REPORT

EVALUATING OPTIONS FOR AN EXPOSURE REDUCTION FRAMEWORK IN AUSTRALIA

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EXECUTIVE SUMMARY

BACKGROUND

Recently the *National Environment Protection (Ambient Air Quality) Measure* (Air NEPM) was reviewed. The recommendations of the review will be responded to through the development of the National Plan for Clean Air.

The development of the National Plan for Clean Air is to take a staged and prioritised approach, with a commitment to action on particulate matter (PM). The first stage of work in the development of the National Plan for Clean Air involves a number of key components:

- Standard setting;
- Development of an exposure reduction framework;
- Identification of emission and exposure reduction actions; and
- Development of an integrated cost-benefit analysis for PM.

This project, *Evaluating Options for an Exposure Reduction Framework in Australia (Reference OEH-147-2012)* has been carried out by PAEHolmes and Air Quality Consultants (AQC) on behalf of New South Wales (NSW) Environmental Protection Authority (EPA). The principal objective of the project is to recommend a preferred approach for an exposure reduction framework for $PM_{2.5}$[a] in Australia.

The scope of work for the study is outlined below:

1. Prepare a review of existing exposure reduction frameworks for reducing population exposure to $PM_{2.5}$.
2. Prepare an analysis of Australian conditions summarising for each jurisdiction, data availability and technical capabilities for implementation of an exposure reduction approach.
3. Prepare an analysis of options based on the review of existing exposure reduction frameworks and the findings for Australian conditions taking into account:
    - the practicalities of implementation;
    - the processes by which exposure/emission-reduction targets would be established;
    - the required monitoring and compliance reporting frameworks;
    - the likely costs; and
    - implementation timescales.
4. Identify a preferred approach to an exposure reduction framework based on the analysis.
5. Investigate the potential for the application of an exposure reduction framework to other ‘non-threshold’ pollutants covered by the Air NEPM.

[a] Particulate matter with an aerodynamic diameter less than 2.5 μm

JUSTIFICATION FOR AN EXPOSURE REDUCTION FRAMEWORK

An exposure reduction framework is justified as there is no convincing evidence of a threshold for health effects arising from exposure to PM, expressed as either PM_{10} or $PM_{2.5}$. Thus, even where a NEPM standard for PM is not exceeded, there is a health benefit in reducing PM concentrations even further, and particularly in areas of higher population density. By way of example, the health benefits associated with reducing average PM exposure by 1 $\mu g/m^3$ across a population of 100,000 people, are ten times greater than those from reducing the average PM exposure by 10 $\mu g/m^3$ across a population of 1,000 people.

It is also important to note that these health benefits are *directly related* to the reduction in PM exposure, and are *unrelated* to the absolute concentration. Thus, reducing the average $PM_{2.5}$ exposure from 28 $\mu g/m^3$ to 27 $\mu g/m^3$ across a population of 10,000 people is expected to deliver *the same health benefit* as reducing the average $PM_{2.5}$ exposure from 12 $\mu g/m^3$ to 11 $\mu g/m^3$ across the same population.

It is important to draw a distinction between approaches which ***maximise the equity*** (whereby individuals most at risk of exposure to the highest concentrations are protected to a uniform, minimum standard, and those which ***maximise the efficiency*** (which relates to the ability to maximise health benefits across the population, e.g. life-years saved). NEPM standards for PM have an important role to play in maximising the equity, but can be usefully complemented by an exposure reduction approach which seeks to maximise the efficiency.

Whilst air quality standards have an important role to play in driving down PM concentrations where exceedances are measured or predicted, localised remedial actions are unlikely to lead to large-scale reductions in population exposure. In addition, in areas of higher population density where there are no exceedances of the standards there is currently no driver to implement measures to reduce exposure to PM.

REVIEW OF EXISTING EXPOSURE REDUCTION FRAMEWORKS AND ASSOCIATED METRICS

The review has summarised existing exposure reduction frameworks in place in other regulatory environments. These are summarised as follows:

Emissions Reduction Approaches

- The ***1979 Geneva Convention on Long Range Transboundary Air Pollution*** (CLRTAP) (UNECE, 1979) was the first internationally-binding instrument to tackle the problems of air pollution on a broad, regional basis. Now ratified by 51 governments, including the USA and Canada, the Central and Eastern European countries and the European Union, the Convention entered into force in 1983, and has since been extended by eight specific protocols. Of greatest relevance to this study is the 1999 Protocol to Abate Acidification, Eutrophication, and Ground-level Ozone (UNECE, 2005), more commonly referred to as the ***"Gothenburg Protocol"***. The Protocol sets emissions ceilings, which were to be attained by 2010, for four pollutants; sulfur oxides, nitrogen oxides, volatile organic compounds (VOCs) and ammonia.

  The Protocol has been recently reviewed, and a new agreement on emissions reduction targets for 2020 was reached in May 2012. This extends the Protocol to include emissions ceilings for $PM_{2.5}$ and measures to prioritise the reduction of short-lived climate pollutants (e.g. elemental carbon).

- The ***National Emissions Ceiling Directive*** (NECD) (2001/81/EC) which came into force in 2001, sets upper limits for each Member State of the European Union, for the total emissions in 2010 for sulfur dioxide, nitrogen oxides, VOCs and ammonia, but leaves it largely up to Member States to decide what measures need to be taken in order to achieve compliance; such measures are required to be submitted to the European Commission in national programmes. The emissions ceilings set within the NECD are complementary to, or more stringent than, those established within the Gothenburg Protocol.

  It is expected that a revised NECD will set new emissions ceilings to be met by 2020, and possibly beyond, for the four already-regulated pollutants and will be extended to include emissions of primary $PM_{2.5}$.

Exposure Reduction Approaches

- Whilst not representing a formal exposure reduction approach, the Canada-wide Standards (CWS) for PM and ozone (CCME, 2006) include the implementation of ***continuous improvement*** (CI) and ***keeping-clean-areas-clean*** (KCAC) programmes where ambient concentrations are below the CWS levels. This is not a mandatory requirement, but jurisdictions with ambient levels below the CWSs are expected to focus implementation measures on CI/KCAC.

  CI/KCAC programmes are required to address the following pollutants:

  - In the ambient environment: ozone and $PM_{2.5}$
  - In emissions: direct $PM_{2.5}$ emissions, the $PM_{2.5}$ and ozone precursors NO_x and VOCs, and the $PM_{2.5}$ precursors SO_2 and NH_3

  Specific targets for reductions in pollutant concentrations or emissions have not been set, but jurisdictions are required to provide comprehensive reports at five year intervals (including progress on CI/KCAC) and should include all significant emission reduction actions on sources within the jurisdiction that contribute to decreases in elevated ambient levels in the reporting region.

- The 2008 ***Ambient Air Quality Directive*** (2008/50/EC) (CEC, 2008) introduced a new national exposure reduction target[b] for $PM_{2.5}$ which applies to each Member State within the European Union. The Directive notes that $PM_{2.5}$ exposure is responsible for significant negative impacts on human health, and that as there is no identifiable threshold below which $PM_{2.5}$ would not pose a risk, this pollutant should not be regulated in the same way as other air pollutants. The approach aims at a general reduction of concentrations in the urban background to ensure that large sections of the population benefit from improved air quality. However, to ensure a minimum degree of health protection everywhere, the new approach is combined with a limit value.

  The EU exposure reduction approach that has been adopted is based on monitoring. A reduction target is applied to the Average Exposure Indicator (AEI), which is the $PM_{2.5}$ concentration averaged across a defined network of urban background monitoring stations throughout the Member State. The AEI is calculated as a three-calendar year running annual mean concentration[c]. Member States are required to establish a minimum of one

[b] Targets within EU Directives have a different legal status than limit values. Limit values are legally enforceable upon Member States, whereas there is no mandatory requirement to comply with Target Values.

[c] For example, the 2010 AEI is calculated as the three-year running mean concentration averaged over all sampling points for the years 2008, 2009 and 2010.

sampling station per million inhabitants summed over the agglomerations in excess of 100,000 inhabitants. The exposure reduction target applicable to each Member State is a percentage reduction by 2020, relative to the reference year AEI of 2010, as shown in Table ES 1.

Table ES 1: EU Exposure Reduction Targets for $PM_{2.5}$

Exposure reduction target relative to the AEI in 2010		Year by which the exposure reduction target should be met
Initial concentration (µg/m^3)	**Reduction target (%)**	2020
<8.5 = 8.5	0%	
>8.5 - <13	10%	
=13 - <18	15%	
=18 - <22	20%	
≥22	All appropriate measures to achieve 18 µg/m^3	

The review also summarised exposure reduction metrics that are used to provide a more understandable message to members of the public and for converting changes in air pollution to monetary values. Air quality metrics that are associated with exposure reduction frameworks are as follows:

<u>Air Pollution Indices</u>

Two air pollution indices are summarised in the report as follows:

- NSW Government AQI. The NSW Air Quality Index is a derived value based on the individual hourly pollutant readings. The AQI is calculated for each pollutant (ozone, nitrogen dioxide, carbon monoxide and particulate matter) on an hourly basis. The **Site AQI** that is reported is the highest calculated AQI value from all of the pollutants measured over the past 24 hours at each individual monitoring station. The **Region AQI** is the highest site AQI for all monitoring stations in the region.
- UK Daily Air Quality Index (DAQI). The UK DAQI operates in a similar manner to the NSW system. The UK system uses an index numbered 1-10, divided into four bands ("Low", "Moderate", High" and "Very High") to provide information in a simple manner. The overall air pollution index for a site or region is determined by the highest concentration of five pollutants (nitrogen dioxide, sulfur dioxide, ozone, PM_{10} and $PM_{2.5}$). The index is updated every hour. The primary function of the DAQI is to provide information to members of the public, specifically with regard to health alerts for at-risk individuals. However, the DAQI also provides information that is used to support the UK Government's annual reporting on the air quality indicator for sustainable development.

Whilst air pollution indices are useful in conveying information to members of the public, they are primarily focused on short-term pollutant concentrations, whereas the focus of exposure reduction for $PM_{2.5}$ is focused on a reduction in chronic (e.g. annual mean) exposure. Where air pollution indices are used to support reporting of improvements to annual mean $PM_{2.5}$ concentrations, no attempt is made to apply any form of population weighting to the data which is an important consideration for exposure reduction.

Damage Cost Approaches

Damage costs are used as a means of approximating the impacts of changes in air pollution. These costs estimate the marginal health benefits, or external cost savings, associated with each tonne of pollutant emission that is reduced.

Damage costs for a specific country or jurisdiction are usually generated via a full impact pathway approach utilising location-specific inputs and data (i.e. using emission estimates, regional air quality modelling, monitoring data and population statistics). This approach provides the most robust and accurate damage costs for that region.

A recent study was completed for OEH that reviewed international approaches for determining damage costs and derived a damage cost function for air pollution in Australia (Aust et al., 2012). The review found that Australia currently lacks sufficient and readily available PM emission modelling information to permit a full impact pathway process and, by extension, to generate a set of accurate, location-specific damage costs. Consequently, an alternative/interim method was provided for calculating damage costs which can be used until more reliable data are available for Australia. The alternative method was based on transferring Defra/IGCB[d] damage costs from the UK. It is important to note that the proposed damage cost method does not include damage costs for secondary PM due to the lack of information regarding secondary PM formation in Australia. This is important as the secondary component is likely to represent some 25-50% of the total $PM_{2.5}$ exposure burden.

ANALYSIS OF AUSTRALIAN CONDITIONS

To inform the design of an exposure reduction framework for Australia, an analysis of Australian conditions in relation to air quality management was completed. The review found that, at present, there is no consistency across the jurisdictions' air emissions inventories, with some inventories not being suitable for regional air quality modelling. Furthermore, no jurisdiction in Australia is currently routinely simulating regional PM with regional air quality models. Population statistics are available for all jurisdictions with base population data collected through the census conducted by the Australian Bureau of Statistics. All jurisdictions have air quality monitoring data available. However a variety of methods are used to monitor the ambient air.

In further detail the review found:

Air Quality Monitoring

- All jurisdictions conduct air quality monitoring for $PM_{2.5}$ under the Air NEPM.
- A wide variety of methods are used to monitor the ambient air, which are not necessarily equivalent to the reference method.
- The most common method for measuring and reporting PM_{10} and $PM_{2.5}$ concentrations is using a Tapered Element Oscillating Microbalance (TEOM)[e].

[d] Defra: UK Department for Environment, Food and Rural Affairs/IGCB: UK Interdepartmental Group on Costs and Benefits

[e] A number of European studies have demonstrated that the TEOM is not equivalent to the European reference sampler (due to the loss of semi-volatile PM) and the TEOM has now effectively been withdrawn from EU compliance networks

- There have been relatively few studies of secondary PM - and in particular secondary organic aerosol - in urban areas of Australia.

Urban Regions

- Using a cut-off of 25,000 people for an urban centre (as per the definition in the Air NEPM) results in 56 urban centres in Australia with a total population coverage of 17 million people.
- Using a cut-off of 100,000 people for an urban centre results in 16 urban centres with a total population of approximately 15 million people.
- The inclusion of an additional 40 urban centres only accounts for an additional 9% of the population.
- The definition of an urban area has large implications on expected costs of implementing an exposure reduction framework. For example, it directly affects the number of monitors and/or the number of emission inventories that need to be maintained.

Regional Air Emission Inventories

The study found that the only complete and active regional air emissions inventories (suitable for an exposure reduction framework approach) in use in Australian jurisdictions are:

- NSW Greater Metropolitan Region (GMR) air emissions inventory, encompassing the regions of Sydney, Newcastle, Wollongong and the Blue Mountains.
- Victoria air emissions inventory – covering the entire state.
- South East Queensland air emissions inventory

It was also found that regional air emission inventories have been used to manage air quality for the Perth and Adelaide airsheds are not up to date.

Regional Air Quality Modelling

The review found that there is currently limited capacity for regional scale modelling within the jurisdictions, and where this is undertaken, the focus is upon ozone (as opposed to PM).

Summary

A summary of Australian conditions for major urban centres in NSW, Victoria, Queensland, Western Australia and South Australia is provided in Table ES 2.

Table ES 2: Summary of current status of tools for air quality management for major Australian urban centres (Sydney, Melbourne, Brisbane, Perth, Adelaide)

Jurisdiction NSW GMR[a]	Victoria	SEQ[b]	Perth	Adelaide
Emissions inventory				
All major sources included?				
Yes	No The most significant source not included is marine aerosol. TAPM could be used to supplement this source. Current update is likely to include estimates for this source.	No Fugitive windborne, marine aerosols and emissions from paved roads (wheel generated dust) not included in 2000 inventory. Current update likely to include estimates for these sources.	No Fugitive windborne and marine aerosols were not included in the diffuse air emissions inventory.	No Biogenic/Geogenic emission sources have not been estimated for the Adelaide airshed.
Model ready?				
Yes The NSW GMR air emissions inventory is suitable for regional air quality modelling and readily exportable in model-ready file formats.	Yes EPA Victoria is currently updating the air emissions inventory to a base year of 2011.	Not yet The air emissions inventory will be in a format suitable for regional air quality modelling when the current update (expected at end of 2012) is completed	No Inventory designed for diffuse sources only. Spatial and temporal variation of emissions not assigned.	No Inventory designed for diffuse sources only. Spatial/ temporal variation of emissions not assigned. Significant emission sources (e.g. biogenic) excluded.
Primary pollutants?				
Yes All primary pollutants are included	Yes All primary pollutants are included	Yes All primary pollutants are included	No PM_{10} and $PM_{2.5}$ are included in the emission estimates but not TSP.	No PM_{10} and $PM_{2.5}$ are included in the emission estimates but not TSP.
Secondary precursor pollutants?				
No Does not include emissions of elemental/organic carbon	Yes Includes emissions of all substances	No Does not include emissions of SO_3 or elemental/organic carbon	No Does not include emissions of SO_3 or elemental/organic carbon	No Does not include emissions of SO_3 or elemental/organic carbon
Regional Modelling				
Modelling platform				
TAPM-CTM	TAPM-CTM	TAPM-CTM	Not applicable	Not applicable
Resources available				
OEH has a team of four modellers working on regional air quality modelling. OEH does not currently model particles.	EPAV does not model regional PM as there is low confidence in the 2006 estimates for windblown PM (EPAV, 2012). No information on resources for regional air quality modelling. CSIRO has modelled particles on behalf of Victoria.	Resources limited to one person that can undertake regional dispersion modelling. Current priorities would need to be considered for PM modelling.	DEC does not currently have the resources to undertake regional air dispersion modelling of PM.	Not applicable
Population statistics				
Population statistics are available for Australia (2011 census year)				
Monitoring				
All jurisdictions conduct ambient air quality monitoring of PM. Care will need to be practised when using monitoring data for model validation in considering the differences in monitoring techniques between sites.				

[a] NSW GMR: NSW Greater Metropolitan Region
[b] SEQ: South East Queensland

ANALYSIS OF OPTIONS

Three broad approaches to an exposure reduction framework based on either a monitoring, emissions ceiling or modelling approach were analysed as part of the study.

The three broad approaches are summarised as follows:

Monitoring Approach

A monitoring approach to the exposure reduction framework would be to establish a base year[f] concentration for $PM_{2.5}$, and to then set a target reduction for a year in the future. The target could be described in terms of a percentage reduction with regard to the base year, or as an absolute (µg/m^3) reduction.

Emissions Ceiling Approach

An emissions ceiling approach to an exposure reduction framework would be to establish a base year of emissions defined to include primary PM, or extended to include secondary precursors of PM, with different ceilings set for different pollutants (as adopted within the Gothenburg Protocol and EU NECD) and a target year to achieve the emission ceilings.

Modelling Approach

An exposure reduction framework based on modelling would involve the application of regional scale models to link emission changes to changes in ambient PM concentrations. Using this approach a population-weighted exposure reduction target for a future year could be set.

The broad advantages and disadvantages of each approach are summarised in Table ES 3.

[f] The "base year" and "target year" concentrations could be based on a single year, or on the average over a number of years.

Table ES 3: Advantages and disadvantages of exposure reduction frameworks based on different approaches

Exposure reduction approach	Positive attributes to achieving the objective	Negative attributes to achieving the objectives
Monitoring approach	Measured $PM_{2.5}$ concentrations representing population exposure can be directly linked to health benefits	Year-to-year variations in $PM_{2.5}$ concentrations (due to the effects of meteorology etc.) can influence long-term trends, making it difficult to measure changes over a specified time period, unless results averaged over several years are used
	A target can be introduced for a reduction in $PM_{2.5}$ concentrations over a specified period of time	There is an assumption that concentrations measured at a number of fixed points adequately represent PM exposure across large urban areas
	Existing monitoring networks are primarily focused on defining urban PM exposure	Scope of $PM_{2.5}$ monitoring is currently limited within some jurisdictions
	A gravimetric reference method has been defined for the measurement of $PM_{2.5}$	$PM_{2.5}$ monitoring is based on a wide range of monitoring techniques across the jurisdictions, some of which will not be reference equivalent
		Due to the relatively low $PM_{2.5}$ concentrations that prevail, it will be more challenging to measure the target reduction
Emissions ceiling approach	Relatively straightforward to introduce	It is the metric furthest removed from population exposure to $PM_{2.5}$ and associated health effects. Links are not transparent to policy makers and members of the public
	Emissions reduction of the secondary PM precursors are beneficial to reducing photochemical pollutants such as ozone	There is no linear relationship between emissions and $PM_{2.5}$ concentrations, and is thus poorly linked to exposure and health effects
	Emissions inventories for primary $PM_{2.5}$ have been prepared for a number of jurisdictions	Emission inventories are subject to change with regard to calculation methods and source components
		Emissions inventories are incomplete with regard to some primary sources and the secondary precursors
		Some jurisdictions do not have up-to-date emission inventories.
		There is no official methodology or guidebook for compiling regional emissions inventories
Modelling approach	Provides a population-weighted $PM_{2.5}$ concentration that should be more accurate than measurements alone (if the model has been appropriately verified against monitoring data), and which can be directly linked to health benefits	Requires robust emissions inventory and regional modelling capabilities, accounting for both primary and secondary components. Some components remain poorly understood at the international level
	Possible to exclude non-anthropogenic sources, to more appropriately target emissions reduction measures	Predicted calculations are subject to changes in emissions inventory methodologies and modelling methodologies
	Can be used to support cost-benefit analysis of emissions reduction measures	Regional modelling capabilities are currently very limited
	Population data in GIS format are available for the major urban centres (>25,000 people)	Emissions inventories not currently well suited to regional modelling of either primary or secondary components

A summary of the advantages and disadvantages of each general approach is provided in Table ES 4.

Table ES 4: Summary of advantages and disadvantages of different approaches to $PM_{2.5}$ exposure reduction

Approach	Link to AQ Impact Pathway	Ease of Implementation	Understandable to Public	Timescale for Implementation	Costs for Implementation[a]
Monitoring					
National level	++++	++++	+++++	Medium	$$$
Jurisdictional level	++++	++	+++++	Medium	$$$
Modelling					
Total primary PM	++	++	++++	Medium	$$$$$
Anthropogenic primary PM	+++	++	++++	Medium	$$$$$
Anthropogenic primary PM + secondary	+++++	+	+++++	Long	$$$$$$
Emissions ceiling					
Primary PM	+	++++	+	Medium	$$$$
Primary PM + damage cost	+++	+++	+++	Medium	$$$$$
Primary PM + secondary precursors	++	++	++	Long	$$$$$$

a Costs for implementation do not include the resources required to develop the required reduction targets

At this stage, an exposure reduction approach based on modelling within Australia is considered impractical, as a substantial resource investment would be required, even if it were implemented at a national level. Based on the assessment provided above, four potential options for an exposure reduction approach in Australia are therefore proposed, based around monitoring or emissions ceilings:

- **Option 1:** A Cleaner Air Programme (CAP) approach similar to the Canadian CI/KCAC programme, with no targets set, but a requirement placed on all jurisdictions to set out programmes to reduce emissions of both primary PM and secondary PM precursors.
- **Option 2:** An exposure reduction system based on monitoring, with target reductions set on an Australia-wide basis. The target reduction could be advisory or mandatory.
- **Option 3:** An exposure reduction system based on an emission ceiling for primary PM, with targets set for individual jurisdictions based on the damage cost approach. The target reduction could be advisory or mandatory (it would differ from Option 1 in that targets are established)
- **Option 4:** A hybrid approach between Options 1 and 3. The emissions ceiling for primary PM would be supported by the CAP approach to reduce emissions of secondary PM precursors.

As part of the development of an exposure reduction approach, a stakeholder workshop was held in Sydney on 14 September 2012 to discuss the options and provide an opportunity for jurisdictions to provide feedback and guidance before preparing the final report.

OUTLINE OF FRAMEWORK PROCESS

For each potential option the outline of the framework process is provided in Table ES 5. With regards to developing targets for each option, with the exception of Option 1, for which no targets would be established, the process for the setting of targets is largely independent of which Option is selected, although the metrics that would be applied are different.

The National Environment Protection Council (NEPC) Service Corporation commissioned an economic analysis project to assess the costs and benefits of introducing an exposure reduction framework into Australia, which will inform the selection of an appropriate target.

The first stage of the process will be to evaluate the current and projected (Business As Usual; BAU) emissions across all eight Australian jurisdictions. Depending on which Option is selected, this will need to include, as a minimum, the emissions of primary $PM_{2.5}$, but it would be highly advantageous to include the secondary precursor emissions (NO_x, SO_2/SO_3, NH_3 and VOCs) for all Options. The projected (BAU) emissions will need to coincide with the target year for the exposure reduction approach, which is anticipated to be 5-10 years forwards.

Abatement measures (for both primary PM and secondary precursors) at both the national and jurisdictional levels will need to be evaluated for a range of scenarios, and the emissions reductions, and associated costs, quantified for each. These emissions reductions then need to be translated into ambient $PM_{2.5}$ concentrations with the values expressed as population-weighted annual means. This will allow a cost benefit analysis to be undertaken for each emissions reduction scenario, and the net benefit (monetised health and other benefits, minus the costs of implementing the required abatement) calculated. The targets required for Option 2 (the reduction in average population-weighted mean $PM_{2.5}$ concentration across the urban populations >100,000) and Option 3 (the reduction in primary PM emissions for each jurisdiction) can then be calculated. The target applied to Option 4 would be identical to that applied for Option 3.

For Option 2, as it is recommended that the target be applied across the average of all Australian monitoring stations, it is appropriate that the target be set as an absolute reduction (e.g. x $\mu g/m^3$) between the "base" and "target" years. For Option 3, it is recommended that the target be set as an emissions ceiling for primary PM (e.g. tonnes per year per jurisdiction/airshed).

Table ES 5: Outline of Framework Process for each Exposure Reduction Option

Aspect	Option 1	Option 2	Option 3	Option 4
Description	Cleaner Air Program approach	Monitoring approach	Emissions Ceiling approach incorporating damage costs	Hybrid approach between Option 1 and Option 3
Basis	The system would focus on those areas where $PM_{2.5}$ concentrations are below the advisory (or new mandatory) NEPM standard, but no targets for exposure reduction (in terms of emissions or concentrations) would be set. Jurisdictions would be required to set out programmes to reduce emissions of both primary PM and secondary PM precursors, and to report progress on regular (e.g. every 5 years) basis.	- 40 $PM_{2.5}$ monitors across 16 urban areas covering 70% of Australia, population. - All urban areas with a population of greater than 100,000 are covered by the framework, and the number of monitors for each urban area is based on one per 400,000 inhabitants	- Based on primary PM emissions only. - Incorporates damage cost functions for primary PM. The damage cost approach provides an approximate method for weighting emission reductions to the expected magnitude of exposure reduction. - Development of regional air emissions inventories across nine urban airsheds in Australia covering 70% of Australia's population. - 5 yearly updates of the emissions inventory to ensure compliance with targets.	- An emissions ceiling would be introduced for primary PM, linked to the damage cost approach, and implemented at the jurisdictional level (i.e. Option 3). - As there is no reliable way, at present, to quantify the health (or cost) benefits associated with the reduction of the secondary precursor emissions, and it is therefore not possible to quantify an emissions ceiling. Jurisdictions would be required to set out programmes to reduce emissions of secondary PM precursors, and to report progress on regular (e.g. every 5 years) basis, but no specific targets would be set (i.e. part of Option 1).
Compliance	Publication of an initial "state-of-the-environment" report by each jurisdiction, to be submitted within a defined timescale. This would include a current-year emissions inventory within each jurisdiction (for primary PM and the secondary precursors), with emissions categorised by sector, together with information on ambient concentrations and trends in $PM_{2.5}$ concentrations.	Compliance checking for Option 2 would be relatively straightforward, based on the reported monitoring data. The average $PM_{2.5}$ concentration measured across the Australian exposure reduction monitoring network, calculated over the three-year base period and three-year period relevant to the "target year" would be directly compared with the adopted target. Issues that may need to be taken	Compliance checking for Option 3 is potentially straightforward and would involve a comparison of the estimated emissions in the target year with the emissions ceiling, for each jurisdiction. Issues that would need to be carefully considered would be any changes to the methodologies used to calculate the emissions, or any changes to the sources included in the calculations. Procedures to	Compliance checking for Option 4 could simply involve the incorporation of the primary PM emissions ceiling (from Option 3) into the five-year reports prepared for Option 1.

Aspect	Option 1	Option 2	Option 3	Option 4
	The development of goals and targets, including emissions reduction strategies. Tracking progress in annual reviews of ambient $PM_{2.5}$ concentrations and actions implemented, or planned, to reduce emissions. Publication of five-year reports, confirming all actions taken to reduce primary PM and secondary precursor emissions, and presenting available data on current emissions levels and trends, as well as ambient $PM_{2.5}$ concentrations and trends.	into account relate to missing sites (due to poor data capture, site closure, significant changes to operational status etc.). Guidance on how to deal with this determination, and the variability's that may occur, has been prepared to assist with the implementation of the exposure reduction approach in Europe (AQUILA, 2012). Adoption of the general principles of this guidance could be made within Australia. Another issue is that while the exposure reduction target is best set at the national level, and the responsibility for monitoring and reporting of $PM_{2.5}$ concentrations is best undertaken by the jurisdictions, there is no clear responsibility for the implementation of measures to reduce primary PM and secondary precursor emissions. This could be tackled in a number of ways, either by establishing target reductions for each jurisdiction across different sectors (derived from the studies used to inform the setting of the exposure reduction target – see Chapter 6), or by simply introducing the Option 1 approach, which requires plans and programmes to be established.	"adjust" the emissions calculation in a transparent and uniform manner would need to be implemented.	
Estimated Costs	~$486,000 per annum	~ $860,000 per annum	~$972,000 per annum and $262,500 to develop a regional air emissions inventory guidebook	~$1,215,000 per annum and $262,500 to develop a regional air emissions inventory guidebook
Estimated Timescale for implementation	2-3 years	3 years	5 years	5 years

RECOMMENDED APPROACH

Background

As part of the development of an exposure reduction approach under the National Plan for Clean Air, a stakeholder workshop was held in Sydney on 14 September 2012 to discuss options and provide an opportunity for jurisdictions to provide feedback and guidance before preparing the final report.

Following the workshop, it seemed important to emphasise that monitoring (in itself) delivers no improvement to PM exposure – it is simply the compliance mechanism by which measures put in place to reduce emissions are judged to have been successful. With an exposure reduction framework based on monitoring, mechanisms are still required to be in place to focus action i.e. an emissions inventory and some form of assessment tool to understand how emissions are related to concentrations (so that appropriate targets can be set).

It is also important to note that all three air quality management tools would need development no matter which exposure reduction framework option was selected. That is:

- Air quality monitoring networks are required to measure ambient levels of $PM_{2.5}$.
- Air emission inventories are required to prioritise emission sources.
- Regional air quality modelling is an important step in any exposure reduction framework as these tools are used to determine exposure reduction targets that are achievable.

Objectives

Based on the stakeholder workshop the agreed objectives of a recommended $PM_{2.5}$ exposure reduction framework are to:

- Drive continued reductions in population exposure to $PM_{2.5}$, even when concentrations are below national compliance standards.
- Have regard to cost-effectiveness and health benefits and the distribution of health benefits for the community.
- Be simple, practical and able to be implemented in all Australian jurisdictions.

Recommended Framework

It is recommended that a framework based on Option 1 is progressed. The recommended framework would be a ***mandatory system*** with an obligation placed on jurisdictions to develop programmes to reduce emissions of primary PM and secondary precursors (i.e. NO_x, VOCs, SO_2 and ammonia). These programmes would be audited at a national level and rejected if they failed to meet a satisfactory standard. It is envisaged that this could be the springboard required to implement a framework of emissions inventories, assessment and monitoring that could later be developed into Options 2, 3 or 4. In the future, there may also be options to explore the use of empirical models (such as the UK Pollution Climate Mapping (PCM) approach) once there is a better understanding of emissions and there is better monitoring data coverage (including monitoring of components, such as sulfate, nitrate, chloride etc).

State and Territory jurisdictions and the Commonwealth Government would be required to report on:

- Emission reduction actions. This would include a description of all actions implemented to reduce ambient PM within each jurisdiction and estimates of the quantified effectiveness of each action, expressed in terms of mass emission reduction of each pollutant (primary PM and secondary precursors) due to each action.

- Current emissions and trends.
- Ambient levels of $PM_{2.5}$ and trends.
- Development of capacity in regional air emission inventories, regional air quality modelling capability and the regional air quality monitoring network for $PM_{2.5}$.

It is recommended that the framework be established within the Air NEPM such that the framework was supported to take forwards the exposure reduction approach to PM within a 10 year timeframe. The framework would consist of three tasks.

- Task 1 – Develop emission reduction programmes.
- Task 2 – Develop $PM_{2.5}$ monitoring networks and regional emission inventories.
- Task 3 – Develop exposure reduction targets.

It is understood that, in the immediate term, it is considered desirable to set an interim exposure reduction target. It is not possible with the current information to set an interim target based on an emissions ceiling. However, based on the information currently available, it is considered that a 10% reduction in total measured $PM_{2.5}$ concentrations is likely to represent the lowest level at which it would be possible to identify any change in monitored ambient levels with reasonable certainty. In terms of timescales for an interim target, a compliance period of 10 years has precedent in Europe and is most likely appropriate for Australia. It is recommended that the baseline concentration is set based on at least three years of monitoring data to reduce inter-annual variability and is based on the network average of monitors either within each jurisdiction or nationally.

It is recommended that any interim target for exposure reduction that is set is reviewed as further information from regional modelling and economic analysis projects becomes available.

APPLICATION TO OTHER POLLUTANTS

The exposure reduction approach is potentially suited to any pollutant where there is convincing evidence of a non-threshold effect. Of those pollutants for which Air NEPM limit values have been established, only ozone is potentially considered to be a non-threshold pollutant.

There are two NEPM limit values for ozone, both based on short-term exposure (1-hour and 4-hour means). In most Australian towns and cities, ozone levels are below the limit values, but exceedances are recorded several times per year in the larger cites, most notably Sydney and Melbourne, but also Brisbane and Perth.

At this stage, it is not certain that ozone is a non-threshold pollutant. In addition, it would be extremely challenging to establish an exposure reduction framework based on concentrations (measured or modelled), as the number of exceedances in any given year will be highly dependent on the prevailing meteorological conditions, and not directly related to the emissions.

If the exposure reduction framework for $PM_{2.5}$ were based on an emissions ceiling which included the secondary precursors for PM, there would be co-benefits in reducing ozone concentrations. Such an approach is set out for both Options 1 and 4, and would also need to be included within Option 2 (with or without target reductions). A possible exposure reduction metric for ozone would be to establish an Air Quality Index across the jurisdictions (similar to that already operating in NSW) with a requirement for annual reporting.

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The *National Environment Protection (Ambient Air Quality) Measure* (Air NEPM) was introduced in 1998. The Air NEPM sets national air quality standards for six pollutants; particulate matter (mandatory standard for PM_{10} and an advisory reporting standard are $PM_{2.5}$), ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide and lead. The Air NEPM has been recently reviewed and the National Environmental Protection Council has stated that the recommendations of the review will be responded to through the development of the National Plan for Clean Air.

The development of the National Plan for Clean Air is to take a staged and prioritised approach, with a commitment to action on particulate matter, as this is the pollutant of greatest concern to human health. The first stage of work in the development of the National Plan for Clean Air involves a number of key components:

- Standard setting;
- Development of an exposure reduction framework;
- Identification of emission and exposure reduction actions; and
- Development of an integrated cost-benefit analysis for particulate matter.

This project, *Evaluating Options for an Exposure Reduction Framework in Australia (Reference OEH-147-2012)* has been carried out by PAEHolmes and Air Quality Consultants (AQC) on behalf of the New South Wales (NSW) Environmental Protection Authority (EPA). The principal objective of the project is to recommend a preferred approach for an exposure reduction framework for $PM_{2.5}$ in Australia.

2 BACKGROUND

2.1 Air NEPM

The *National Environment Protection (Ambient Air Quality) Measure* (Air NEPM) was introduced in 1998. It sets national air quality standards (limit values) for six pollutants:

- particulate matter (PM) (mandatory reporting for PM_{10} and advisory reporting for $PM_{2.5}$);
- ozone;
- nitrogen dioxide;
- sulfur dioxide;
- carbon monoxide; and
- lead.

The Air NEPM has been recently reviewed (NEPC, 2011) and a key recommendation from the review report was that an exposure reduction framework and targets be developed for priority pollutants as shown in Figure 1.

Recommendation 2
Revise the desired environmental goal to make reference to the air quality standards and incorporation of exposure reduction targets for priority pollutants.

Recommendation 8
Introduce an exposure reduction framework and targets for priority pollutants.

Figure 1: Recommendations related to the development of an exposure reduction framework in the review report for the Air NEPM (NEPC, 2011)

The limit values set out in the Air NEPM are summarised in Table 1.

Table 1: Air NEPM limit values

Item	Pollutant	Averaging period	Maximum concentration	Goal within 10 years Maximum allowable exceedances
1	Carbon monoxide	8 hours	9.0 ppm	1 day a year
2	Nitrogen dioxide	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year none
3	Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm 0.08 ppm	1 day a year 1 day a year
4	Sulfur dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year none
5	Lead	1 year	0.50 µg/m³	none
6	Particles as PM_{10}	1 day	50 µg/m³	5 days a year
	Particles as $PM_{2.5}$ [a]	1 day 1 year	25 µg/m³ 8 µg/m³	NA

[a] Advisory reporting standard - goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of the review of this Measure

2.2 Justification for an Exposure Reduction Framework

There is no convincing evidence of a threshold for health effects arising from exposure to particulate matter, expressed as either PM_{10} or $PM_{2.5}$. Thus, even where an NEPM standard for PM is not exceeded, there is a health benefit in reducing PM concentrations even further, and particularly in areas of higher population density. By way of example, the health benefits associated with reducing average PM exposure by 1 µg/m^3 across a population of 100,000 people, are ten times greater than those from reducing the average PM exposure by 10 µg/m^3 across a population of 1,000 people.

It is also important to note that these health benefits are *directly related* to the reduction in PM exposure, and are *unrelated* to the absolute concentration. Thus, reducing the average PM exposure from 28 µg/m^3 to 27 µg/m^3 across a population of 10,000 people, is expected to deliver *the same health benefit* as reducing the average $PM_{2.5}$ exposure from 11 µg/m^3 to 10 µg/m^3 across the same population.

It is important to draw a distinction between approaches which ***maximise the equity*** (whereby individuals most at risk of exposure to the highest concentrations are protected to a uniform, minimum standard, and those which ***maximise the efficiency*** (which relates to the ability to maximise health benefits across the population, e.g. life-years saved). NEPM standards for PM have an important role to play in maximising the equity, but can be usefully complemented by an exposure reduction approach which seeks to maximise the efficiency.

Whilst air quality standards have an important role to play in driving down PM concentrations where exceedances are measured or predicted, localised remedial actions are unlikely to lead to large-scale reductions in population exposure. In addition, in areas of higher population density where there are no exceedances of the standards there is currently no driver to implement measures to reduce exposure to PM.

PM_{10} levels in Australian capital cities are significantly below the Air NEPM standard for 95% of the time (Figure 2). However, exposure to these relatively low pollution levels for the vast majority of the time drives the health costs of fine particle exposure. The estimated health costs from this exposure are estimated to be up to billions of dollars per year. For example, the health costs of exposure to PM_{10} in Sydney are estimated at $4.7 billion per year (NSW DEC, 2005). The health costs of transport emissions of PM_{10} alone are estimated at $2.7 billion per year in Australia (BTRE, 2006). The health benefits of reducing fine particle concentrations are independent of compliance with air quality standards (OEH, 2012b).

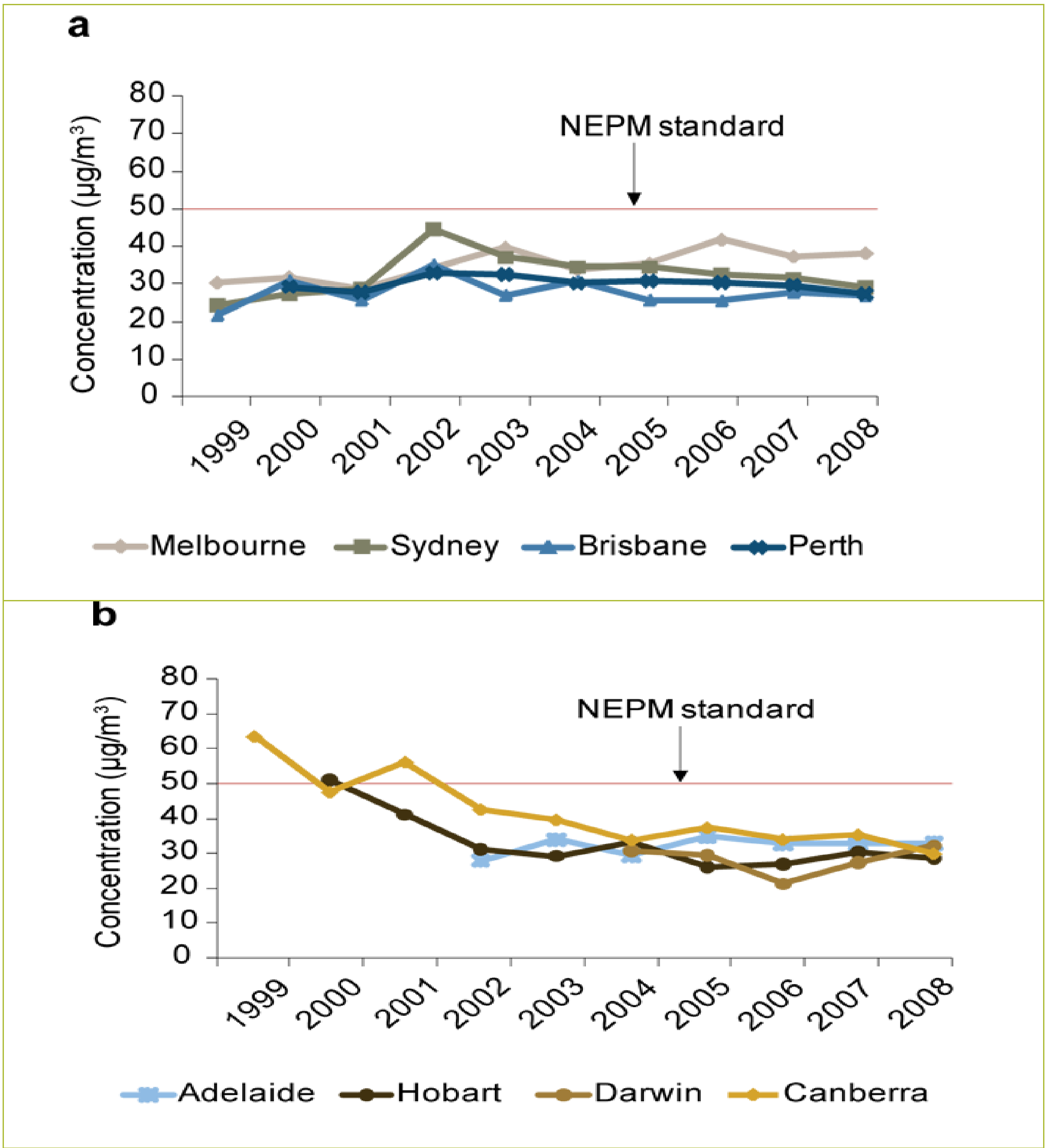
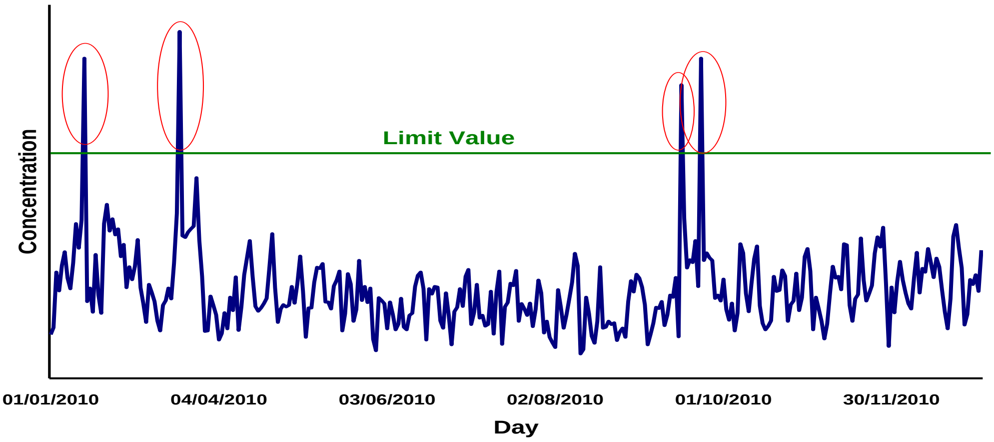


Figure 2: Average 24-hour PM_{10} concentrations in Australian cites, 1999 – 2008 - Average 95th percentile 24-hour average PM_{10} concentrations (OEH, 2012b)

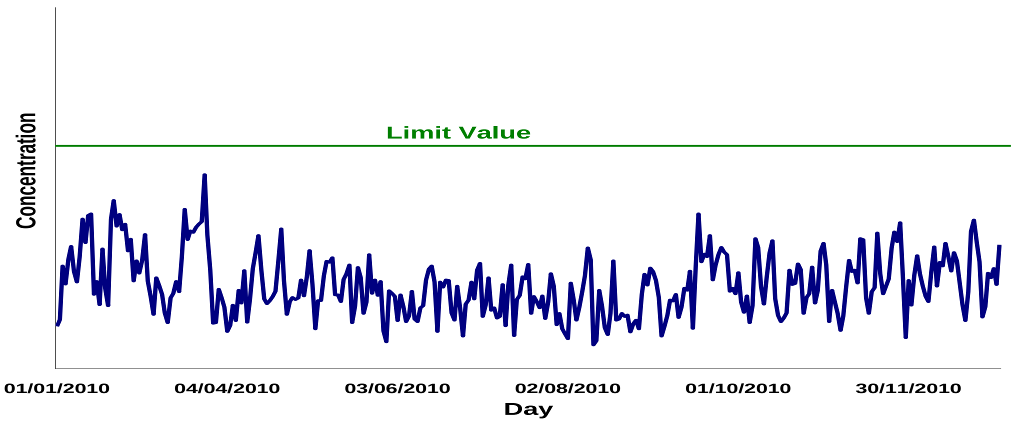
The current Air NEPM approach uses limit values to drive improvements to air quality nationally. This approach concentrates on reducing exceedances of the limit values (Figure 3) at particular locations (Figure 4). In the illustrative examples shown in Figure 3 and Figure 4 there is likely to be little difference in the health burden of example A and example B (OEH, 2012b).

EXAMPLE A



The existing Air NEPM focuses action on eliminating exceedances of the standards.

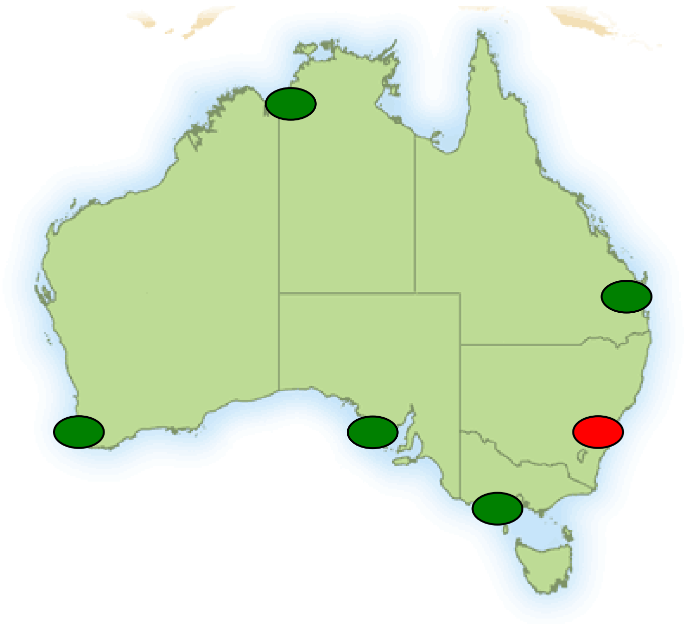
EXAMPLE B



When exceedances are eliminated, there is no driver for further reductions, even though these concentrations are impacting on community health.

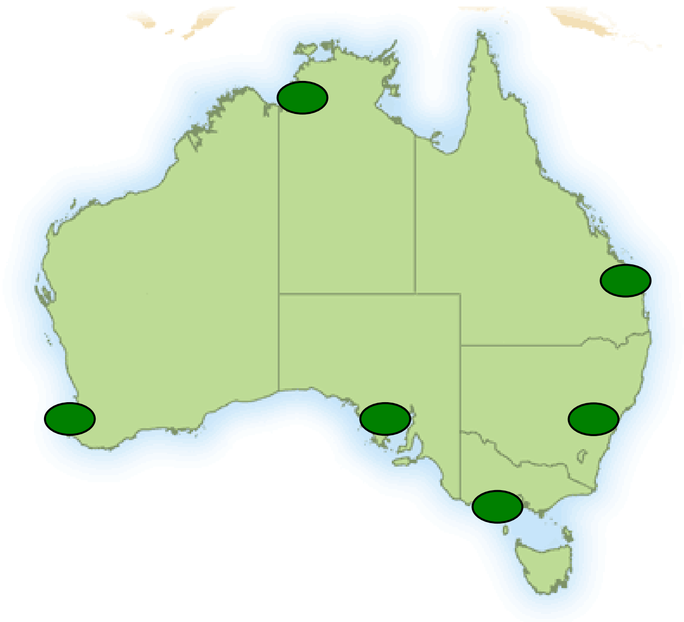
Figure 3: Compliance with limit value approach – focus on exceedances (OEH, 2012b)

EXAMPLE A



Standards focus action on locations where the standard is exceeded.

EXAMPLE B



Where all concentrations are less than the standard, there is no driver to reduce concentrations even though these concentrations are impacting on community health.

KEY

Green marker	Marginally below NEPM limit statndard – no driver for further reduction in pollution
Red marker	Marginally above NEPM limit standard – driver to reduce pollution

Figure 4: Compliance standard approach – focus on hot spots (OEH, 2012b)

The National Plan for Clean Air has identified reducing exposure to PM as an immediate priority due to the magnitude of the potential health benefits, the current population exposure, and the range of control options available. This importance is reflected in the Air NEPM review report, which provides a specific recommendation to introduce an exposure reduction framework and targets for priority pollutants (Recommendation 8) (NEPC, 2011).

3 REVIEW OF EXPOSURE REDUCTION FRAMEWORKS AND ASSOCIATED METRICS

The continued reduction of overall population exposure to a non-threshold pollutant such as $PM_{2.5}$ is expected to have significant health benefits. There are a variety of ways in which policy measures can be used to encourage or require a reduction in $PM_{2.5}$ emissions (or the gaseous precursors of secondary $PM_{2.5}$). This Chapter explores the various international approaches that have been adopted to reduce emissions and environmental exposure to pollution, including $PM_{2.5}$. It also considers the different approaches taken to the setting of air quality standards, the use of air pollution indices as headline indicators of air quality conditions, and the approaches taken to estimate damage costs as a means of approximating the impacts of changes in air pollution.

3.1 Emissions-Reduction Approaches

3.1.1 Gothenburg Protocol

The ***1979 Geneva Convention on Long Range Transboundary Air Pollution*** (CLRTAP) (UNECE, 1979) was the first internationally-binding instrument to tackle the problems of air pollution on a broad, regional basis. Now ratified by 51 governments, including the USA and Canada, the Central and Eastern European countries and the European Union, the Convention entered into force in 1983, and has since been extended by eight specific protocols. Of greatest relevance to this report is the 1999 Protocol to Abate Acidification, Eutrophication, and Ground-level Ozone (UNECE, 2005), more commonly referred to as the "***Gothenburg Protocol***". The Protocol sets emissions ceilings, which were to be attained by 2010, for four pollutants; sulfur oxides, nitrogen oxides, volatile organic compounds (VOC) and ammonia. The basic obligations of the Protocol require each Party to:

- Reduce and maintain emissions in accordance with the established national ceilings (apart from the USA and Canada which have a bilateral agreement);
- Apply emissions limits to new and existing stationary (point) sources in accordance with the established limit values; and
- Apply limit values (sulfur content) for fuels and control of mobile sources.

Parties are required to report on a periodic basis to the Executive Body for the Convention, the levels of emissions of each defined substance with respect to the 1990 reference year, using the same methodologies and temporal and spatial resolutions, and data on projected emissions and reduction plans. The Centre for Emissions Inventories and Projections at the Austrian *Unwelbundesampt* ("Environment Agency") and the Meteorological Synthesising Centre-West at the Norwegian Meteorological Office use these emissions inventories in EMEP model runs, and are able to audit and identify any discrepancies in the data.

The Protocol has been recently reviewed, and new agreement on emissions reduction targets for 2020 was reached in May 2012. This extends the Protocol to include emissions ceilings for $PM_{2.5}$ and measures to prioritise the reduction of short-lived climate pollutants (e.g. elemental carbon).

3.1.2 National Emissions Ceiling Directive

The ***National Emissions Ceiling Directive*** (NECD) (2001/81/EC) which came into force in 2001, sets upper limits for each Member State of the European Union, for the total emissions in 2010 for sulfur dioxide, nitrogen oxides, VOCs and ammonia, but leaves it largely up to Member

States to decide what measures need to be taken in order to achieve compliance; such measures are required to be submitted to the European Commission in national programmes. The emissions ceilings set within the NECD are complimentary to, or more stringent than those established within the Gothenburg Protocol. Fundamental to the negotiations on the Gothenburg Protocol and the NECD was the availability of an integrated assessment tool, the Regional Air Pollution Information and Simulation model, RAINS (IIASA, 2000), which allowed policy makers to estimate the costs and impacts of different emission control strategies, in both current and future years, in a transparent and uniform manner.

The revision of the NECD is part of the Thematic Strategy on Air Pollution and will follow the publication of the amended Gothenburg Protocol. It is expected that the revised NECD will set new emissions ceilings to be met by 2020, and possibly beyond, for the four already-regulated pollutants and will be extended to include emissions of primary $PM_{2.5}$.

The emissions inventories that form the basis of annual reporting to the Commission and the European Environment Agency (EEA) are required to be calculated in accordance with internationally agreed methodologies, and are requested to use the Joint EMEP/CORINAIR guidebook. The NECD principally relies on the same process for checking of emissions inventories as for the Gothenburg Protocol.

3.1.3 Issues with Emissions-Reduction Approaches

It is useful to briefly explore some of the issues with implementation of these emissions-reduction approaches, as this may inform potential implications for the introduction of such an approach into Australia.

The NECD requires all 27 Member States of the European Union to report information annually concerning emissions and projections. The EEA status report for 2010 (EEA, 2011) highlighted the following issues:

- Only 15 of the 27 Member States anticipated they would have met all four of the pollutant-specific emissions ceilings specified in the NECD. The 2010 emissions ceiling for NO_x is the most challenging, and is related to road transport emissions. This is partly due to growth in the sector, but is also related to the failure of more stringent road vehicle emissions standards in Europe (particularly for diesel vehicles) in delivering the expected reductions in emissions of NO_x (Carslaw et al, 2011), upon which the emissions ceilings were founded. As the NECD requires Member States to report emissions in accordance with methodologies agreed under CLRTAP, there is no allowance to adjust inventories if policies are found to deliver much lower reductions than originally anticipated.
- There is incompleteness of data reporting, and only 24 Member States provided the mandatory information for 2008 emissions, and only 23 Member States provided projections or emissions estimates for 2020.
- Since the original integrated assessment modelling was completed to support the determination of the 2010 emissions ceilings, improved knowledge has become available on sources of air pollutants, and "new" emission source categories have been identified (examples include NO_x and NMVOC emissions from the agricultural sector). EEA analysis demonstrates that incomplete reporting of these "new pollutant-source categories is likely to have significantly underestimated emissions in some Member States". The revised Gothenburg Protocol under CLRTAP now includes a facility to revise inventories and obligations, subject to detailed scrutiny, where such methodological changes occur.

- Reduced rates of economic activity as a result of the financial recession are expected to have reduced emissions, but only limited information is provided on whether these impacts have been taken into account.
- Under the NECD, Member States are only required to submit two years emissions data. This hampers any reliable assessment of long-term emissions trends.
- Only a limited number of Member States report key socioeconomic data used in preparing projections, although this is a formal requirement. The transparency of submitted data is limited as inventory reports and explanatory information to describe the methods and sources of data is not mandatory.

3.2 Exposure Reduction Approaches

3.2.1 Canadian CI/KCAC Approach

Whilst not representing a formal exposure reduction approach, the Canada-wide Standards (CWS) for PM and ozone (CCME, 2006) include the implementation of continuous improvement (CI) and keeping-clean-areas-clean (KCAC) programmes where ambient concentrations are below the CWS levels. This is not a mandatory requirement, but jurisdictions with ambient levels below the CWSs are expected to focus implementation measures on CI/KCAC. A guidance document on CI/KCAC was issued by the Canadian Council of Ministers and the Environment (CCME) in 2007 (CCME, 2007). This recognises that:

- The current CWS numerical targets “may not be fully protective” of human health and the environment;
- These two pollutants [$PM_{2.5}$ and ozone] have no apparent lower threshold for adverse health effects;
- Numerical targets are a “balance between the desire to achieve the best health and environmental protection possible in the relative near-term and the feasibility and costs of reducing the pollutant emissions that contribute to elevated levels of PM and ozone in ambient air”.

CI/KCAC programmes are required to address the following pollutants:

- In the ambient environment: ozone and $PM_{2.5}$
- In emissions: direct $PM_{2.5}$ emissions, the $PM_{2.5}$ and ozone precursors NO_x and VOCs, and the $PM_{2.5}$ precursors SO_2 and NH_3

Specific targets for reductions in pollutant concentrations or emissions have not been set, but jurisdictions are required to provide comprehensive reports at five year intervals (beginning 2006 and including progress on CI/KCAC) and should include all significant emission reduction actions on sources within the jurisdiction that contribute to decreases in elevated ambient levels in the reporting region. Also reports on achievement and maintenance of standards are required annually beginning 2011. The five year reports for 2010 are expected to be released towards the end of 2012. Jurisdictions must report for communities above 100,000 residents.

Canada has also just reviewed its standards for PM and ozone and its air quality management approach. A package of recommendations will be going to federal and provincial environment ministers in October 2012 and an announcement is expected towards the end of 2012/early 2013.

3.2.2 EU Exposure Reduction Target

The 2008 Ambient Air Quality Directive (2008/50/EC) (CEC, 2008) introduced a new national exposure reduction target[9] for $PM_{2.5}$ which applies to each Member State within the European Union. The Directive notes that $PM_{2.5}$ exposure is responsible for significant negative impacts on human health, and that as there is no identifiable threshold below which $PM_{2.5}$ would not pose a risk, this pollutant should not be regulated in the same was as other air pollutants. The approach aims at a general reduction of concentrations in the urban background to ensure that large sections of the population benefit from improved air quality. However, to ensure a minimum degree of health protection everywhere, the new approach is combined with a limit value.

The exposure reduction (E-R) approach adopted in the Directive was informed by a report prepared on behalf of the UK Department for Environment, Food and Rural Affairs (Defra) (Laxen & Moorcroft, 2005). Some of the key issues arising from this report, and which influenced the selection of the exposure reduction approach in Europe, are summarised below:

Limit Values

- The Limit Values are assumed to apply at any location where there is public access, and thus they apply at "hotspots" such as locations close to the kerbside of busy roads in urban areas. As the Limit Values are legally enforceable across all Member States, they have to be set at a level where they are reasonably achievable across a wide range of locations with differing pollution climates. It is therefore not practicable to consider lowering of the Limit Value.
- Limit Values provide equity of protection across Europe and a cap on the individual risk of health effects for those people exposed to elevated PM concentrations in hotspots. However, there are few exceedances of the Limit Values in many Member States, at locations away from hotspots, and without a new approach there is no requirement to reduce PM concentrations. In addition, there is the potential for general PM concentrations to increase, provided levels do not exceed the Limit Values.

Emissions Reduction

- There are still important sources of primary of PM that are not well understood, and the contributions of some of the secondary components (in particular Secondary Organic Aerosol) are not well characterised. Any exposure reduction approach founded on emissions-reduction targets would need to take account of changes to scientific understanding and emissions calculations to ensure that the benefits of reduced PM exposure were being delivered in practice.
- Total emissions are poorly related to human exposure. As an example, a significant reduction in primary PM emissions from tall stacks is likely to have a minimal impact on population exposure within urban areas. It could be possible to attain an exposure reduction target based on a reduction in emissions from point sources outside of major urban areas that would contribute little to reducing urban PM exposure.
- Emissions are not well understood by the public and other stakeholders, and there is no clear link between emissions reduction and health benefits.

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[9] Targets within EU Directives have a different legal status than limit values. Limit values are legally enforceable upon Member States, whereas there is no mandatory requirement to comply with Target Values.

Exposure Reduction – Modelling

- Use of regional scale modelling provides a simple approach to deriving population-weighted concentrations which can be directly linked to reductions in PM exposure.
- The performance of models is directly linked to the emissions databases that are used, and any changes in the methods used to calculate emissions, or the inclusion of new sources, would affect the modelled concentrations, and would have to be adjusted to calculate the exposure reduction.
- The Data Quality Objectives for modelling uncertainty (50%) are much weaker than the measurement uncertainty (25%) for annual mean PM concentrations, which could lead to much greater uncertainties in any exposure reduction metric based on modelling. Use of different modelling approaches across the Member States could lead to different conclusions.
- Compliance checking would necessarily have to be dependent on emissions inventories.

Exposure Reduction – Monitoring

- Relatively straightforward approach. Requirements for PM monitoring are explicitly described in the Directive, and measurement methods must conform with the appropriate reference method (or be demonstrated to be equivalent).
- Provides a metric (reduction in PM concentration) that can be directly linked to health benefits. Choice of monitoring site locations is critical so as to measure concentrations that are broadly representative of urban population exposure; sites should be away from significant local pollution sources.
- Monitoring sites must remain operational and unchanged over the exposure reduction target period, and there should be no substantive changes to the monitoring approach that would affect concentrations. Potential problems are reduced by having a larger rather than a smaller number of monitoring stations in the E-R network, and by averaging the concentrations across all sites, as opposed to reporting concentrations for individual sites for comparison with the E-R target. This also reduces the effects of measurement uncertainties at individual sites.
- Effects of year-to-year variations in PM concentrations associated with meteorology need to be accounted for with regard to determining compliance with the E-R target. The use of a 3-year rolling average concentration reduces the effect of a particular year on the calculated concentration.
- Exposure reduction targets could be based on fixed or percentage reductions in PM concentrations. A fixed target has the advantage that the same absolute improvement is achieved across all Member States, but the reduction will be harder to achieve in those countries where PM levels are lower (as many of the potential abatement measures will already have been implemented), and the effort required to meet the E-R target will not be equitable. A percentage reduction approach delivers the greatest benefits to human health in those Member States with the highest exposure, and offers a more equitable approach.

The EU exposure reduction approach that has been adopted is based on monitoring. A reduction target is applied to the Average Exposure Indicator (AEI), which is the $PM_{2.5}$ concentration averaged across a defined network of urban background monitoring stations throughout the Member State. The AEI is calculated as a three-calendar year running annual mean concentration[h]. Member States are required to establish a minimum of one sampling

[h] For example, the 2010 AEI is calculated as the three-year running mean concentration averaged over all sampling points for the years 2008, 2009 and 2010.

station per million inhabitants summed over the agglomerations in excess of 100,000 inhabitants. The exposure reduction target applicable to each Member State is a percentage reduction by 2020, relative to the reference year AEI in 2010, as shown in Table 2.

Table 2: EU exposure reduction targets for $PM_{2.5}$

Exposure reduction target relative to the AEI in 2010		Year by which the exposure reduction target should be met
Initial concentration (µg/m^3)	**Reduction target (%)**	2020
<8.5 = 8.5	0%	
>8.5 - <13	10%	
=13 - <18	15%	
=18 - <22	20%	
≥22	All appropriate measures to achieve 18 µg/m^3	

A lower threshold level at 8.5 µg/m^3 was selected as the AEI concentration below which no additional reduction would be required. This was selected, in part, as reflecting the "natural background" level across much of Europe, below which actions by individual Member States would have very limited effect in reducing concentrations further.

The Directive also sets an Exposure Concentration Obligation, expressed as an AEI of 20 µg/m^3, to be met by 2015 (calculated as the three-year running mean concentration averaged over all sampling points for the years 2013, 2014 and 2015). This sets a minimum obligation on all Member States.

Issues Associated with EU Implementation

It is again useful to briefly explore some of the issues with implementation of the exposure reduction approach into Europe, as this may inform potential implications for the introduction of such an approach into Australia (even if it were founded on a different metric).

- There was resistance to the introduction of a new concept for air quality management across a number of Member States, largely associated with a lack of understanding of the important issues at the political level.
- There was opposition to the new approach by the campaigning Non-Governmental Organisations, who interpreted the approach as a softening of measures to reduce PM exposure at hotspots. As a result, the Limit Value has been retained as the mandatory driver for PM reduction (with primary focus still on hotspot areas). The exposure reduction targets are not mandatory.
- There was considerable negotiation over establishing the Exposure Reduction targets, and ensuring that the obligations on Member States were equitable in circumstances where existing $PM_{2.5}$ concentrations were very high, or very low. The potential reduction targets were informed by the use of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (IIASA, 2012), that was developed to support the 2008 Directive, and by regional modelling conducted by individual Member States.

Recently, a report has been published in the UK (Stacey, 2011) which highlights potential issues associated with the variance in the measurement of the exposure reduction target (expected to be about 2 μg/m^3, between 2010 and 2020). The issues considered include:

- Analyser measurement uncertainty
- Effects of meteorology
- Effects of analyser maintenance
- Effects of analyser replacement
- Changes to the EU Reference Method
- Relocation of monitoring stations

It is important to note that some of the issues outlined in this report (Stacy, 2011) have not yet been fully peer-reviewed, and the potential implications should be regarded as work in progress. In addition, many of the issues are as relevant to measuring compliance with the Limit Value, as they are to the exposure reduction target. Whilst issues related to analyser measurement uncertainty, meteorology and changes to the EU Reference Method could affect the measurement of the 2020 AEI concentration, suitable statistical procedures should be able to be developed and agreed to account for these changes. It is also important to recognise that a number of the more significant issues identified are specifically related to the measurement technique that has been adopted by the UK for the measurement of $PM_{2.5}$ - i.e. the Filter Dynamic Measurement System (FDMS)[i].

Based on the tapered element oscillating microbalance (TEOM) analyser, the FDMS independently measures the volatile component of the air sample, which is then added back to the "base concentration". The analyser has been declared as equivalent to the European reference sampler for $PM_{2.5}$ measurements. However, the selection of this analyser introduces a number of difficulties which are not evident in other analyser types (and which would not be wholly relevant to TEOM analysers, upon which the Australian network is currently founded):

- There are currently four variations of the FDMS analyser in the UK Network, associated with different drier types. Each of these FDMS types demonstrates different performance characteristics.
- Practical experience of site operation has shown that changing even minor components of the FDMS can significantly affect performance. This, in particular, affects the drier, which is a replaceable component, with a life expectancy of less than 2 years.
- A number of FDMS analysers in the UK Network (which totals 66 sites) will need to be replaced before 2020. A like-for-like replacement will not be possible as the analyser types currently deployed are no longer in production.

Issues related to measurement techniques and uncertainties in the Australian context are explored in greater detail in Chapter 5 of this report.

3.3 Air Pollution Indices

Air pollution indices are widely used around the world to provide a more understandable message to members of the public. They allow information on poor air quality conditions to be disseminated without the need for reference to multiple pollutants and complex metrics (such as

[i] This instrument was introduced as the TEOM instruments could not be demonstrated to be equivalent to the reference method.

parts per hundred million, or micrograms per cubic metre). Such indices can also be used as indicators of improving air quality.

3.3.1 NSW Government AQI

The NSW Air Quality Index is a derived value based on the individual hourly pollutant readings using the following formula:

$$AQIpollutant = \frac{Pollutant\ Data\ Reading}{Standard} \times 100$$

The AQI is calculated for each pollutant (ozone, nitrogen dioxide, carbon monoxide and particulate matter) on an hourly basis. The **Site AQI** that is reported is the highest calculated AQI value from all of the pollutants measured over the past 24 hours at each individual monitoring station. The **Region AQI** is the highest site AQI for all monitoring stations in the region.

Bandings range from "Very Good", through "Good", "Fair", "Poor" and "Very Poor", to "Hazardous".

3.3.2 UK Daily Air Quality Index

The UK DAQI operates in a similar manner to the NSW system. The UK system uses an index numbered 1-10, divided into four bands ("Low", "Moderate", High" and "Very High") to provide information in a simple manner. The overall air pollution index for a site or region is determined by the highest concentration of five pollutants (nitrogen dioxide, sulfur dioxide, ozone, PM_{10} and $PM_{2.5}$). The index is updated every hour. The DAQI for $PM_{2.5}$ is reproduced in Table 3.

The primary function of the DAQI is to provide information to members of the public, specifically with regard to health alerts for at-risk individuals. However, the DAQI also provides information that is used to support the annual reporting on the air quality indicator for sustainable development. The indicator is based on annual mean concentrations of Particulate Matter and ozone, which are the two pollutants thought to have the greatest health impacts, as well as the number of days on which any one of the pollutant concentrations in the DAQI were Moderate or higher.

Table 3: UK data air quality index for $PM_{2.5}$

Band	Index	Running 24-hour Mean ($\mu g/m^3$)[a]
Very High	10	70 or more
High	9	65 - 69
	8	59 - 64
	7	53 - 58
Moderate	6	47 - 52
	5	42 - 46
	4	35 - 31
Low	3	24 - 34
	2	12 - 23
	1	0 - 11

[a] Unrounded values are rounded before comparison, so 64.49 $\mu g/m^3$ is index 8 and 64.51 $\mu g/m^3$ is index 9.

Whilst air pollution indices are useful in conveying information to members of the public, they are primarily focused on short-term pollutant concentrations, whereas the focus of exposure reduction for PM2.5 is focused on a reduction in chronic (e.g. annual mean) exposure. Where air pollution indices are used to support reporting of improvements to annual mean PM2.5 concentrations, no attempt is made to apply any form of population weighting to the data which is an important consideration for exposure reduction.

3.4 Damage Cost Approaches

Damage costs are used as a means of approximating the impacts of changes in air pollution. These costs estimate the marginal health benefits, or external cost savings, associated with each tonne of pollutant emission that is reduced. The approach is often used to screen potential mitigation scenarios, prior to undertaking a more detailed modelling evaluation.

The main disadvantage of the damage cost approach is that it is only able to account for the issues that link pollutant emissions and ground level concentrations in an approximate manner. For example, the health benefits actually accrued from a reduction in emissions will depend on the location of the source with regard to the location and size of populations and the conditions of the release (road traffic, elevated point source, meteorological conditions etc.).

Damage costs for a specific country or jurisdiction are usually generated via a full impact pathway approach utilising location-specific inputs and data. This approach provides the most robust and accurate damage costs for that location.

Examples of this approach include the damage costs from the UK Interdepartmental Group on Costs and Benefits (IGCB) and the EU Clean Air for Europe (CAFE) programme. It is worth noting that the specific damage costs for a particular country or region are usually developed using the impact pathway approach and location-specific inputs (e.g. population density, life expectancy).

In the UK, a simple decision tree is used to determine when it is appropriate to use the more detailed impact pathway approach or damage costs. For cases that involve state (or national) level policies that affect air quality, an impact pathway approach is probably required. For individual policy proposals, a damage cost approach may be sufficient.

In the UK the damage cost approach is used when the estimated impacts of a proposal on air quality are less than £20 million, when the impacts will last for less than 20 years, or where air quality impacts are ancillary to the policy or policies (Defra, 2011). The use of damage costs is not, however, considered a replacement for detailed modelling and analysis. Damage costs are more appropriate as part of a filtering mechanism to narrow down a wide range of policy options into a smaller number that are then taken forward for more comprehensive assessment.

3.4.1 Australian examples

An international review of the approaches used for valuing the health impacts of PM emissions and concentrations was recently completed on behalf of OEH[j] (Aust et al., 2012). The review covered work undertaken by overseas jurisdictions - including the EU, the US, Canada and New Zealand - and also Australian jurisdictions. For the international methodologies the reader is referred to the original review. The Australian studies are briefly summarised in Table 4.

Table 4: Summary of damage cost values from Australian studies

Study	Details	Unit damage cost (A$/tonne)				
		PM_{10}	NOx	THC	SO_2	CO
NSW EPA (1997)		1,810	1,490	960	-	25
NSW EPA (1998)		310	68	-	-	-
Environment Australia (2000b)		17,600	1,385	1,440	-	12
Beer (2002)	Ozone included	147,429[(b)]	870[(b)]	19,331[(b)]	-	3[(b)]
	Ozone excluded	147,429	11	18,719	-	3
Watkiss (2002)	Band 1: Inner areas of larger capital cities	341,650	1,750	875	11,380	-
	Band 2: Outer areas of larger capital cities	93,180	1,750	875	4,380	-
	Band 3: Other capital cities and urban areas	93,180	260	175	2,800	-
	Band 4: Non-urban areas	1,240	0	0	52.5	-
Coffey (2003)		232,000	8,500[(a)]	2,200	-	12.9
USEPA (2003)		-	1,100 to 7,500[(C)]	800 to 3,600[(C)]	-	-
DEC (2005b)	Sydney	236,000[(b)]	-	-	-	-
	Hunter	63,000[(b)]	-	-	-	-
	Illawarra	47,000[(b)]	-	-	-	-
DIT (2010)	Capital cities	235,261[(b)]	-	-	-	-
	Rest of Australia	55,827[(b)]	-	-	-	-

(a) Ozone formation
(b) Central estimate
(c) Converted at A$-US$0.65

The most recent cost-benefit analysis of air pollution in the GMR was completed by Jalaludin et al. (2011). The authors estimated the number of adverse health effects that could be avoided (and the associated monetary benefit) by reducing concentrations of $PM_{2.5}$, PM_{10} and O_3 to near-background levels. It was found that the associated health benefit for the GMR equated to A$5.7 billion, the greatest proportion of which was due to avoiding premature deaths due to long-term exposure to $PM_{2.5}$. However, unit damage costs for emissions were not determined.

[j] OEH project (OEH-1072-2011 – Methodology for Valuing the Health Impacts of Changes in Particle Emissions).

3.4.2 Updated Australian methodology

Aust et al. (2012) concluded that the most robust method for valuing health impacts from air pollution follows the impact pathway approach, and the most advanced and detailed studies have been those undertaken in Europe and the US. These studies have also captured the complexity associated with chronic health effects. This is not reflected in the earlier Australian studies, though this is in part due to their age.

The authors proposed a methodological framework based on a two-level approach, as used in the UK, in which the impact pathway or damage cost approach is recommended based on the type of application and the anticipated effects of the changes. However, it was concluded that Australia currently lacks sufficient and readily available PM emission modelling information to permit a full impact pathway process and, by extension, to generate a set of accurate, location-specific damage costs. Consequently, an alternative/interim method was provided for calculating damage costs which can be used until more reliable data are available for Australia. The alternative method was based on transferring Defra/IGCB damage costs from the UK.

The interim method presents the calculation of derived damage costs from primary PM emissions from transport using the 'central estimate' function developed for Australia from UK data by Aust et al (2012) as follows:

$$C_{2011} = 1.55 \times (34.489 \times D_{pop}) \times 5.4$$

where:

C_{2011}	=	The unit damage cost for primary PM emissions from transport	(A$/tonne)
D_{pop}	=	The population density	(people/km²)

The constant 1.55 is used to convert UK pounds sterling to Australian dollars, and the constant 5.4 is a factor which takes into account differences in the health valuations in the UK and Australia.

Damage costs from non-transport sources are also presented based on UK data as provided in Table 5.

Table 5: Non-transport damage cost values (primary PM) for Australia

Damage Cost ($/tonne)				
Domestic	Industry	Electricity supply industry	Waste	Agriculture
208,774	187,177	17,998	154,781	71,991

The damage cost function is only applicable to primary PM emissions. No method was provided for estimating the costs associated with exposure to secondary particles. On a cost-per-tonne basis, the non-transport damage costs are substantially lower than those for transport.

4 ANALYSIS OF AUSTRALIAN CONDITIONS

Air quality management in Australia is complex, and differences in resources and available information exist between the individual state jurisdictions. Within each state, there is also variation in regional and urban information. Selecting an appropriate exposure reduction method for use within such a multifaceted system requires an evaluation of local circumstances and information to assist this process. Of note are the differences in population densities and the issue of equity[k] when proposing a particular framework. It is also important to identify appropriate set of skills to provide the support to jurisdictions that will be required.

Generally air quality is managed in Australian jurisdictions through the use of the following tools (each to varying degrees):

- Ambient air monitoring (determine the current exposure level);
- Development of air emissions inventories (source specific/regional);
- Modelling (determine impact on population);
- Development of emission reduction strategies.

The generic air quality management cycle is shown in Figure 5.

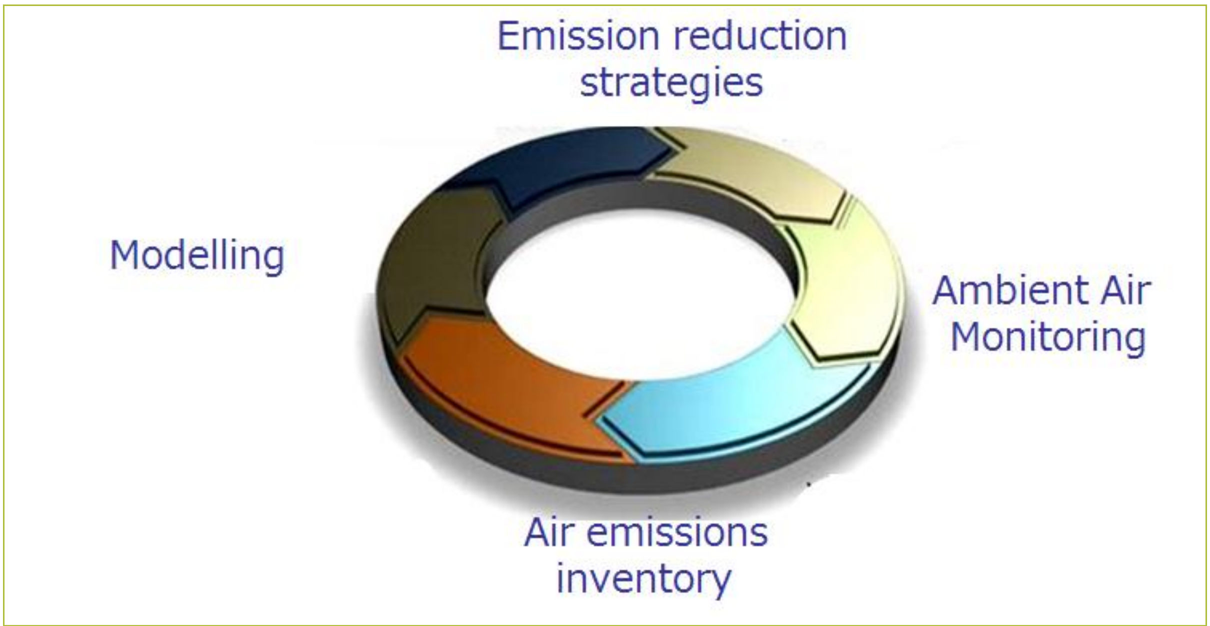

Figure 5: Air Quality Management Cycle

How each tool is potentially used to manage air quality in each Australian jurisdiction is described in Table 6.

[k] With the introduction of an exposure reduction framework, there may be a diminished obligation to tighten the existing NEPM standard for PM_{10}, or to introduce mandatory reporting of the short-term $PM_{2.5}$ standard. This has implications for members of the population living in areas where existing levels are close to the NEPM standard.

Table 6: Potential use of air quality management tools in each jurisdiction

Tool	Area of application
Monitoring	- Characterisation of past and current pollutant levels and identification of exceedances of AQ standards, objectives and targets - Time series of ambient concentrations at population-based monitoring sites for trend analysis in relation to emission reductions - Determining the relations between ambient concentrations at population-based monitoring sites and a range of health endpoints (concentration-response function) - The relationship between ambient concentrations of primary and secondary pollutants and emission source categories (source apportionment or receptor models) - Development and evaluation of conceptual models and source orientated models
Emissions inventories	- Current estimated emission rates by source type and locations serve as the starting point for assessing the need for and feasibility of reductions - Projected emission rates by source type and location and detailed information on the causes of future changes in emissions - Evaluation of air quality policy actions aimed at reducing emissions
Emission reduction strategies	- Identification of broad based and detailed emission reduction strategies and technologies by source type and their effectiveness (includes cost considerations)
Models	- Simulation of emission scenarios and quantification of resulting benefits and disbenefits by prediction of ambient concentrations at multiple time and space scales for: - Base case - Emission scenarios - Estimation of emission changes to attain AQ objectives or standards - Evaluation of emission estimates - Quantification of source-receptor relationship - Characterisation of governing chemical regimes and limiting reactants for current and future conditions - Simulation and design of new or modified measurement systems (network optimisation, site selection, input into data assimilation and analysis routines).

As part of this project each jurisdiction was sent a questionnaire requesting information on air quality monitoring, use of emission inventories, available population data and current status of regional air quality modelling. The results of the jurisdictional questionnaires are provided in Appendix B.

4.1 Monitoring

The Air NEPM is made under the National Environment Protection Council (NEPC) Acts which aim to provide equivalent environmental protection to all Australians wherever they live. The desired environmental outcome of the Air NEPM is ambient air quality that allows for the adequate protection of human health and well-being. All monitoring sites selected for NEPM monitoring are selected based on the NEPM Monitoring Protocol (PRC, 2001).

The objective of the NEPM Monitoring Protocol is to provide a consistent approach to the measurement of ambient air quality experienced in populated areas throughout Australia. Ambient air quality monitoring must be conducted in a manner that provides confidence to assessing whether or not the general population is being exposed to levels greater than the specified standards. Therefore, it can be considered that PM monitoring performed in Australia under the existing Air NEPM is based on population exposure and not monitoring of maximum expected levels (e.g. near road sides).

Performance monitoring under the Air NEPM is required by each jurisdiction to determine whether the Air NEPM standards and goals have been met within populated areas in a region/jurisdiction. The NEPM Monitoring Protocol states that to achieve this, it is necessary to locate some monitoring stations in populated areas which are expected to experience relatively high concentrations, providing a basis for reliable statements about compliance within the region as a whole. These stations are called generally representative upper bound (GRUB) for community exposure sites (PRC, 2001).

However, it is also necessary to ensure that a NEPM monitoring network provides a widespread coverage of the populated area in a region and provides data indicative of the air quality experienced by most of the population. Monitoring plans must demonstrate an adequate balance of GRUB and population-average measurements. In regions where only one performance monitoring site (PMS) is required, it is expected that the PMS will tend to be a GRUB site.

Siting criteria for neighbourhood (GRUB) monitoring stations defined in AS3580.1.1 – 2007 include minimum set back distances from roads (as shown in Table 7) and other siting criteria (as shown in Table 8).

Table 7: Minimum setback distances from roads for neighbourhood (GRUB) monitoring stations

Roadway traffic. Estimated average number of vehicles per day	Minimum distance between monitoring site and road, in metres		
	Carbon monoxide	Nitrogen oxides, VOCs & ozone	Particles, PAH, lead
≤ 10,000	10	10	50
15,000	25	20	*
20,000	45	30	75
30,000	80	See Note and *	*
40,000	115	50	100
50,000	135	*	*
60,000	150	*	*
70,000	*	100	*
≥ 110,000	*	250	*

* Distances should be interpolated for intermediate traffic flows

NOTE: The above table is consistent with Tables published in the USA Code of Federal Regulations, Title 40, Chapter 1, Part 58, Appendices D and E.

Table 8: Other monitoring criteria – particulate matter

Pollutant	Type of monitoring station [a,b,c]	Height above ground to sampling inlet or 80% of monitoring path (m)	Other locating criteria (minimum requirements)	Relevant measurement Standard
PM_{10}, $PM_{2.5}$	Peak	1.0 - 15	- Unrestricted air flow of 180° around sample inlet with no obstruction between the major source and the sample inlet - No extraneous sources nearby - ≥ 2 m from source and as close as practicable - No trees or bushes between the sampling inlet and source	AS/NZS 3580.9.6 AS 3580.9.7 AS 3580.9.8 AS/NZS 3580.9.9 AS/NZS 3580.9.10
PM_{10}, $PM_{2.5}$ [d]	Neighbourhood and background	1.0 – 15	- Clear sky angle 120° - Unrestricted airflow of 270° around sample inlet or 180° if inlet is on the side of a building - 10 m from nearest object or dripline of trees that are higher than 2 m below the height of the sample inlet - No extraneous sources nearby - > 50 m from road (see Table 7)	AS/NZS 3580.9.6 AS 3580.9.7 AS 3580.9.8 AS/NZS 3580.9.9 AS/NZS 3580.9.10
TSP	Peak and neighbourhood and background	1.0 – 5	- Unrestricted airflow of 180° around the sample inlet with no obstruction between the major source and the sample inlet - No extraneous sources nearby *	AS/NZS 3580.9.3

[a] Peak site – Peak sites are located where the highest concentration and exposure are expected to occur e.g. near roads, in the CBD or near industrial sources. These sites are especially useful for air quality compliance monitoring and sources monitoring.

[b] Neighbourhood site – Neighbourhood sites are located in areas which typify a broad area of uniform land use e.g. residential, industrial and commercial. These sites are especially useful for determining urban air quality trends, compliance with air quality standards and effects of major, non-localised sources of pollutants (GRUB and population average sites are consistent with the siting criteria for a neighbourhood site).

[c] Background site – Background sites are located in urban or rural areas to provide information on background levels. Background sites are usually in areas of homogenous land use and geography. These sites can be especially useful for assessing transportation of pollutants in a region.

[d] Siting criteria for GRUB and population average measurements.

The Air NEPM reference methods for monitoring PM_{10} and $PM_{2.5}$ under the Air NEPM are provided in Table 9.

Table 9: Reference methods for PM measurement under the Air NEPM

Pollutant	Method title	Method number
Particles as PM_{10}	Determination of Suspended Particulate Matter PM_{10} High Volume Sampler with Size Selective Inlet-Gravimetric Method	AS3580.9.6-1990
	Determination of Suspended Particulate Matter-PM_{10} Dichotomous Sampler-Gravimetric Method	AS3580.9.7-1990
Particles as $PM_{2.5}$	Class 1 and Class 2 equivalent manual gravimetric methods designated in the USEPA Federal Reference Method (USEPA reference method; *US Code of Federal Regulations Title 40 Part 50 Appendix L Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere*)	40 CFR Part 50

For $PM_{2.5}$, continuous direct mass methods using a tapered element oscillating microbalance (TEOM) may also be used in addition to the reference method. However the values obtained by using these methods cannot be used for comparison with the Air NEPM Advisory Reporting Standards until the outcomes of the $PM_{2.5}$ Equivalence Program have been formally included in the Air NEPM.

The $PM_{2.5}$ equivalency program involves jurisdictions performing monitoring with collocated instruments for the purpose of determining equivalent methods for monitoring $PM_{2.5}$. Other alternative methods (other than using a TEOM) may be used. Equivalence between the reference method and the alternative method must be demonstrated by collocation of samplers over a three-year period.

Current particulate matter monitoring methods vary between each jurisdiction. The most common method for measuring and reporting PM_{10} and $PM_{2.5}$ concentrations is the TEOM. The reference method for monitoring $PM_{2.5}$ is the manual gravimetric method. The method is a non-continuous (batch), 1-day-in-3 technique that requires pre and post laboratory weighing. This introduces a significant time delay in acquiring data. The main advantage of the TEOM is that concentrations are reported on a continuous basis. The TEOM does not have reference or equivalence status through the USEPA designations for monitoring of $PM_{2.5}$ due to issues related with loss of volatiles.

It was noted in the Air NEPM Review Report that as high-volume samplers(a NEPM reference method) is labour-intensive and there are advantages of obtaining continuous measurements, Tapered Element Oscillating Microbalance (TEOM) samplers have almost universally been adopted by jurisdictions to measure PM_{10}. The PRC's '*Technical paper no. 10: Collection and reporting of TEOM PM10 data'* (2001) provides guidance on the handling of TEOM PM_{10} data by way of an adjustment factor to generate equivalent information to the NEPM reference methods. These recommendations have not been implemented consistently by all jurisdictions and, according to commentators, equivalence remains an area of concern for PM_{10} data (NEPC, 2011).

The Air NEPM Review Team recommended that some flexibility needs to be built into the Air NEPM framework to allow for adoption of alternative methods to enable a faster response to technological advances in instrumentation. A review of methods in the Air NEPM monitoring protocol would be beneficial to ensure they are reflective of international best practice for air quality monitoring and to resolve discrepancies in current monitoring methods (NEPC, 2011).

Extensive work has been carried out internationally to determine equivalency between approved methods used for monitoring particles in ambient air. It should be noted that the tests carried out in Europe have failed to demonstrate equivalence between the TEOM and the EU reference sampler, and the TEOM analyser has now effectively been withdrawn from the compliance networks. The Air NEPM Review Team considers that the NEPM should allow the use of any methods that have been tested and approved by the US EPA or the EU as reference or equivalence methods for monitoring ambient air quality. The findings of the $PM_{2.5}$ equivalence program, implemented after the NEPM was varied in 2003, should also be taken into account (NEPC, 2011).

A summary of methods used to report concentrations of particulate matter by each jurisdiction is provided in Table 10.

Table 10: Particulate matter monitoring methods used by jurisdictions

Jurisdiction	PM_{10}	$PM_{2.5}$
New South Wales	Gravimetric reference method TEOM	Gravimetric reference method TEOM
Victoria	TEOM	Gravimetric reference method TEOM
Queensland	FDMS TEOM TEOM	FDMS TEOM TEOM DOAS
Western Australia	TEOM	TEOM
South Australia	TEOM	TEOM
Tasmania	Gravimetric reference method TEOM Microcal air sampler Dusttrack	Gravimetric reference method TEOM Dusttrack
Australian Capital Territory	Gravimetric reference method BAM	Gravimetric reference method BAM
Northern Territory	Partisol dichotomous sampler TEOM	Partisol dichotomous sampler

[a] TEOM: tapered element oscillating microbalance; FDMS: Filter Dynamic Measurement System; DOAS: Differential Optical Absorption Spectroscopy; BAM: Beta Attenuation Monitor

A summary of particulate matter monitoring performed by jurisdictions as part of the Air NEPM is provided in Table 11.

Table 11: Ambient PM monitoring in Australia (under the Air NEPM)

Jurisdiction	PM_{10}	$PM_{2.5}$
New South Wales		
Sydney	Yes	Yes[1]
Illawarra	Yes	Yes[1]
Lower Hunter	Yes	Yes[1]
Upper Hunter	Yes	Yes[1]
Albury	Yes	No
Bathurst	Yes	No
Tamworth	Yes	No
Wagga Wagga	Yes	Yes[2]
Total number of monitors	*19*	*7*
Victoria		
Melbourne	Yes	Yes[1]
Geelong	Yes	No
Latrobe Valley	Yes	No

Jurisdiction	PM_{10}	$PM_{2.5}$
Total number of monitors	*10*	*2*
Queensland		
South East Qld (including Brisbane)	Yes	Yes[2]
Gladstone	Yes	Yes[2]
Mount Isa	Yes	No
Mackay	Yes	No
Townsville	Yes	No
Total number of monitors	*11*	*5*
Western Australia		
Perth	Yes	Yes[1]
Albany	Yes	No
Bunbury	Yes	Yes[1]
Busselton	Yes	Yes[1]
Collie	Yes	No
Geraldton	Yes	No
Total number of monitors	*3*	*4*
South Australia		
Adelaide	Yes	No
Whyalla	Yes	No
Port Pirie	Yes	No
Mount Gambier	Yes	Yes[2]
Total number of monitors	*7*	*1*
Tasmania		
Hobart	Yes[2]	Yes[1]
Launceston	Yes[2]	Yes[1]
Tamar Valley	Yes[2]	Yes[1]
Georgetown	Yes[2]	Yes[1]
Total number of monitors	*1*	*1*
Australian Capital Territory		
Canberra	Yes	Yes
Total number of monitors	*2*	*1*
Northern Territory		
Darwin	Yes	Yes
Total number of monitors	*N/A*	*N/A*

NOTES

For each jurisdiction, the total number of monitoring sites shown includes only those sites currently operating within urban centres >100,000 people. Where the monitoring site has more than one PM_{10} or $PM_{2.5}$ analyser, it has only been counted once.

New South Wales

1. Most monitoring sites in the NSW Greater Metropolitan Region (GMR) use TEOMs for monitoring $PM_{2.5}$ rather than the reference method in the Air NEPM
2. Most $PM_{2.5}$ data for Wagga Wagga is limited and does not use the reference method in the Air NEPM

Victoria

1. $PM_{2.5}$ monitoring is conducted using a combination of gravimetric methods and TEOMs

Queensland

1. Pollutants at selected sites are monitored using DOAS (Differential Optical Absorption Spectroscopy) (not a reference method).

Western Australia

1. $PM_{2.5}$ monitoring is conducted using a TEOM

Jurisdiction	PM_{10}	$PM_{2.5}$
South Australia		
1. Mt Gambier has campaign monitoring so data is limited		
2. $PM_{2.5}$ monitoring was conducted using an APS (airborne particle sensor) (not a reference method)		
Tasmania		
1. $PM_{2.5}$ monitoring is conducted using Low Volume Air Samplers		
2. PM_{10} is monitored using a combination of TEOM and Low Volume Air Samplers		
3. Additional particle monitoring is conducted in other locations in Tasmania however this is conducted using DustTrack monitors (not a reference method)		
Australian Capital Territory		
1. PM_{10} is monitored using TEOM and BAM		
2. $PM_{2.5}$ is monitored using gravimetric methods		

4.1.1 Secondary Particulate Matter

There have been relatively few studies of secondary PM - and in particular secondary organic aerosol - in urban areas of Australia. The main activities and existing literature are summarised in this section.

The main data available in Australia for aerosol sampling are from the Australian Nuclear Science and Technology Organisation (ANSTO). ANSTO has been sampling $PM_{2.5}$ – mainly along the east coast of Australia - since 1991. During this time fine particles have been routinely collected at selected urban, rural and industrial sites. Ion beam analysis and positive matrix factorisation have been used to characterise particles and to identify sources. This long term aerosol sampling study is the only one of its kind taking place in Australia (ANSTO, 2010). One of the largest components of $PM_{2.5}$ at the ANSTO sites is ammonium sulfate. Between 1998 and 2008 the average ammonium sulfate concentration at 10 sites was 25% (range 18-31%) (ANSTO, 2008). Data for specific sites are available from the ANSTO web site[l].

Receptor modelling of various PM size fractions has been conducted extensively in Brisbane - and to a lesser extent in Melbourne, Sydney and Adelaide - by Griffith University (Chan et al., 1997, 1999, 2000, 2008, 2011). These studies have shown that secondary particles form a significant component of PM_{10} and $PM_{2.5}$. It was observed by Chan et al. (1999) that secondary organics and secondary sulfates accounted for 21% and 14% of $PM_{2.5}$ respectively at a suburban site in Brisbane surrounded by forest. Most of the secondary products were related to motor vehicle exhaust. In a study in the four cities mentioned above, Chan et al. (2008) found that, on average, secondary nitrates/sulfates contributed about 25% of the mass of the $PM_{2.5}$ samples. Secondary sulfates and nitrates were found to be spread out evenly within each city. The average contribution of secondary nitrates to fine particles was also rather uniform in different seasons, rather than being higher in winter as found in other studies. It was suggested that this could be due to the low humidity conditions in winter in the Australian cities which makes the partitioning of the particle phase less favourable in the NH_4NO_3 equilibrium.

The composition of $PM_{2.5}$ was determined by Friend et al. (2011) for two sites in the South-East Queensland region (Rocklea and South Brisbane), and sources were analysed using a receptor model. The five common sources of $PM_{2.5}$ at both sites were motor vehicle emissions, biomass burning, secondary sulfate, sea salt and soil. Secondary sulfate was the most significant contributor (up to 40%) to $PM_{2.5}$ aerosols at the South Brisbane site, and the second most important at the Rocklea site. Biomass burning was the most significant source at the Rocklea

[l] http://www.ansto.gov.au/discovering_ansto/what_does_ansto_do/live_weather_and_pollution_data/aerosol_sampling_program

site. In addition, dust storms that caused the $PM_{2.5}$ concentration to exceed the NEPC standard were observed at both sites.

The earliest estimates of the contribution of SOA to particulate mass in Australian cities were obtained by Gras et al. (1992) and Gras (1996), although SOA was grouped with secondary inorganic aerosol. The first study to determine the specific contribution of SOA to $PM_{2.5}$ in an Australian urban context (Melbourne) was by Keywood et al. (2011). SOA was estimated indirectly using the elemental carbon tracer method. The median annual SOA concentration was found to be 1.1 $\mu g/m^3$, representing 13% of $PM_{2.5}$. Significantly higher SOA concentrations were determined when bushfire smoke affected the airshed, and SOA displayed a seasonal cycle. The SOA fraction of $PM_{2.5}$ was greatest during the autumn and early winter months when the formation of inversions allowed build-up of particles produced by domestic wood-heaters. Keywood et al. (2011) also suggested that biogenic VOCs are a source of SOA at both urban and non-urban sites. During summer the oxidation of biogenic VOCs oxidation is the most likely source of SOA, whereas during winter the oxidation of volatile species associated with wood-smoke emissions are a probable source of non-fossil SOA.

An important issue in Australia is biomass burning. In rural towns, smoke from biomass burning such as prescribed burning of forests, bushfires and stubble burning is often claimed to be the major source of air pollution. Reisen et al. (2011) measured $PM_{2.5}$ at two rural locations in southern Australia. Monitoring clearly showed that, on occasions, air quality in rural areas was significantly affected by smoke from biomass combustion, with $PM_{2.5}$ showing the greatest impact. Biomass burning emits a complex mixture of air pollutants, both as gases and particulate matter. Gaseous species include carbon monoxide, hydrocarbons and a large range of trace gases. Significantly higher SOA concentrations have been observed when bushfire smoke affects an airshed.

4.1.2 Non-anthropogenic Particulate Matter

There are a number of sources of non-anthropogenic PM emissions, including windblown dusts and sea salt. These are expected to vary considerably across Australia. Data provided by ANSTO (2008) for 10 east coast sites from 1998 to 2008, suggests that sea salt contributes approximately 16% to measured $PM_{2.5}$ concentrations.

4.1.3 Analysis of Monitoring Data

Analysis of the data has been conducted to inform the evaluation of the application of monitoring to the exposure reduction approach.

Semi-volatile $PM_{2.5}$ concentrations: It is possible to derive an estimate of the semi-volatile $PM_{2.5}$ component by comparing data at sites with collocated gravimetric reference samplers and TEOM analysers. This analysis is predicated on the assumption that there will be no loss of semi-volatile $PM_{2.5}$ from the reference sampler (which there will be) and that all semi-volatile $PM_{2.5}$ is lost from the TEOM (which it will not be). The estimate must therefore be treated with caution.

Based on the data collected for this study, there are only two sites with collocated $PM_{2.5}$ data available, at Footscray and Alphington in Port Phillip, Victoria. A summary of the data analysis is provided in Table 12. It may be concluded from this analysis that the proportion of semi-volatiles ranges from 21-37%, with an average of 29%.

Table 12: Ratio of measured $PM_{2.5}$ concentrations (TEOM/reference sampler)

Year	Footscray	Alphington
2011	NA	0.68
2010	0.71	0.67
2009	0.66	0.74
2008	0.78	0.74
2007	0.76	0.79
2006	0.73	0.71
2005	NA	0.64
2004	0.63	0.68
2003	0.68	1.01[a]
Average	**0.71**	**0.71**

[a] This value was excluded from the calculation of the average

Defining average exposure: The average PM exposure, defined by the average concentration, will be affected by the number of monitoring stations included in the network. This has been investigated by analysing PM_{10} concentrations for 26 sites in 2010 (there were insufficient $PM_{2.5}$ monitoring stations to perform this analysis). The stations included in the analysis are described in 9Appendix B, and the results summarised as the deviation from the mean, in Figure 6 (% deviation) and Figure 7 (μg/m^3 deviation).

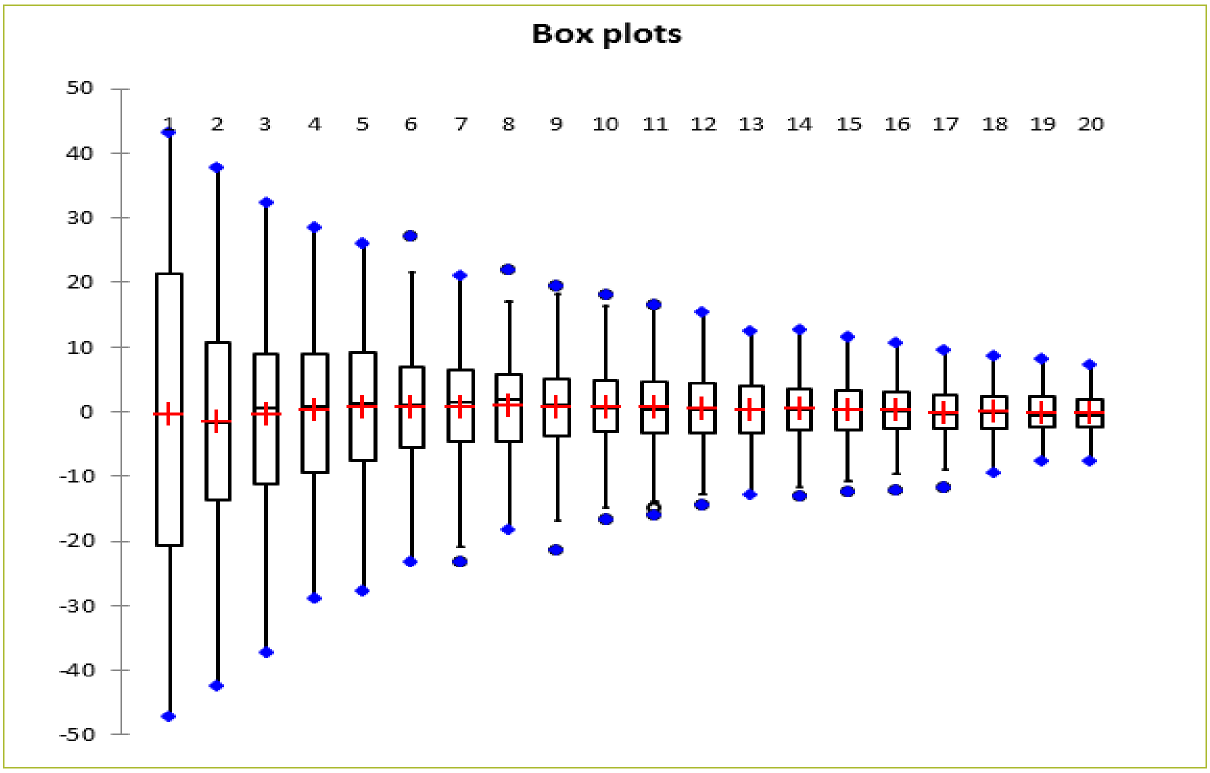

Figure 6: Deviation (%) from the overall average annual mean PM10 concentration measured at 26 sites in 2010. (Y-axis: % deviation from mean; X-axis: no. sites)

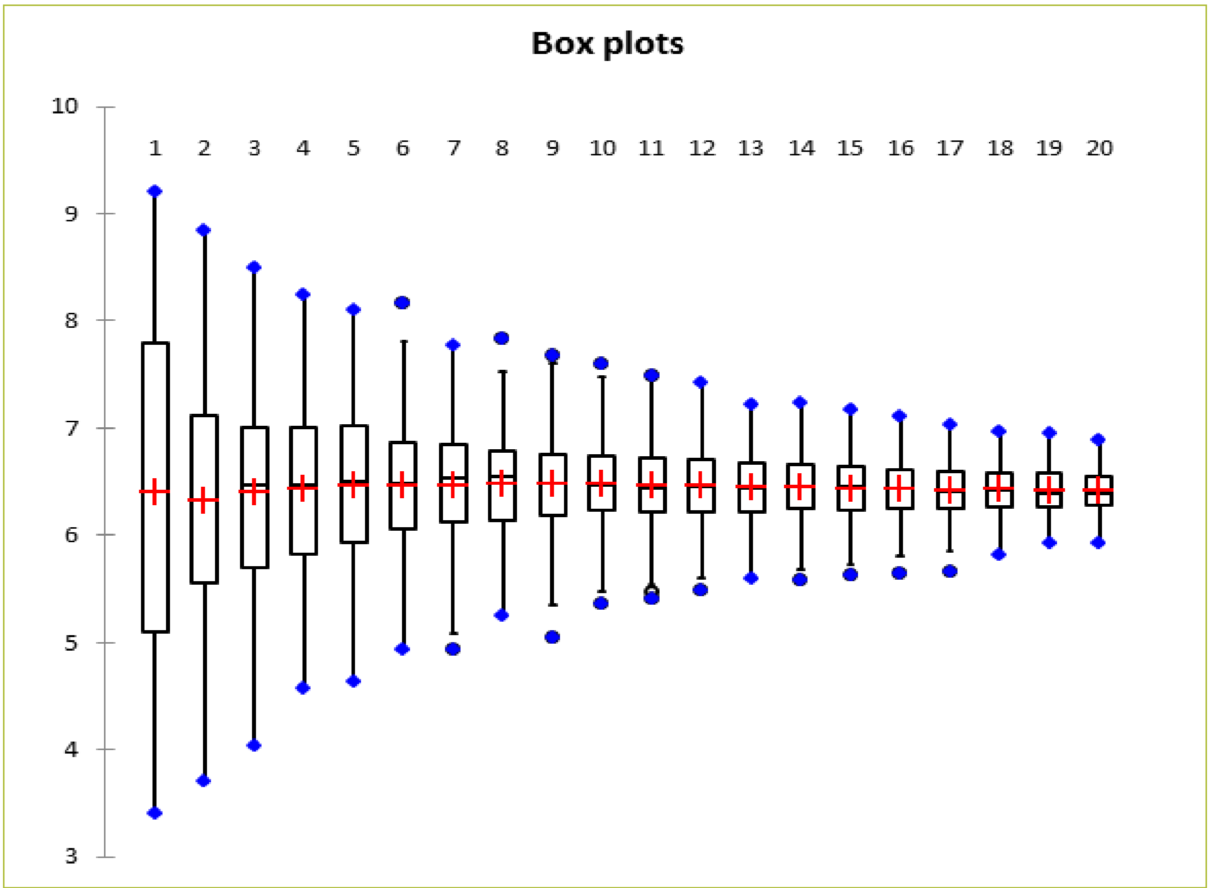

Figure 7: Deviation (µg/m^3) from the overall average annual mean PM_{10} concentration measured at 26 sites in 2010 (Y-axis: deviation (µg/m^3) from mean; X-axis: no. sites)

If the "true" PM_{10} exposure is assumed to be represented by the average concentration measured across the 26 sites, then reducing the number of sites to 20 would provide a value within 5.9-6.9 µg/m^3 (-7.7 to +7.0%) for the full range, or within 6.3-6.5 µg/m^3 (-2.4 to +1.8%) for the interquartile range. A reduction to 10 sites would generate a concentration that is approximately within ±20% of the "true" concentration. The range is reduced if the values used in the analysis are 3-year averages for each site rather than the one year values (analysis not shown).

Year-to year variations in concentrations: Annual mean concentrations of PM are affected by year-to-year variations in meteorology. The effect of averaging annual mean (TEOM) $PM_{2.5}$ concentrations at seven long-running sites, over periods ranging from 1 to 5 years, is described in Figure 8[m]. The stations included in the analysis are described in Appendix B. The substantial year-to-year variations based on individual annual mean concentrations can be seen. The effect is gradually smoothed out with the use of running-means based on more than three years data.

[m] There are insufficient $PM_{2.5}$ data collected using reference samplers (or FDMS analysers) to permit any assessment. The year-to-year pattern may be different from that shown in Figure 4.4 due to variations in secondary particulate matter.

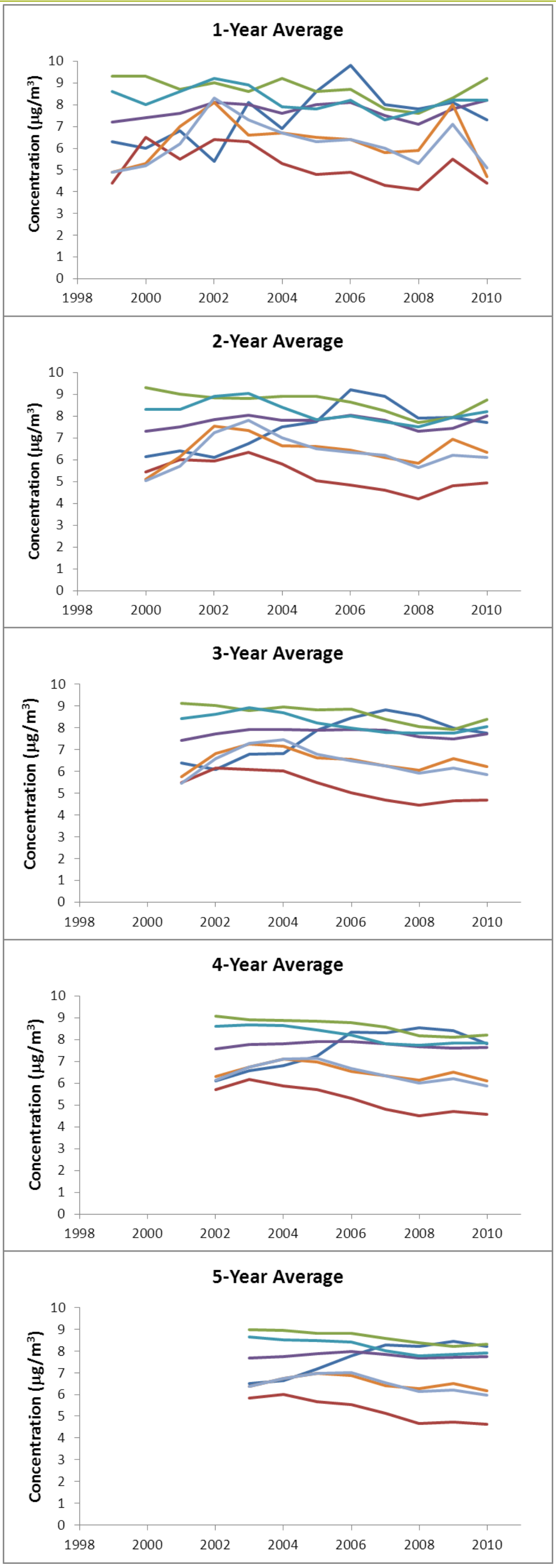

Figure 8: Annual mean $PM_{2.5}$ concentrations (1999-2010) with 2, 3, 4 and 5 year running averages

4.2 Urban Regions

The Air NEPM specifies a population threshold of 25,000 for the monitoring of pollutants within a region. The Air NEPM also defines a region as *"an area within a boundary surrounding population centres as determined by the relevant participating jurisdiction"*.

The Peer Review Committee report, *Selection of Regions* provides guidance on the use of population data from the Australian Bureau of Statistics (ABS) for use with the Air NEPM. The report recommends that the Australian Standard Geographical Classification (ASGC) "urban centre/locality" be used to define urban centres under the NEPM (PRC, 2001).

Population data collected by the ABS for the 2011 census were obtained for this study (ABS, 2012). Summary population statistics for urban centres greater than the NEPM threshold of 25,000 and 100,000 people in each jurisdiction are shown in Table 13. As can be seen from the population statistics, using a cut-off of 25,000 people results in 56 urban centres and a total population coverage of 17 million people whereas using a population cut-off of 100,000 people results in 16 urban centres and a total population of approximately 15 million people.

Table 13: Summary population statistics for urban centres within each jurisdiction

Jurisdiction	Number of Urban Centres	
	>25,000	>100,000
New South Wales	18	4
Victoria	12	2
Queensland	11	6
Western Australia	8	1
South Australia	2	1
Australian Capital Territory	1	1
Tasmania	2	1
Northern Territory	2	0
Total	*56*	*16*
Total Population	**17,004,140**	**15,131,821**

Source: ABS, 2012

Urban centres with a population of greater than 25,000 are detailed in Table 14 for each jurisdiction.

Urban centres with a population of greater than 100,000 are detailed in Table 15 for each jurisdiction.

Table 14: Urban centres with a population of greater than 25,000

Jurisdiction	Urban Centre	Population
New South Wales	Sydney	4,109,503
	Newcastle	319,457
	Central Coast	305,128
	Wollongong	259,744
	Maitland	70,274
	Gold Coast-Tweed Heads (Tweed Hds Pt)	58,662
	Wagga Wagga	51,990
	Albury-Wodonga (Albury Part)	47,595
	Port Macquarie	44,509
	Canberra-Queanbeyan (Queanbeyan Part)	39,337
	Tamworth	37,374
	Orange	34,765
	Dubbo	33,847
	Bathurst	32,623
	Nowra-Bomaderry	30,920
	Coffs Harbour	29,563
	Lismore	29,316
	Richmond-Windsor	26,298
Victoria	Melbourne	3,841,957
	Geelong	152,052
	Ballarat	89,709
	Bendigo	86,341
	Melton	45,780
	Shepparton-Mooroopna	43,501
	Sunbury	33,791
	Mildura	33,718
	Pakenham	32,899
	Albury-Wodonga (Wodonga Part)	32,605
	Warrnambool	31,544
	Traralgon	25,274
Queensland	Brisbane	1,935,670
	Gold Coast-Tweed Heads (Gold Coast Part)	488,455
	Sunshine Coast	223,788
	Townsville-Thuringowa	152,721
	Cairns	120,639
	Toowoomba	107,754
	Mackay	79,707
	Rockhampton	67,592
	Bundaberg	53,111
	Hervey Bay	51,458
	Gladstone	34,484
Western Australia	Perth	1,480,597
	Mandurah	90,109
	Rockingham	76,110
	Bunbury	68,134
	Kalgoorlie-Boulder	32,841
	Geraldton	32,029

Jurisdiction	Urban Centre	Population
	Albany	29,271
	Kwinana	26,122
South Australia	Adelaide	1,140,725
	Mount Gambier	25,688
Australian Capital Territory	Canberra-Queanbeyan (Canberra Part)	358,821
Tasmania	Hobart	134,810
	Launceston	76,018
Northern Territory	Darwin	77,259
	Palmerston	30,151
Grand Total		**17,004,140**

Source: ABS, 2012

Table 15: Urban centres with a population centre of greater than 100,000

Jurisdiction	Urban Centre	Population
New South Wales	Sydney	4,109,503
	Newcastle	319,457
	Central Coast	305,128
	Wollongong	259,744
Victoria	Melbourne	3,841,957
	Geelong	152,052
Queensland	Brisbane	1,935,670
	Gold Coast-Tweed Heads (Gold Coast Part)	488,455
	Sunshine Coast	223,788
	Townsville-Thuringowa	152,721
	Cairns	120,639
	Toowoomba	107,754
Western Australia	Perth	1,480,597
South Australia	Adelaide	1,140,725
Australian Capital Territory	Canberra-Queanbeyan (Canberra Part)	358,821
Tasmania	Hobart	134,810
Grand Total		**15,131,821**

Source: ABS, 2012

4.3 Air Emission Inventories

Within Australia, two types of regional pollutant inventories exist, the National Pollutant Inventory (NPI) and regional air emission inventories.

The NPI is a broad based emissions inventory designed to collect data on pollutant emissions to air, land and water, and pollutant transfers to designated transfer destinations. Data is collected and published annually from industrial facilities that trigger certain reporting thresholds (such as fuel used or total pollutant handled) whereas diffuse sources (e.g. domestic wood heaters) are required to be reported by jurisdictions on a period agreed by each jurisdiction. Emissions data from the NPI is aggregated into total stack and total fugitive emissions from each facility point or diffuse source. Temporal and spatial variation that would be required to use the emissions data for air quality modelling purposes are only collected on an annual basis and for the facility centroid. Furthermore, there is no requirement to provide source parameters required for air quality modelling such as stack height, exit temperature, exit velocity or stack diameter.

Regional air emission inventories are developed and maintained by some jurisdictions in order to inform air quality management decisions and policy analysis. Generally regional air emissions inventories contain more detailed data that the NPI.

The air emission inventories are described in more detail in the following sections.

4.3.1 National Pollutant Inventory

Australia's National Pollutant Inventory (NPI) is one of many pollutant release and transfer registers (PRTRs) around the world (DEWHA, 2009).

Others include the European PRTR, Canada's National Pollutant Release Inventory (NPRI) and the United States' Toxics Release Inventory (TRI).

Governments provide these registers as a means of informing the community about chemicals being emitted into the environment. The community's 'right to know' was identified as a priority in the 1996 Organisation for Economic Cooperation and Development (OECD) recommendation that all OECD member countries provide public access to information concerning pollutant releases and transfers from various sources (DEWHA, 2009).

The legislative framework underpinning the NPI is called the NPI National Environment Protection Measure (NPI NEPM). This was the nation's first NEPM and was agreed to by the Australian, state and territory governments in 1998. NEPMs set out agreed national objectives for protecting or managing particular aspects of the environment (DEWHA, 2009).

The main purpose of the NPI is to collect and publish information about emissions of substances on a geographical basis to help environmental decision making, to meet community right-to-know obligations, and to promote the need for cleaner production and waste minimisation programs in industry, government and the community.

The NPI reporting facilities, airsheds and catchments Australia-wide are shown in Figure 9.

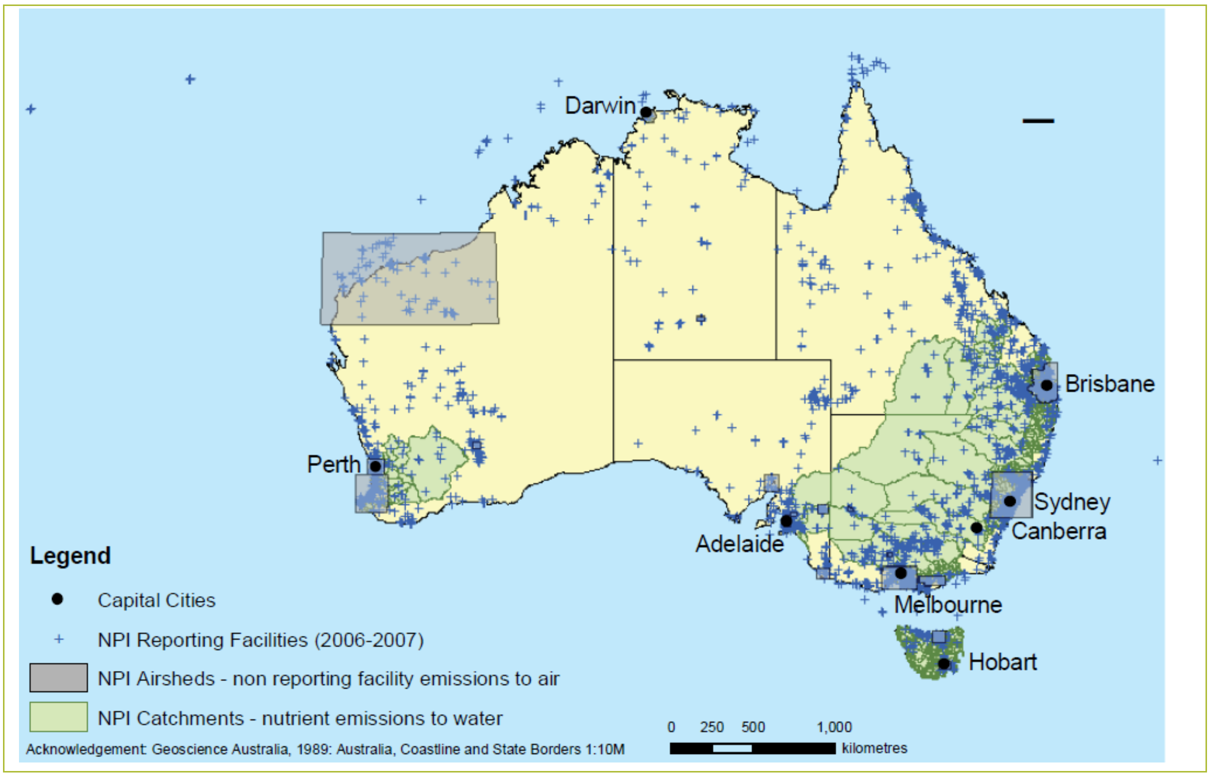

Figure 9: NPI reporting facilities, airsheds and catchments (DEWHA, 2009)

The blue crosses on the map in Figure 9 show NPI reporting facilities for 2006-07, as well as the locations of completed diffuse emission studies for water catchments and airsheds. Regions included in the diffuse studies cover more than 75 per cent of Australia's population (DEWHA, 2009).

Industrial facilities that trigger certain reporting thresholds are required to report annual emissions (and transfers) to the NPI of certain substances. The number of pollutants reported to the NPI varies depending on the reporting threshold that is triggered. The total number of substances included under the NPI NEPM is 93. Reporting thresholds under the NPI NEPM are shown in Table 16.

Table 16: Summary of reporting thresholds under the NPI NEPM

Category	Description	Substances
Category 1	Reporting required if "use" of a Category 1 substance is more than 10 tpa. Category 1 substances are the most common and include substances that are present in materials (such as coal, overburden). Example substances include antimony, cadmium The Category 1 trigger captures mainly fugitive emissions from bulk loading operations (such as found in the mining industry)	Generally substance found in production materials e.g. - Speciated VOCs (e.g. acetone, ethylbenzene) - Ammonia - Sulfuric acid
Category 1a	Reporting of Total VOCs if "use" is greater than 25 tpa. Specifically for reporting of Total VOCs from facilities that do not use combustion (e.g. bulk fuel facilities).	- Total VOCs
Category 1b	Category 1b contains only mercury and compounds. Due to the high toxicity of mercury and exposure potential, it has a lower threshold than Category 1 substances. The threshold for mercury and compounds is the use of 5 kg or more in the reporting year. The Category 1b threshold was introduced in 2008 under a NEPM variation to capture a higher proportion of total mercury emissions under the NPI NEPM (mercury was previously categorised as a Category 1 substance)	- Mercury & compounds
Category 2a	Reporting of emissions is required if a facility: - Combusts more than 400 tpa of fuel and/or waste; or - Combusts more than of 1 tonne or more of fuel and/or waste in an hour at any time during the year (designed to capture emissions from peaking power plants and similar operations) The category 2a threshold captures emissions of common air pollutants associated with combustion. Most reported emissions under the NPI NEPM are triggered through the Category 2a threshold. Four of the six pollutants covered under the Air NEPM are included under the Category 2a threshold. Ozone is not included as it is not relevant for emission inventories (a secondary pollutant) and lead is included as a category 1 and 2b substance.	- Carbon monoxide - Fluoride compounds - Hydrochloric acid - Oxides of nitrogen - Particulate matter ≤ 2.5 μm[a] - Particulate matter ≤ 10 μm - Polycyclic aromatic hydrocarbons - Sulfur dioxide - Total VOCs
Category 2b	Reporting of emissions is required if a facility: - Burns more than 2,000 tpa of fuel or waste; - Consumes more than 60,000 MWh of electrical energy (for other than lighting or motive purposes), or - Has a maximum potential power consumption of 20 MW or more (for other than lighting or motive purposes) The category 2b threshold captures emissions of trace metals and combustion products such as dioxins	- Arsenic & compounds - Beryllium & compounds - Cadmium & compounds - Chromium (III) compounds - Chromium (VI) compounds - Copper & compounds - Lead & compounds - Magnesium oxide fume - Nickel & compounds

Category	Description	Substances
	and furans. The category 2b threshold is designed to capture emissions from large facilities.	- Polychlorinated dioxins & furans
Category 3	Relevant for water pollution	- Total nitrogen - Total phosphorus

[a] From combustion sources only

It is noted that only $PM_{2.5}$ from combustion sources are reportable under the NPI. $PM_{2.5}$ from other sources, such as wind erosion or material handling are not reported or covered by the NPI.

Jurisdictions are required to report emissions from pre-defined airsheds within each jurisdiction of "aggregated" emissions. Aggregated emissions data are emissions of substances emitted to the environment annually from:

a) Facilities which are not reporting facilities (under the NPI NEPM) (i.e. sub-threshold facilities); and
b) Anthropogenic sources other than from facilities, which emit a significant amount of that substance to the environment (i.e. diffuse sources).

Jurisdictions are not required to report emissions on an annual basis. Emissions are reported on a basis that is consistent with the Memorandum of Understanding that exists between jurisdictions and the Commonwealth. Handbooks/emission estimation technique manuals are published by the Commonwealth Government for estimating emissions for the NPI (DSEWPC, 2012).

4.3.2 Regional Air Emission Inventories

Regional emission inventories are developed and maintained by some jurisdictions in order to:

- Inform air quality policy.
- Assess the effectiveness of regulations.
- Enable environmental reporting (e.g. state of environment reports, reporting aggregated emissions to the NPI).
- Perform air quality modelling and forecasting.

Regional air emission inventories contain more detailed information than that stored and collected by the NPI NEPM. The following key differences between the two inventory types are:

- Emissions are stored on a source level (i.e. emissions across a facility can be separated into each of each of its source emissions (e.g. coal fired boiler, coal stockpile, front end loader).
- Temporal variation for each source is recorded to enable air quality modelling and seasonal analysis) (e.g. monthly, weekday/weekend day, hourly variation).
- Source parameters are generally recorded within the emissions inventory to enable to emissions data to be used for air quality modelling purposes.
- No threshold for inclusion of sources exists in the regional emissions inventories (all practical sources of emissions are included).
- There is no defined list of pollutants for a regional air emissions inventory (jurisdictions decide which pollutants to include in order to suit the planned inventory objectives).

Based on consultation with jurisdictions and literature search as part of this project, five jurisdictions in Australia were found to use air emission inventories to manage air quality. A summary of each air emissions inventory is provided in Table 17.

Table 17: Summary of active regional air emission inventories in Australia

Regional Air Emissions Inventory	Latest Base Year	Summary
NSW GMR air emissions inventory (DCC, 2007; OEH, 2012a)	2008	The study area covers 57,330 km^2 (including ocean), which includes the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR). Approximately 75% of the NSW population resides in the GMR (approximately 5.3 million people in 2008). OEH aims to update the inventory every 5 years (OEH, 2012c).
Victoria air emissions inventory (Delaney & Marshall, 2011)	2006	The study area covers the whole state and includes the airsheds of Port Phillip, Latrobe Valley, Bendigo and Mildura. The population of the region was estimated to be 5.1 million people in 2006. EPA Victoria is currently updating the air emissions inventory to a base year of 2011.
South east Queensland (QEPA & BCC, 2004)	2000	The study area covers 23,316 km^2 (land-based area), which includes the Sunshine Coast, Brisbane, Toowoomba and the Gold Coast regions, known collectively as the south east Queensland region (SEQR). Approximately 70% of the Queensland population resides in the south east Queensland region (approximately 2.5 million people in 2000). Queensland Department of Science, Information Technology, Innovation and the Arts is currently updating the SEQ air emissions inventory for all emission sources with completion expected at end of 2012 (DSITIA, 2012).
Perth air emissions inventory (DEP, 2003; Rostampour V., 2010)	Motor vehicles: 2006/2007 Other sources: 1998/1999	The Perth air emissions inventory was constructed in order to report emissions to the National Pollutant Inventory (NPI). The original Perth airshed emissions inventory was compiled for the year 1992, with a later update based on the 1998/1999 period (DEP 2002). In addition to these inventories, a diffuse emissions study was undertaken by a consultant on behalf of DEC based on the 2004/2005 period. Due to the rapidly increasing number of motor vehicles in the Perth metropolitan area, an update of the vehicle emissions inventory has recently been completed based on the years 2006/2007. The vehicle emissions inventory is generally updated every five years. The vehicle kilometres travelled (VKT) map will be updated for the vehicle emissions inventory for 2011-2012. The inventory is provided to universities on request and the National Pollutant Inventory and may be used for background information in the development of airshed studies (DEC, 2012). The study area covers 8,613 km^2, which includes the major population centre and emission sources in Western Australia Approximately 70% of the Western Australia population resides in the Perth airshed (approximately 1.3 million people in 1998/1999).
Adelaide air emissions inventory (Ciuk, 2002; SA EPA, 2012)	Motor vehicles: 2006 Other sources: 1998/1999	The South Australian air emissions inventory was constructed in order to report emissions to the National Pollutant Inventory (NPI). The emissions inventory is based on activity that occurred during the 1998/1999 period. The study area covers the five major regional areas of South Australia. Approximately 76% of the South Australia population resides in the study regions (approximately 1.1 million people in 1998/1999). South Australia EPA also recently completed a gridded air emissions inventory for the entire state covering motor vehicle emissions. The base year for the study was 2006.

No official methodology or guidebook exists for compiling regional air emissions inventories in Australia (such as the Joint EMEP/CORINAIR guidebook in Europe). Handbooks/emission estimation technique manuals are published by the Commonwealth Government for estimating emissions for the NPI. These manuals have facilitated a certain level of consistency in constructing regional emission inventories. However, the techniques presented in aggregated manuals are largely outdated and have not received much focus in subsequent updates to emission estimation techniques. Consequently, some jurisdictions now prefer to use more up-to-date methodologies, such as those outlined in:

- *ARB's Emissions Inventory, Area-Wide Source Methodologies, Index of Methodologies by Major Category* (CARB, 2008);
- *EMEP/EEA air pollutant emission inventory guidebook 2009* (EEA, 2009);
- *National Pollutant Inventory Emission Estimation Technique Manuals* (DSEWPC, 2012);
- *USEPA AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources* (USEPA, 1995);
- *USEPA Emission Inventory Improvement Program, EIIP Technical Report Series, Volumes 1-10* (USEPA, 2007);
- *USEPA 2008 National Emissions Inventory Data* (USEPA, 2011a); and
- *USEPA Nonroad Engines, Equipment, and Vehicles* (USEPA, 2011b).

Furthermore, each jurisdiction constructs a regional air emissions inventory to perform a range of functions (the inventory scope). The scope of the inventory is tailored to each jurisdiction's requirements at the time of construction. Therefore, the variance in each jurisdiction's requirements changes the sources that are included; how each source is estimated; and how each source is represented, in the inventory.

A comparison of the sources included in each operational regional air emissions inventory in Australia is shown in Table 18. As noted the methodology to estimate each source is likely to be significantly different between jurisdictions.

Table 18: Summary of source coverage for each regional air emissions inventory (over major urban areas)

Source Type	Source	Inventory/Airshed				
		NSW GMR	Victoria	SEQ	Perth	Adelaide
Biogenic /Geogenic	Agricultural burning	✓	✓	✓	✓	✗
	Bushfires and prescribed burning	✓	✓	✓	✓	✗
	Fugitive/windborne - agricultural lands and unpaved roads	✓	✓	✗	✗	✗
	Soil nitrification and de-nitrification	✓	✓	✓	✓	✗
	Tree canopy	✓	✓	✓	✓	✗
	Un-cut grass and cut grass	✓	✗	✗	✗	✗
	Marine aerosol	✓	✗	✗	✗	✗
Industrial	All industrial sources	✓	✓	✓	✓	✓
Commercial	All major commercial sources	✓	✓	✓	✓	✓

Source Type	Source	Inventory/Airshed				
		NSW GMR	Victoria	SEQ	Perth	Adelaide
Off-Road	Aircraft (flight and ground support operations)	✓	✓	✓	✓	✓
	Commercial boats	✓	✓	✓	✓	✓
	Commercial off-road vehicles and equipment	✓	✓	✓	✓	✗
	Industrial off-road vehicles and equipment	✓	✓	✓	✓	✗
	Locomotives	✓	✓	✓	✓	✓
	Recreational boats	✓	✓	✓	✓	✓
	Ships	✓	✓	✓	✓	✓
Domestic-Commercial	Aerosols and solvents	✓	✓	✓	✓	✓
	Barbecues	✓	✓	✓	✗	✗
	Cutback bitumen	✓	✓	✗	✓	✓
	Gaseous fuel combustion	✓	✓	✓	✓	✓
	Graphic arts	✓	✓	✓	✓	✓
	Lawn mowing and garden equipment	✓	✓	✓	✓	✓
	Liquid fuel combustion	✓	✓	✓	✓	✓
	Natural gas leakage	✓	✓	✓	✓	✗
	Portable fuel containers	✓	✗	✗	✗	✗
	Solid fuel combustion	✓	✓	✓	✓	✓
	Surface coatings	✓	✓	✓	✓	✓
On-Road	All - evaporative	✓	✓	✓	✓	✓
	All - non-exhaust PM	✓	✓	✓	✓	✓
	Heavy duty commercial diesel - exhaust	✓	✓	✓	✓	✓
	Light duty commercial petrol - exhaust	✓	✓	✓	✓	✓
	Light duty diesel - exhaust	✓	✓	✓	✓	✓
	Others - exhaust	✓	✓	✓	✓	✓
	Passenger vehicle petrol - exhaust	✓	✓	✓	✓	✓
Other	Architectural and industrial surface coatings	✓	✓	✓	✓	✓
	Pets and humans	✗	✓	✗	✗	✗
	Tobacco smoking	✗	✗	✓	✓	✗
	Swimming pools	✗	✗	✗	✓	✗

Diffuse emission estimates exist for the major population centres in the other three Australian jurisdictions. However, the emission estimates are out of date having been completed close to the inception of the NPI, with all urban centres having a base year of 1999. The emission estimates are published on the NPI database. A comparison of source coverage for each urban area is provided in Table 19.

Table 19: Summary of source coverage for diffuse emission estimates performed by other jurisdictions

Jurisdiction Emission Source	ACT Canberra	Tas Tasmania	NT Darwin
Aeroplanes	✓	✓	✓
Architectural surface coating	✓	✓	✓
Backyard incinerators	✗	✓	✓
Bakeries	✓	✓	✓
Barbeques	✓	✗	✓
Burning (fuel reduction, regeneration, agricultural)/Wildfires	✓	✓	✓
Cigarettes	✓	✗	✗
Commercial shipping/boating	NA	✓	✓
Cutback bitumen	✓	✓	✓
Domestic/commercial solvents/aerosols	✓	✓	✓
Fuel combustion - sub threshold	✓	✓	✓
Lawn mowing	✓	✓	✓
Liquid fuel combustion	✓	✓	✓
Gaseous fuel burning	✓	✓	✓
Motor vehicles	✓	✓	✓
Motor vehicle refinishing	✓	✓	✓
Paved/unpaved roads	✗	✓	✗
Print shops/Graphic arts	✗	✓	✗
Railways	✗	✓	✓
Recreational boating	NA	✓	✓
Service stations	✓	✓	✓
Solid fuel burning	✓	✓	✗
Structural metal product manufacturing n.e.c.	✗	✗	✓
Traffic (road line) marking	✓	✗	✗

The substances included in each air emissions inventory are also variable between jurisdictions. Substances that could be relevant to an exposure reduction framework for particulate matter include pollutants relevant for primary PM formation and pollutants relevant for secondary PM formation (NO_x, NH_3, SO_2, SO_3 and VOC). The coverage of each regional air emissions inventory of these substances changes depending on the inventory. Furthermore, as the methodologies used to estimate emissions for each inventory are significantly different, even if an inventory contains a particular substance, the source coverage of each inventory is likely to vary considerably between each inventory. This is particularly true for secondary substances such as ammonia and sulfur trioxide. A summary of pollutant coverage for each regional air emissions inventory is provided in Table 20.

Table 20: Substance coverage for each regional air emissions inventory

Pollutant type	Pollutant	Inventory/Airshed				
		NSW GMR	Vic	SEQ	Perth	Adelaide
Primary pollutants	TSP	✓	✓	✓	✗	✗
	PM_{10}	✓	✓	✓	✓	✓[a]
	$PM_{2.5}$	✓	✓	✓	✓	✓[a]
Secondary - nitrates	NO_x	✓	✓	✓	✓	✓[a]
	NH_3	✓	✓	✓	✓	✓[a]
Secondary - sulfates	SO_2	✓	✓	✓	✓	✓[a]
	SO_3	✓	✓	✗	✗	✗
Secondary - organic	VOCs	✓	✓	✓	✓	✓[a]
	Organic carbon	✗	✓	✗	✗	✗
	Elemental carbon	✗	✓	✗	✗	✗

[a] Not all sources are included

4.4 Regional Air Quality Modelling

Air quality modelling for policy development is typically undertaken by the jurisdictions, often with support from CSIRO. The modelling is generally based on hindcasting in which a series of representative historical air quality episodes or seasons or years are modelled in detail for a business–as–usual emissions base case, and one or more scenarios which represent a potential change in a significant source group (Cope et al, 2006).

The extent that each jurisdiction uses regional air quality modelling to inform the air quality management decisions varies considerably. Understanding the extent each jurisdiction employs regional air quality modelling will inform the assessment of the feasibility of options addressed in Chapter 5. Each jurisdiction was sent a questionnaire requesting information on:

- Regional air dispersion modelling programs currently undertaken.
- Whether regional PM modelling is conducted and whether secondary particulate formation is assessed.
- Resources available internally to perform regional air dispersion modelling.

The extent that regional modelling is conducted by Australian jurisdictions is summarised in this section.

4.4.1 NSW

Information received from NSW EPA and from published literature indicates the following (OEH, 2012c):

- NSW EPA undertakes regional air quality modelling using TAPM-CTM model.

  The Air Pollution Model (TAPM) (Hurley, 2008) is an integrated prognostic meteorological/air quality model. TAPM is widely used in Australia and was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine & Atmospheric Research. The Chemical Transport Model (CTM) add-on to TAPM is used for urban airsheds requiring more complex treatment of chemistry (such as through using the Lurmann Carter Coyner (LCC) or Carbon Bond (CB) 04 mechanisms) (Cope et al., 2009). The TAPM-CTM model includes modules for simulating inorganic aerosol formation and secondary organic aerosol formation.

- NSW EPA does not currently simulate regional PM. Regional modelling has been on photochemical pollution.

  Regional modelling of particulate matter has not been simulated by OEH. The NSW GMR air emissions inventory is however, constructed to export PM emissions data in formats compatible with the TAPM-CTM model (DEC, 2007b).

- NSW EPA has a team of four modellers working on regional air quality modelling.

In a recently published report, *State of Knowledge – Ozone* (DECCW, 2010), the utilisation of regional air quality modelling by NSW EPA for informing air quality management decision making is clear. The report outlines the following:

- Simulation of emission scenarios and quantification of resulting benefits and disbenefits of ambient concentrations (for varying scenarios).
- Estimation of emission changes to attain air quality objectives.

  The Air NEPM limits for ozone are not always achieved in the Sydney basin. As such OEH has performed a detailed regional air quality modelling assessment to determine the required percentage of emission reduction of ozone precursors to meet the Air NEPM standard. The regional modelling assessment showed that a 25% reduction in emissions of ozone precursors (from the 2003 baseline) would be required to meet the ozone limit values. This calculated emissions reduction was incorporated into OEH's *Action for Air* which outlined NSW Government's 25-year air quality management plan (DECCW, 2009).

- The importance of emission inventory validation is highlighted.
- Characterisation of governing chemical regimes and limiting reactants for current and future scenarios.

4.4.2 Victoria

Information received from EPA Victoria (EPAV) and from published literature indicates the following (EPAV, 2012):

- EPA Victoria conducts regional air quality modelling using TAPM-CTM model (Walsh et al, 2011).

A multi-year collaborative project is currently underway with CSIRO to estimate future concentrations of a range of air pollutants in Victoria, with an initial focus on the city of Melbourne (Walsh et al. 2011).

- EPA Victoria does not currently simulate regional PM

EPA Victoria do not conduct regional PM modelling specifically as there is low confidence in the current 2006 emission estimates for windblown PM (EPAV, 2012).

No information is available on resources available to perform regional air quality modelling internally by EPAV.

4.4.3 Queensland

Information received from the Department of Science, Information Technology, Innovation and the Arts indicates that (DSITIA, 2012):

- Regional air dispersion modelling is conducted using CALMET/CALPUFF and TAPM packages.
- No regional PM modelling is currently undertaken.
- DSITIA has capacity to undertake PM modelling incorporating secondary formation for the south east Queensland and Gladstone regions. However resources are limited to one person and priorities would need to be considered if DSITIA were to reallocate these to regional PM modelling.

4.4.4 Western Australia

Information received from the Department of Environment and Conservation (DEC) Western Australia and from published literature indicates that (DEC, 2012):

- Regional air dispersion modelling was previously conducted for the development of the Perth Air Quality Management Plan (DEP, 2000).
- No regional PM modelling is currently routinely employed.
- DEC does not currently have the resources to undertake regional air dispersion modelling of PM.

4.4.5 South Australia

No information on regional air quality modelling capability was provided by the Environmental Protection Authority South Australia for this project.

Regional air quality modelling is not believed to be conducted for any pollutant in South Australia.

4.4.6 Other Jurisdictions

Regional modelling of pollutants is not conducted by any other Australian jurisdiction and as such these jurisdictions are not expected to currently have resources to conduct regional modelling for any pollutant.

4.5 Summary

The analysis of Australian air quality management conditions and capabilities has focused primarily on each jurisdiction's emission inventories, modelling capabilities, monitoring activities, population statistics and air pollution monitoring.

At present, there is no consistency across the jurisdictions' air emissions inventories, with some inventories not being suitable for regional air quality modelling. Furthermore, no jurisdiction in Australia is currently routinely simulating regional PM with regional air quality models. Population statistics are available for all jurisdictions with base population data collected through the census conducted by the Australian Bureau of Statistics. All jurisdictions have air quality monitoring data available. However a variety of methods are used to monitor the ambient air.

A summary of the current status of air quality management tools is provided in Table 21 for major urban centres in Australia (i.e. Sydney, Melbourne, Brisbane, Perth and Adelaide).

Table 21: Summary of current status of tools for air quality management for major Australian urban centres (Sydney, Melbourne, Brisbane, Perth, Adelaide)

Jurisdiction				
NSW GMR[a]	**Victoria**	**SEQ[b]**	**Perth**	**Adelaide**
Emissions inventory				
All major sources included?				
Yes	No The most significant source not included is marine aerosol. TAPM could be used to supplement this source. Current update is likely to include estimates for this source.	No Fugitive windborne, marine aerosols and emissions from paved roads (wheel generated dust) not included in 2000 inventory. Current update likely to include estimates for these sources.	No Fugitive windborne and marine aerosols were not included in the diffuse air emissions inventory.	No Biogenic/Geogenic emission sources have not been estimated for the Adelaide airshed.
Model ready?				
Yes The NSW GMR air emissions inventory is suitable for regional air quality modelling and readily exportable in model-ready file formats.	Yes EPA Victoria is currently updating the air emissions inventory to a base year of 2011.	Not yet The air emissions inventory will be in a format suitable for regional air quality modelling when the current update (expected at end of 2012) is completed	No Inventory designed for diffuse sources only. Spatial and temporal variation of emissions not assigned.	No Inventory designed for diffuse sources only. Spatial/ temporal variation of emissions not assigned. Significant emission sources (e.g. biogenic) excluded.
Primary pollutants?				
Yes All primary pollutants are included (TSP, PM_{10}, $PM_{2.5}$)	Yes All primary pollutants are included (TSP, PM_{10}, $PM_{2.5}$)	Yes All primary pollutants are included (TSP, PM_{10}, $PM_{2.5}$)	No PM_{10} and $PM_{2.5}$ are included in the emission estimates but not TSP.	No PM_{10} and $PM_{2.5}$ are included in the emission estimates but not TSP.
Secondary precursor pollutants?				
No Does not include emissions of elemental/organic carbon	Yes Includes emissions of all substances	No Does not include emissions of SO_3 or elemental/organic carbon	No Does not include emissions of SO_3 or elemental/organic carbon	No Does not include emissions of SO_3 or elemental/organic carbon
Regional Modelling				
Modelling platform				
TAPM-CTM	TAPM-CTM	TAPM-CTM	Not applicable	Not applicable
Resources available				
OEH has a team of four modellers working on regional air quality modelling. OEH does not currently model particles.	EPAV does not model regional PM as there is low confidence in the 2006 estimates for windblown PM (EPAV, 2012). No information on resources for regional air quality modelling. CSIRO has modelled particles on behalf of Victoria.	Resources limited to one person that can undertake regional dispersion modelling. Current priorities would need to be considered for PM modelling.	DEC does not currently have the resources to undertake regional air dispersion modelling of PM.	Not applicable
Population statistics				
Population statistics are available for Australia (2011 census year)				
Monitoring				
All jurisdictions conduct ambient air quality monitoring of PM. Care will need to be practised when using monitoring data for model validation in considering the differences in monitoring techniques between sites.				

[a] NSW GMR: NSW Greater Metropolitan Region

[b] SEQ: South East Queensland

5 ANALYSIS OF OPTIONS

This section of the report draws together the information provided in Chapters 3 and 4, and provides an analysis of the potential options for an exposure reduction framework in Australia. It focuses on the three principal options for an exposure reduction approach, i.e. monitoring, modelling and emissions reduction.

For each potential option identified, there are a number of sub-options that need to be considered. Some of the overarching considerations are:

- Should the exposure reduction approach be targeted at the national or jurisdictional level?
- If the exposure reduction approach is targeted at the jurisdictional level, should the same metric be adopted within each jurisdiction, or is it appropriate to adopt different metrics?
- If the same metric is adopted throughout Australia, is it appropriate to adopt different exposure reduction targets within each jurisdiction?

These particular issues are examined more fully at the end of this Chapter.

It also needs to be recognised that measures for the reduction of $PM_{2.5}$ exposure can only be realistically targeted at the anthropogenic component of the emissions. This has potential implications for the manner in which each approach could be implemented. These issues are considered within the following evaluations of each approach.

For the exposure reduction options based on monitoring or modelling, which estimate or calculate the benefits to population exposure to $PM_{2.5}$ concentrations, it is possible to express the metric in terms of health benefits i.e. the reduction in DALYs or the number of life-years lost. Whilst this may be more transparent to policy makers and members of the public, it does open the potential question as to how many lives are still being lost due to urban PM exposure. Thus, whilst the estimation of health benefits is crucial to any cost-benefit analysis used to justify an exposure reduction approach, setting any target as a health-based metric should be taken with caution.

It is also important to recognise that whilst there may be variations in toxicity between the various components of $PM_{2.5}$, there is no conclusive evidence that the primary components are more toxic than the secondary components. Whilst particles arising directly from combustion sources (such as road traffic, wood heaters, power stations etc.) are indicated by many studies to be especially toxic, sulfate, which is a secondary component, also features strongly in the positive results of many epidemiological studies. A detailed review of the available evidence was carried out by the UK Committee on the Medical Effects of Air Pollutants (COMEAP) in 2009, which concluded that there was no strong evidence to recommend the separate quantification of the effects of the components of $PM_{2.5}$ (COMEAP, 2009). Any exposure reduction approach should thus ideally be focused on both the primary and secondary components.

5.1 Monitoring Approach

5.1.1 Initial Appraisal

In many respects, an exposure reduction framework based on measured $PM_{2.5}$ concentrations provides the most straightforward and transparent approach, and was a principal driver for its adoption within the EU. The basic approach would be to set a target for a reduction in urban background $PM_{2.5}$ concentrations across a defined network of monitoring sites, to be achieved within a defined time period. A more complex approach would involve the subtraction of an estimated non-anthropogenic component. An initial appraisal of the advantages and disadvantages of a monitoring approach is provided in Table 22.

Table 22: Advantages and disadvantages of an exposure reduction approach based on monitoring

	Positive attributes to achieving the objective	Negative attributes to achieving the objective
Internal origin (attributes of the framework)	Measured $PM_{2.5}$ concentrations representing population exposure can be directly linked to health benefits	Year-to-year variations in $PM_{2.5}$ concentrations (due to the effects of meteorology etc.) can influence long-term trends, making it difficult to measure changes over a specified time period, unless results averaged over several years are used
	A target can be introduced for a reduction in $PM_{2.5}$ concentrations over a specified period of time	There is an assumption that concentrations measured at a number of fixed points adequately represent PM exposure across large urban areas
External origin (attributes of the Australian environment)	Existing monitoring networks are primarily focused on defining urban PM exposure	Scope of $PM_{2.5}$ monitoring is currently limited within some jurisdictions
	A gravimetric reference method has been defined for the measurement of $PM_{2.5}$	$PM_{2.5}$ monitoring is based on a wide range of monitoring techniques across the jurisdictions, some of which will not be reference equivalent
		Due to the relatively low $PM_{2.5}$ concentrations that prevail, it will be more challenging to measure the target reduction

Australia is in a potentially good position to introduce an exposure reduction framework based on monitoring of $PM_{2.5}$ concentrations. Although the scope of $PM_{2.5}$ monitoring is currently limited in some jurisdictions, if it is assumed that the outcome of the NEPM review will result in the introduction of a compliance standard for $PM_{2.5}$ (as opposed to the current advisory status), then additional monitoring sites would need to be commissioned in any case. In addition, the current NEPM Monitoring Protocol focuses PM monitoring towards the measurement of population exposure, as opposed to the monitoring of concentrations at hotspots (such as near-roadside sites), and includes siting criteria such as minimum set-back distances from roads, and the avoidance of other extraneous sources. Thus, there is the potential to combine the NEPM standard with an exposure reduction approach.

A simple approach to the exposure reduction framework would be to establish a base year[n] concentration for $PM_{2.5}$, and to then set a target reduction for a year in the future. The target could be described in terms of a percentage reduction with regard to the base year, or as an absolute (μg/m^3) reduction. If an assumption were made regarding the size of the population affected by the reduction in measured $PM_{2.5}$ concentrations, then a direct quantification of the health benefits could be conducted. There would thus be clear link to the air quality impact pathway, with the effects of measures to reduce emissions directly associated to the health benefits achieved.

[n] The "base year" and "target year" concentrations could be based on a single year, or on the average over a number of years.

There are a number of approaches that could be taken to the introduction of an exposure reduction framework based on monitoring, such that the required reduction in concentration, or the level of ambition, were applied to:

- Individual monitoring sites; or
- The average concentration measured across all monitoring sites in individual jurisdictions; or
- The average concentration measured across all monitoring sites in Australia.

The application of the required reduction to individual monitoring sites is not recommended as the system would be too susceptible to local changes (e.g. necessary closure of a monitoring site, factors affecting very local pollution conditions etc.) and it would conflict with the NEPM standard[o]. The potential benefits and disbenefits of a system focused at the national or jurisdictional levels are picked up in the discussion below.

5.1.2 Issues

There are a number of issues that need to be considered in the use of monitoring as the exposure reduction framework:

- How many monitoring sites would be needed?
- What monitoring methods could be used?
- Could the non-anthropogenic component be removed?
- How might the approach be affected by uncertainty in the measurement method?
- How might the approach be affected by other uncertainties e.g. meteorology, changes to the $PM_{2.5}$ monitoring method etc.?

How many monitoring sites would be needed: An analysis of the population distributions within each jurisdiction in Australia is provided in Chapter 4 to this report. Inclusion of those 16 urban centres with >100,000 people accounts for approximately 15 million people (about 70% of the Australian population); extending this to include those 56 urban centres with >25,000 people, accounts for approximately 17 million people (about 79% of the Australian population). Thus, the inclusion of an additional 40 urban centres only accounts for an additional 9% of the population.

The other factor to take into account is that the uncertainty in the average exposure (concentration) is dependent on the number of monitoring sites used to derive that average, as shown from the data analysis in Chapter 4. Thus, with only 10 sites, the average concentration would only be defined with approximately ±20%. Increasing the number of sites to 20 reduces this uncertainty to approximately ±7%. Combining these two pieces of information suggests that an exposure reduction network founded on all urban centres >100,000 population, with one site for every ~400,000 people could be appropriate, with a total network of approximately 40 sites.

What monitoring methods could be used: As described in Chapter 4 to this report, PM (both PM_{10} and $PM_{2.5}$) monitoring is founded on a number of different methods across the jurisdictions. The reference method for $PM_{2.5}$ is based directly on the USEPA Federal Reference Method (40 CFR Part 50, Appendix L), which is a filter-based gravimetric method. The principal

[o] The NEPM standard would apply at individual sites providing a "cap" on $PM_{2.5}$ exposure, while the exposure reduction target would apply to the average concentration across the network.

disadvantage of this method is that it is labour-intensive, and as the filters need to be weighed after exposure, there is a significant delay between sampling and reporting; in addition, the method can only provide daily mean concentrations. For these reasons, many jurisdictions currently undertake the majority of $PM_{2.5}$ monitoring using variety of continuous analysers, most notably the TEOM; however, due to the loss of the semi-volatile component, TEOM data are not used for reporting compliance with the Advisory Standard[p].

As described in Chapter 4, the $PM_{2.5}$ Equivalence Programme is intended to allow individual jurisdictions to undertake local comparisons between the reference sampler and continuous samplers. The outcomes of equivalence tests conducted in the US and the EU[q] can also be taken into account (and as noted in Chapter 4, the TEOM has now been effectively replaced in EU compliance networks). Whilst different jurisdictions may select different monitoring techniques, provided the selected analyser is equivalent to the reference method, this should not introduce any specific problems to an exposure reduction approach.

Could the non-anthropogenic component be removed: As stated above, measures for the reduction of $PM_{2.5}$ exposure can only be realistically targeted at the anthropogenic component of the emissions (including both primary PM and secondary precursors). Subtraction of the measured concentration associated with non-anthropogenic emissions would allow exposure reduction targets within the direct control of the jurisdictions to be established, but would introduce additional complexity into the system, and would require substantial additional research to be conducted:

- Based on the limited information available, the non-anthropogenic component varies considerably from site to site, but at coastal sites, the sea salt component alone is approximately 16%.
- It would not be possible to determine the non-anthropogenic component based on rural monitoring data, as this would also subtract the secondary component. There is insufficient information available in Australia to add this secondary component back in, based either on sulfate and nitrate measurement data or modelling results.

How might the approach be affected by the uncertainty in the measurement method: Existing annual mean $PM_{2.5}$ concentrations in Australia are relatively low (~8 μg/m^3), which presents potential difficulties with the application of monitoring to the exposure reduction approach. The detection limit of the method defines the lowest concentration that can be reliably determined, whilst measurement uncertainty describes the deviation from the true $PM_{2.5}$ concentration that is being determined, and can include both random and systematic components, defined by the precision and accuracy of the method.

In the absence of knowledge as to which measurement method would be used, it is not possible to quantify precisely what the detection limits and uncertainties would be, but reference can be made to the Data Quality Objectives Process as defined by USEPA for $PM_{2.5}$ (as this is the reference method adopted in Australia).

[p] It should be noted that there will also be losses of the semi-volatile component from the reference sampler, which will vary according to ambient conditions and the nature of the PM, but these losses are deemed to be zero by convention.

[q] It is also noted that the European Committee for Standardisation (CEN) is expected to publish a Standard for Automated Continuous Monitoring Systems (AMS) for both PM_{10} and $PM_{2.5}$.

The detection limit using filter-based methods for $PM_{2.5}$ is usually quoted as being <2 μg/m^3, and is normally substantially improved for automatic analysers. The detection limit of the method should not introduce any specific problems to an exposure reduction approach.

As there are no calibration standards for $PM_{2.5}$, the uncertainty of methods (in terms of both precision and accuracy) can only be determined by the operation of duplicate instruments in comparison with reference method samplers. The USEPA Data Quality Objective defines an uncertainty of <10%, but many analysers are capable of performing well within this criterion.

If it is assumed that the "base year" $PM_{2.5}$ concentration were 8 μg/m^3, then a 10% uncertainty would be equivalent to 0.8 μg/m^3. However, it is recommended that the exposure reduction approach could be based on the average concentration measured across a number of monitoring stations. In this case, the uncertainty of the combined measurement can be estimated by dividing the individual uncertainty by the square root of the number of analysers: the effect of this for increasing numbers of monitoring stations in the exposure reduction network is illustrated in Table 23.

Table 23: Effect of increasing the number of sampling points on estimated uncertainty

Number of sampling points	Estimated uncertainty (%)[a]	"Base year" concentration
5	4.46%	8 ± 0.38 μg/m^3
10	3.16%	8 ± 0.25 μg/m^3
20	2.24%	8 ± 0.18 μg/m^3
30	1.82%	8 ± 0.15 μg/m^3
40	1.58%	8 ± 0.13 μg/m^3
50	1.41%	8 ± 0.11 μg/m^3

[a] The value stated is the standard uncertainty. The expanded uncertainty with 95% confidence (k=2) would be double the standard uncertainty.

If the "base year" and "target year" concentrations were calculated from the average concentration measured over a number of years (see below) then the uncertainty would be reduced even further. For example, with 40 sampling points, and the "base year" concentration calculated as the average over three years, the standard uncertainty[r] would be 8 ± 0.07 μg/m^3.

It is also important to note that such measurement uncertainty currently affects reporting against the NEPM $PM_{2.5}$ advisory standard (and would equally affect any new NEPM mandatory standard). This issue was recently considered by AQUILA[s] in their recommendations to the European Commission for the 2013 revision of the EU air quality legislation (AQUILA, 2012). AQUILA notes that the measurement uncertainties stated in the EU Directive's Data Quality Objectives are not taken into account when reporting any exceedances of the limit/target values; thus a quoted exceedance could be just a few percent above the limit/target value, while the measurement uncertainty could be much larger than this. AQUILA recommends that a similar position be taken with regard to the three-year average AEI values and the calculated National Exposure Reduction Targets, such that the numerical values are reported from the calculations, with no account assigned to the measurement uncertainties in these. It would be logical to adopt a similar approach in any Australian exposure reduction approach.

[r] Standard uncertainty = 10%/(SQRT(3*40))

[s] AQUILA is the European network of National Reference Laboratories

How might the approach be affected by other uncertainties: There are a number of other issues that could contribute to the overall uncertainty of measuring the reduction in $PM_{2.5}$ concentrations between the base and target years. These include:

- The effects of year-to-year changes in measured concentrations due to meteorological variability
- Effects of analyser replacement or maintenance
- Changes to, or relocation of monitoring stations

It is known that annual mean $PM_{2.5}$ concentrations are affected by year-to-year variations meteorological conditions, such as ambient temperature and wind speed. An analysis of the pattern of both PM_{10} and $PM_{2.5}$ concentrations at a number of long-term Australian sites has been provided in Chapter 4. This suggests that the substantial year-to-year variations can be considerably smoothed by the use of running-mean concentrations over a period of three years or more.

The performance characteristics of any analyser type can be affected by changes to a number of critical components. Such changes, if they occur between the base and target years for exposure reduction, could add to the uncertainty of the measurement. The monitoring methods that will be selected by each jurisdiction are not known at this stage, but the following general comments can be made:

- Such changes are unlikely to affect the performance of filter-based gravimetric samplers (such as the $PM_{2.5}$ reference sampler) as there are no moving parts within the sampling system (the size-selective inlet and filter holder). Items such as the pump are external to the sampling system
- Based on international experience, it is unlikely that the TEOM analysers, that are in widespread use across the jurisdictions for $PM_{2.5}$ monitoring, will be declared as equivalent to the reference sampler
- It is thus expected that any network established for $PM_{2.5}$ monitoring across the jurisdictions would need to be largely founded on new analysers. There is thus the opportunity to ensure in establishing these networks that account is taken of the reliability of different systems.

The exposure reduction system would also need to be able to account for changes to monitoring sites, or loss of data due to poor data capture. Temporary changes to the environment around a monitoring site could potentially affect concentrations, and poor data capture could mean the invalidation of data. Procedures could be established to deal with these events by interpolating for the missing data. There is also potential for sites to be closed, but if the network has been established for the purposes of the exposure reduction approach, then this should not represent a significant problem.

5.2 Emissions Ceiling Approach

5.2.1 Initial Appraisal

An exposure reduction approach founded on emissions ceilings could be implemented to control both primary PM and secondary precursor emissions, from all sources, or from a number of targeted sources. An initial appraisal of the advantages and disadvantages of an emissions ceiling approach is provided in Table 24.

Table 24: Advantages and disadvantages of an exposure reduction approach based on emissions

	Positive attributes to achieving the objective	Negative attributes to achieving the objective
Internal origin (attributes of the framework)	Relatively straightforward to introduce	It is the metric furthest removed from population exposure to $PM_{2.5}$ and associated health effects. Links are not transparent to policy makers and members of the public
	Emissions reduction of the secondary PM precursors are beneficial to reducing photochemical pollutants such as ozone	There is no linear relationship between emissions and $PM_{2.5}$ concentrations, and is thus poorly linked to exposure and health effects
		Emission inventories are subject to change with regard to calculation methods and source components
External origin (attributes of the Australian environment)	Emissions inventories for primary $PM_{2.5}$ have been prepared for a number of jurisdictions	Emissions inventories incomplete with regard to some primary sources and the secondary precursors
		Some jurisdictions do not have up-to-date emission inventories.
		There is no official methodology or guidebook for compiling regional emissions inventories

A particular advantage of the emissions ceiling approach is that it is potentially much simpler to quantify the reduction, as opposed to approaches based on $PM_{2.5}$ concentrations[t]. In addition, if the emissions ceiling includes the secondary precursors to PM (as well as primary PM), there will be associated benefits from a reduction in the formation of photochemical pollutants, such as ozone. A particular disadvantage of this approach, however, is that it is the metric furthest removed from the desired outcome of an exposure reduction framework, and does not provide a transparent link to the air quality impact pathway.

5.2.2 Issues

There are a number of approaches that could be taken to the introduction of an exposure reduction framework based on an emissions ceiling:

- The emissions ceiling could be set at the national or jurisdictional level;
- The emissions ceiling could include just primary PM, or could be extended to include the secondary precursors;
- The emissions ceiling could include all sources, or be targeted towards low-level sources, across the jurisdiction, or confined to urban airsheds.

Methodologies for emissions compilation: Whilst guidance on methodologies for compiling emissions estimates for the NPI are available, there is no corresponding guidance for the preparation of regional emission inventories. Consequently, the pollutants included in the inventory, the sources covered, and the methodology for estimating emissions, varies between the jurisdictions. The emissions estimates currently prepared by the jurisdictions are thus not comparable. If the exposure reduction framework were introduced at the jurisdictional level,

[t] Relatively large changes to emissions give rise to only small changes to annual mean $PM_{2.5}$ concentrations

different methodologies could potentially be applied, but this would lead to a lack of equity regarding the control measures that were implemented. A critical issue with regard to the implementation of an emissions ceiling would be the preparation of detailed guidance on estimating emissions. This guidance would need to include:

- Clear definition of the source categories to be included (e.g. based on source type, size etc.);
- Precise methodologies for estimating emissions;
- Procedures to revise inventories retrospectively where new source categories or methodological changes occur.

Scope of the emissions ceiling: The emissions ceiling could be defined to include primary PM, or extended to include secondary precursors of PM, with different ceilings set for different pollutants (as adopted within the Gothenburg Protocol and EU NECD). It would be much simpler to set the emissions ceiling based on primary PM alone, but this would not necessarily deliver the health benefits associated with a reduced exposure to secondary $PM_{2.5}$; as described in Chapter 4 of this report, the secondary component is likely to represent some 25-50% of the total $PM_{2.5}$ exposure burden[u]. In addition, an emissions ceiling restricted to primary PM would not deliver the co-benefits of reduced ozone concentrations. It would be appropriate to exclude the non-anthropogenic sources of primary PM, such as marine aerosol (although these sources are only expected to make a small contribution to $PM_{2.5}$ concentrations).

An important issue related to emissions ceilings is that of relating the emissions to public exposure. As an example, emissions from tall stacks will have a very different impact on ground-level $PM_{2.5}$ concentrations as compared with emissions from low-level sources, such as road traffic, wood heaters etc. In addition, emissions from low-level sources in areas of lower population will also have little impact of exposure. These issues are specific to emissions of primary PM, and do not apply to emissions of the secondary precursors.

A modification of the emissions ceiling could be applied to target only the low-level sources (e.g. excluding emissions from stacks above a certain height) and/or to include only those emissions arising from within a defined airshed corresponding to the major urban populations. Whilst this may be a satisfactory approach for primary PM emissions, it would not be satisfactory in targeting emissions of the secondary precursors.

Application of damage cost approach: The damage cost approach described in Chapter 3 (Section 3.4.2) could potentially be used to link the emissions reduction to an estimated health (or cost) benefit. However, as noted in Chapter 3, the approach can only link emissions and concentrations (and thus health and cost benefits) in an approximate manner, and there are important issues regarding the locations of the sources with regard to the populations; such uncertainties cannot be easily quantified. In addition, the damage cost functions that have been derived are only applicable to primary PM emissions, and no account is taken of the secondary precursors.

The benefit of incorporating the damage cost approach into an emissions ceiling framework is that emissions are not well correlated to PM exposure. For example, reducing emissions from tall stacks such as electricity generation by the same amount as reducing emissions from diffuse urban sources, such as wood heaters, would deliver a different outcome in terms of population exposure. Ideally, this is dealt with through regional scale modelling, however, this capability is

[u] The estimated loss of semi-volatile $PM_{2.5}$ will not include secondary particles such as ammonium sulfate.

not readily available in Australia. Therefore, the damage cost approach provides an approximate method for weighting emission reduction to the expected magnitude of exposure reduction.

5.3 Modelling Approach

5.3.1 Initial Appraisal

The application of regional scale models to an exposure reduction approach provides a link between changes in emissions and $PM_{2.5}$ concentrations, and, combined with population information in GIS format, can be used to derive population-weighted $PM_{2.5}$ exposures. The approach to population weighting is potentially more accurate than can inferred from monitoring data alone (which assumes concentrations at a number of fixed points are representative of exposure across much wider areas).

An initial appraisal of the advantages and disadvantages of a modelling approach is provided in Table 25.

Table 25: Advantages and disadvantages of an exposure reduction approach based on modelling

	Positive attributes to achieving the objective	**Negative attributes to achieving the objective**
Internal origin (attributes of the framework)	Provides a population-weighted $PM_{2.5}$ concentration that should be more accurate than measurements alone (if the model has been appropriately verified against monitoring data), and which can be directly linked to health benefits	Requires robust emissions inventory and regional modelling capabilities, accounting for both primary and secondary components. Some components remain poorly understood at the international level
	Possible to exclude non-anthropogenic sources, to more appropriately target emissions reduction measures	Predicted calculations are subject to changes in emissions inventory methodologies and modelling methodologies
	Can be used to support cost-benefit analysis of emissions reduction measures	
External origin (attributes of the Australian environment)	Population data in GIS format are available for the major urban centres (>25,000 people)	Regional modelling capabilities are currently very limited
		Emissions inventories not currently well suited to regional modelling of either primary or secondary components

Other advantages of this approach are that it would be possible to exclude the non-anthropogenic sources (by omitting them from the emissions included in the modelling process) thus targeting the exposure reduction approach to those sources that can be controlled. The modelling could also cover both primary and secondary $PM_{2.5}$. The output of the model could be directly used to estimate the health benefits, providing a transparent link to the air quality impact pathway[v].

[v] As the health benefits are derived from risk factors applied to the population-weighted exposure, the two metrics are effectively identical in all but presentation.

5.3.2 Issues

There would need to be a significant investment in resources within the jurisdictions to support and implement regional modelling studies at a suitably robust standard:

Emissions inventories

- The information recorded under the National Pollutant Inventory (NPI) is of limited use in support of regional modelling studies, as only $PM_{2.5}$ emissions from industrial and diffuse (e.g. wood heaters) combustion sources are included. Required metadata to support modelling, such as conditions of release (e.g. stack height, exit temperature etc.) are not recorded;
- There is reasonably good coverage of primary $PM_{2.5}$ emissions, with data available for New South Wales (Greater Metropolitan Region), Victoria, South East Queensland, Perth and Adelaide, but some of the inventories date back to pre-2000. The major sources of anthropogenic emissions have been included. Emissions of marine aerosol should probably be excluded from any emissions reduction approach.
- There are no data for Australian Capital Territory, Tasmania or Northern Territory.
- The development of emission inventories for the secondary precursors is more limited, and with the exception of Victoria, emissions of elemental/organic carbon are missing, and with the exception of Victoria and New South Wales, emissions of SO_3 are missing.
- The metadata that are required to support the use of emissions inventories into regional models are largely incomplete (e.g. spatial and temporal variation of emissions is not always collated). Temporal and spatial variation of emissions are only collated for the NSW GMR, Victoria and SEQ emission inventories.
- There is no consistent methodology between the jurisdictions for compilation of the regional emissions inventories (and no consistency with base years), and as such, the emissions data are not directly comparable.

Regional Modelling

- There is currently limited capacity for regional scale modelling within the jurisdictions, and where this is undertaken, the focus is upon ozone (as opposed to PM).

5.4 Analysis of Potential E-R Metrics

A summary of the advantages and disadvantages of each general approach, based on the preceding discussion, is provided in Table 26.

Table 26: Summary of advantages and disadvantages of different approaches to $PM_{2.5}$ exposure reduction

Approach	Link to AQ Impact Pathway	Ease of Implementation	Understandable to Public	Timescale for Implementation	Costs for Implementation[a]
Monitoring					
National level	++++	++++	+++++	Medium	$$$
Jurisdictional level	++++	++	+++++	Medium	$$$
Modelling					
Total primary PM	++	++	++++	Medium	$$$$$
Anthropogenic primary PM	+++	++	++++	Medium	$$$$$
Anthropogenic primary PM + secondary	+++++	+	+++++	Long	$$$$$$
Emissions ceiling					
Primary PM	+	++++	+	Medium	$$$$
Primary PM + damage cost	+++	+++	+++	Medium	$$$$$
Primary PM + secondary precursors	++	++	++	Long	$$$$$$

[a] Costs for implementation do not include the resources required to develop the required reduction targets

At this stage, an exposure reduction approach based on modelling within Australia is considered impractical, as a substantial resource investment would be required, even if it were implemented at a national level. Based on the assessment provided above, four potential options for an exposure reduction approach in Australia are therefore proposed, based around monitoring or emissions ceilings:

- **Option 1:** A Cleaner Air Programme (CAP) approach similar to the Canadian CI/KCAC programme, with no targets set, but a requirement placed on all jurisdictions to set out programmes to reduce emissions of both primary PM and secondary PM precursors on a regular basis e.g. every five years.
- **Option 2:** An exposure reduction system based on monitoring, with target reductions set on an Australia-wide basis. The target reduction could be advisory or mandatory.
- **Option 3:** An exposure reduction system based on an emission ceiling for primary PM, with targets set for individual jurisdictions based on the damage cost approach. The damage cost approach provides an approximate method for weighting emission reductions to the expected magnitude of exposure reduction. The target reduction could be advisory or mandatory (it would differ from Option 1 in that targets are established)
- **Option 4:** A hybrid approach between Options 1 and 3. The emissions ceiling for primary PM would be supported by the CAP approach to reduce emissions of secondary PM precursors.

These options are explored in greater detail below.

5.4.1 Option 1

The Canadian CI/KCAC approach, as described in Chapter 2 of this report, would provide the basis for an exposure reduction approach to $PM_{2.5}$, but would place a lesser burden on jurisdictions. The Cleaner Air Programme (CAP) would focus on those areas where $PM_{2.5}$ concentrations are *below* the advisory (or new mandatory) NEPM standard, but no targets for exposure reduction (in terms of emissions or concentrations) would be set. Jurisdictions would be required to set out programmes to reduce emissions of both primary PM and secondary PM precursors, and to report progress on regular (e.g. every 5 years) basis. Guidance issued by the Canadian Council of Ministers and the Environment (CCME) could be used as the basis for establishing guidelines and protocols within Australia. Measures aimed at primary PM emissions reduction could be usefully focused within the established urban airsheds, and/or targeted at those sources below a certain release height (this could be easily established from a number of simple modelling assessments of primary PM emissions from tall stacks); measures aimed at reducing the secondary PM precursors should encapsulate the entire jurisdiction. Reporting of measured $PM_{2.5}$ concentrations (as part of the current NEPM advisory standard, or any new mandatory standard) would feed into this approach, and provide supporting evidence to the success of the programmes.

5.4.2 Option 2

An exposure reduction system based on monitoring provides the most straightforward and transparent approach. It is recommended that the exposure reduction target should be established at a national level, with the obligation for monitoring and reporting of data devolved to the jurisdictions. The exposure reduction target could be mandatory or advisory. With only limited $PM_{2.5}$ monitoring data available, and no modelling information to support any assessment, it is difficult to judge the spatial variability of concentrations within urban areas. In the absence of this information, a network of approximately 40 $PM_{2.5}$ analysers is suggested, distributed across the urban population centres of >100,000. A suggested network configuration is set out in Table 27 below.

The strategy behind Table 27 assumes that each airshed would have a minimum of one sampling point, and that the larger airsheds would have approximately one sampling point per 400,000 people.

Table 27: Proposed exposure reduction monitoring network for $PM_{2.5}$

Jurisdiction	Urban Centre	Airshed	Population		No. Monitors	No. Monitors/Pop
New South Wales	Sydney	NSW GMR	4,109,503	4,993,832	12	416,153
	Newcastle		319,457			
	Central Coast		305,128			
	Wollongong		259,744			
Victoria	Melbourne	Port Phillip	3,841,957	3,994,009	10	399,401
	Geelong		152,052			
Queensland	Brisbane	South East Queensland	1,935,670	2,755,667	7	393,667
	Gold Coast-Tweed Heads (Gold Coast Part)		488,455			
	Sunshine Coast		223,788			
	Toowoomba		107,754			
	Cairns	Cairns	120,639	120,639	1	152,721
	Townsville-Thuringowa	Townsville	152,721	152,721	1	120,639
Western Australia	Perth	Perth	1,480,597	1,480,597	4	370,149
South Australia	Adelaide	Adelaide	1,140,725	1,140,725	3	380,242
Australian Capital Territory	Canberra-Queanbeyan (Canberra Part)	Canberra	358,821	358,821	1	358,821
Tasmania	Hobart	Hobart	134,810	134,810	1	134,810
Grand Total			**15,131,821**		**40**	

The exposure reduction target should be based on the average $PM_{2.5}$ concentration measured across all monitoring stations, with the "base" and "target year" values calculated from the average concentration over three consecutive years. Siting criteria for GRUB and population-average monitoring stations are already defined for NEPM monitoring networks; however, for the purpose of the exposure reduction network, it is suggested that these criteria could be useful compared with, and if necessary refined, to comply with a Guidance Document issued by AQUILA (2012). It is further noted that AQUILA intend to issue further guidance on the measurement uncertainties on the exposure reduction target in the near future.

Whilst jurisdictions may select different monitoring techniques, these should all have demonstrated equivalence to the reference method for $PM_{2.5}$, and obligations would need to be in place to ensure the continued operation of the stations over the compliance period, and that minimal changes were made to the instruments.

One issue that does arise with Option 2 is that while the exposure reduction target is best set at the national level, and the responsibility for monitoring and reporting of $PM_{2.5}$ concentrations is best undertaken by the jurisdictions, there is no clear responsibility for the implementation of measures to reduce primary PM and secondary precursor emissions. This could be tackled in a number of ways, either by establishing target reductions for each jurisdiction across different sectors (derived from the studies used to inform the setting of the exposure reduction target – see Chapter 6), or by simply introducing the Option 1 approach, which requires plans and programmes to be established.

It is noted that Northern Territory (NT) is excluded from the proposed exposure reduction framework based on a monitoring approach, as there are no urban centres with a population of greater than 100,000 within NT. This could be overcome by lowering the population threshold so that Darwin (population 77,259 (ABS, 2012)) triggers the requirements of an "urban centre". This would substantially increase the cost of the exposure reduction framework. Despite the fact that NT is not included in the proposed monitoring framework, all jurisdictions and urban centres (regardless of the population size) will benefit from an exposure reduction framework. In order to achieve the reduction targets, jurisdictions will be required to introduce emission reduction actions. Many of these emission reduction actions are likely to be for nationally regulated diffuse sources (such as off-road vehicles). Therefore, the emission and exposure reductions will also be experienced in urban centres that are not specifically included in a monitoring framework. However, as the monitoring framework is designed around large urban centres, reduction actions are focussed on dominant emission sources in large population centres.

5.4.3 Option 3

An emissions ceiling approach focussed on primary PM, combined with the damage cost approach that has been developed for Australia, has the advantage of being relatively straightforward to implement, whilst providing a metric that can be directly linked to the air quality impact pathway. As suggested for Option 1, the emissions ceiling could focus on primary PM emissions within the established urban airsheds, and/or be targeted at those sources below a certain release height. As the approach would be founded on the compilation of regional emissions inventories, the emissions ceilings would be best implemented at the jurisdictional level. The emissions ceiling could be either mandatory or advisory.

At present, there is no national guidance provided for the compilation of regional emissions inventories, in particular with regard to the sources that are included, and the estimation techniques that are employed. However, reference is made to a number of international guidance documents in Chapter 4 that could be used to develop national guidance for Australia.

Reporting of measured $PM_{2.5}$ concentrations (as part of the current NEPM advisory standard, or any new mandatory standard) would feed into this approach, and provide supporting evidence as to the success of the emissions reductions.

5.4.4 Option 4

A specific, and important disadvantage of Option 3, is that no account is taken of emissions of the secondary PM precursors. As set out in Chapter 4, based on the information available, the secondary component is likely to represent some 25-50% of the $PM_{2.5}$ mass, and there is no conclusive evidence at this time that this component is any less toxic than the primary component.

Option 4 presents a hybrid between Options 1 and 3. An emissions ceiling would be introduced for primary PM, linked to the damage cost approach, and implemented at the jurisdictional level (i.e. Option 3). However, as there is no reliable way, at present, to quantify the health (or cost) benefits associated with the reduction of the secondary precursor emissions, and it is therefore not possible to quantify an emissions ceiling. Jurisdictions would therefore be required to set out programmes to reduce emissions of secondary PM precursors, and to report progress on regular (e.g. every 5 years) basis, but no specific targets would be set (i.e. part of Option 1). Reporting of measured $PM_{2.5}$ concentrations (as part of the current NEPM advisory standard, or any new mandatory standard) would feed into this approach, and provide supporting evidence to the success of implementation.

A summary of the advantages and disadvantages of each option, based on the preceding discussion, is provided in Table 28.

Table 28: Summary of advantages and disadvantages of the proposed options to $PM_{2.5}$ exposure reduction

Approach	Link to AQ Impact Pathway	Ease of Implementation	Understandable to Public	Timescale for Implementation	Costs for Implementation[a]
Option 1	+	+++++	+++	Medium	$$
Option 2	+++++	++++	+++++	Medium	$$
Option 3	+++	+++	+++	Medium	$$$$
Option 4	+++	+++	++++	Medium	$$$$

[a] Costs for implementation do not include the resources required to develop the required reduction targets

6 OUTLINE OF FRAMEWORK PROCESS

6.1 Target Development

With the exception of Option 1, for which no targets would be established, the process for the setting of targets is largely independent of which Option is selected, although the metrics that would be applied are different.

The National Environment Protection Council (NEPC) Service Corporation has commissioned an economic analysis project to assess the costs and benefits of introducing an exposure reduction framework into Australia, which will provide the evidence base for selecting an appropriate target.

The first stage of the process will be to evaluate the current and projected (Business As Usual) emissions across Australian jurisdictions. Depending on which Option is selected (see Chapter 5), this will need to include, as a minimum, the emissions of primary $PM_{2.5}$, but it would be highly advantageous to include the secondary precursor emissions (NO_x, SO_2/SO_3, NH_3 and VOCs) for all Options. The projected (BAU) emissions will need to coincide with the target year for the exposure reduction approach, which is anticipated to be 5-10 years forwards.

Abatement measures (for both primary PM and secondary precursors) at both the national and jurisdictional levels will need to be evaluated for a range of scenarios, and the emissions reductions, and associated costs, quantified for each. These emissions reductions then need to be translated into ambient $PM_{2.5}$ concentrations with the values expressed as population-weighted annual means. This will allow a cost benefit analysis to be undertaken for each emissions reduction scenario, and the net benefit (monetised health and other benefits, minus the costs of implementing the required abatement) calculated. The targets required for Option 2 (the reduction in average population-weighted mean $PM_{2.5}$ concentration across the urban populations >100,000) and Option 3 (the reduction in primary PM emissions for each jurisdiction) can then be calculated. The target applied to Option 4 would be identical to that applied for Option 3.

For Option 2, as it is recommended that the target be applied across the average of all Australian monitoring stations, it is appropriate that the target be set as an absolute reduction (e.g. x $\mu g/m^3$) between the "base" and "target" years. For Option 3, it is recommended that the target be set as an emissions ceiling for primary PM (e.g. tonnes per year per jurisdiction/airshed).

6.2 Compliance

Option 1: Compliance for Option 1 could involve a number of stages:

- Publication of an initial "state-of-the-environment" report by each jurisdiction, to be submitted within a defined timescale. This would include a current-year emissions inventory within each jurisdiction (for primary PM and the secondary precursors), with emissions categorised by sector, together with information on ambient concentrations and trends in $PM_{2.5}$ concentrations;
- The development of goals and targets, including emissions reduction strategies;
- Tracking progress in annual reviews of ambient $PM_{2.5}$ concentrations and actions implemented, or planned, to reduce emissions; and

- Publication of five-year reports, confirming all actions taken to reduce primary PM and secondary precursor emissions, and presenting available data on current emissions levels and trends, as well as ambient $PM_{2.5}$ concentrations and trends

Option 2: Compliance checking for Option 2 would be relatively straightforward, based on the reported monitoring data. The average $PM_{2.5}$ concentration measured across the Australian exposure reduction monitoring network, calculated over the three-year base period and three-year period relevant to the "target year" would be directly compared with the adopted target.

Issues that may need to be taken into account relate to missing sites (due to poor data capture, site closure, significant changes to operational status etc.). Guidance on how to deal with this determination, and the variability's that may occur, has been prepared to assist with the implementation of the exposure reduction approach in Europe (AQUILA, 2012). Adoption of the general principles of this guidance could be made within Australia.

Option 3: Compliance checking for Option 3 is potentially straightforward and would involve a comparison of the estimated emissions in the target year with the emissions ceiling, for each jurisdiction.

Issues that would need to be carefully considered would be any changes to the methodologies used to calculate the emissions, or any changes to the sources included in the calculations. Procedures to "adjust" the emissions calculation in a transparent and uniform manner would need to be implemented.

Option 4: Compliance checking for Option 4 could simply involve the incorporation of the primary PM emissions ceiling (from Option 3) into the five-year reports prepared for Option 1.

6.3 Costs and timescales

6.3.1 Option 1

It is not straightforward to estimate costs for the implementation of Option 1, as the requirements for each jurisdiction, and the resources that are currently in place, are widely different. In particular, while some (five) jurisdictions have developed regional emissions inventories of varying sophistication, there is little or no information available within Australian Capital Territory, Northern Territory or Tasmania. Estimated costs for updating and maintaining regional emissions inventories are provided for Option 3 (see Table 31), but the requirements for the CAP approach would not necessarily need to be so rigorous (as compliance with targets is not required), but sufficient to allow adequate identification of priority measures to reduce emissions, and to track progress. As a ball-park estimate, it is suggested that the cost estimates in Table 31 (for Option 4) could be halved. It is assumed that $PM_{2.5}$ monitoring in accordance with the NEPM standard (advisory or mandatory) would be required, and no additional costs would be incurred.

The timescale for implementation (the publication of the initial state-of-the-environment report and identification of emissions reduction strategies) could be 2-3 years.

6.3.2 Option 2

Costs associated with the implementation of Option 2 would involve the expansion and maintenance of the $PM_{2.5}$ monitoring network. To facilitate this, estimated costs of $PM_{2.5}$ monitors were obtained from Ecotech and ANSTO. The estimated cost per sampler is presented in Table 29.

Table 29: Estimated cost per PM sampler

Establishment costs	Value	Unit
Hi-Vol	$10,000	Source: Ecotech
Lo-Vol	$5,000	Source: Ecotech
Sequential sampler (Partisol)	$20,000	Source: Ecotech
ANSTO ASP sampler	Variable (depending on the site)	ANSTO
Installation and commissioning	$1,200	Based on 1/2 day labour and 1/2 day travel time.
Ancillary costs	$20,000	Fencing, footings, power
	$100,000	Estimated cost of selecting and securing a site and obtaining planning approval (for a site not already established)
Maximum cost for installation and commissioning (site already established)	*$41,200*	
Maximum cost for installation and commissioning (new site)	*$141,200*	
Annualised over 10 years (site already established)	*$4,120*	*Price per annum/sampler (spread over 10 years)*
Annualised over 10 years (new site)	*$14,120*	*Price per annum/sampler (spread over 10 years)*
Operating costs	**Value**	**Unit**
Filter analysis (one every three days)	$5,200	Based on $50 per filter and two filters per week per sampler
Manual filter collection and maintenance of sampler	$11,397	Based on 0.5 days per filter, 1 in three day samples and $80,000 per year salary cost
Nominal maintenance cost	$10,000	Estimated annual cost for additional maintenance
Operating cost	*$26,597*	*Per sampler*
Total (establishment + operational) cost per sampler (site already established)	**$30,717**	**Per annum (with capital costs spread over 10 years)**
Total (establishment + operational) cost per sampler (new site)	**$40,717**	**Per annum (with capital costs spread over 10 years)**

The estimated annualised costs to establish and operate a network of 40 $PM_{2.5}$ monitoring stations across Australia, based on the suggested allocation of stations in Table 27, is set out below in Table 30.

Table 30: Estimated costs to establish and operate a $PM_{2.5}$ monitoring network per jurisdiction

Jurisdiction	Current No. Monitors	No. Monitors Required for ER	No. Required Additional Monitors[a]	Annualised Establishment Cost (10 years)[b]	Additional Annual Operating Costs[c]
New South Wales	7	12	5	$99,440	$132,986
Victoria	2	10	8	$121,200	$212,778
Queensland	5	9	4	$77,080	$106,390
Western Australia	4	4	0	$16,480	$0
South Australia	1	3	2	$32,360	$53,195
Australian Capital Territory	1	1	0	$4,120	$0
Tasmania	1	1	0	$4,120	$0
Grand Total	**21**	**40**	**18**	**$354,800**	**$505,349**

[a] It is expected that some of the existing $PM_{2.5}$ monitors will need to be upgraded following the outcome of the $PM_{2.5}$ Equivalence Programme, but it is assumed that this would be required in any case.

[b] Total annualised establishment costs are based on the cost of establishing monitoring sites for additional monitoring sites plus the annualised establishment cost for the current number of monitors (as it is assumed that existing monitors would be required to be replaced in a 10 year period).

[c] Additional annual operating costs are based on the costs of running the additional monitors only and do not include costs for running existing $PM_{2.5}$ monitors as these costs are already incurred due to NEPM monitoring requirements.

The establishment costs include the purchase of the $PM_{2.5}$ monitor, the associated enclosure and ancillary equipment, installation and commissioning, and have been annualised over a ten year period. Annual operational costs include site servicing, maintenance, consumables, data collection and validation, and QA/QC.

The timescale for implementation of an exposure reduction network founded on monitoring is directly linked to the timescale for completion of the $PM_{2.5}$ Equivalence Programme in Australia (as one is inherently linked to the other), but initial works could be undertaken to review the status of existing sites, and identify the new sites, in advance of this. The establishment of the "base year" concentration would then take 3 years. A base year concentration over the period 2014-2016 is feasible.

6.3.3 Option 3

The estimated costs to develop a regional emissions inventory are detailed in Table 31. It is noted that the annualised cost of $156,800 per annum is the estimated annual cost, whether or not a jurisdiction has an existing regional air emissions inventory (as emission inventories need to be maintained). This cost is based on an update period of once every five years.

Five years has been chosen as the update frequency for this assessment as it is consistent with the update frequency reported by NSW and Victoria. One of reasons for a five year update frequency is that Census data from the ABS are published every five years and a lot of statistics underpinning domestic based emission estimates rely on these data. Another reason is that updating once every five years (as opposed to annually or biannually) reduces the cost of maintaining an inventory.

The downside to such long update frequencies, in terms of using an emissions ceiling approach for a exposure reduction framework, is that tracking progress towards targets may become more challenging with less frequent inventory updates. Furthermore, with such infrequent updates, it is common for emission inventory teams to be dismantled and then reassembled, which reduces continuity between updates. The advantage of more frequent updates is that the emission inventory teams stay together and can work on improving the inventories, both in terms of total emissions and the spatial and temporal disaggregation. Changes in emission estimation methodologies/sources are thus simpler to manage.

Using an update frequency of every five years, particular care will need to be taken to ensure that any changes to the methodology or source coverage are fully accounted for in the reporting.

The estimated additional cost to upgrade existing 'model-ready' emission inventories with additional substances (such as elemental and organic carbon), is considered to be negligible, at approximately $20,000 (salary cost).

Table 31: Estimated costs to update and maintain a regional emission inventory per jurisdiction

Cost Item	Value	Unit
Salary (including 10% superannuation)	$132,000	$/year/person
Number of people	3	people
Years	1.5	years
Salary Cost	*$594,000*	*per inventory update*
Fees (buying data, domestic surveys)	**Value**	**Unit**
Domestic survey	$50,000	per update
Other fees (purchasing data, stationary)	$20,000	per update
Hardware (server, programs)	$20,000	per update
Software (custom built or off the shelf)	$100,000	per update
Total Fees to update air emissions inventory	*$190,000*	*per inventory update*
Total cost to update air emissions inventory	**$784,000**	
Annual cost to update and maintain air emissions inventory (based on a five year update period)	**$156,800**	**(per annum)**

Based on previous updates to the NSW GMR, Victoria and south east Queensland air emissions inventories, it is estimated that the timescale required to update an emissions inventory is 2 – 3 years. This timescale could be reduced if more resources were allocated to the task; however, this is likely to increase the cost of maintaining the emissions inventory.

The cost estimate presented in Table 31 is also based on the development and maintenance of a large urban air emissions inventory (such as those for NSW GMR, Port Phillip or South East Queensland). Emission inventories for smaller urban areas, such as Canberra, Hobart, Cairns or Townsville would not be expected to cost the same as updating an emissions inventory for a large urban area such as the NSW GMR. Therefore, the estimated cost to create and maintain regional emission inventories for all urban areas with population centres of greater than 100,000 is presented in Table 32.

Table 32: Estimated costs to update and maintain each regional emission inventory (based on an inventory being required for urban centres with a population > 100,000)

Airshed	Population	Scalar Factor [a]	Estimated Cost per Annum [b]
NSW GMR	4,993,832	1	$156,800
Port Phillip	3,994,009	1	$156,800
South East Queensland	2,531,879	1	$156,800
Townsville	152,721	0.3	$47,040
Cairns	120,639	0.3	$47,040
Perth	1,480,597	1	$156,800
Adelaide	1,140,725	1	$156,800
Canberra	358,821	0.3	$47,040
Hobart	134,810	0.3	$47,040
Total			**$972,160**

[a] Scalar factor providing an estimate of the work effort involved in developing each inventory (i.e. It is estimated that the work effort required to develop emission inventories for Townsville, Cairns, Canberra or Hobart is equivalent to 30% of developing an emissions inventory for a major urban area)

[b] Based on an update period of once every five years.

In order to develop a nationally consistent framework for the development of regional emission inventories, a guidebook would be required, similar to the Joint EMEP/CORINAIR guidebook used to compile emission inventories under the NECD in Europe. Recently, NSW OEH finalised the update the NSW GMR air emissions inventory. As part of this update OEH developed a comprehensive series of methodology documents for all emission sources that could be considered under a regional air emissions inventory. It is also expected that emission inventory specialists from Victoria, South East Queensland and Western Australia would have developed Australian specific methodologies for developing air emission inventories. These methodology documents could serve as a good starting point for a nationally consistent approach for developing air emissions inventories. Consultation would need to occur between all jurisdictions to develop the workbooks and reach agreement with the approaches.

Based on experience, it is likely that the most difficult methodology to reach national consensus on would be that for estimating motor vehicle emissions (due to the wide variety of data sources, assumptions and models available worldwide to estimate emissions in comparison to other sources). Common methodologies used overseas and locally, include using a vehicle emissions model coupled with nationally derived emission tests from in-service vehicles (for e.g. COPERT 4 in Europe and MOVES/Mobile 6 in the U.S coupled with local emission testing results for e.g. results from the Australian Federal Government's NISE 1 and NISE 2[w] studies). Therefore, it is estimated that a one-off cost would be involved in developed a nationally consistent approach for motor vehicle emissions inventories of approximately $150,000.

A cost estimate is presented in Table 33 for the development of a nationally consistent emission inventory guidebook. The cost estimate is based on:

- Two months' time or approximately 300 hours (salary cost) per person involved. Assuming five inventory specialists are involved in the development of the workbook, this allows for approximately 1,500 hours of development time in total.
- A one-off estimated cost of $150,000 to develop a nationally consistent approach to compiling motor vehicle emissions inventory.

[w] National In-Service Emissions testing

- Travel costs for five people to travel to two meetings during the development of the guidebook.

Table 33: Estimated costs for the development of a nationally consistent emission inventory guidebook for regional inventories

Cost Item	Value	Unit
Number of people	5	People
Time required	0.17 (2 months per person)	years
Salaries (including 10% superannuation)	$132,000	$/year
Salary Cost	*$110,000*	
Development of nationally consistent motor vehicle emission inventory methodology	*$150,000*	
Fees (travel costs)		
Two meetings in a capital city	$2,500	
Total Fees	*$2,500*	
Total cost to develop nationally consistent emission inventory guidebook	**$262,500**	

It is estimated that an emissions inventory guidebook could be developed and endorsed within a year.

6.3.4 Option 4

The estimated costs and timescales for Option 4 would effectively be very similar to those for Option 3. It is estimated that the additional obligation of reporting for CAP would be 50% of the cost of implementing Option 1.

6.4 Interim Conclusions

No one approach is an obvious selection for an exposure reduction framework in Australia, as all possible approaches have positive and negative attributes. Thus, it was decided that the most appropriate way forward would be to present the identified options for a recommended exposure reduction framework. These options could then be considered by stakeholders before a final recommendation is made.

A summary of the estimated annualised costs of each exposure reduction framework option for each jurisdiction is provided in Table 34.

Table 34: Estimated annualised costs for each proposed exposure reduction framework

	Estimated Additional Annualised Costs ($/annum)			
Jurisdiction	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Description	Cleaner Air Program (CAP) approach	Monitoring approach	Emissions ceiling approach incorporating damage costs	Hybrid approach between Option 1 and Option 3
New South Wales	$69,429	$232,426	$156,800	$191,514
Victoria	$69,429	$333,978	$156,800	$191,514
Queensland	$69,429	$183,470	$250,880	$285,594
Western Australia	$69,429	$16,480	$156,800	$191,514
South Australia	$69,429	$85,555	$156,800	$191,514
Australian Capital Territory	$69,429	$4,120	$47,040	$81,754
Tasmania	$69,429	$4,120	$47,040	$81,754
TOTAL	**$486,000**	**$860,149**	**$972,160**	**$1,215,160**

7 RECOMMENDED EXPOSURE REDUCTION FRAMEWORK

7.1 Background

As part of the development of an exposure reduction approach under the National Plan for Clean Air, a stakeholder workshop was held in Sydney on 14 September 2012 to discuss options and provide an opportunity for jurisdictions to provide feedback and guidance before preparing the final report. A list of attendees at the stakeholder workshop is provided in Appendix C.

Following the workshop, it seemed important to emphasise that monitoring (in itself) delivers no improvement to PM exposure – it is simply the compliance mechanism by which measures put in place to reduce emissions are judged to have been successful. With an exposure reduction framework based on monitoring, mechanisms are still required to be in place to focus action i.e. an emissions inventory and some form of assessment tool to understand how emissions are related to concentrations (so that appropriate targets can be set).

It is also important to note that all three air quality management tools would need development no matter which $PM_{2.5}$ exposure reduction framework option was selected. That is:

Air quality monitoring network	An air quality monitoring network is required to measure ambient levels of $PM_{2.5}$. The monitoring network is required to measure ambient levels of particulate matter (public exposure), and to validate air quality modelling and regional air emission inventories. Further monitoring information on the composition of $PM_{2.5}$ in urban regions would greatly assist the development of a more informative exposure reduction framework. An air quality monitoring network will always be required to measure the actual response to ambient $PM_{2.5}$ levels resulting from emission reduction actions.
Air emissions inventories	Air emission inventories are required to prioritise emission sources of primary PM and secondary precursors, characterise the current level of emission control and describe the spatial and temporal variation of each source. The emissions inventory is required to identify potential emission reduction actions that could be introduced to further reduce exposure.
Regional air quality modelling capability	Regional air quality modelling is an important step in any exposure reduction framework. Regional air quality modelling can be used to set exposure reduction targets that are achievable given the current level of emission control. Regional air quality modelling is useful to determine the sensitivity in ambient concentrations to changes in emission rates and to further prioritise emission reduction options based on exposure metrics.

7.2 Objectives

Based on the stakeholder workshop the agreed objectives of a recommended $PM_{2.5}$ exposure reduction framework are to:

- Drive continued reductions in population exposure to $PM_{2.5}$, even when concentrations are below national compliance standards.
- Have regard to cost-effectiveness and health benefits and the distribution of health benefits for the community.
- Be simple, practical and able to be implemented in all Australian jurisdictions.

7.3 Recommended Framework

Taking into account the issues raised at the stakeholder workshop it is recommended that a framework based on Option 1 is progressed. The recommended framework would be a ***mandatory system*** with an obligation placed on jurisdictions to develop programmes to reduce emissions of primary PM and secondary precursors (i.e. NO_x, VOCs, SO_2 and ammonia). It is important the framework is mandatory as identified by jurisdictional stakeholders by the workshop and this is consistent with issues found with the Canadian CI/KCAC framework in that it was found in their review that there was a lack of accountability and reporting with the initial framework proposed. These programmes would be audited at a national level and rejected if they failed to meet a satisfactory standard. It is envisaged that this could be the springboard required to implement a framework of emissions inventories, assessment and monitoring that could later be developed into Options 2, 3 or 4. In the future, there may also be options to explore the use of empirical models (such as the UK Pollution Climate Mapping (PCM) approach) once there is a better understanding of emissions and there is better monitoring data coverage (including monitoring of components, such as sulfate, nitrate, chloride etc).

State and Territory jurisdictions and the Commonwealth Government would be required to report on:

- Emission reduction actions. This would include a description of all actions implemented to reduce ambient PM within each jurisdiction and estimates of the quantified effectiveness of each action, expressed in terms of mass emission reduction of each pollutant (primary PM and secondary precursors) due to each action.
- Current emissions and trends. Reporting should include available data on current emission levels and emission trends for both past and forecast future for primary PM and secondary precursors.
- Ambient levels of $PM_{2.5}$ and trends. Reporting would be in-line with current NEPM reporting by each jurisdiction. In addition to reporting ambient levels in-line with NEPM reporting forms, jurisdictions may wish to report the data in other statistical forms such as:
  - Annual averages
  - Seasonal averages
  - Annual or seasonal maximums
  - As a cumulative exposure index

  Trends in ambient levels from past to present should be reported for each jurisdiction. Estimates should be made of probable future trends in ambient $PM_{2.5}$ based on the projected trends in emissions in the jurisdiction.
- Development of capacity in regional air emission inventories, regional air quality modelling capability and the regional air quality monitoring network for $PM_{2.5}$.

It is recommended that the framework be established within the Air NEPM such that the framework was supported to take forwards the exposure reduction approach to PM within a 10 year timeframe. The framework would consist of three tasks.

TASK 1 – DEVELOP EMISSION REDUCTION PROGRAMMES

This would introduce a mandatory requirement for jurisdictions to develop programmes to reduce emissions so as to reduce exposure to PM (i.e. the CAP in Option 1).

The jurisdictions would have two years to develop their programmes which should be submitted to the Council of Australian Governments (COAG) Standing Council on Environment and Water (SCEW) for review and approval.

Jurisdictions would then report every three years on progress with the programme which would be reviewed and approved at a national level. These reports would also include information derived from Task 2 (see below). There is potential for the scope of what is required to be tailored to the scale of the problems within the different jurisdictions. Similar, to the revised changes to air quality management in Canada, trigger levels could be incorporated into the framework outlining the different levels of response strategies for each level.

National guidance would need to be developed; this could be based upon, and developed from, the *Guidance Document on Continuous Improvement (CI) and Keeping-Clean Areas-Clean (KCAC)* published by the Canadian Council of Ministers of the Environment.

TASK 2 – DEVELOP $PM_{2.5}$ MONITORING NETWORKS AND REGIONAL EMISSION INVENTORIES

This would be a requirement to focus particulate matter monitoring on $PM_{2.5}$ and to carry out a minimum level of monitoring following appropriate national guidance.

This task would also encourage jurisdictions to develop emission inventories according to national guidance. National guidance on emission inventory development could utilise the knowledge developed through construction of contemporary regional air emission inventories developed by jurisdictions (e.g. NSW, Victoria and Queensland) and could potentially use the National Pollutant Inventory (NPI) framework to publish nationally consistent methodologies (for e.g. through the *NPI Emission Estimation Technique Manuals for Diffuse Sources* (SeWPaC, 2012)). Guidance on developing a guidebook for emission inventories could also be sourced from the European Environment Agency by considering the framework of the *EMEP/EEA air pollutant emission inventory guidebook – 2009.* This guidebook was designed to facilitate reporting of emission inventories by countries to the UNECE Convention on Lang-range Transboundary Air Pollution and the EU National Emissions Ceiling Directive.

These two requirements should be in place within three years of implementing the Framework.

TASK 3 – DEVELOP EXPOSURE REDUCTION TARGETS

Work would be carried out at a national level using available information to identify sources and suitable cost-effective control programmes in the two main air-sheds (Sydney and Melbourne).

As a start to this task, the National Environment Protection Council (NEPC) Service Corporation has commissioned an economic analysis project to assess the costs and benefits of introducing an exposure reduction framework into Australia, which will provide the evidence base for selecting an appropriate target.

The first stage of the process will be to evaluate the current and projected (Business As Usual) emissions across Sydney and Melbourne airsheds (as these airsheds have up-to-date air emission inventories. This will need to include, as a minimum, the emissions of primary $PM_{2.5.}$ The projected (BAU) emissions will need to coincide with the target year for the exposure reduction approach, which is anticipated to be 5-10 years forwards.

Abatement measures (for both primary PM and secondary precursors) at both the national and jurisdictional levels will need to be evaluated for a range of scenarios, and the emissions reductions, and associated costs, quantified for each. These emissions reductions then need to be translated into ambient $PM_{2.5}$ concentrations with the values expressed as population-weighted annual means. This will allow a cost benefit analysis to be undertaken for each emissions reduction scenario, and the net benefit (monetised health and other benefits, minus the costs of implementing the required abatement) calculated.

This information could be supplemented by new information arising from other jurisdictions as results of Task 2 are developed to determine whether it will be practicable to set targets for a national emission reduction approach based on monitoring.

It is understood that, in the immediate term, it would be desirable to set an exposure reduction target. It is not possible with the current information to set an interim target based on an emissions ceiling. However, based on the information currently available, it is considered that a 10% reduction in total measured $PM_{2.5}$ concentrations is likely to represent the lowest level at which it would be possible to identify any change in monitored ambient levels with reasonable certainty. It is important to note that if the focus on emissions reduction was on primary PM alone, then this could translate to a minimum reduction of approximately 20% in primary emissions (as up to 40% of monitored $PM_{2.5}$ is secondary and there is also a non-anthropogenic primary component from marine aerosols and wind-blown dust). In terms of timescales for an interim target, a compliance period of 10 years has precedent in Europe and is most likely appropriate for Australia. It is recommended that the baseline concentration is set based on at least three years of monitoring data to reduce inter-annual variability and is based on the network average of monitors either within each jurisdiction or nationally.

It is recommended that any interim target for exposure reduction that is set is reviewed as further information from regional modelling and economic analysis projects becomes available.

8 APPLICATION TO OTHER POLLUTANTS

The exposure reduction approach is potentially suited to any pollutant where there is convincing evidence of a non-threshold effect. Of those pollutants for which Air NEPM limit values have been established, only ozone is potentially considered to be a non-threshold pollutant.

OZONE

There are two NEPM limit values for ozone, both based on short-term exposure (1-hour and 4-hour means) – see Table 1. In most Australian towns and cities, ozone levels are below the limit values, but exceedances are recorded several times per year in the larger cites, most notably Sydney and Melbourne, but also Brisbane and Perth.

At this stage, it is not certain that ozone is a non-threshold pollutant. In addition, it would be extremely challenging to establish an exposure reduction framework based on concentrations (measured or modelled), as the number of exceedances in any given year will be highly dependent on the prevailing meteorological conditions, and not directly related to short-term changes in the emissions.

If the exposure reduction framework were based on an emissions ceiling which included the secondary precursors for PM, there would be co-benefits in reducing ozone concentrations. Such an approach is set out for both Options 1 and 4, and would also need to be included within Option 2 (with or without target reductions). A possible exposure reduction metric for ozone would be to establish an Air Quality Index across the jurisdictions (similar to that already operating in NSW) with a requirement for annual reporting.

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APPENDIX A

Monitoring Approach Analysis – Defining Average Exposure

This appendix sets out the sites used to demonstrate the sensitivity of the quoted average to the number of sites averaged. The analysis is based on randomly selecting from one through to 26 sites to average and doing this on 200 occasions. The notional 'true' average is taken to be the average of the 26 sites. For the purposes of this analysis sites with $PM_{2.5}$ concentrations measured in 2010 were selected, irrespective of site type and monitoring method, (which are not relevant for this indicative analysis). The sites summarised in Table A.1 were used for the analysis.

Table A.1: Monitoring approach analysis –monitoring stations used in the analysis of number of station averages and sensitivities

JURISDICTION	REGION	MONITORING STATION
VICTORIA	PORT PHILLIP	ALPHINGTON
		FOOTSCRAY
QUEENSLAND	GLADSTONE	SOUTH GLADSTONE
		CLINTON
		TARGINIE (SWANS ROAD)
		BOAT CREEK
		BOYNE ISLAND
	SOUTH EAST QUEENSLAND	WYNNUM
		WOOLLOONGABBA
		SOUTH BRISBANE
		ROCKLEA - SITE 3
		SPRINGWOOD
WESTERN AUSTRALIA	WESTERN AUSTRALIA	BUNBURY
		BUSSELTON
		CAVERSHAM
		DUNCRAIG
		QUINNS ROCK
		SOUTH LAKE
NEW SOUTH WALES	SYDNEY CENTRAL-EAST	CHULLORA
	SYDNEY NORTH-WEST	EARLWOOD
	SYDNEY SOUTH-WEST	LIVERPOOL
	SYDNEY NORTH-WEST	RICHMOND
	LOWER HUNTER	BERESFIELD
		WALLSEND
	ILLAWARRA	WOLLONGONG
AUSTRALIAN CAPITAL TERRITORY	CANBERRA	MONASH

The sites used in the analysis of the year-to-year variations in concentrations are set out in Table A.2. These sites were selected for the analysis as there was data available for each of the 12 years from 1999 to 2010.

Table A.2: Monitoring approach analysis – monitoring stations used in the analysis of inter-annual variability

JURISDICTION	REGION	MONITORING STATION
VICTORIA	PORT PHILLIP	ALPHINGTON
QUEENSLAND	SOUTH EAST QUEENSLAND	SPRINGWOOD
WESTERN AUSTRALIA	WESTERN AUSTRALIA	BUNBURY
		CAVERSHAM
		DUNCRAIG
NEW SOUTH WALES	LOWER HUNTER	WALLSEND
	ILLAWARRA	WOLLONGONG

APPENDIX B

Jurisdictional Questionnaire Responses

B.1 NSW

B.1.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

SUMMARY OF AMBIENT PM MONITORS

NSW air monitoring strategy is detailed here:

http://www.environment.nsw.gov.au/air/nepm/index.htm

PM monitoring data are published online by NSW OEH and are available for public download here:

http://www.environment.nsw.gov.au/AQMS/hourlydata.htm

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

PM monitoring stations in NSW are provided in Table B.1.

Table B.1: NSW PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Sydney										
Blacktown	PM_{10}	TEOM	1992	2004	Trend	GRUB	33° 46' 20"	150° 54' 18"	Residential area	
Bringelly	PM_{10}	TEOM	1992	Present	Trend	GRUB	33° 55' 10"	150° 45' 40"	Residential area	
Central Coast	PM_{10}	TEOM	TBA		Campaign	GRUB			Residential area	
Chullora	PM_{10}	TEOM	2003	Present	Trend	GRUB	33° 53' 38"	151° 02' 43"		
	$PM_{2.5}$	TEOM								
Earlwood	$PM_{2.5}$	TEOM	1998	Present	Campaign	GRUB	33° 55' 04"	151° 08' 05"		Does not meet a number of the siting compliance standards: No clear sky and <120°, less than 20m from trees
Liverpool	PM_{10}	TEOM	1990	Present	Campaign	GRUB	33° 55' 58"	150° 54' 21"	Residential area	Does not meet a number of the siting compliance standards: No clear sky and <120°
	$PM_{2.5}$	TEOM								
Macarthur	PM_{10}	TEOM	2003	Present	Trend	GRUB	34° 04' 16"	150° 46' 54"	Residential area	
Oakdale	PM_{10}	TEOM	1996	Present	Performance	GRUB – used to assess NEPM compliance	34° 03' 11"	150° 29' 50"	Rural area	
Prospect	PM_{10}	TEOM	2007	Present	Trend	GRUB	33° 47' 41"	150° 54' 45"		
Richmond	PM_{10}	TEOM	1992	Present	Trend	GRUB	33° 37' 06"	150° 44' 45"	Residential area	
	$PM_{2.5}$	TEOM								
Rozelle	PM_{10}	TEOM	1978	Present	Trend	GRUB	33° 51' 57"	151° 09' 45"	Residential area	Does not meet a number of the siting compliance standards: No clear sky and <120°, less than 20m from trees
St Marys	PM_{10}	TEOM	Pre-1994	Present		GRUB	33° 47' 50"	150° 45' 57"		
Vineyard	PM_{10}	TEOM	1996	Present		GRUB	33° 39' 28"	150° 50' 48"		
Lower Hunter										

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Newcastle	PM_{10}	TEOM	1992	Present	Trend	GRUB	32° 55' 57"	151° 45' 30"	CBD	
Beresfield	PM_{10}	TEOM	1993	Present	Campaign	GRUB	32° 47' 54"	151° 39' 36"	Semi-rural area	
	$PM_{2.5}$	TEOM								
Wallsend	PM_{10}	TEOM	1994	Present		GRUB	32° 53' 46"	151° 40' 09"		
	$PM_{2.5}$	TEOM	1992	Present	Campaign	GRUB				
Illawarra										
Albion Park	PM_{10}	TEOM	1978	2005	Performance	GRUB – used to assess NEPM compliance			Semi-rural area	Decommissioned
Albion Park South	PM_{10}	TEOM	2005	Present	Performance	GRUB – used to assess NEPM compliance	34° 34' 50"	150° 46' 54"		
Kembla Grange	PM_{10}	TEOM	1994	Present	Performance	GRUB – used to assess NEPM compliance	34° 28' 35"	150° 49' 03"	Residential area	
Wollongong	PM_{10}	TEOM	1993	Present	Trend	GRUB	34° 25' 07"	150° 53' 11"	CBD	
	$PM_{2.5}$	TEOM								
Regional NSW										
Albury	PM_{10}	TEOM	2000	Present	Campaign	Population exposure - rural	36° 03' 06"	146° 58' 27"	Rural area	
Bathurst	PM_{10}	TEOM	2000	Present	Campaign	Population exposure – rural	33° 24' 12"	149° 34' 24"	Rural area	
Dubbo	PM_{10}	TEOM	dependent on results		Campaign	Population exposure – rural			Rural area	
Lismore	PM_{10}	TEOM	dependent on results		Campaign	Population exposure			Rural area	

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Orange	PM_{10}	TEOM	dependent on results		Campaign	Population exposure n			Rural area	
Tamworth	PM_{10}	TEOM	2000	Present	Campaign	Population exposure - rural	31° 06' 38"	150° 54' 51"	Rural area	- Does not meet a number of the siting compliance standards: less than 20m from trees - Site operated in collaboration with local council
Wagga Wagga	PM_{10}	TEOM	2001	Present	Campaign	Population exposure - rural	35° 07' 02"	147° 22' 35"	Rural area	Does not meet a number of the siting compliance standards: less than 20m from trees
Upper Hunter										
Merriwa	PM_{10}	TEOM	2012	Present					Rural area – coal mining	The Upper Hunter monitoring network was established to monitor PM levels in the Upper Hunter region. The region is heavily influenced by coal mining PM emissions.
Wybong	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Muswellbrook	PM_{10}	TEOM	2010	Present					Rural area – coal mining	
	$PM_{2.5}$	BAM	2010	Present					Rural area – coal mining	
Muswellbrook NW	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Aberdeen	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Camberwell	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
	$PM_{2.5}$	BAM	2011	Present					Rural area – coal mining	
Jerrys Plains	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Warkworth	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Maison Dieu	PM_{10}	TEOM	2011	Present					Rural area – coal mining	

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Singleton	PM_{10}	TEOM	2010	Present					Rural area – coal mining	
	$PM_{2.5}$	BAM	2010	Present					Rural area – coal mining	
Singleton NW	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Singleton South	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Bulga	PM_{10}	TEOM	2011	Present					Rural area – coal mining	
Mt Thorley	PM_{10}	TEOM	2011	Present					Rural area – coal mining	

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade

Performance stations - located at a site for at least five years and used to evaluate against the NEPM

Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition (NSW OEH, 2011) http://www.environment.nsw.gov.au/air/nepm/summary.htm

B.1.2 Emissions Inventory

If an emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?

- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

1. What methodology is undertaken?

The NSW air emissions inventory uses emission estimation methodologies as follows:

- *ARB's Emissions Inventory, Area-Wide Source Methodologies, Index of Methodologies by Major Category* (CARB, 2008);
- *EMEP/EEA air pollutant emission inventory guidebook 2009* (EEA, 2009);
- *National Pollutant Inventory Emission Estimation Technique Manuals* (NEPC, 2012);
- *USEPA AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources* (USEPA, 1995);
- *USEPA Emission Inventory Improvement Program, EIIP Technical Report Series, Volumes 1-10* (USEPA, 2007);
- *USEPA 2008 National Emissions Inventory Data* (USEPA, 2011a); and
- *USEPA Nonroad Engines, Equipment, and Vehicles* (USEPA, 2011b).

Detailed information about emission estimation methodologies is available as follows:

- http://www.environment.nsw.gov.au/air/airinventory.htm
- Biogenic-geogenic http://www.environment.nsw.gov.au/resources/air/tr3aei077.pdf

- Commercial http://www.environment.nsw.gov.au/resources/air/tr4aei078.pdf
- Domestic-Commercial http://www.environment.nsw.gov.au/resources/air/tr5aei079.pdf
- Industrial http://www.environment.nsw.gov.au/resources/air/tr6aei0710.pdf
- Off-Road Mobile http://www.environment.nsw.gov.au/resources/air/tr7aei0711.pdf
- On-Road Mobile http://www.environment.nsw.gov.au/resources/air/tr8aei0713.pdf

The Emissions Data Management System (EDMS v1.0) (DECC, 2007) is an overarching air emissions inventory database that links to individual source-specific databases comprising all the data necessary to service policy and technical related queries. The EDMS uses the Microsoft® SQL Server 2005™ relational database management system (Microsoft, 2008) which is a comprehensive, integrated data management and analysis software package.

CARB (2008), *ARB's Emissions Inventory, Area-Wide Source Methodologies, Index of Methodologies by Major Category*, California Air Resources Board, 1001 "I" Street, P.O. Box 2815 Sacramento, CA 95812, USA.
http://www.arb.ca.gov/ei/areasrc/index0.htm

DECC (2007), *Technical Report No. 9, Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, Emissions Data Management System (EDMS v1.0): User's Manual,* Department of Environment and Climate Change NSW, Sydney, NSW 2000, Australia.
http://www.environment.nsw.gov.au/resources/air/tr9aei08181.pdf

EEA (2009), *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, European Environment Agency, Kongens Nytorv 6, DK - 1050 Copenhagen K, Denmark.
http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/#

Microsoft (2008), Microsoft® SQL Server 2005™. web page last accessed on 17th March 2008.
http://www.microsoft.com/sql/default.mspx

NEPC (2012), *National Pollutant Inventory, Emission Estimation Technique Manuals,* Environment Protection & Heritage Council, Level 5, 81 Flinders Street, Adelaide, SA 5000, Australia.
http://www.npi.gov.au/publications/emission-estimation-technique/index.html

USEPA (1995), *AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, Technology Transfer Network, Clearinghouse for Inventories & Emissions Factors, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, USA.
http://www.epa.gov/ttn/chief/ap42/index.html

USEPA (2007), *Emission Inventory Improvement Program, EIIP Technical Report Series, Volumes 1-10*, Technology Transfer Network, Clearinghouse for Inventories & Emissions Factors, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, USA.
http://www.epa.gov/ttn/chief/eiip/techreport/

USEPA (2011a), *2008 National Emissions Inventory Data*, Technology Transfer Network, Clearinghouse for Inventories & Emissions Factors, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, USA.
http://www.epa.gov/ttn/chief/net/2008inventory.html#inventorydoc

USEPA (2011b), *Nonroad Engines, Equipment, and Vehicles*, Transportation and Air Quality, United States Environmental Protection Agency, Office of Transportation and Air Quality, 1200 Pennsylvania Avenue, NW Washington, DC 20460, USA.
http://www.epa.gov/nonroad/

2. Which pollutants are included?

The NSW air emissions inventory includes over 850 substances, which include:

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

3. What areas are covered (geographic area and sources)?

The NSW air emissions inventory is a detailed listing of pollutants discharged into the atmosphere by each source type during a given time period and at a specific location. The study area covers 57,330 km^2, which includes the greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR).

The GMR, Sydney, Newcastle and Wollongong regions are shown in Figure B.1. Approximately 75% of the NSW population resides in the GMR (approximately 5.3 million people in 2008).

Figure B.1: Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong regions

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

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

Air emissions data can be presented either for the GMR, Sydney, Newcastle or Wollongong regions, or each of the local government areas (LGAs) within the GMR. Emissions vary by month, weekday/weekend day and hour of the day, and can be presented on an annual, monthly, daily or hourly basis.

4. How current is inventory data?

The NSW air emissions inventory data currently published on the OEH web site is for the 2003 calendar year (DECC, 2007). OEH has prepared an inventory for the 2008 calendar year (OEH, 2012), which will be published in the first half of 2012.

DECC (2007)*, Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2003 Calendar Year,* Department of Environment and Climate Change NSW, Sydney, NSW 2000, Australia.
http://www.environment.nsw.gov.au/air/airinventory.htm

OEH (2012)*, Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2008 Calendar Year,* Department of Environment and Climate Change NSW, Sydney, NSW 2000, Australia. In Press.

5. How often inventory is updated?

The NSW air emissions inventory has been prepared for the 1992 (Carnovale et. al., 1996), 2003 and 2008 calendar years. OEH aims to update the inventory every 5 years.

Carnovale, F., Tilly, K., Stuart, A., Carvalho, C., Summers, M. and Eriksen, P. (1996), Metropolitan Air Quality Study – Air Emissions Inventory, Environment Protection Authority of Victoria, April 1996.

6. What plans (if any) are there for inventory upgrade and improvements?

OEH plans to update the NSW air emissions inventory for the 2013 calendar year. OEH continues to scan the literature and use state-of-the-art science, techniques, data and software. For example, the need for improvement in natural emissions has been identified, which includes volatile organic compounds (VOC) from vegetation using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) (Guenther et. al., 2006), oxides of nitrogen (NOx) from lightening (Radian, 1996).

Guenther, A., T. Karl, P. Harley, C. Wiedinmyer, P. Palmer, and C. Geron (2006), *Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature)*, Atmos. Chem Phys., 6, 3181- 3210, 2006.
http://bai.acd.ucar.edu/Megan/index.shtml

Radian (1996), *Biogenic Sources Preferred Methods, EIIP Technical Report Series Volume V, Emission Inventory Improvement Program*, Radian Corporation, Post Office Box 13000, Research Triangle Park, NC 27709, USA.
http://www.epa.gov/ttn/chief/eiip/techreport/volume05/v01.pdf

7. What is the current use of the inventory by yourselves and whoever you may pass the information on to?

As part of its role in air quality management, OEH uses the NSW air emissions inventory in a variety of ways, including:

- Policy development – examples include:

    - Estimating the effectiveness of implementing best practice measures at coal mine in NSW

  http://www.environment.nsw.gov.au/air/coalminingNSW.htm
  http://www.environment.nsw.gov.au/resources/air/KE1006953volumeI.pdf
  http://www.environment.nsw.gov.au/resources/air/KE1006953volumeII.pdf

    - Potential measures to reduce pollution from NSW ports

  http://www.environment.nsw.gov.au/air/ports.htm
  http://www.environment.nsw.gov.au/resources/air/PortsPreliminaryStudy.pdf

- Regulation – examples include:

    - Protection of the Environment Operations (Clean Air) Regulation 2010 Regulatory Impact Statement

  http://www.environment.nsw.gov.au/air/poeocleanair.htm
  http://www.environment.nsw.gov.au/resources/air/10504caris.pdf

- Economic analysis – examples include:

    - Cost curves for abatement of air emissions

  http://www.environment.nsw.gov.au/air/costcurves.htm
  http://www.environment.nsw.gov.au/resources/air/CostCurveAirEmissionRedn.pdf

- Environmental reporting

    - New South Wales State of the Environment 2009

  http://www.environment.nsw.gov.au/soe/soe2009/
  http://www.environment.nsw.gov.au/soe/soe2009/chapter4/

- Air quality modelling – examples include:

    - State of Knowledge: Ozone

  http://www.environment.nsw.gov.au/resources/aqms/10577sokozone.pdf

8. Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

Information about the NSW air emissions inventory is included in response to Questions 1 to 7.

B.1.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

1. Please provide current population data for your jurisdiction (if available)
    - Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
    - Statistical Local Areas (SLAs) population data

Data included in Excel spreadsheet 2006_2036_Gridded_Population.xls.

2. Please also provide supporting information for this data in terms of:
    - How current is the population data?
    - What methods were employed to gather this data?

References included in Excel spreadsheet 2006_2036_Gridded_Population.xls.

B.1.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

1. OEH undertakes regional air quality modelling using TAPM-CTM.

2. OEH does not currently simulate regional PM, work has been on photochemical pollution.

4. OEH has a team of four modellers working on regional air quality modelling.

B.2 VICTORIA

B.2.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://www.epa.vic.gov.au/air/monitoring/monitoring_reports.asp

PM monitoring stations in Victoria are provided in Table B.2.

Table B.2: Victoria PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/OPERATOR	COMMENTS
Port Phillip										
Alphington	PM_{10}	TEOM	Dec-1994	Present	Trend - GRUB	Residential/light industry	37° 46′ 42.4″ S	145° 1′ 49.9″ E	EPA Victoria	Trees within 20m of site
	$PM_{2.5}$	Gravimetric Reference method	Jul-2002							
	$PM_{2.5}$	TEOM	Dec-1996							
Box Hill	PM_{10}	TEOM	Apr-1998	Present	Trend	Residential	37° 49′ 44.0″ S	145° 7′ 56.9″ E	EPA Victoria	
Brighton	PM_{10}	TEOM	Dec-1996	Present	Performance - Population average	Residential	37° 54′ 48.8″ S	144° 59′ 52.7″ E	EPA Victoria	
	$PM_{2.5}$	TEOM	Dec-1996	Sep-2002						
Dandenong	PM_{10}	TEOM	Apr-1998	Present	Performance - Population average	Light industry	37° 59′ 8.9″ S	145° 11′ 55.1″ E	EPA Victoria	
Deer Park	PM_{10}	TEOM	Jul-2006	Present	Trend	Residential	37° 45′ 22.0″ S	144° 45′ 56.0″ E	EPA Victoria	
Footscray	PM_{10}	TEOM	Nov-1996	Present	Trend - GRUB	Industrial/residential	37° 48′ 17.2″ S	144° 52′ 22.1″ E	EPA Victoria	
	$PM_{2.5}$	Gravimetric Reference method	Jul-2002							
	$PM_{2.5}$	TEOM	Nov-1996							
Geelong South	PM_{10}	TEOM	Sep-2002	Present	Trend - GRUB	Light industry/residential	38° 10′ 25.0″ S	144° 22′ 12.8″ E	EPA Victoria	
Mooroolbark	PM_{10}	TEOM	May-2002	Present	Performance - Population average	Residential	37° 46′ 29.7″ S	145° 19′ 42.2″ E	EPA Victoria	
Richmond	PM_{10}	TEOM	Jan-2001	Present	Performance - GRUB	Residential	37° 49′ 24.2″ S	145° 0′ 14.7″ E	EPA Victoria	Trees within 20m of site
	$PM_{2.5}$	TEOM	Jan-2001	Jul-2002						

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/OPERATOR	COMMENTS
RMIT (CBD)	PM_{10}	TEOM	Oct-2002	Oct-2006	Trend - GRUB	CBD	37° 48′ 6.1″ S	144° 57′ 52.3″ E	EPA Victoria	
Latrobe Valley										
Moe	PM_{10}	TEOM	Nov-2002	Oct-2009	Performance - GRUB	Residential	38° 11′ 1.9″ S	146° 15′ 28.8″ E	EPA Victoria	Trees within 20m of site
Traralgon	PM_{10}	TEOM	Nov-2002	Present	Trend - GRUB	Residential	38° 11′ 39.1″ S	146° 31′ 52.6″ E	EPA Victoria	

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition

Note that Box Hill and Deer Park are non-NEPM stations

Rural stations have been omitted from this analysis as the monitoring at those locations typically covered a 12 month period which crossed two calender years, meaning the requirement for 75% data capture was not met in either year.

B.2.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?
- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

The Victoria air emissions inventory is a detailed listing of pollutants discharged into the atmosphere by each source type during a given time period and at a specific location. The study area covers the whole state and includes the airsheds of Port Phillip, Latrobe Valley, Bendigo and Mildura.

The region is shown in Figure B.2. The population of the region was estimated to be 5.1 million people in 2006.

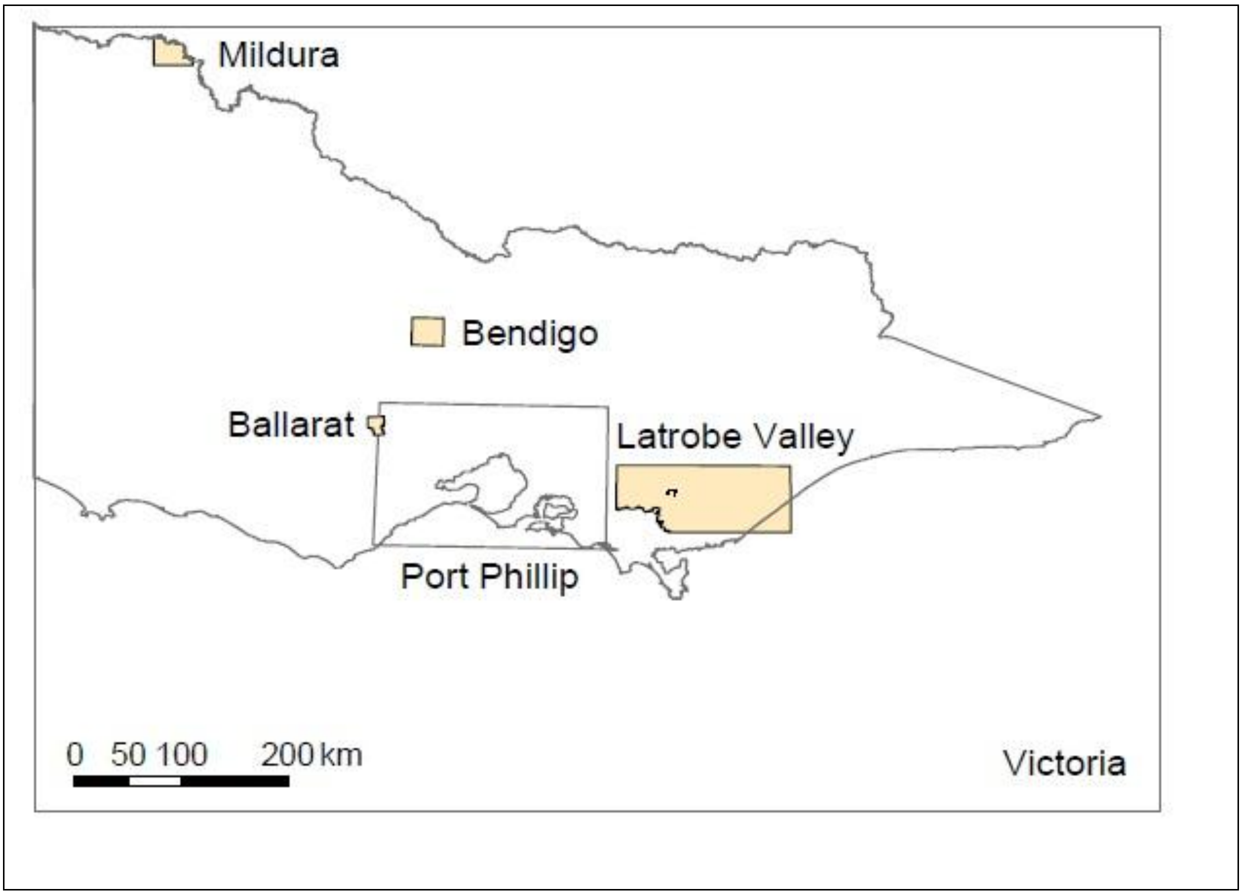

Figure B.2: Coverage of Victoria Air Emissions Inventory (Delaney & Marshall, 2011)

The inventory includes emissions from biogenic/geogenic (i.e. natural) and anthropogenic (i.e. human) derived sources as outlined below:

- Industry: all large industrial sources
- Transport: all on-road and off-road land vehicles, shipping, rail and air transport
- Solid fuel combustion: burning of coal, wood, briquettes etc
- Subthreshold fuels: fuel combustion by smaller industries (not reported to NPI)
- Fires: bushfires and planned burns
- Road dust: re-suspended dust associated with paved roads
- Windblown dust: windblown dust from agricultural lands and unpaved roads
- Biogenic: natural emissions from vegetation and soils
- Commercial/domestic sources: all other minor source types (lawnmowing, surface coatings, etc.)

The inventory includes predominately NPI substances as outlined below (Delaney & Marshall, 2011):

- Criteria pollutants (i.e. carbon monoxide (CO), lead, oxides of nitrogen (NO_x), PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2) and volatile organic compounds (VOCs))
- 26 inorganic species and 48 organic species including organic air toxics, such as benzene,toluene, xylene and formaldehyde.

Emissions vary by season, weekday/weekend day and hour of the day, and can be presented on an annual, monthly, daily or hourly basis.

The air emissions inventory for Victoria is compatible with regional air dispersion models.

B.2.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

2006 Census Data used (inventories updated in line with the census to make use of the census data)

- Population density obtained by dividing the population of a census collection district by its area
- The population densities were intersected with the inventory grids using GIS software to calculate the population density in each inventory grid cell
- These gridded population densities are multiplied by the area of the grids to calculate gridded populations

B.2.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

Multi-year collaborative project underway with CSIRO to estimate future concentrations of a range of air pollutants in Victoria, with an initial focus on the city of Melbourne (Walsh et al. 2011).

Air Toxics modelling

Not so much work done specifically with regional PM modelling as we only have a low confidence in 2006 emissions estimates for PM emissions from windblown dust

REFERENCES

Delaney, W. and Marshall, A. 2011, 'Victorian Air Emissions Inventory for 2006', *20th International Clean Air and Environment Conference*, Auckland, 5-8 July 2011, Clean Air Society of Australia & New Zealand, Eastwood, NSW, Australia

Walsh, S., Middleton, M., Cope, M., Delaney, W. and Metzeling, L., 'Predicting Future Air Quality In Victoria: Literature Review And Project Design', *20th International Clean Air and Environment Conference*, Auckland, 5-8 July 2011, Clean Air Society of Australia & New Zealand, Eastwood, NSW, Australia

B.3 QUEENSLAND

B.3.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

Please attach any information that may assist this study.

SUMMARY OF AMBIENT PM MONITORS

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://www.derm.qld.gov.au/environmental_management/air/air_quality_monitoring/search.php

PM monitoring stations in Queensland are provided in Table B.3.

PM data in Queensland provided in File: QLD Air Quality Monitoring Data rev 1.2.xls

Table B.3: Queensland PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/ OPERATOR	COMMENTS
Mt Isa										
The Gap	PM10	TEOM 1400	2009	Present	Population average	Residential	-20.7264	139.4977	DSITIA	Not included in 2009 Monitoring report
Townsville										
Townsville Port	PM10	TEOM 1400	1994	Present		Industrial	-19.2502	146.8304	Port of Townsville Limited	- Not included in 2009 Monitoring report - Site offline during 2011 due to cyclone damage/site relocation
South Townsville	PM10	High volume sampler	1994	2004		Industrial/residential	-19.2605	146.8244	DSITIA	
Garbutt	PM10	High volume sampler	1994	2004		Industrial/commercial	-19.2671	146.7678	DSITIA	
Pilmico	PM10	TEOM 1400	2004	Present	Campaign - Population average	Residential	-19.2871	146.7813	DSITIA	Major roads, industry (port operations, metals processing)
Ayr										
Ayr	PM10	TEOM 1400	2011	Present		Residential	-19.5839	147.4059	DSITIA	Agricultural burning
Mackay										
West Mackay	PM10	TEOM 1400	1998	2010	Performance - GRUB	Light industry/residential	-21.1472	149.1604	DSITIA	Agricultural burning
West Mackay	PM10	TEOM 1400	2010	Present	Performance - GRUB	Rural/residential	-21.1595	149.1549	DSITIA	Agricultural burning
Moranbah										
Moranbah	PM10	TEOM 1400	2011	Present		Residential/mining	-21.9983	148.0708	DSITIA	Coal mining
Rockhampton										
Parkhurst	PM10	High volume sampler	1998	2004		Residential/industry	-23.3103	150.5215	DSITIA	
Gladstone										
Barney Point	PM10	High volume sampler	1993	2004		Industry/residential	-23.8510	151.2688	DSITIA	

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/ OPERATOR	COMMENTS
South Gladstone	PM10	TEOM 1400	2000	2008	Trend - GRUB	Industry/residential	-23.8618	151.2691	DSITIA	Major roads, industry (power generation, metals processing) Not included in 2009 Monitoring report
	PM10	FDMS TEOM 1405 dichotomous	2009	Present	Trend - GRUB	Industry/residential	-23.8626	151.2705		
	PM2.5									
Clinton	PM10	High volume sampler	1993	2004		Airport/residential	-23.8701	151.2216	DSITIA	Not included in 2009 Monitoring report
	PM10	TEOM 1400	2001	2009		Airport/residential				
	PM10	FDMS TEOM 1405 dichotomous	2009	Present		Airport/residential				
	PM2.5									
Targinie (Swans Rd)	PM10	FDMS TEOM 1405 dichotomous	2009	Present		Rural/industrial	-23.7744	151.1055	DSITIA	Not included in 2009 Monitoring report
	PM2.5									
Targinie (Stupkin L)	PM10	TEOM 1400	2001	2008		Rural/industrial	-23.7917	151.1074	DSITIA	
Boat Creek	PM10	FDMS TEOM 1405 dichotomous	2008	Present		Rural/industrial	-23.8199	151.1538	DSITIA	Not included in 2009 Monitoring report
	PM2.5									
Boyne Island	PM10	FDMS TEOM 1405 dichotomous	2008	Present		Residential area	-23.9408	151.3507	DSITIA	Not included in 2009 Monitoring report
	PM2.5									
South East Queensland										
Mountain Creek	PM10	TEOM 1400	2001	Present	Performance - GRUB	Residential	-26.6917	153.1038		Major roads, forestry/agriculture and burning
Eagle Farm	PM10	High volume sampler	1994	2003		Industrial	-27.4383	153.0798	DSITIA	
	PM10	TEOM 1400	1998	2005						
Pinkenba	PM10	High volume sampler	1987	1994		Industrial	-27.4310	153.1160	DSITIA	
Pinkenba	PM10	TEOM 1400	2002	Present		Industrial	-27.4205	153.1208	BP Refineries	Not included in 2009 Monitoring report
Wynnum	PM10	TEOM 1400	1999	2002		Industry/residential	-27.4309	153.1615	DSITIA	
	PM10	TEOM 1400	2005	Present		Industry/residential	-27.4296	153.1581	Caltex Refineries	Not included in 2009 Monitoring report
	PM2.5	TEOM 1400	2008	Present						

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/ OPERATOR	COMMENTS
Brisbane CBD	PM10	TEOM 1400	2005	Present		CBD	-27.4774	153.0281	DSITIA	Not included in 2009 Monitoring report
Woolloongabba	PM10	High volume sampler	1986	2004		Roadside	-27.4975	153.0350	DSITIA	- Not included in 2009 Monitoring report - Traffic - Site offline April 2007 to April 2008
	PM10	TEOM 1400	1998	2007						
	PM10	FDMS TEOM 1405 dichotomous	2008	Present						
	PM2.5									
South Brisbane	PM10	TEOM 1400	2002	2008		Roadside	-27.4848	153.0321	DSITIA	- Not included in 2009 Monitoring report - Traffic
	PM10	FDMS TEOM 1405 dichotomous	2009	Present						
	PM2.5									
Rocklea	PM10	High volume sampler	1986	1998	Trend - GRUB	Light industrial/residential	-27.5415	153.0091	DSITIA	- Major roads - Site offline Jan 2011 to April 2012
	PM10	High volume sampler	1999	2004			-27.5441 (to June 2007) -27.5358 (from June 2007)	152.9987 (to June 2007) 152.9934 (from June 2007)		
	PM10	TEOM 1400	1996	Oct 2009						
	PM2.5	TEOM 1400	1998	Jun 2009						
	PM2.5	FDMS TEOM 1400	Feb 2008	Oct 2009						
	PM10	FDMS TEOM 1405 dichotomous	Oct 2009	Present						
	PM2.5									
	PM2.5	Partisol sampler 2025	2004	Present						
Darra	PM10	High volume sampler	1987	1999		Industrial	-27.5623	152.9527	DSITIA	Industry (cement manufacture)
Springwood	PM10	TEOM 1400	1999	Present	Performance - Population average	Residential	-27.6125	153.1356	DSITIA	Major roads
	PM2.5	TEOM 1400								
	PM2.5	Partisol sampler 2025	2004	2008						
Arundel	PM10	FDMS TEOM 1405 dichotomous	2010	2011	Campaign - Population average	Residential	-27.9441	153.3656	DSITIA	Not included in 2009 Monitoring report
	PM2.5									
Helensvale	PM10	TEOM 1400	1998	2002		Residential	-27.9191	153.3366	DSITIA	

MONITORING SITE	POLLUTANT	METHOD	START	END	PURPOSE	LOCATION	LATITUDE (SOUTH)	LONGITUDE (EAST)	OWNER/ OPERATOR	COMMENTS
Flinders View	PM10	TEOM 1400	1993	Present	Trend - GRUB	Industry/residential	-27.6528	152.7741	DSITIA	- Major roads, industry (coal fired power station) - Trees within 20m of site
Swanbank	PM10	TEOM 1400	2008	2009		Industry	-27.6523	152.8013	DSITIA	
North Toowoomba	PM10	TEOM 1400	2003	2010	Campaign - GRUB	Commercial/residential	-27.5504	151.9531	DSITIA	Major roads, solid fuel heaters
	PM2.5	TEOM 1400	2003	2007						

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition

B.3.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?

- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

SOUTH EAST QUEENSLAND REGION

Summary information on the south east Queensland air emissions inventory is available here:

http://www.derm.qld.gov.au/air/pdf/reports/air-emissions-inventory-seq.pdf

The south east Queensland air emissions inventory is a detailed listing of pollutants discharged into the atmosphere by each source type during a given time period and at a specific location. The study area covers 23,316 km^2 (land-based area), which includes the Sunshine Coast, Brisbane, Toowoomba and the Gold Coast regions, known collectively as the south east Queensland region (SEQR).

The SEQR is shown in Figure B.3. Approximately 70% of the Queensland population resides in the south east Queensland region (approximately 2.5 million people in 2000).

Figure B.3: Definition of South East Queensland region

The inventory includes emissions from biogenic (i.e. natural) and anthropogenic (i.e. human) derived sources as outlined below:

- Biogenic (e.g. bushfires, trees and soil)
- Commercial businesses (e.g. quarries, service stations and smash repairers)
- Domestic activities (e.g. house painting, lawn mowing and wood heaters)
- Industrial premises (e.g. oil refineries, power stations and steelworks)
- Off-road mobile (e.g. aircraft, railways and recreational boats)
- On-road mobile (e.g. buses, cars and trucks).

The inventory includes all criteria pollutants and grouped photochemical air pollutants required for photochemical modelling as outlined below:

- Criteria pollutants (i.e. carbon monoxide (CO), lead, oxides of nitrogen (NO_x), PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2) and volatile organic compounds (VOCs))
- Grouped organics (e.g. alkanes, terminal alkenes, mono-alkyl benzenes).

Notable emission sources that were not included in the 2000 SEQ air emissions inventory (in relation to PM) were:

- Marine aerosols; and
- Wheel generated dust.

Emissions vary by season (summer or winter), weekday/weekend day and hour of the day. The latest publicly available air emissions inventory for the south east Queensland region was published in 2004 and is based on activities that occurred in the calendar year 2000.

Queensland Department of Science, Information Technology, Innovation and the Arts is currently updating the SEQ air emissions inventory for all emission sources with completion be end of 2012.

B.3.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

Population data supplied as SLAs in the file 'SLA-QLD.xls'.

Description of data in file 'ABS Statistical Local Areas (ANZLIC).doc'. Data is obtained from Australian Bureau of Statistics and is based on the 2006 Census of Population & Housing

B.3.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

- Calmet/Calpuff and TAPM.
- No.
- Have capacity to undertake PM modelling incorporating secondary formation for SEQ and Gladstone.
- Resources limited to 1 person that can undertake regional dispersion modelling. Current priorities would need to be considered if Queensland were to reallocate these to PM modelling.

B.4 WESTERN AUSTRALIA

B.4.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

SUMMARY OF AMBIENT PM MONITORS

PM monitoring stations in Western Australia are provided in Table B.4. These stations are owned and operated by the WA Department of Environment and Conservation.

The annual average $PM_{2.5}$ concentrations are available in the annual Western Australia Air Monitoring Reports submitted to National Environment Protection Council (NEPC). The annual average PM_{10} concentrations are not routinely calculated.

Summary ambient air quality monitoring reports submitted to the NEPC are available at:
http://www.ephc.gov.au/taxonomy/term/34

The *2010 Western Australia Air Monitoring Report* (DEC, 2011) is available at:
http://www.dec.wa.gov.au/content/view/6945/2491/1/5/

Previous Western Australia Air Monitoring Reports are available at:
http://www.dec.wa.gov.au/content/view/6945/2491/

Table B.4: Western Australia PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Albany	PM_{10}	TEOM	2006	Present	Campaign	Population average	-35.011	117.88	Regional area	
Bunbury	PM_{10}	TEOM	1999	Present	Campaign	Population average	-33.3416	115.6433	Regional area	Does not meet a number of the siting compliance standards: 15m to small to medium eucalyptus trees present
	$PM_{2.5}$	TEOM	1997	Present	Trend	Population average	-33.3416	115.6433		
Busselton	$PM_{2.5}$	TEOM	2006	Present	Trend	Population average	-33.6482	115.352	Regional area	Does not meet a number of the siting compliance standards: 15m to small to medium eucalyptus trees present
Caversham	PM_{10}	TEOM	2004	Present	Performance	GRUB	-31.8758	115.9774	Metropolitan area	
	$PM_{2.5}$	TEOM	1994	Present	Performance	GRUB	-31.8758	115.9774		
Collie	PM_{10}	TEOM	2008	Present	DEC		-33.3599	116.1468	Regional area	
Duncraig	PM_{10}	TEOM	1996	Present	Trend	GRUB	-31.8264	115.7829	Metropolitan area	Does not meet a number of the siting compliance standards: No clear sky angle of 120°, 6m to medium trees and power pole present
	$PM_{2.5}$	TEOM	1995	Present	DEC		-31.8264	115.7829		
Geraldton	PM_{10}	TEOM	2005	Present	Campaign		-28.7695	114.6323	Regional area	
Quinns Rock	$PM_{2.5}$	TEOM	2006	Present	Trend	GRUB	-31.6779	115.6961	Metropolitan area	Does not meet a number of the siting compliance standards: 15m to small to medium trees and low scrub present
South Lake	PM_{10}	TEOM	2000	Present	Performance	GRUB	-32.1106	115.8348	Metropolitan area	Sited close to residential housing
	$PM_{2.5}$	TEOM	2006	Present	DEC		-32.1106	115.8348		Sited close to residential housing

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition

B.4.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?
- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

The Perth air emissions inventory was constructed in order to report emissions to the National Pollutant Inventory (NPI). The original Perth airshed emissions inventory was compiled for the year 1992, with a later update based on the 1998/1999 period (DEP, 2002). In addition to these inventories, a diffuse emissions study was undertaken by a consultant on behalf of DEC based on the 2004/2005 period. The study area covers 8,613 km^2, which includes the major population centre and emission sources in Western Australia. The Perth airshed is shown in Figure B.4. Approximately 70% of the Western Australia population resides in the Perth airshed (approximately 1.3 million people in 1998/1999).

The Perth air emissions inventory includes emissions from biogenic/geogenic (i.e. natural) and anthropogenic (i.e. human) derived sources as outlined below:

- Biogenics (e.g. bushfires, trees)
- Commercial businesses (e.g. dry cleaning and smash repairers)
- Domestic activities (e.g. lawn mowing, aerosols and solvents and wood heaters)
- Off-road mobile (e.g. aircraft, railways and recreational boats)
- On-road mobile (e.g. buses, cars and trucks).

Industrial emissions are reported to the National Pollutant Inventory (NPI) by individual industrial facilities.

The Perth air emissions inventory is considered to be sufficiently accurate for decision making under the NEPM (Ambient Air Quality). Various groups have validated the Perth air emissions inventory over time and the region was used as the demonstration region and validation of TAPM for the development of a screening procedure for the monitoring NO_2 and ozone for small to medium sized cities (CSIRO, 2001).

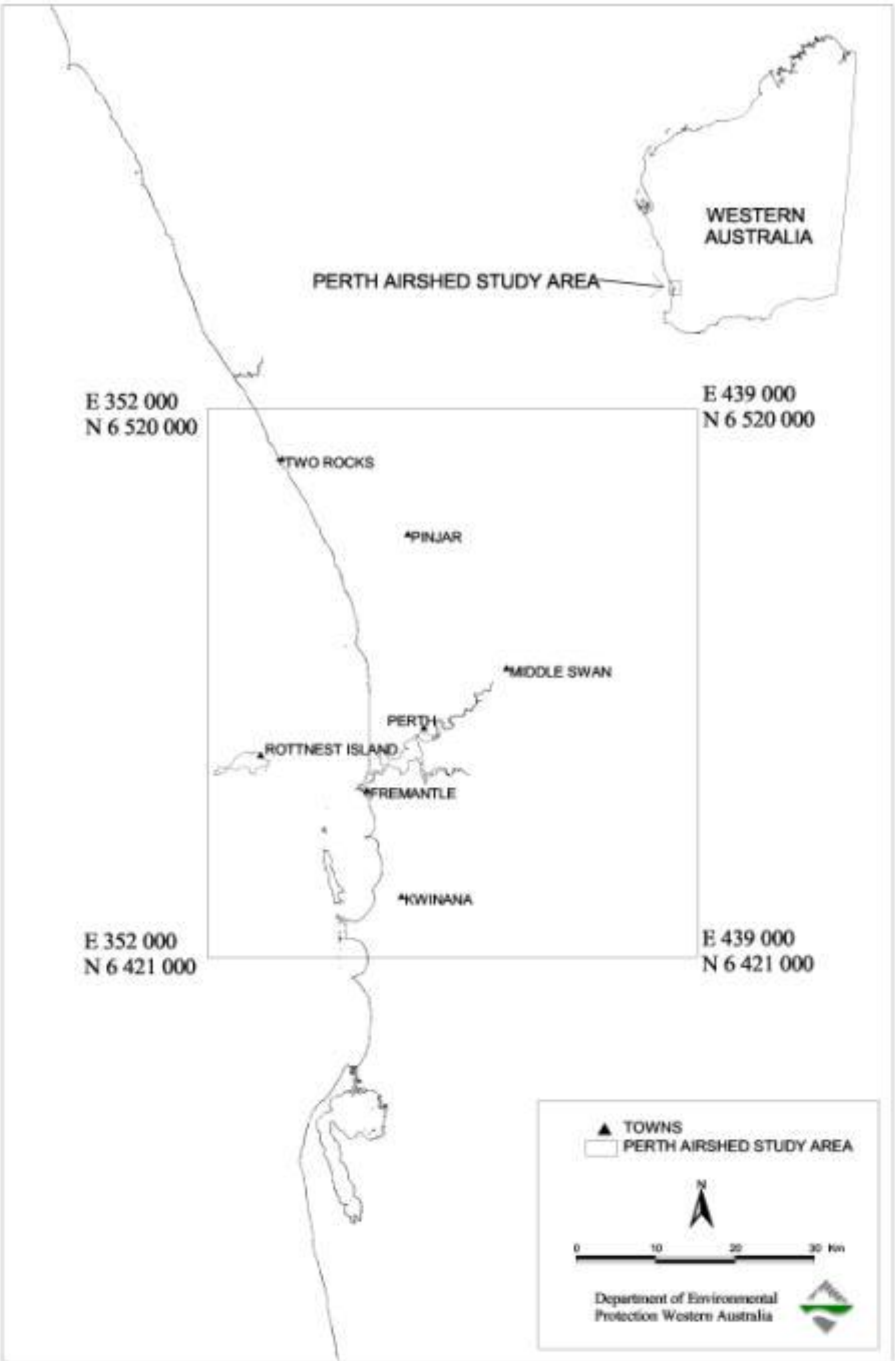

Figure B.4: Definition of Perth Airshed

The inventory includes emissions for a maximum of 90 air pollutants as outlined below:

- Criteria pollutants (i.e. carbon monoxide (CO), lead, oxides of nitrogen (NOx), PM10, PM2.5, sulfur dioxide (SO2) and volatile organic compounds (VOCs))
- Metal air toxics (e.g. antimony, arsenic, beryllium, chromium and nickel)
- Organic air toxics (e.g. benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), toluene and xylenes).

The *Perth Airshed Inventory Update 1998-1999, Technical Series 110* (DEP, 2002) is available at: http://www.dec.wa.gov.au/content/view/6945/2491/1/12/

Due to the rapidly increasing number of motor vehicles in the Perth metropolitan area, an update of the Perth vehicle emissions inventory has recently been completed based on the years 2006-2007. Lead, PM, SOx, NOx, VOCs (evaporative and exhaust), and greenhouse gases were included in the inventory. The vehicle emissions inventory is generally updated every five years. The vehicle kilometres travelled (VKT) map will be updated for the vehicle emissions inventory for 2011-2012. The inventory is provided to universities on request and the National Pollutant Inventory and may be used for background information in the development of airshed studies.

The *Perth Vehicle Emissions Inventory 2006-2007* (DEC, 2010) is available at:
http://www.dec.wa.gov.au/content/view/6945/2491/1/6/

B.4.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

WA Department of Environment and Conservation does not maintain population data. WA population data is available from the Australian Bureau of Statistics.

B.4.4 Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

Regional air dispersion modelling was previously conducted for the development of the Perth Air Quality Management Plan (2000). No regional PM modelling is currently routinely employed. WA Department of Environment and Conservation does not currently have the resources to undertake regional air dispersion modelling of PM.

B.5 SOUTH AUSTRALIA

It is noted that no response was received from South Australia. Data summarised in this section is from the public domain.

B.5.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

SUMMARY OF AMBIENT PM MONITORS

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://www.epa.sa.gov.au/environmental_info/air_quality/air_monitoring_and_modelling/monitoring_information

PM monitoring stations in the South Australia are provided in Table B.5.

Table B.5: South Australia PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Adelaide										
Elizabeth Downs	PM_{10}	TEOM	2002	Present	Performance	GRUB			Residential area	Does not meet a number of the siting compliance standards: not located 20m from trees
Netley	PM_{10}	TEOM		Present	Trend	GRUB			Residential/Light industrial area, heavy traffic	Does not meet a number of the siting compliance standards: not located 20m from trees
	$PM_{2.5}$	TEOM								
Kensington Gardens	PM_{10}	TEOM		Present	Trend	GRUB			Residential area	Does not meet a number of the siting compliance standards: No clear sky angle of 120 °, restricted airflow, 30m high gums at 10m, but clear aspect - thin, high canopy
Christie Downs	PM_{10}	TEOM		Present	Trend	GRUB			Residential area	Does not meet a number of the siting compliance standards: Boiler or incinerator located nearby
Spencer										
Pt Pirie, Oliver Street	PM_{10}	TEOM		Present	Trend	GRUB			Residential/industrial	
Pt Pirie, Frank Green Park	PM_{10}	TEOM		Present	Trend	GRUB			Residential/industrial	
Whyalla, Schulz Park	PM_{10}	TEOM		Present	Trend	GRUB			Residential/industrial	

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition

B.5.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?
- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

The South Australian air emissions inventory was constructed in order to report emissions to the National Pollutant Inventory (NPI). The emissions inventory is based on activity that occurred during the 1998/1999 period. The study area covers the five major regional areas of South Australia.

The South Australian air emissions inventory is shown in Figure B.5. Approximately 76% of the South Australia population resides in the study regions (approximately 1.1 million people in 1998/1999).

South Australia EPA also recently completed a gridded air emissions inventory for the entire state covering motor vehicle emissions. The base year for the study was 2006.

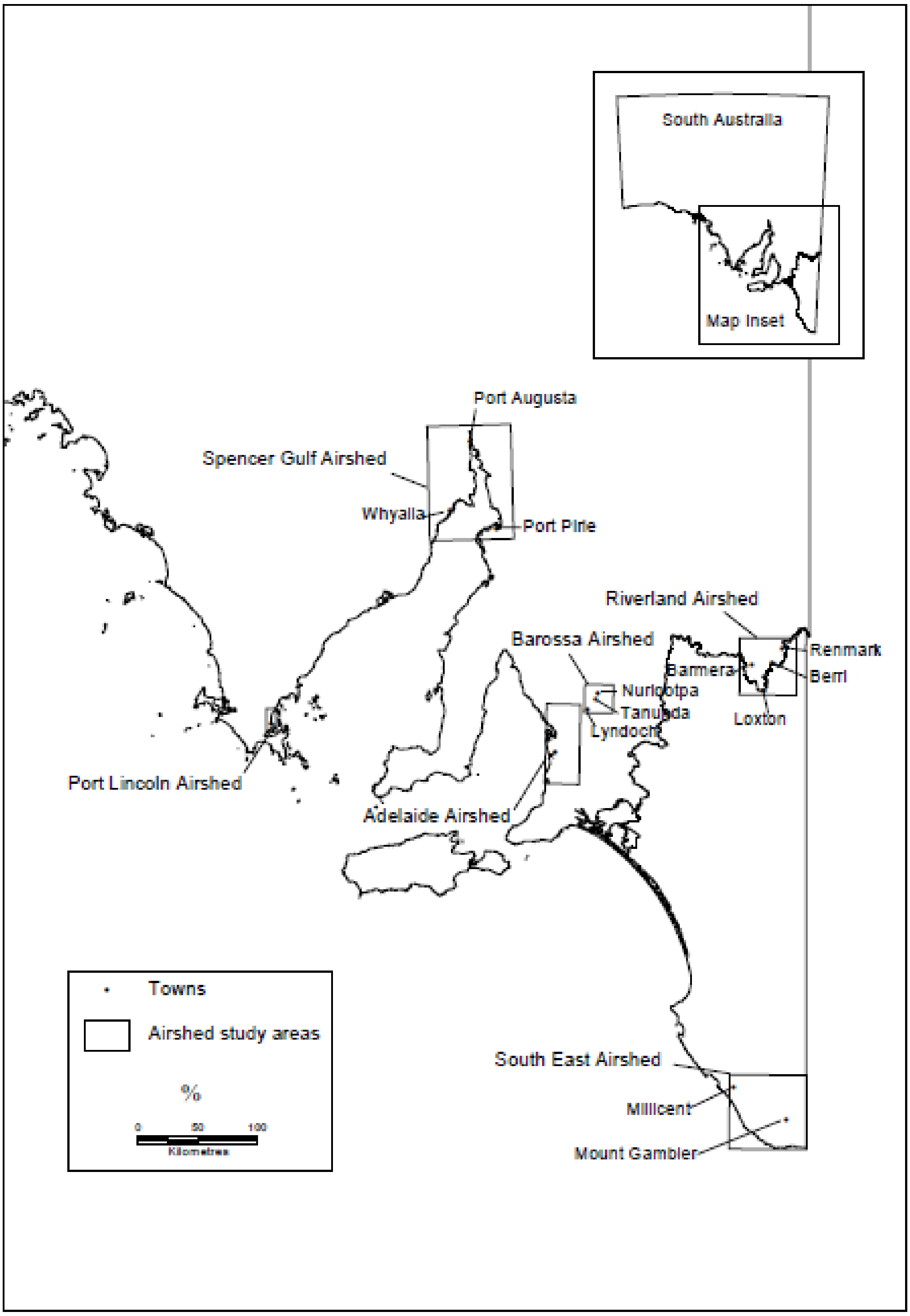

Figure B.5: Coverage of South Australia Air Emissions Inventory

The inventory includes emissions from anthropogenic (i.e. human) derived sources only. The following sources are included in the diffuse emissions inventory for South Australia:

- On-road mobile (e.g. buses, cars and trucks)
- Off-road mobile (e.g. aircraft, railways and recreational boats)
- Area based sources (service stations, paved roads, domestic fuel combustion)
- Sub-reporting threshold facilities (industrial and commercial facilities that do not report separately to the NPI)

Industrial emissions are reported to the National Pollutant Inventory (NPI) by individual industrial facilities.

In its present sate, the South Australian air emissions inventory is not suitable for regional air quality modelling. Several major sources (such as biogenics) are excluded and the air emissions inventory was not designed as with accurate spatial resolution. However, the recently updated motor vehicle emissions inventory was designed to be model ready.

The inventory includes over emissions for a maximum of 90 air pollutants as outlined below:

- Criteria pollutants (i.e. carbon monoxide (CO), lead, oxides of nitrogen (NO_x), PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2) and volatile organic compounds (VOCs))
- Metal air toxics (e.g. antimony, arsenic, beryllium, chromium and nickel)
- Organic air toxics (e.g. benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), toluene and xylenes).

B.5.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

No information provided.

B.5.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

No information provided.

B.6 AUSTRALIAN CAPITAL TERRITORY

B.6.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, E-BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://www.environment.act.gov.au/environment2/environment_protection_authority_legislation_and_policies/air_quality_monitoring_reports

PM monitoring stations in the Australian Capital Territory are provided in Table B.6.

Table B.6: ACT PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Monash	PM_{10}	BAM	2010	Present	Performance	GRUB – used to assess NEPM compliance	-35 25' 6.60''	149 5' 43.94''	Residential	
	PM_{10}	TEOM	2002	2008						
	$PM_{2.5}$	Partisol	2004	Present						
Civic	PM_{10}	BAM	2010	Present	Performance	GRUB – used to assess NEPM compliance	-35 17' 7.4''	149 7' 53.4''	CBD	Does not meet a number of the siting compliance standards: No clear sky angle <120°, restricted air flow, less than 20m from trees, not min distance from road/trffic, not min distance from support structure
	PM_{10}	Gravimetric Reference method	2002	2008						

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

B.6.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?
- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

No regional air emission inventory is available in the public domain beyond those emission estimates that are published on the NPI database.

B.6.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

We don’t have any of this info.

B.6.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

No modelling capability

B.7 TASMANIA

B.7.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

Please attach any information that may assist this study.

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://epa.tas.gov.au/epa/air-pollution-data

Specific data were supplied by Tasmania EPA.

PM monitoring stations in Tasmania are provided in Table B.7.

Table B.7: Tasmania PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Launceston										
Ti Tree Bend	PM_{10}	TEOM	2002	Present	Trend	GRUB			Light Industry	Does not meet a number of the siting compliance standards
	PM_{10}	Low Volume Air Samplers	2005	Present						
	$PM_{2.5}$	Low Volume Air Samplers	2005	Present						
Hobart										
New Town	PM_{10}	TEOM	2006	Present	Trend	GRUB			Residential	Does not meet a number of the siting compliance standards
	PM_{10}	Low Volume Air Samplers								
	$PM_{2.5}$	Low Volume Air Samplers								
Tamar										
Rowella (Level 1)	PM_{10}	Microcol air sampler		Present	NA	NA				- Monitoring sites not for NEPM - Developed by the Tasmanian Regional Planning and Development Council (RPDC) as part of the baseline environmental study required prior to construction and operation of proposed pulp mill and Longreach
Rowella (Level 2)	PM_{10}	TEOM	2006	Present	NA	NA				
	$PM_{2.5}$	TEOM			NA	NA				
Beauty Point	PM_{10}	Microcol air sampler		Present	NA	NA				
Deviot	PM_{10}	Microcol air sampler		Present	NA	NA				
Riverside	PM_{10}	Microcol air sampler		Present	NA	NA				
Tippogorrie Hills	PM_{10}	Microcol air sampler		Present	NA	NA				
Base-Line Air Network of EPA Tasmania (BLANkET Stations)										
Hobart	PM_{10}	Dustrak (TSI 8533 DRX)	2009/2010	Present		Baseline air quality				- Monitoring sites not for NEPM - Repetition of
	$PM_{2.5}$	Dustrak (TSI								

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
		8533 DRX)								monitoring sites?
George Town	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Smithton	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Wynyard	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Emu River (Brunie)	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
West Ulverstone	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Sheffield	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Exeter	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Carrick	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
South Launceston	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Lilydale	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Scottsdale	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Derby	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
St Helens	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Fingal	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Bryn Estyn	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Gretna	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Clearya Gates	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Huonville	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Judbury	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Geeveston	PM_{10}	As above	2009/2010	Present		Baseline air quality				
	$PM_{2.5}$	As above								
Other Regions										
George Town	PM_{10}	Low Volume Air Samplers	2007	Present					Industrial	- Monitoring site not for NEPM - Developed in partnership with local heavy industries
	PM_{10}	Optical dust monitor								
	$PM_{2.5}$	Low Volume Air Samplers								
	$PM_{2.5}$	Optical dust monitor								
	PM_1	Optical dust monitor								

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade
Performance stations - located at a site for at least five years and used to evaluate against the NEPM
Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

[b] Trend sites are generally representative of regional population exposure and generally approximate the PRC GRUB definition

B.7.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?
- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

No regional air emissions inventory has been developed for Tasmania.

B.7.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

None provided.

B.7.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

None provided.

B.8 NORTHERN TERRITORY

B.8.1 Monitoring

Please provide details of current PM monitoring undertaken within your jurisdiction in terms of:

- Locations (latitude and longitude)
- Owners/operators
- Equipment type/method (e.g. TEOM, BAM, Hivol etc)
- Instrument type and model number
- Pollutants measured (TSP, PM_{10}, $PM_{2.5}$)
- Purpose (e.g. to monitor the impact of industry on surrounding residential areas, Generally Representative Upper Bound (GRUB) etc)

- **Please provide annual average PM levels for each monitoring site or links to data downloads**
- **Please indicate if any site location or equipment type has changed location since the site was commissioned.**

Summary ambient air quality monitoring reports submitted to the National Environment Protection Council are available here:

http://www.ephc.gov.au/taxonomy/term/34

http://www.nretas.nt.gov.au/environment-protection/air

PM monitoring stations in the Northern Territory are provided in Table B.8.

Table B.8: Northern Territory PM Monitoring Station Summary

MONITORING SITE	POLLUTANT	METHOD	START	END	STATION TYPE	PURPOSE	LAT (SOUTH)	LONG (EAST)	LOCATION	COMMENTS
Charles Darwin University, Casuarina, Darwin	PM_{10}	TEOM	2004	Present	Performance	Population average			Residential / light industrial	Does not meet a number of the siting compliance standards partly due to the location atop adjacent two story buildings
	PM_{10}	Partisol Dichotomous sampler								
	$PM_{2.5}$	Partisol Dichotomous sampler								

[a] Trend stations – represent long-term monitoring trends and are located at a nominated site for at least a decade

Performance stations - located at a site for at least five years and used to evaluate against the NEPM

Campaign monitoring is conducted to determine whether monitoring is necessary is other regions

B.8.2 Emissions Inventory

If an air emission inventory has been developed for your jurisdiction, please provide the following details:

- What methodology is undertaken?
- Which pollutants are included?
- What areas are covered (geographic area and sources)?
- How current is inventory data?
- How often inventory is updated?
- What plans (if any) are there for inventory upgrade and improvements?
- What is the current use of the inventory by yourselves and whoever you may pass the information on to?

- Please attach any information that may assist this study. If no information is provided, it will be assumed that no emissions inventory is employed by your jurisdiction.

No regional air emission inventory has been compiled for the Northern Territory.

B.8.3 Population Data

Please provide current population data for your jurisdiction (if available). Examples of the format required include:

- Gridded population data (e.g. 1km x 1km or 3km x 3km resolutions)
- Statistical Local Areas (SLAs) population data

Please also provide supporting information for this data in terms of:

- How current is the population data?
- What methods were employed to gather this data?

Population statistics are available through the Australian Bureau of Statistics.

B.8.4 Regional Modelling

If regional air dispersion modelling is currently undertaken within your jurisdiction, please provide the following details:

- What regional air dispersion modelling programs are currently employed?
- Is regional PM modelling currently undertaken? Please describe.
- If so, does regional PM modelling incorporate secondary formation? Please describe.
- Please briefly describe resources available internally to perform regional air dispersion modelling of particulate matter.

Please attach any information that may assist this study. If no information is provided, it will be assumed that no regional air dispersion modelling is currently routinely employed by your jurisdiction.

Please note that we are only interested in city-wide/regional scale models. Modelling studies of individual point sources or roads is not relevant for this study.

No regional air quality modelling is conducted in the Northern Territory.

APPENDIX C

Exposure Reduction Framework Workshop – 14 September 2012

PRESENT

Name	Title	Organisation
Frank Henry	Principal Officer, Environmental Policy and Advisory Services	Brisbane City Council
Amala Jayasekara	Assistant Director Air Quality Section	DSEWPAC
Jane O'Sullivan	Director Air Quality Section	DSEWPAC
Khokan Bagchi	Assistant Director National Pollutant Inventory	DSEWPAC (NPI)
Sean Walsh	Air Quality Scientist	EPA Victoria
Tina Runnion		DEC WA
Martin Cope	Principal Research Scientist	CSIRO
Jon Millard	Manager Environmental Applications Unit	Bureau of Meteorology
Wayne Smith	Director Environmental Health	NSW Health
Geoff Morgan	Deputy Director Research, Dept of Rural Health	University of Sydney
Damon Roddis	General Manager (NSW, Vic, TAS)	PAE Holmes
Paul Boulter	Principal Air Quality Scientist	PAE Holmes
Kelsey Bawden	Principal Environmental Engineer	PAE Holmes
Andrew Mattes	Manager Air Technical Advisory Services Unit	NSW OEH
Ann-Louise Crotty	Manager Air Policy	NSW OEH
Chris Eiser	Manager Atmospheric Science	NSW OEH
Kerry Lack	Senior Policy Officer	NSW OEH
Mladen Kovac	Chief Economist	NSW OEH
Roger Bluett	Manager National Projects	NSW OEH
Suzanne Quigley	Atmospheric Science	NSW OEH
Peta Pippos	Senior Policy Analyst	NSW Health
Jeff Lin	Economist	NSW OEH
Richard Broome	Medical Adviser	NSW Health
Nicole Balodis	Air Policy and Programs Assistant	NSW OEH
Duncan Laxen	Managing Director	Air Quality Consultants, (UK consultant via video conference)
Stephen Moorcroft	Director	Air Quality Consultants, (UK consultant via video conference)
Bob Hyde		Tasmanian EPA

Apologies: Kelvyn Steer SA EPA, Peter Dolan SA EPA, Peter Hutchison Qld DERM