



# **Emission Estimation Technique Manual**

for

**Aggregated Emissions from  
Architectural Surface Coatings  
Version 1.1**

**24 March 2003**



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**Erratum for the NPI Architectural Surface Coating - Aggregated Emissions Data Manual (Version 1.1 – 24 Mar 2003).**

<b>Page</b>	<b>Outline of alteration</b>
11	Table 4 had factors too low by two orders of magnitude.

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**EMISSIONS ESTIMATION TECHNIQUE MANUAL:  
AGGREGATED EMISSIONS FROM ARCHITECTURAL SURFACE  
COATINGS**

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## **1.0 Introduction**

### **1.1 *The NPI***

The National Pollutant Inventory (NPI) was established under a National Environment Protection Measure (NEPM) made by the National Environment Protection Council (NEPC) under Commonwealth, State and Territory legislation on 27 February 1998. This Measure is to be implemented progressively through the laws and administrative arrangements of each of these participating jurisdictions (i.e. State and Territory Governments).

The NEPM and an associated Memorandum of Understanding for the NPI, which have been published as a single document by the NEPC, provide more details on the purpose and structure of the NPI, and the arrangements for implementation of the NEPM that have been agreed by the jurisdictions. Users of this Manual should read this publication if they are unfamiliar with the NEPM or the NPI.

### **1.2 *Purpose and Scope of the Manual***

The NPI will be developed as an internet database designed to provide information on the types and amounts of certain chemical substances being emitted to the air, land and water environments. If the NPI is to achieve its aim of communicating useful and reliable information to the community, industry and governments on pollutants present in our environment, the emissions estimation techniques (EETs) used to generate inputs to the NPI need to be consistent, and the process for developing these techniques needs to be transparent. This Manual has been developed, reviewed and finalised in this context.

The NEPM contains a list of substances for which emissions will be reported on an annual basis to the Commonwealth Government, which will then compile and publish the NPI. The aggregated emissions (AE) manuals, of which this is one, have been prepared to assist State and Territory Governments in preparing these submissions, and to facilitate consistent reporting between these jurisdictions.

State and Territory Governments will also be compiling and submitting emissions data based on annual inputs from reporting facilities. These facilities are primarily industrial enterprises which use (or handle, manufacture or process) more than specified amounts of certain polluting substances, burn more than specified amounts of fuel, or consume more than certain amounts of energy. These amounts or “thresholds” (which are clearly defined in the NEPM) govern whether an industrial facility is required to report and what substances it is required to report on, and industry handbooks are being developed to help industries to prepare the information for these reports.

The aggregated emissions manuals complement these handbooks, and are intended to enable Governments to estimate emissions from non-industrial activities (e.g. transportation, domestic and commercial activities) and

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emissions from industry which are not reported because the relevant thresholds are not exceeded.

Annual submissions are also to be prepared and submitted in conformance with the NPI Data Model and Data Transfer Protocol. For emissions to the air environment, this Protocol only requires jurisdictions to submit data on emissions into the particular airsheds that are listed in the Protocol, and not to the rest of each jurisdictional area. For example, in Victoria, emissions data are only required for the Port Phillip and Latrobe Valley Regions. In addition, emissions data are required to be submitted on a gridded basis, with each jurisdiction determining a grid domain and grid cell size appropriate to its needs and responsibilities (e.g. for air quality modelling purposes).

Therefore, in addition to recommending and providing details and examples of appropriate emissions estimation techniques (EETs) for the relevant NPI substances, this Manual provides guidance on the spatial allocation of emissions and the use of area-based surrogates for accurately distributing the activities or sources in question.

### **1.3 Application of the Manual**

Each of the AE manuals provides details of:

- the NPI substances that are expected to be emitted from the relevant aggregated source type;
- the origins or sources of the emissions, and the processes that may generate them;
- the impacts of any control equipment or procedures on those emissions;
- the broad approaches that may be employed in the estimation and spatial allocation of emissions;
- details of emission factors to be used in the estimation of emissions; and
- a series of illustrative sample calculations for each estimation technique.

Each of the manuals also contains a section on “Uncertainty Analysis”, which provides information and guidance to users on the reliability of the various estimation techniques, problems and issues associated with their development and application, and recommendations for their improvement. In preparing the AE manuals it has been recognised that some jurisdictions already undertake detailed emissions inventories on a regular basis, based on relatively sophisticated methodologies. For these jurisdictions the manuals offer techniques which represent commonly available best practice for emissions estimation in Australia (i.e. techniques of high quality which can be employed by larger or more experienced jurisdictions with an acceptable expenditure of time and effort). The most recent developments in inventory methodology in Australia and overseas have been considered in selecting and documenting these techniques.

Where a more simplified methodology for emissions estimation of acceptable quality is available, it is recommended in the manual for the use of those jurisdictions which may, for the time being at least, lack the data, resources or

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expertise to employ a more sophisticated approach, or not see the need for highly reliable estimates in that particular part of the inventory.



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## 2.0 Emissions Covered by the Manual

### 2.1 NPI Substances

Architectural surface coatings protect the substrates to which they are applied from corrosion, abrasion, decay, ultra-violet light damage and water damage. Architectural surface coatings may also be applied to increase the aesthetic value of structures by changing the colour and texture of surfaces.

Architectural surface coatings generally have three main components:

- resins, which form the final paint film after application and drying of the coating;
- pigments, which produce the desired colours and are composed of finely divided organic and inorganic materials; and
- solvents, which act as carriers for the resins and pigments, and evaporate as the paint film forms during the drying process.

The predominant emissions from architectural surface coatings are volatile organic compounds (VOCs) contained in the architectural coatings themselves (i.e. paint, paint primer, varnish or lacquer) and in the solvents used as thinners and for clean up purposes.

Architectural surface coatings are generally classified as solvent-based or water-based. Solvent-based coatings contain between 30% and 70% VOCs by weight and water-based coatings contain approximately 6%. NPI substances typically emitted from these surface coatings are listed in Table 1.

**Table 1: NPI Substances Typically Emitted from Use of Architectural Surface Coatings**

Acetone	Methanol
Benzene	Methyl ethyl ketone
Cyclohexane	Methyl isobutyl ketone
Dichloromethane	n-Hexane
Ethanol	Toluene
Ethylene glycol	Total VOC
2-Ethoxyethanol acetate	Xylenes

Emissions of particulate matter do not generally arise when architectural surface coatings are applied using brushes and rollers. However, some commercial contractors use spray guns and, if a significant amount of coating is applied in this manner (particularly to exterior surfaces), inventories of emissions may need to be compiled. In these cases point source emission estimation techniques (EETs) can be used to estimate PM10 emissions and allocate them to the appropriate inventory grid cells.

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## **2.2 Emission Sources and Related Processes**

NPI substances may be emitted into the air through the evaporation of these substance from architectural surface coatings and thinners. VOCs used as solvents in the coatings are emitted during the application of the coating and as the coating dries. The volumes of coatings used, the VOC contents of the coatings, and the weight fractions of NPI substances within the VOCs, are the key factors that primarily determine emissions from architectural surface coating activities. Emissions may also arise from solvents used to clean the application equipment and as reaction by-products while the coatings dry and harden.

## **2.3 Emission Controls**

Since the use of organic solvents in architectural surface coatings is the primary source of emissions, control techniques involve either product substitution or product reformulation. Alternate formulations include low-solvent products, water-based coatings and powder coatings. The Australian surface coating market is currently in a state of flux as water-based product continues to capture market share from solvent-based coatings. More than 80 per cent of architectural paints sold in Australia are now water-based (EA 1999).

Recycling of unused coatings by manufacturers is also a form of emission control, although to date the culture of returning and recycling unused product has gained only limited currency in Australia.

Structural maintenance practices also indirectly influence emissions by controlling the total coating consumption on a long-term basis. Regular inspection and maintenance programs can be used to reduce the need for entire surface re-coating.

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## 3.0 Emissions Estimation Techniques

### 3.1 Approaches Employed

This section describes best practice and default techniques for estimating emissions from architectural surface coatings. EETs for architectural surface coating activities assume that all VOCs in the coating formulation evaporate into atmosphere, and hence that the total VOCs in products distributed within a region over a particular period (e.g. annually) are equivalent to the total emissions of those VOCs over the same period.

The best method for determining emissions from architectural surface coatings is to obtain accurate sales and distribution data for solvent- and water-based surface coatings, thinners and cleaning solvents. In the context of the NPI, composition data for the VOC contained in the coatings, thinners and solvents is also required.

Where this information is not available for an NPI region (or airshed) emission factors based on emissions per dwelling may be used, provided they are based on data from a comparable region, preferably the same State or Territory (jurisdiction) or country (Dames and Moore 1996).

#### 3.1.1 Estimating Emissions from Use of Architectural Surface Coatings

##### Best Practice EET

The recommended technique is based on data on the volumes of both solvent- and water-based coatings which are distributed throughout the airshed in the reporting period. This approach ensures that emissions estimates reflect the actual use and contents of coatings used in an airshed, and automatically takes into account any local controls and geographical differences in usage between airsheds.

The data required are as follows:

- volume of each coating type consumed (distributed) in the reporting year;
- density of each coating type; and
- the VOC content of each product type and weight fraction of each NPI substance contained in these product types.

Throughout a jurisdiction aggregated product data can be obtained from the Australian Paint Manufacturers' Federation Inc. (APMF). Use of APMF data for total volumes, total VOC content and VOC speciation by coating type serves to avoid the resource intensive requirement of conducting an industry survey. However, given the variation in individual product formulations, use of overall figures for VOC content and VOC speciation may introduce some estimation errors in particular applications.

If the density and total VOC content cannot be obtained for various products, the VOC emission factors in Table 2 can be used. If data on VOC composition are not available, the values in Table 3 be used.

**Equation 1: Estimating total VOC emissions by emission factors based on product consumption**

Total VOC emissions from architectural surface coating activities in a jurisdiction can be calculated by multiplying the amount of each coating type used by the emission factor for that coating type

$$E_{\text{voc}} = \sum_i V_i \times EF_i$$

where

$E_{\text{voc}}$	=	Total VOC emissions, kg yr <sup>-1</sup>
$V_i$	=	Amount of coating type i used in the reporting year, L yr <sup>-1</sup>
$EF_i$	=	Emission factor for coating type i, kg L <sup>-1</sup>

Once total VOC emissions have been estimated, VOC speciation is required for those NPI substances contained in the coatings.

**Equation 2: Estimating emissions of a VOC species**

Emissions of an individual VOC species can be calculated by multiplying total emissions by the individual weight fraction speciation for that species

$$E_j = E_{\text{voc}} * WFS_i$$

where

$E_j$	=	Emissions of VOC species i, kg yr <sup>-1</sup>
$E_{\text{voc}}$	=	Total VOC emissions, kg yr <sup>-1</sup>
$WFS_i$	=	Weight fraction speciation of VOC species i

Default EET

Emission factors based on estimates of emissions per dwelling may be used as an acceptable alternative EET, provided they are based on reasonably relevant data and circumstances. The use of US emission factors is not recommended for architectural surface coatings as it is unlikely that solvent use would be similar (Dames and Moore 1996).

Emission factors developed for the South East Queensland Trial (SEQT) for are preferred for the default EET. The factor for each NPI substance,

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calculated on a per dwelling basis, was based on APMF distribution data by coating type (water- and solvent-based) throughout the jurisdiction.

**Equation 3: Estimating emissions using emission factors based on dwellings**

The default method calculates the emissions of an NPI substance from architectural surface coating activities by multiplying the emission factor by the number of dwellings within an airshed

$$E_i = EF * D$$

where

$$\begin{aligned} E_i &= \text{Total emissions of substance } i, \text{ kg yr}^{-1} \\ EF_i &= \text{Emission factor for substance } i, \text{ kg dwelling}^{-1} \text{ yr}^{-1} \\ D &= \text{Total dwellings in the airshed} \end{aligned}$$

**3.2 Spatial Surrogates and Spatial Allocation**

Spatial allocation using scaling factors is required to estimate emissions from architectural surface coating activities at an airshed and grid cell level.

*3.2.1 Allocation of Jurisdiction Emissions to the Airshed*

Best Practice EET

When spatially allocating State or Territory emissions to an airshed, scaling by the number of dwellings is the preferred approach. Annual emissions for the year and jurisdiction are scaled down by the ratio of dwellings in the airshed and jurisdiction.

**Equation 4: Calculating the dwelling scaling factor**

$$DSF = AD / JD$$

where

$$\begin{aligned} DSF &= \text{Dwelling scaling factor} \\ AD &= \text{Number of dwellings in the airshed of interest} \\ JD &= \text{Number of dwellings in the jurisdiction} \end{aligned}$$

**Equation 5: Scaling jurisdiction emissions to the airshed of interest**

Airshed emissions of a substance can be calculated by multiplying total jurisdiction emissions of the substance by the DSF

$$AE_i = JE_i * DSF$$

where

$$\begin{aligned} AE_i &= \text{Airshed emissions of substance } i, \text{ kg yr}^{-1} \\ JE_i &= \text{Jurisdiction emissions of substance } i, \text{ kg yr}^{-1} \\ DSF &= \text{Dwelling scaling factor} \end{aligned}$$

If the number of dwellings cannot be obtained, population figures can be used as an alternative.

### 3.2.2 Allocation of Airshed Emissions to the Spatial Grid

#### Best Practice EET

When allocating airshed emissions to a grid, it should be recognised that significant amounts of surface coatings are used in industrial and commercial precincts. Because the numbers of people living in these areas is relatively low, the use of population distribution as a surrogate is not entirely suitable. Thus, the recommended surrogates for spatial allocation of emissions are, in order of preference, building square metreage (BSM), dwelling distribution, and population data.

#### **Equation 6: Allocating airshed emissions to grid cells by BSM**

$$E_{ij} = (AE_i / BSM) * BSM_j$$

where

$$\begin{aligned} E_{ij} &= \text{Emissions of substance } i \text{ in grid cell } j, \text{ kg yr}^{-1} \\ AE_i &= \text{Airshed emissions of substance } i, \text{ kg yr}^{-1} \\ BSM &= \text{Total building square metreage in the airshed, m}^2 \\ BSM_j &= \text{Building square metreage in grid cell, m}^2 \end{aligned}$$

Where BSM data is unavailable, data on dwelling distribution can be obtained from the Australian Bureau of Statistics (ABS), which collects statistical data on the numbers of privately occupied dwellings by Collection District. These data can be allocated to grid cells using a specific program or Geographic Information System.

#### Default EET

This technique uses emission factors per dwelling (see Section 3.1.1). Therefore, the only method available to allocate emissions to grid cells is by

data on dwelling distribution, which can be derived by adapting ABS data (as described immediately above).

**Equation 7: Allocating airshed emissions to grid cells by distribution of dwellings**

This equation illustrates the application of data on the distribution of dwellings to the allocation of emissions to grid cells

$$E_{ij} = (AE_i / D) * D_j$$

where

- $E_{ij}$  = Emissions of substance i in grid cell j, kg yr<sup>-1</sup>
- $AE_i$  = Airshed emissions of substance i, kg yr<sup>-1</sup>
- $D$  = Total number of dwelling numbers in the airshed
- $D_j$  = Number of dwellings in grid cell j

**3.3 Emission and Speciation Factors**

*3.3.1 Best Practice Emissions Estimation Technique*

Table 2 displays emission factors for estimating VOC emissions based on surface coatings consumption. Data on particular NPI substances and estimates of their respective weight fractions in the different product types can found in Table 3. The data in Table 3 provide estimates of the overall speciation of each product type as a whole, which ideally should be derived by combining data on the relative production volumes, densities and specific VOC compositions of individual products. Such speciation profiles are an acceptable alternative to analysing detailed production and composition data, but may introduce inaccuracies when applied to particular regions.

**Table 2: VOC Emission Factors Based on Consumption of Architectural Surface Coatings**

Coating Type	Emission Factor <sup>a</sup> (kg L <sup>-1</sup> )
<b>Solvent-based</b>	
Decorative	0.45
Industrial	0.60
Wood Stains	0.55
Thinners	0.95
<b>Water-based</b>	
Decorative	0.1

<sup>a</sup> QDEH (1998)

**Table 3: Speciating VOC Emissions from Architectural Surface Coatings**

<b>NPI Substance</b>	<b>Weight Fraction<sup>a</sup></b>
<b>Solvent-based Coatings</b>	
Acetone	0.0320
Cyclohexane	0.2070
2-Ethoxyethanol acetate	0.0130
Ethanol	0.0060
Ethylene glycol	0.0060
n-Hexane	0.2070
Methanol	0.0390
Methyl ethyl ketone	0.0560
Methyl isobutyl ketone	0.0060
Toluene	0.0520
Xylenes	0.0260
<b>Water-based Coatings</b>	
Benzene	0.0030
Dichloromethane	0.0550
Ethylene glycol	0.0050

<sup>a</sup> CARB (1991)

### 3.3.2 Default Emissions Estimation Technique

In cases where the APMF cannot provide jurisdiction data for total solvent sales, coating density or coating VOC content then the use of factors for emissions per dwelling is the best alternative approach. Table 4 provides emission factors developed from the SEQT.

**Table 4: Emission Factors for NPI Substances from Architectural Surface Coatings**

<b>NPI Substance</b>	<b>Emission Factors<sup>a</sup> (kg dwelling<sup>-1</sup> yr<sup>-1</sup>)</b>
<b>Solvent Based Coatings</b>	
Acetone	2.58E-01
Cyclohexane	1.67
2-Ethoxyethanol acetate	1.05E-01
Ethanol	4.83E-02
Ethylene glycol	4.83E-02
n-Hexane	1.67
Isomers of xylene	2.09E-01
Methanol	3.14E-01
Methyl ethyl ketone	4.51E-01
Methyl isobutyl ketone	4.83E-02
Toluene	4.19E-01



<b>Water Based Coatings</b>	
Benzene	4.54E-03
Dichloromethane	8.33E-02
Ethylene glycol	7.57E-03
Total VOC	9.56
<b>Note</b>	
1. Scientific notation is used; e.g. 7.38E-02 represents 7.38 x 10 <sup>-2</sup> or 0.0738 and 7.38E+02 represents 7.38 x 10 <sup>+2</sup> or 738.	

<sup>a</sup> QDEH (1998)

### 3.4 Sample Calculations

The following sample are provided to assist jurisdictions in estimating emissions from architectural surface coatings. The calculations provide a complete example of the methodology for both best practice and default methods.

#### 3.4.1 Best Practice Emissions Estimation Technique

Distribution data by coating type (water- or solvent-based) can usually be provided by the APMF in a format similar to Table 5, which contains sample data for illustration purposes.

**Table 5: Yearly Consumption of Architectural Surface Coatings in a Notional Jurisdiction**

Coating Type	Consumption (L yr <sup>-1</sup> )	Emission Factor (kg L <sup>-1</sup> )
<b>Solvent-based</b>		
Decorative	45 000	0.45
Industrial	90 000	0.60
Wood Stains	8 000	0.55
Thinners	51 000	0.95
<b>Water-based</b>		
Decorative	810 000	0.1

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**Example 1: Estimating annual total VOC emissions from solvent-based coatings in the jurisdiction**

Equation 1 and Table 5 can be used to calculate the total annual VOC emissions from solvent-based architectural surface coatings in the jurisdiction

$$\begin{aligned} E_{\text{voc}} &= \sum (V_i * EF_i) \\ &= (4.5 * 10^4 * 0.45) + (9.0 * 10^4 * 0.6) + (8.0 * 10^3 * 0.55) + \\ &\quad (5.1 * 10^4 * 0.95) \\ &= 1.56 * 10^5 \text{ kg yr}^{-1} \end{aligned}$$

**Example 2: Calculating annual cyclohexane emissions in the jurisdiction**

The cyclohexane WFS for solvent-based coatings (0.2070 from Table 3) can be used with Equation 2 to estimate emissions of cyclohexane in the jurisdiction

$$\begin{aligned} E_j &= E_{\text{voc}} * WFS_i \\ &= 1.56 * 10^5 * 0.2070 \\ &= 3.23 * 10^4 \text{ kg yr}^{-1} \end{aligned}$$

Table 6 provides sample population data that can be used to calculate a scaling factor to convert jurisdiction emissions to the airshed emissions.

**Table 6: Dwelling Numbers for a Notional Jurisdiction and Airshed**

Region	Dwellings
Airshed	1 400 000
Jurisdiction	2 250 000

**Example 3: Calculating the dwellings scaling factor**

The data from Table 6 and Equation 4 can be used to determine the scaling factor

$$\begin{aligned} DSF &= AD / JD \\ &= 1.40 * 10^6 / (2.25 * 10^6) \\ &= 0.62 \end{aligned}$$

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**Example 4: Allocating cyclohexane emissions in the jurisdiction to the airshed of interest**

Airshed emissions can be derived by multiplying jurisdiction emissions by the DSF (as per Equation 5)

$$\begin{aligned} AE_i &= JE_i * DSF \\ &= 3.23 * 10^4 * 0.62 \\ &= 2.00 * 10^4 \text{ kg yr}^{-1} \end{aligned}$$

**Example 5: Allocating airshed emissions to grid cells**

Using Equation 6, and assuming BSM figures of 120 million m<sup>2</sup> for the airshed as a whole and 95,000 m<sup>2</sup> for a particular grid cell, annual cyclohexane emissions from the grid cell are estimated as

$$\begin{aligned} E_{ij} &= (AE_i / BSM) * BSM_j \\ &= (2.00 * 10^4 / 1.2 * 10^8) * 9.5 * 10^4 \\ &= 15.8 \text{ kg yr}^{-1} \end{aligned}$$

### 3.4.2 Default Emissions Estimation Technique

**Example 6: Estimating annual cyclohexane emissions**

If the airshed has 1,400,000 dwellings, the emission factor for cyclohexane from Table 4 can be used with Equation 3 to estimate the annual cyclohexane emissions for the airshed

$$\begin{aligned} E_i &= EF * D \\ &= 1.67 * 10^{-2} * 1.4 * 10^6 \\ &= 2.34 * 10^4 \text{ kg yr}^{-1} \end{aligned}$$

**Example 7: Allocating airshed emissions to grid cells**

Assuming there are 1,100 dwellings in a particular grid cell, Equation 7 can be applied to estimate the emissions of cyclohexane from that grid cell

$$\begin{aligned} E_{ij} &= (AE_i / D) * D_j \\ &= \{2.34 * 10^4 / (1.4 * 10^6)\} * 1.1 * 10^3 \\ &= 18.4 \text{ kg yr}^{-1} \end{aligned}$$

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## **4.0 Uncertainty Analysis**

This section discusses the reliability of the data and emission factors presented, problems and issues encountered, and makes recommendations for further work to improve and refine the emission estimation techniques.

### **4.1 Data Reliability**

The surface coatings data supplied by APMF is production data. Since most of the surface coating production is consumed in Australia (Hambrook, M., APMF June 1997), these data are considered to be highly reliable for emissions estimation.

### **4.2 Reliability of Emission Factors**

The VOC emission factors based on surface coating consumption are derived from data on density and VOC content of different surface coating types, which are supplied by APMF. Since there are a large number of coating formulations in use, the reliability of using such emission factors in emission estimation is considered to be medium. For the same reason, the use of a single overall speciation profile to estimate the emissions of individual NPI substances is not considered to be highly reliable. There is considerable variation in the type and amount of individual NPI substances in each surface coating product and the reliability of using a single speciation profile for emissions estimation is assessed as medium to low.

The per dwelling emission factors listed in Table 4 were derived for South East Queensland and may not offer the same level of accuracy when applied elsewhere in Australia. Also, the factors were derived from an average speciation profile.

### **4.3 Recommendations for Further Work**

Further development of the EETs is not required. However, data based on local architectural coating formulations and consumption would assist in the development of specific emission factors for each Australian jurisdiction. These State or Territory-wide emission factors could then be applied to the smaller regions where consumption data may be more difficult to obtain (Dames and Moore 1996).

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## 5.0 Glossary of Terms and Abbreviations

ABS	Australian Bureau of Statistics
AE	Aggregated emissions
APMF	Australian Paint Manufacturers' Federation Inc.
BSM	Building square metreage
CBD	Central Business District
DSF	Dwelling scale factor
EA	Environment Australia
EET	Emissions estimation technique
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
PM10	Particulate matter less than 10 µm
QDEH	Queensland Department of Environment and Heritage
SEQT	South East Queensland Trial
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WFS	Weight fraction speciation

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## 6.0 References

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