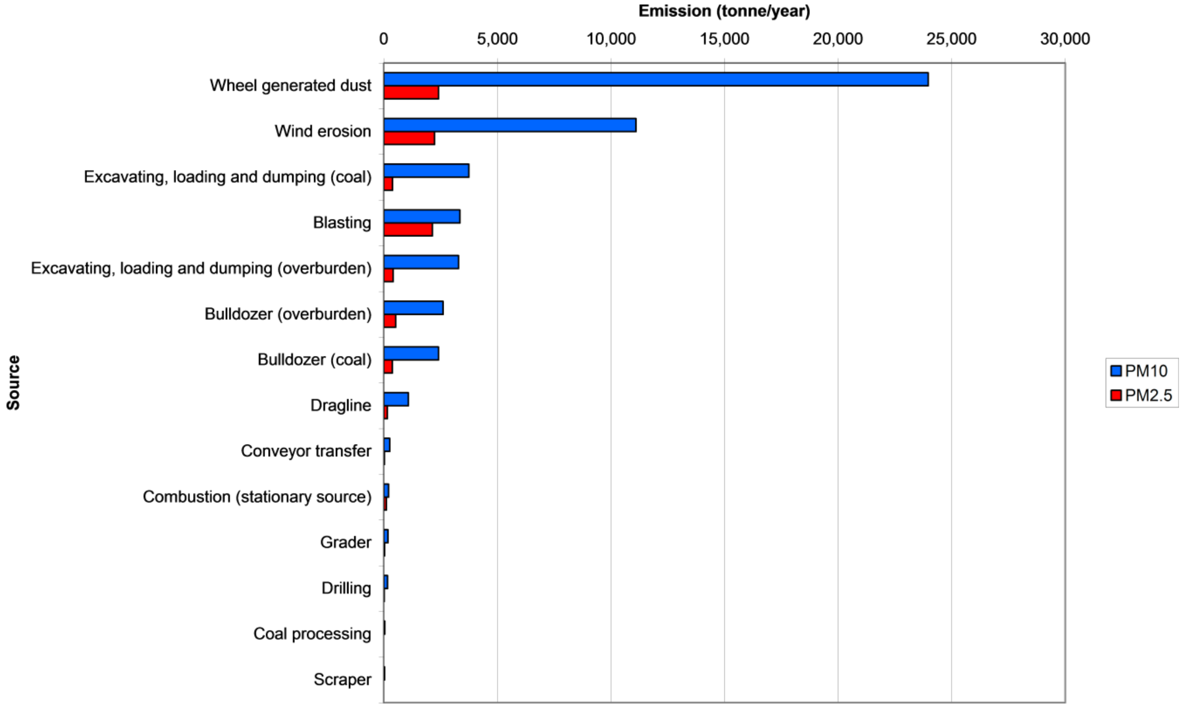
Australia is the world's largest exporter of black coal, with NSW contributing 40% of Australia's coal production. Coal mining is the largest human-made source of $PM_{2.5}$ and PM_{10} pollution in the GMR, accounting for nearly 30% of annual $PM_{2.5}$ (Figure 13) and nearly 60% of PM_{10} human-made emissions. In the Upper Hunter, it contributes two thirds of all $PM_{2.5}$ (Figure 15) and close to 90% of all PM_{10} emissions annually.

The industry has progressively expanded and shifted to open-cut operations. Local communities around NSW major coalfields, primarily in the Hunter Valley and areas in central NSW, such as around Gunnedah and Mudgee, are impacted by dust from mining operations, coal stockpiles and transportation, particularly where multiple mines are located in close proximity. Air quality around mines is also impacted by emissions from diesel-fuelled mining equipment.

Research, scoping and consultation

Having identified coal mines as a key source of particle emissions in the GMR and Upper Hunter, the air emissions inventory then gives a breakdown of those emissions according to the various activities conducted as part of mining operations. Figure 23 presents inventory estimates showing that the most significant coal mining activities generating PM_{10} and $PM_{2.5}$ are wheel generated dust, as coal is transported along haul roads, and erosion, when operations are undertaken in windy conditions.

Figure 23: Coal mining activities generating PM_{10} and $PM_{2.5}$



The EPA's broad approach to evidence gathering through the inventory has been supported by targeted investigation of the coal mines. The 'Dustbuster' campaign, begun in 2009, involved surveillance of mines across the Hunter Valley. As well as triggering immediate enforcement action, it identified inconsistencies in the application of dust control standards. As a first step, the EPA developed a dust assessment handbook (EPA 2011), a glove-box size pictorial guide to help mining machinery operators assess and reduce dust emissions from haul roads and drilling rigs. As well as providing an educational tool for mining operators, the handbook supports consistency in regulation.

Having provided guidance, the EPA turned its focus to further improving the environmental performance of coal mines through its licensing conditions. In 2010, the EPA commissioned a study to identify the major sources of air particle emissions from coal mining activities in the NSW GMR and recommend international best practice measures that could feasibly be implemented in NSW to reduce particle emissions (OEH 2011b). The full study report is available at:
www.environment.nsw.gov.au/resources/air/KE1006953volumeI.pdf

Implementing a major recommendation of the study, in 2011 the EPA commenced the Dust Stop Program which required all coal mines, through pollution reduction programs (PRPs) attached to their environment protection licences, to assess their operations against international best practice dust management, then identify feasible improvements and report back to the EPA.

The coal mine reports indicated that the most significant sources of particulate matter from coal mines are wheel-generated dust, overburden handling and wind erosion from exposed surfaces, together accounting for around 80% of PM_{10} emissions from NSW open cut coal mines.

New targeted actions

As a further stage in the Dust Stop Program, the EPA has issued all NSW open-cut coal mines with three new binding PRPs (see www.epa.nsw.gov.au/prpoeo/index.htm). These require:

- best practice controls of wheel-generated dust and monitoring over a year to ensure controls are effective
- modifying or stopping of handling of overburden during adverse weather conditions and monitoring of outcomes
- building on these initiatives and finding additional, better ways to control dust while handling overburden.

The PRPs require the mines to report back to the EPA on their investigations and the effectiveness of the new controls by August 2014. Following review of this phase, the EPA will continue to improve regulation of coal mining dust emissions.

Under NSW planning and environment laws and regulations, coal mines must operate in a proper and efficient manner to minimise dust emissions and meet specific project approval and environment protection licence conditions.

The EPA advises the Department of Planning and Infrastructure (DP&I) on air quality assessments for coal mines and recommends conditions to be set if a mine is approved. The EPA and DP&I are working together to streamline consents and licensing and improve the transparency and enforcement of their requirements.

The EPA has stepped up ongoing enforcement actions of licensing conditions, including coordinated campaigns to assess and audit coal mines, unannounced inspections and surveillance of operations, and issuing penalty notices or launching other legal action where breaches occur.

Diesel emissions from coal mining operations

Data on fuel consumption from licensed EPA activities and 2008 air emissions inventory estimates highlight that coal mining is by far the greatest consumer of fuel among EPA licensed activities. Coal mining diesel equipment consumes more than 600,000 kilolitres of diesel fuel per annum. Looking at fuel consumption by local government area, the bulk of this industrial diesel fuel consumption is very strongly concentrated in the Upper Hunter, in the areas of Muswellbrook and Singleton.

Associated with this high diesel consumption, the emissions inventory shows that, after coal mining dust emissions, non-road diesel engines are the next major contributor of $PM_{2.5}$ in the Upper Hunter (Table 5).

Using the successful Dust Stop Program model, the EPA has initiated a project to review and apply best practice measures for managing diesel emissions from equipment used in coal mines. Again, the EPA is using its regulatory powers and pollution reduction programs attached to licences to require all operating NSW open-cut coal mines to review operations against best practice and identify ways to improve their performance. Separate non-regulatory EPA action on diesel equipment is described in the next ‘clean machine’ case study.

Table 5: $PM_{2.5}$ emissions by activity in the Upper Hunter region

Activity	**$PM_{2.5}$ (tonnes/year)**
Coal mining	7,940
Non-road vehicles & equipment	1,629
Electricity generation	1,587
Prescribed burning and bushfires	607
Windblown dust	79
Residential wood heating	75
Non-metallic mineral mining and quarrying	74
Diesel vehicle exhaust	24
Waste collection, treatment and disposal services	18
Petroleum and coal product manufacturing	16
Others	65

Vehicles, engines and fuels case study: Clean Machine Program

The issue

The International Agency on Cancer Research of the World Health Organisation has declared diesel exhaust a human carcinogen, based on sufficient evidence that it causes lung cancer (IARC 2012).

While on-road diesel vehicles sold in Australia, such as highway registered trucks and buses, are regulated to meet strict emission limits, there are no regulations or standards in place to control emissions from non-road diesel engines. These engines, such as in bulldozers, graders, forklifts and tractors, have long working lives and are significant sources of fine particles and oxides of nitrogen in metropolitan and regional areas. Around 100,000, or 15%, of Australia's non-road engines are located in the NSW GMR and around 9000 engines are purchased in the GMR every year.

Emission limits for this type of engine have been regulated in the United States and the European Union since the mid-1990s and, more recently, in Canada, Japan, China and India.

Research, scoping and consultation

In 2012, the EPA led a nation-wide survey and study by Environ to profile the non-road engine fleet in Australia, estimate fuel use and emissions, compare with best technology available, and estimate costs and benefits of moving to international best practice (DECCW 2010a).

The study found that the non-road diesel sector (excluding rail and marine transport) produced around 13,500 tonnes of PM_{10} annually. It found that Australia lagged behind the US and EU, with only 5% of engines used in Australia meeting the most recent US or EU standards.

The study estimated that implementing the latest emission standards in Australia could achieve a reduction in PM_{10} of between 5600 and 10,200 tonnes annually to 2020, increasing to 7300 to 14,100 tonnes by 2030. There would be an estimated $2.5 to $4.7 billion health saving by 2030 as a result of the PM_{10} and oxides of nitrogen emissions reductions (DECCW 2010a). Further analysis of the non-road sector is being undertaken as part of developing the National Plan for Clean Air.

Targeted actions

The EPA operates the Clean Machine Program to reduce diesel exhaust emissions from non-road diesel machinery operating in the GMR. Under the program, the EPA partners with councils and private companies to promote development of better worksite practices and the procurement of cleaner machines, and to subsidise the retrofit of diesel particle filters to existing machines.

The program targets users of non-road diesel equipment in the construction, maintenance, waste and port sectors, identified through the air emissions inventory and EPA regulatory activities. Partners range from councils operating small non-road engine fleets to major port operators and waste managers operating large fleets of equipment at multiple locations throughout the GMR. The program achieves local scale improvements in air quality for NSW communities and significant emission reductions overall.

By the end of June 2013, 30 organisations had become partners to the program, including 20 that retrofitted 118 diesel machines. Retrofits alone will reduce about 2.6 tonnes of diesel particles per year, leading to an estimated public health benefit of $629,000. Cleaner procurement and worksite practice will also result in beneficial diesel emissions reductions.

Example: Dubai Port World, Port Botany Achievements

DP World has been one of the largest retrofit partners in the Clean Machine Program and worked with the EPA to reduce diesel exhaust from its Port Botany stevedoring operations. It completed the installation of diesel particulate filters to nine of its gantry cranes, resulting in reductions to diesel exhaust emissions of about 1.3 tonnes per annum. DP World also purchased four new large gantry cranes with engines conforming to recent US EPA Tier 3 emissions standards. Each new crane will reduce diesel particle emissions by 170 kg per year compared to the older engine it replaces.

Commercial and domestic source case study: wood smoke management

The issue

Major reductions in pollution from open burning activities have been achieved in NSW since the late 1980s, particularly in metropolitan areas with the prohibition of backyard incinerators.

The POEO Clean Air Regulation 2010 provides regulatory measures to control open burning. It operates to effectively ban backyard burning in metropolitan areas and restricts it to varying levels in more rural areas. These various levels are prescribed in the regulation but are chosen locally by each local council.

The key smoke management issues that are now affecting Sydney and many regional towns and centres are smoke from bushfires and hazard reduction burning, and smoke from domestic wood heaters in winter. The EPA is developing an approach to the management of wood heaters that builds on the success of the backyard burning controls, which allowed councils to opt for the form of control that would work best for their area and community.

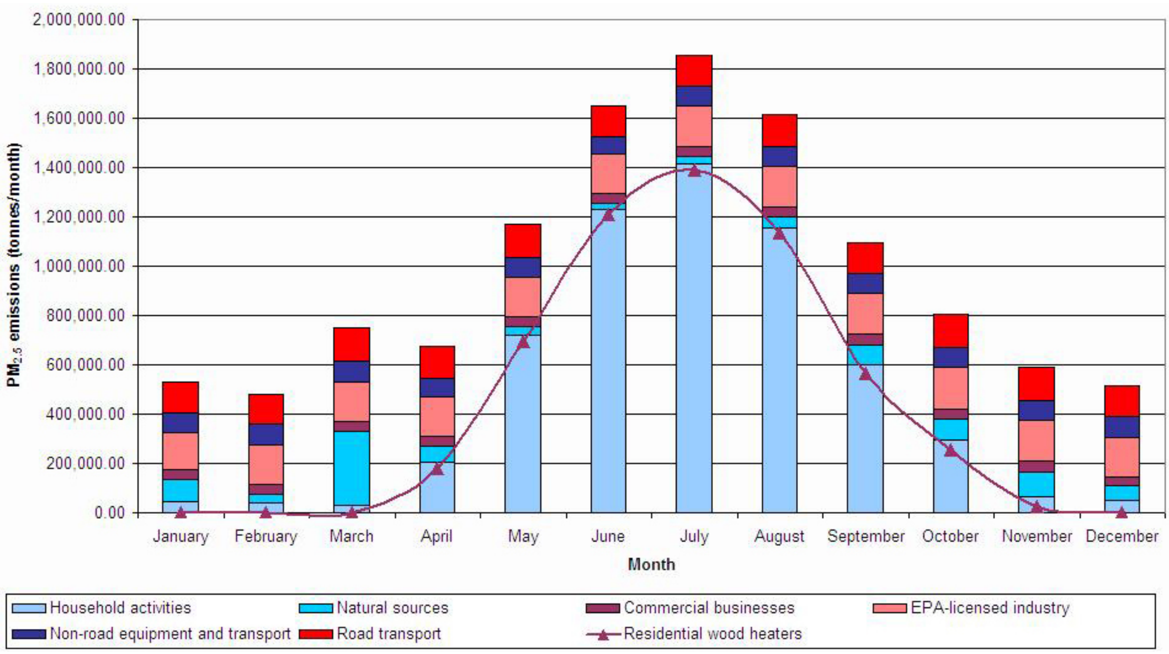
Low-emission wood heaters, if they are operated correctly, can be an efficient, low-cost form of heating. However, many parts of Sydney and regional NSW are exposed in winter to unacceptable levels of wood smoke. Between 2003 and 2008 there was a 21% increase in $PM_{2.5}$ emissions from wood smoke in Sydney. Wood smoke is the second highest contributor in the GMR (Figure 13) and the highest contributor in Sydney (

Figure 14).

Research, scoping and consultation

The effect of wood smoke varies from locality to locality, subject to local topography, weather conditions, population density, the number of wood heaters in use and how they are operated. During July in Sydney, wood heaters contribute up to 57% of PM_{10} and 75% of $PM_{2.5}$ (see household activities emissions in Figure 24 below). The percentage contribution of wood smoke in cold areas, like Armidale, is higher.

Figure 24: Monthly PM2.5 emissions in the Sydney region



Projections indicate that tightening of national wood heater emissions standards would achieve a 10% reduction in PM_{10} emissions by 2036, even with continued growth in new wood heaters.

In 2011 the EPA commissioned AECOM to conduct an economic appraisal of wood smoke control measures, to inform a review of the current wood smoke management framework for NSW (OEH 2011a).

The study considered options for controlling wood smoke, such as restricting or prohibiting installation of wood heaters or highly polluting heaters, or offering householders incentives to switch to cleaner heating. It then assessed the costs and benefits for consumers, industry and government of introducing the different options or different combinations of options.

Recognising that geographical and socio-economic conditions vary throughout NSW and that these affect the need for and feasibility of introducing wood smoke control measures, the study investigated case studies for a range of areas.

A major study finding was that, without new control measures, wood smoke could add $8 billion to NSW health costs by 2030. See www.environment.nsw.gov.au/resources/air/WoodsmokeControlReport.pdf

Informed by the study's findings, the EPA developed a discussion paper, *Options for wood smoke control in New South Wales*, outlining six possible new wood smoke controls and a potential new regulatory implementation framework (EPA 2012). The Minister for the Environment announced the release of the discussion paper in late 2012. See www.environment.nsw.gov.au/resources/woodsmoke/120267WoodSmoke.pdf

Community, industry and local and state governments were invited to give feedback. The EPA also held a workshop with targeted local councils and meetings with key stakeholders to gain more detailed feedback.

Targeted actions

The EPA is developing recommendations for a new wood smoke management framework for NSW. This would offer councils a set of management options from which they could choose the most suitable for local conditions, taking into account housing density, weather conditions and the number of wood heaters already in use. Where wood smoke is not a concern, councils could choose to take no action.

The EPA is also currently investing $1 million over three years in the Wood Smoke Reduction Program. Under the program, funds of up to $60,000 per council, backed up by training and resources from the EPA, are made available to carry out:

- community education programs on the health impacts of wood smoke pollution and how best to operate wood heaters
- smoky chimney surveys by councils and appropriate educational/enforcement action
- targeted cash incentives to replace old polluting wood heaters and fireplaces with cleaner alternatives.

In 2013, grants were awarded to 16 councils and one organisation of councils located across NSW, including in metropolitan, tableland, western, south-western and Hunter Valley regions. The Wood Smoke Reduction Program is designed to achieve reductions in particle emissions where they are most needed, along with greater community awareness of wood smoke issues and the importance of operating wood heaters correctly.

In September 2013, councils and regional organisations of councils were invited to apply for grants of up to $60,000 and $100,000 respectively, to carry out wood smoke reduction initiatives in 2014.

Example: Bathurst Wood Smoke Reduction Program

With a $52,000 grant from the EPA, Bathurst Regional Council launched a campaign in winter 2013 to help residents reduce wood smoke.

The grant enabled the council to improve enforcement dealing with smoky chimneys, carry out a campaign to raise community awareness of the health impacts of wood smoke and how they can be avoided and also offer cash incentives for residents to replace older, polluting heaters with cleaner alternatives. Residents were offered up to $500 to replace wood heaters while those on low incomes eligible to claim up to $700.

The EPA has pursued a long-term Wood Smoke Reduction Program based on:

- **providing councils, as the regulatory authorities for domestic wood smoke, with training and resources to help them fulfil their responsibilities effectively**
- **requiring, via the Clean Air Regulation, that new wood heaters meet national emission standards, and undertaking periodic audits at point of sale to ensure compliance**
- **urging tighter wood heater emission limits at national level, by working with governments and industry through the National Plan for Clean Air and Standards Australia processes.**

Next steps

Continuing to reduce particle emissions

The EPA has committed additional funding to the following particle reduction projects in 2013–14.

Wood smoke grants to local councils

Continuing the successful EPA wood smoke reduction program, a further round of grants will be made to NSW councils to support community education, improved enforcement of wood smoke regulation and upgrading of older wood heaters to cleaner alternatives.

Clean Machine Program

The EPA will extend its successful program of partnering with businesses and councils to retrofit polluting equipment used at construction sites, ports and the like throughout the Greater Metropolitan Region. There will be increased focus on working with EPA regional offices to encourage EPA industry licensees to become partners in the program so that machines that they or their contractors use will be retrofitted with particle filters.

Industry priority facility review

The EPA will undertake best practice benchmarking and review of its environment protection licences for facilities with hazardous emissions. Reducing hazardous emissions from industry facilities will reduce the risk of these emissions to health at the local level and their contribution to total air pollution load.

Coal seam gas fugitive emissions project

Background fugitive emissions from coal seam gas mines will be measured and analysed to inform new management measures, again supporting new action to reduce emissions that contribute to the formation of ozone and secondary particles in the atmosphere.

Continuing to strengthen and communicate the evidence on particles

The EPA and OEH have committed to particle research and communication projects to increase information to government, the community and business on the levels and types of particles impacting on NSW communities.

Expanded monitoring network

Work is underway to ensure there is sufficient air quality monitoring in regional NSW as industry expands and has the potential to impact on communities.

The EPA is investigating establishing additional monitoring for the heavy industrial precinct around the port of Newcastle. Input is being sought from the community, local government and industry via the Newcastle Community Consultative Committee on the Environment. Commissioning of new monitoring sites is expected during 2014. Meanwhile, Orica, with advice from the EPA and OEH, has established an air quality monitoring station at Stockton and live data is available to the community on its website.

As industry expands, work is underway to improve air quality monitoring in regional NSW. In addition to the Upper Hunter network, the establishment of a new industry-funded air quality monitoring network in the New England North West area (encompassing Gunnedah and Narrabri) is being investigated in consultation with local communities.

Where a need is identified, OEH may also conduct ‘campaign’ monitoring. This is monitoring carried out in a particular location for a limited period. Industrial premises will also continue to be required to undertake and report on air emissions monitoring as part of environment protection licence conditions.

As part of an approach of improved and innovative presentation of information, the EPA is also working to make air quality information on its website more accessible to the public.

Particle characterisation

To develop an enhanced understanding of $PM_{2.5}$ composition, studies have been completed in Sydney (Sydney Particles Study) and the Upper Hunter (Upper Hunter Particle Characterisation Study). A key objective of these studies is to determine the major components and sources of $PM_{2.5}$ within the study regions.

The EPA is also initiating a new particle characterisation study for the Lower Hunter. The Lower Hunter particle characterisation study will estimate the contribution to particle pollution, as $PM_{2.5}$ and PM_{10}, of sources such as industry, coal related activities, vehicles and wood heaters. The study will develop and communicate our understanding of primary and secondary particles and investigate new actions to address particles and secondary particle precursors.

Updated inventory and new web communication tool

The air emissions inventory is being updated with 2013 calendar year data to improve the picture on current contributions from all particle sources and past and future trends in emissions. The EPA will also investigate primary particle emissions and principal emissions of particle precursors, such as sulfur dioxide and ammonia. This work will enable the EPA to communicate more accurate information to stakeholders and government and to develop more closely targeted, cost effective programs.

A new graphic web-based inventory tool will give the public, business and government ready access to information on sources of air pollutants in areas of the GMR. Using the tool it will be possible to display information on emissions of particles and other pollutants from 84 source types for a selected geographic area down to the resolution of individual postcodes.

Increased collaborative research with stakeholders

The EPA will continue working with stakeholders and leveraging the knowledge of experts and local communities, to further improve particles knowledge and management. This will include scanning emerging health and air science around the world and international best practice approaches to managing particles, which we can investigate, adapt and implement for NSW.

The EPA will work with NSW Health and the independent Centre for Air Quality and Health Research Evaluation to initiate new research to increase understanding of the health impacts, risks and costs of particle pollution in NSW. A Lower Hunter Community Research Project will combine air pollution education and information initiatives with community-led research on air quality. The EPA is also supporting the University of Tasmania in an interstate study on the relative health effects of smoke pollution from bushfire events and planned hazard reduction.

Appendix 1: Health effects of particles

Effects of short-term and long-term exposures

Short-term and long-term exposures to particulate matter are associated with mortality and morbidity from cardiopulmonary disease.

Over the short term, increases in 24 hour average concentration of $PM_{2.5}$ and PM_{10} are associated with mortality and hospitalisations from cardiovascular and respiratory diseases. In the longer term, a robust association has also been demonstrated between annual average $PM_{2.5}$ and mortality from all-causes and cardiopulmonary causes. The International Agency for Research on Cancer has classified outdoor air pollution, and specifically the particulate matter component, and also diesel exhaust, as carcinogenic to human beings, based on sufficient evidence that exposure to these causes lung cancer (IARC 2012).

Short-term and long-term exposures are thought to have different mechanisms of effect. Short-term exposure appears to exacerbate pre-existing diseases while long-term exposure most likely causes disease and increases the rate of progression.

Health benefits of reducing particles

The health impacts of particles place a cost burden on the community. A 2005 study into the health impacts of air pollution in Sydney estimated that particle pollution costs the NSW economy between $1 billion and $8.4 billion annually, with an average cost of $4.7 billion (DEC 2005a).

In 2011, the EPA commissioned AECOM to undertake an economic assessment of a range of policy options for controlling smoke from domestic solid fuel heaters in residential locations with potentially high population exposure to wood smoke. The study *Economic Appraisal of Wood Smoke Control Measures* predicts that particle pollution from wood smoke could result in $8 billion dollars in health costs by 2030 (OEH 2011a).

These studies show that there are substantial health and economic gains to be made by reducing particle pollution. A 2010 study, Final Regulation Impact Statement for Review of Euro 5/6 Light Vehicle Emissions Standards, prepared by the Commonwealth Department of Infrastructure and Transport, also found that tightening Australian emission standards for light vehicles to match European standards would yield up to $807 million worth of benefits nationally, primarily due to the reduction in mortality associated with reducing particles (Department of Infrastructure and Transport 2010).

There is no evidence of a threshold below which exposure to particulate pollution is not associated with adverse health effects. Any additional exposure to PM_{10} and $PM_{2.5}$ is associated with an increased risk of adverse health outcomes, and there are significant health and economic gains to be made from reducing exposure to particle pollution.

Research on the health impacts of particles

Numerous health studies have shown an association between exposure to fine particles and adverse health effects in Australia and overseas. These include studies of health impacts of particles in Australian cities, studies of impacts on respiratory effects in children and studies focusing on specific particle sources such as diesel emissions along busy roads, wood smoke, and bushfires and hazard reduction burning.

Relevant studies have been reviewed and summarised as part of the current review of the Air NEPM. The EPA and NSW Health have contributed funding to a number of these studies and NSW Health researchers have also done some of them. These are listed in **References and links**.

The EPA, in collaboration with NSW Health and health research institutions, will continue to scan new international developments on the health impacts of particles and to support new health research in Australia. This will include, for example, tracking emerging science on the health impacts of ultrafine particles.

Appendix 2: Researching and analysing potential particle abatement measures

To determine how to maximise the emission reductions and public health gains delivered for every dollar of public money spent, the EPA undertakes extensive research, economic analysis and stakeholder consultation.

The EPA has used 'cost curve' analysis to investigate the sectors that contribute to the most harmful pollutants in regions most subject to particle pollution, and to identify and rank possible new measures according to their emission reduction potential and cost-effectiveness. Cost curve analysis for NSW has reinforced that it is important to include wood heater, coal mining and non-road diesel emissions reduction measures in a package of cost-effective actions to achieve compliance with $PM_{2.5}$ standards (DECCW 2010b).

Having identified target sectors and potential actions, the EPA pursues more detailed research into best available options using scoping studies and cost benefit analysis.

Consistent with the cost curve findings, significant studies have been undertaken on the levels of dust emissions from NSW coal mines, feeding into the Dust Stop Program (see NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining), and wood smoke control measures, informing current development of a wood smoke reduction framework for NSW (see: www.epa.nsw.gov.au/woodsmoke/smokecontrolopts.htm)

Programs to reduce emissions from these sectors are progressing in NSW and additional measures to reduce wood smoke and non-road diesel emissions are also being developed at national level. A key part of the current development of the National Plan for Clean Air has been detailed economic analysis, led by the NSW EPA, of potential changes to national particle standards and the measures that would be needed to achieve them.

Glossary

Ambient air	The external air environment (not the air environment inside buildings or structures)
Clean Air Regulation	The Protection of the Environment Operations (Clean Air) Regulation 2010 (Clean Air Regulation), which provides regulatory measures to control emissions from wood heaters, open burning, motor vehicles and fuels and industry
Cost abatement curve/ cost curve	Graph presenting potential emission reduction actions ranked according to their cost effectiveness and showing potential amount of emission reductions from each
GMR	Greater Metropolitan Region; comprises Greater Sydney, Newcastle, Central Coast, Wollongong and surrounding areas
Micrometres or microns (symbol: µm)	$1x10^{6}$ of a metre; one thousandth of a millimetre or one millionth of a metre; also known as a micron
NEPC	National Environment Protection Council
NO_x	Oxides of nitrogen gases
NEPM	National Environment Protection Measure – the Ambient Air Quality NEPM sets air quality standards for six pollutants (including PM_{10}) and an advisory standard for $PM_{2.5}$ (http://www.scew.gov.au/nepms/ambient-air-quality)
NSW EPA	NSW Environment Protection Authority
NSW OEH	NSW Office of Environment and Heritage
Particles/particulate matter	Solid matter or liquid droplets in the atmosphere small enough to be inhaled
PM_{10}	Particles measuring less than 10 microns in diameter
$PM_{2.5}$	Particles measuring less than 2.5 microns in diameter – these particles are a sub-set of PM_{10}
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
ppm	Parts per million (a measurement of concentration in a gas or liquid)
Primary particles	Particles emitted directly to the atmosphere from a source such as industry or vehicle exhausts
SCEW	Standing Council on Environment and Water (Ministerial Council reporting to Council of Australian Governments – COAG)
Secondary particles	Particles formed in the atmosphere from a chemical reaction between other substances; precursors of secondary particles include oxides of nitrogen, sulfur dioxide and ammonia
TSP	Total suspended particles – particles measuring less than 50 microns in diameter
Ultrafine particles (PM_1)	Particles less than 1 micron in diameter (one millionth of a metre); particles in this range may be measured in nanometres (nm); 1 nm is one thousandth of a micrometre (µm)
µm	Shortened form for micrometre

References and links

ANSTO (2008), 'A Long Term Fine Particle Database Along the Australian East Coast', *Australian Nuclear Science and Technology Organisation Fine Particle Aerosol Sampling Newsletter*, Number 38, July 2008, available at http://www.ansto.gov.au/cs/groups/corporate/documents/webcontent/mdaw/mday/~edisp/acstest_040330.pdf.

ANSTO (2010), 'Long Term Trends in Newcastle (Mayfield) – a 12 Year Study (1998–2009)', *Australian Nuclear Science and Technology Organisation Fine Particle Aerosol Sampling Newsletter*, Number 40, July 2010.

Department of Environment and Conservation NSW (2005a), *Air Pollution Economics: Health costs of air pollution in the Greater Metropolitan Region*, Department of Environment and Conservation NSW, Sydney, available at www.epa.nsw.gov.au/resources/air/airpollution05623.pdf

Department of Environment and Conservation NSW (2005b), *Approved methods for the modelling and assessment of air pollutants*, NSW Department of Environment and Conservation, Sydney.

Department of Environment and Conservation NSW (2007), *Approved methods for the sampling and analysis of air pollutants in NSW*, NSW Department of Environment and Conservation, Sydney.

Department of Environment, Climate Change and Water (2010a), *Cleaner Non-road Diesel Engine Project - Identification and Recommendation of Measures to Support Uptake in Australia: Final report*, report prepared by Environ Australia Pty Ltd, NSW Department of Environment, Climate Change and Water, Sydney, available at www.epa.nsw.gov.au/resources/air/nonroaddieselrpt.pdf

Department of Environment, Climate Change and Water (2010b) *Cost Abatement Curves for Air Emission Reduction Actions*, NSW Department of Environment, Climate Change and Water, Sydney, available at www.environment.nsw.gov.au/resources/air/CostCurveAirEmissionRedn.pdf

Department of Infrastructure and Transport (2010), *Final Regulation Impact Statement for Review of Euro 5/6 Light Vehicle Emissions Standards*, Commonwealth Department of Infrastructure and Transport, Canberra, available at www.infrastructure.gov.au/roads/environment/files/Final_RIS_Euro_5_and_6_Light_Vehicle_Emissions_Review.pdf

Environment Protection Authority (2011), *Upper Hunter Valley open cut coal mine interim dust assessment handbook*, NSW Environment Protection Authority, Newcastle.

Environment Protection Authority (2012), *2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW*, NSW Environment Protection Authority, www.epa.nsw.gov.au/air/airinventory2008.htm

Environment Protection Authority (2012), *Options for Wood Smoke Control in New South Wales: Discussion paper*, NSW Environment Protection Authority, available at http://www.environment.nsw.gov.au/resources/woodsmoke/120267WoodSmoke.pdf

Environment Protection Authority (2013), *Upper Hunter Air Particles Action Plan*, NSW Environment Protection Authority, available at www.epa.nsw.gov.au/aqms/130158uphuntap.htm

Hibberd, MF, Selleck, PW, Keywood, MD, Cohen, DD, Stelcer, E and Atanacio, AJ (2013), *Upper Hunter Fine Particle Characterisation Study: Final report*, report prepared for the NSW Officer of Environment and Heritage and NSW Health, CSIRO, Aspendale, VIC, available at www.environment.nsw.gov.au/resources/aqms/UHFPCSFinal.pdf.

International Agency for Research on Cancer, World Health Organisation (2012), *IARC: Diesel Engine Exhaust Carcinogenic*, Press Release No 213, 12 June 2012, www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf

National Environment Protection Council (2003), *National Environment Protection (Ambient Air Quality) Measure*, July 2003 taking into account amendments up to Variation 2003, Air Archive, National Environment Protection Council, available at www.comlaw.gov.au/Details/C2004H03935

National Environment Protection Council (2010), *Review of the National Environment Protection (Ambient Air Quality) Measure, Discussion Paper Air Quality Standards*, National Environment Protection Council, available at www.scew.gov.au/sites/www.scew.gov.au/files/resources/9947318f-af8c-0b24-d928-04e4d3a4b25c/files/aaqdiscpprreviewoftheaaqnepmdiscussionpaperaqstandardsfinal201007.pdf

National Environment Protection Council (2011), Ambient Air Quality NEPM Review – Review Report, National Environment Protection Council, available at www.scew.gov.au/resource/national-environment-protection-ambient-air-quality-measure-review-review-report

Office of Environment and Heritage (2011a), *Economic Appraisal of Wood Smoke Control Measures: Final report*, report prepared for the Office of Environment and Heritage NSW, AECOM Australia Pty Ltd, Brisbane, QLD, available at www.epa.nsw.gov.au/resources/air/WoodsmokeControlReport.pdf.

Office of Environment and Heritage (2011b), *NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining*, report prepared by Katestone Environmental Pty Ltd, Milton, QLD, available at www.environment.nsw.gov.au/resources/air/KE1006953volumeI.pdf.

Standing Committee on Environment and Water (2012), *Public statement on the development of the National Plan for Clean Air*, Standing Committee on Environment and Water, Canberra, www.scew.gov.au/system/files/pages/eabd6720-1c40-4f73-a326-acafa51cd799/files/national-plan-clean-air-public-statement.pdf

Stelcer, E, Cohen, D and Prior, M (2007), 'Ion Beam Analysis and Positive Matrix Factorisation modelling; tools for exploring aerosol source fingerprints', *Proceedings of the 15th Nuclear and complementary techniques of Analysis Conference*, pp. 318–321, University of Melbourne, Victoria, Australia, 21–23 November 2007.

WHO (2011), *Urban outdoor air pollution database*, September 2011, Department of Public Health and Environment, World Health Organization, Geneva, Switzerland, available from www.who.int/phe.