Emissions Estimation Technique Manual

for

Aggregated Emissions from Domestic Solid Fuel Burning

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EMISSIONS ESTIMATION TECHNIQUE MANUAL:
AGGREGATED EMISSIONS FROM DOMESTIC SOLID FUEL BURNING

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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 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

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

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, under the 1998 to 2000 Memorandum of Understanding, 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 necessary to meet its obligations under Section 7 of the NEPM.

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 aggregated emissions 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 aggregated emissions 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

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

2.0 Emissions Covered by the Manual

This manual provides guidance on the estimation of aggregate emissions of NPI substances from domestic solid fuel burning for heating.

Wood is the main solid fuel in use in Australia. Coal and briquettes are also used in smaller amounts. Other solid fuel sources are unlikely to be significant contributors to aggregate emissions.

Domestic solid fuel combustion can be a significant contributor to overall area-based emissions.

2.1 NPI Substances

Emissions from wood and coal/briquette burning may include a number of the substances listed in Table 2 to Annex A of the NEPM, as detailed in Table 1 below.

Table 1: NPI Substances Emitted from Solid Fuel Combustion [a]

Acetaldehyde	n-Hexane
Acetone	Hydrochloric acid
Antimony and compounds	Lead and compounds
Arsenic and compounds	Manganese and compounds
Benzene	Mercury and compounds
Beryllium and compounds	Methyl ethyl ketone
1,3-Butadiene	Nickel and compounds
Cadmium and compounds	Oxides of nitrogen
Chromium (III) compounds	Particulate matter ≤10µm (PM10)
Chromium (VI) compounds	Phenol
Carbon disulphide	Polycyclic aromatic hydrocarbons
Carbon monoxide	Selenium and compounds
Cobalt and compounds	Sulphur dioxide
Cyanide compounds	Styrene
Dichloromethane	Tetrachloroethylene
Ethylbenzene	Toluene
Di-(2-Ethylexyl) phthalate (DEHP)	Total volatile organic compounds (VOCs)
Fluoride compounds	Xylenes
Formaldehyde	Zinc and compounds

[a] Paragraph 2 (e) of Schedule A to the NEPM requires that, for the purposes of emissions estimation, a substance listed in Tables 1 and 2 of that Schedule as " (a metal) and a compound" refers only to the amount of metal that may be emitted. The EETs described in this manual have been prepared accordingly. Thus, the emission factors for metals and their compounds relate only to the amount of the metal itself that may be emitted as a part of these compounds.

2.2 Emission Sources and Related Processes

The quantity and composition of emissions from domestic wood combustion are highly variable and are a function of the type of wood heaters used, the characteristics of the wood being consumed, and operating practices.

There are three main types of wood heaters and stoves used in Australia: open fireplaces, conventional heaters and controlled combustion heaters. Open fireplaces are the least efficient and have the highest emissions. Controlled combustion heaters are the most efficient and have the least emissions.

Open fireplaces can be either integral to the structure of the building (typically masonry and built into the wall structure) or prefabricated (either freestanding or inserted into an existing masonry fireplace). These heaters warm by radiant heat.

Conventional heaters and stoves are enclosed and control burn time by limiting the amount of air that can be used for combustion. Conventional stoves do not have specific technology or design features for emission control. Examples of conventional stoves are pot bellied stoves and older style slow combustion heaters.

Controlled combustion heaters employ emission reduction technology such as baffles or secondary combustion chambers. Wood stoves meeting the Australian Standard AS4013 would fit into this category. The Australian Standard AS4013 was released in 1992. Requirements for compliance with the standard have varied between jurisdictions.

Other stove types, such as catalytic stoves, pellet stoves and masonry heaters are not popular in Australia at this time. Estimation techniques for these heaters are not provided in this manual, but may be needed at a later date if their usage increases significantly.

2.3 Emission Controls and Other Factors Affecting Emissions

Emission factors are presented below (Section 3.3) for the three different types of heaters commonly in use in Australia. The emissions performance and effectiveness of emission controls are integral to the heater type and use, and are reflected in the emission factors provided.

It is possible to achieve overall reductions in emissions in several ways. In order to decrease PM10 and CO emissions from fireplaces and wood stoves, combustion efficiency must increase by increasing burn rate and flame intensity. Public awareness and education could assist in achieving better operation. Also, the increased introduction of heaters compliant with AS4013 will reduce emissions. This can be achieved through appropriate promotion and/or jurisdictional control.

Different types of wood have different burning qualities. The density and rates of release of volatile gases vary significantly from one species of wood to another. It is generally accepted that softwoods (e.g. pine) produce higher PM10 emissions than hardwoods (e.g. eucalyptus). However, emission factors for different species of wood are not readily available and general emission factors therefore need to be used.

The following factors also influence emissions from solid fuel burning:

- emissions may vary with the stage of development of the fire, being higher during the early stages of burning or when the burn rate or flame intensity is low;

- fuel piece size and fuel load geometry (e.g. positioning of wood within the fire) can also affect emissions by causing variations in temperature variations and air availability; and

- heater efficiency and hence emissions can also vary with heater age, due to deterioration of door seals and other components.

Emissions from solid fuel combustion are strongly seasonal, and can also vary with time of day, distance from coast, altitude, age of residence and economic factors. While it is possible to incorporate seasonal and temporal variations into the EETs, the NPI currently requires reporting of annual emissions. Therefore, this is not addressed in this manual.

Future work could lead to development of emission factors or factor adjustments that address some of the effects discussed above.

3.0 Emissions Estimation Techniques

The information required to calculate aggregate emissions from domestic solid fuel combustion is as follows:

- the weight of wood burnt for each type of heater in the relevant NPI region (airshed), or State or Territory (jurisdiction);
- the proportion of wood heaters compliant with the AS4013 standard;
- the weight of briquettes burnt in the airshed or jurisdiction; and
- the number of households or population by Collection District (CD) and the co-ordinates of the CDs.

If data are obtained at the jurisdiction level, they need to be scaled down to the airshed by number of households or population.

3.1 Approaches Employed

3.1.1 Amount of Wood Consumed in Each Heater Type

The preferred methodology for obtaining information about domestic solid fuel consumption and heater types is to conduct a domestic survey. The required sampling program may vary with the size of the airshed. In larger regions a large sample size covering a range of sub-regions may be required to account for sectoral differences, while for a smaller region a single sample may be sufficient. Appendix A provides guidelines for the design and conduct of domestic surveys.

Information on briquette usage can also be obtained from suppliers or from ABARE (1999). ABARE publishes data on residential briquette use for Australia. This needs to be scaled down to jurisdiction level and then separated from that used for barbeques to avoid double counting of the consumption.

If reported as volumes, softwood and hardwood usage needs to be converted to weight using density conversions. Hardwood is denser than softwood. Local density figures should be used where possible. If no local figures are available, a density of 600 kg m^{-3} for hardwoods and 345 kg m^{-3} for softwoods can be used (QDEH 1998).

It may be difficult for some survey respondents to determine whether their appliance complies with the Australian Standard AS4013. Quality assurance checking of survey results for percentage of stoves meeting AS4013 should take into account the year of introduction of the standard in the jurisdiction. Estimates of percentage of heaters compliant with AS4013 may also be obtained from the Australian Home Heating Association (AHHA).

The amount of fuel consumed in each heater type for the airshed can be calculated using Equation 1, using domestic survey data.

Equation 1: Calculating the amount of wood consumed in a heater type

$$W_i = W_{hi} * (H_{w\,i} / 100) * P$$

where

W_i = Total consumption of wood for heater type i, kg yr^{-1}

W_{hi} = Average household consumption of wood for heater type i, kg yr^{-1}

$H_{w\,i}$ = Percentage of households using wood for heater type i

P = Number of households in the airshed

An alternative methodology for estimating domestic solid fuel use would be to use the consumption data from the national survey conducted by Forestry Technical Services and University of Tasmania (DPIE 1989). In the absence of other data, this can be allocated to the following uses: 30% in open fires, 52.5% in conventional heaters and 17.5% in controlled combustion heaters (EPAV 1999).

3.1.2 Emissions of Each NPI Substance for Each Heater Type from Wood Burning

Once the annual amount of wood used in each heater type is known, the annual emission of each NPI substance from that heater type can be calculated from Equation 2.

Equation 2: Calculating emissions for a heater type from wood burning

$$E_{ij} = W_i * EF_{ij} * 10^{-3}$$

where

E_{ij} = Total annual emissions of substance j from heater type i burning wood, kg yr^{-1}

W_i = Total amount of wood consumed annually in heater type i, kg yr^{-1}

EF_{ij} = Emission factor of substance j for heater type i burning wood, g kg^{-1}

3.1.3 Amount of Coal Consumed

For coal combustion, the EET does not require information on the relative usage in each heater type, so data on usage in the various heater types can be summed. Coal and briquette combustion is expected to be only a small proportion of total solid fuel usage. Equation 3 can be used to calculate the

amount of coal/briquettes consumed in different heater types and then the airshed as a whole.

Equation 3: Determination of the amount of coal consumed

$$C_i = C_{hi} * (H_{ci} / 100) * P$$

where

C_i = Total annual consumption of coal in heater type i, kg yr^{-1}
C_{hi} = Average annual household consumption of coal in heater type i, kg yr^{-1}
H_{ci} = Percentage of household using coal in heater type i
P = Number of households in the airshed

and

$$C = \sum_i C_i$$

where

C = Total annual consumption of coal for domestic heating, kg yr^{-1}

3.1.4 Emissions of Each NPI Substance for Coal Combustion

The emissions of each NPI substance can be calculated from Equation 4.

Equation 4: Calculating emissions for coal combustion

$$E_{cj} = EF_{cj} * C$$

where

E_{cj} = Total annual emissions of substance j from coal combustion, kg yr^{-1}
C = Total annual coal consumption, tonne yr^{-1}
EF_{cj} = Emission factor for substance j from coal combustion, g kg^{-1}

3.1.5 Total Emissions for Each NPI Substance

The total annual emissions of each NPI substance can then be calculated by summing the annual emissions from each heater type and from coal combustion (Equation 5).

Equation 5: Calculating total emissions

$$E_j = E_{cj} + \sum_i E_{ij}$$

where

E_j = Total emissions of substance j from domestic solid fuel burning

E_{ij} = Total annual emissions of substance j from heater type i burning wood

E_{cj} = Total annual emissions of substance j from coal combustion

3.2 Spatial Surrogates and Spatial Allocation

Annual emissions should be spatially allocated on the basis of household distribution or population, taking into account any sub-regional variations in solid fuel usage that are detected through the domestic survey.

The Australian Bureau of Statistics collects household and population number data by Collection District (CD). These data can be converted to household or population by grid cells using a specific program or Geographic Information System. Emissions in a grid cell can then be estimated from Equation 6.

Equation 6: Allocating emissions to grid cells

$$E_{jk} = E_j * (P_k / P)$$

where

E_{jk} = Emissions of substance j in grid cell k

E_j = Aggregated emissions of substance j

P_k = Number of households in grid cell k

P = Number of households in the airshed

3.3 Emission Factors

Emission factors for wood burning in the three different heater types are given in Table 2. General emission factors for coal/briquette combustion are also provided in the table.

Table 2: Emission Factors for Solid Fuel Combustion

Substance	Emission Factor (g kg^{-1})[a]			
	Wood Burning			Coal (all heater types)
	Open Fireplace	Conventional Heater	Controlled Heater	
Acetaldehyde	8.87 [b]	2.05 [b]	0.465 [b]	2.85×10^{-4}
Acetone	6.56 [b]	1.52 [b]	0.344 [b]	-
Antimony and compounds	1.13×10^{-4} [c]	7.22×10^{-5} [c]	3.31×10^{-5} [c]	-
Arsenic and compounds	7.52×10^{-5} [c]	4.81×10^{-5} [c]	2.21×10^{-5} [c]	9.5×10^{-5}
Benzene	-	0.969	0.732	6.5×10^{-4}
Beryllium and compounds	-	-	-	1.55×10^{-4}
1,3-Butadiene	0.36 [d]	-	-	-
Cadmium and compounds	9.40×10^{-5} [c]	1.10×10^{-5}	1.0×10^{-5}	3.55×10^{-5}
Chromium (III) compounds		3.53×10^{-7} [e]	3.53×10^{-7} [e]	9.05×10^{-5}
Chromium (VI) compounds	-	1.47×10^{-7} [e]	1.47×10^{-7} [e]	3.95×10^{-5}
Carbon disulphide	-	-	-	6.5×10^{-5}
Carbon monoxide	126.3	115.4	70.4	138
Cobalt and compounds	1.88×10^{-5} [c]	1.20×10^{-5} [c]	5.52×10^{-6} [c]	-
Cyanide compounds	-	-	-	1.25×10^{-3}
Dichloromethane	-	-	-	2.65×10^{-4}
Ethylbenzene	-	-	-	4.7×10^{-5}
Di-(2-Ethylexyl) phthalate (DEHP)	-	-	-	3.65×10^{-5}
Fluoride compounds	-	-	-	0.075
Formaldehyde	9.55 [b]	2.21 [b]	0.5 [b]	1.2×10^{-4}
n-Hexane	-	-	-	3.35×10^{-5}
Hydrochloric acid				0.6
Lead and compounds	3.01×10^{-4} [c]	1.93×10^{-4} [c]	8.83×10^{-5} [c]	4.45×10^{-3}
Manganese and compounds	5.45×10^{-4} [c]	8.5×10^{-5}	7.0×10^{-5}	1.8×10^{-3}
Mercury and compounds	-	-	-	6.5×10^{-5}
Methyl ethyl ketone	-	0.145	0.031	1.95×10^{-4}
Nickel and compounds	-	7.0×10^{-6}	1.0×10^{-5}	1.3×10^{-4}
Oxides of nitrogen	1.3	1.4	1	1.5
PAHs	8.0×10^{-4}	0.365	0.25	1.12×10^{-3}
Phenol	-	-	-	8.0×10^{-6}
PM10	17.3	12 [f]	5.5 [f]	1.15

Selenium and compounds	1.88 x 10^{-5} [c]	1.20 x 10^{-5} [c]	5.52 x 10^{-6} [c]	6.5 x 10^{-4}
Sulphur dioxide	0.20	0.2	0.2	3.9 [g]
Styrene	0.175 [d]	-	-	1.25 x 10^{-5}
Tetrachloroethylene	-	-	-	2.15 x 10^{-5}
Toluene	1.17	0.365	0.26	1.2 x 10^{-4}
Total VOCs	114.5	26.5	6.75	5
Xylenes	0.710	0.101	0.093	1.85 x 10^{-5}
Zinc and compounds	0.0139 [c]	8.92 x 10^{-3} [c]	4.09 x 10^{-3} [c]	-

[a] USEPA (1995), unless otherwise specified.
[b] CARB (1991a).
[c] CARB (1991b).
[d] EPAV (1996).
[e] Assuming the same fraction of chromium(VI) (29.5%) as that emitted from wood waste combustion (USEPA 1999).
[f] AHHA, and Todd, J., University of Tasmania (June 1998), pers. comm.
[g] Assuming a sulphur content of 0.2% (Davidson, D., Energy Brix (May 1997), pers. comm.).

3.4 Sample Calculations

The following sample calculations are based on an airshed with 200,000 households, of which 2,000 were surveyed. The notional domestic survey data in Table 3 will also be employed in the sample calculations.

Table 3: Domestic Survey Data for Sample Calculations

	Open Fire	Conventional	Controlled Combustion
% households burning wood	5.0	8.0	2.0
Consumption of firewood (kg yr^{-1} per household)	900	800	750
% households burning coal (or briquettes)	0	0.3	0.2
Consumption of coal (kg yr^{-1} per household)	0	50	60

Example 1: Scaling up of survey results

Total wood consumption in open fireplaces in the airshed can be calculated from Equation 1

$$W_i = W_{hi} * (H_{w\,i} / 100) * P$$

so

$$W_{open\ fires} = (5.0/100) * 900 * 2 * 10^5$$
$$= 9 * 10^6 \text{ kg yr}^{-1}$$

Example 2: Calculating PM10 emissions from open fireplaces

Using the result from Example 1 and the relevant PM10 emission factor from Table 2, total annual airshed emissions of PM10 from open fireplaces can be calculated from Equation 2

$$E_{ij} = W_i * EF_{ij} * 10^{-3}$$

so

$$E_{\text{open fires, PM10}} = 17.3 * 9 * 10^6 * 10^{-3}$$
$$= 1.58 \times 10^5 \text{ kg yr}^{-1}$$

Example 3: Calculating PM10 emissions from coal burning

Equation 3 can be used with the survey data to calculate the average household consumption of coal in different types of heaters and hence the total coal consumption

$$C_i = C_{hi} * (H_{ci} / 100) * P$$

so

$$C_{conv} = 50 * (0.3 / 100) * 2 * 10^5$$
$$= 3.0 * 10^4 \text{ kg yr}^{-1}$$

and

$$C_{\text{cont comb}} = 60 * (0.2 / 100) * 2 * 10^5$$
$$= 2.4 * 10^4 \text{ kg yr}^{-1}$$

therefore

$$C_{total} = 5.4 * 10^4 \text{ kg yr-1}$$

Then Equation 4 can be used with the relevant emission factor from Table 2 to calculate total airshed emissions of PM10 from coal combustion

$$E_{cj} = EF_{cj} * C$$
$$= 1.15 * 5.4 * 10^4$$
$$= 6.2 * 10^4 \text{ kg yr-1}$$

4.0 Uncertainty Analysis

In the following discussion, reliability is classified into 3 levels of confidence: high (uncertainty of 20% or less), medium (uncertainty of between 20% and 80%) and low (uncertainty of greater than 80%).

4.1 Data Reliability

Data from domestic surveys should be of high reliability, provided appropriate care is taken in the design and conduct of surveys. However, there may be some inaccuracies in the reporting of appliances which comply with AS4013. Guidelines for domestic surveys are contained in Appendix A.

Using data from ABARE or DPIE is of medium reliability, as it must be scaled to airsheds and broken down by heater type.

4.2 Reliability of Emission Factors

4.2.1 Wood Emission Factors

Emission factors for carbon monoxide, sulphur dioxide, oxides of nitrogen and total volatile organic compounds for all heater types are from USEPA AP42. The factor for particulate matter less than 10 μm (PM10) from open fireplaces is also from USEPA. These factors were obviously not developed for Australian fuels, and are considered to have medium reliability.

PM10 emission factors for conventional and controlled combustion heaters were developed by the AHHA and the reliability is considered to be high.

Factors for metals and individual VOC species are obtained from USEPA (1995) or derived from speciation profiles developed by CARB. These factors are considered to be of low reliability.

4.2.2 Coal Emission Factors

The emission factors for coal and briquette use are from AP-42 for coal combustion in hand-fed units and so are considered to be of low reliability.

4.3 Problems and Issues Encountered

There are a number of factors which affect the emissions performance of wood and coal burning domestic appliances (see Section 2.3) that cannot be accounted for in developing the EETs in this manual. Data on the effects of these factors and mechanisms on emissions is currently not available, and this obviously limits the accuracy of the EETs proposed herein.

4.4 Recommendations for Further Work

Further investigation and development of emission factors for Australian timbers (including separate factors for softwoods and hardwoods) and for coal fuels in different heater types would improve the accuracy of emissions estimates.

Determination of emission factors for in-use heaters under a range of operating conditions would allow variations due to heater operation, age and fuel type to be indirectly incorporated into the EETs.

Priority work should be directed into investigating emissions of PM10 from the various domestic heater types with different fuel types.

5.0 Glossary of Terms and Abbreviations

AE	Aggregated emissions
ABARE	Australian Bureau of Agricultural and Resource Economics
AHHA	Australian Home Heating Association
CARB	California Air Resources Board
CO	Carbon monoxide
DPIE	Department of Primary Industry and Energy
EET	Emissions estimation technique
EF	Emission factor
EPAV	Environment Protection Authority of Victoria
QDEH	Queensland Department of Environment and Heritage
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
PAHs	Polycyclic aromatic hydrocarbons
PM10	Particulate matter less than or equal to 10 µm
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

6.0 References

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7.0 Appendices

APPENDIX A: GUIDELINES FOR CONDUCT OF DOMESTIC SURVEYS

APPENDIX A
GUIDELINES FOR CONDUCT OF DOMESTIC SURVEYS

1 Background

Manuals for estimating aggregated emissions are required to assist State and Territory Governments in preparing annual inputs to the Commonwealth for the National Pollutant Inventory (NPI). The aggregated emissions manuals complement the industry handbooks, and are intended to enable Governments to estimate emissions from non-industrial activities (e.g. transportation, domestic and commercial activities) and emissions from industry which are not reported because the relevant NEPM thresholds are not exceeded.

For emissions from domestic sources the estimation techniques are generally based on estimates of overall household activity levels, such as the combustion of fuel, consumption of materials, and usage of equipment and appliances. Information on some of these activities can be derived to an acceptable accuracy with a survey questionnaire distributed to a representative number of households in a particular airshed.

For other activities accurate data may be available from other sources (e.g. usage of surface coatings and aerosols) and so a survey will not be required. Also, although the usual estimation technique may be relatively crude (e.g. for domestic and commercial solvents the estimate is based on a US EPA per capita emission factor), it is unlikely that a survey would be particularly useful because of the large number of products involved.

In summary, a survey should be used where sufficiently accurate data are not available from other sources, where a survey is appropriate and practicable, and where it offers the prospect of better data than other approaches.

2 Development of Survey Technique

Surveys of this type have been successfully undertaken as part of NPI Trials in Dandenong, Launceston, Newcastle and Port Pirie in 1995 and 1996, and for the Port Phillip Region emissions inventory in 1997. These surveys in turn evolved from earlier exercises undertaken for the Brisbane, Sydney and Auckland regions in the early 1990s.

For the NPI trials project, assistance was obtained from ABS in refining previous surveys and sampling processes, and a market firm was engaged for the PPR survey to further refine survey techniques. Best practice in survey design and execution is now considered to provide highly reliable data for emission estimation purposes.

These techniques are now sufficiently trialled that pilot surveys are not considered necessary, although minor adaptations for each survey region are usually required.

3 The Survey Process

A typical domestic survey can be completed within about three months. The process can be summarised as follows:

- The jurisdiction engages a market research or similar firm to assist with survey design and execution.
- The jurisdiction and firm jointly design the questionnaire.
- The firm designs a sampling plan.
- The firm prints the questionnaire and, with input from the jurisdiction, prepares covering letters and envelopes using the latter's letterhead, and reply-paid envelopes addressed to the jurisdiction.
- The population is sampled by the firm with a mail-out questionnaire.
- The jurisdiction receives the completed returns and provides an initial technical check.
- The returns are passed to the firm for data entry.
- The firm sends a second mail-out to increase return rate.
- Again, the second round of returns is checked by the jurisdiction, and the additional data is entered by the firm.
- The full data set analysed by the jurisdiction and/or firm.
- The jurisdiction uses the survey data to generate emissions data.

One of the key tasks of the assisting firm is to design the sample, ensuring that the sample size leads to an overall return which keeps sampling error to an acceptable level, and that the sample obtained is genuinely representative of the population within the region.

It is possible to divide the survey region into sub-regions to improve the spatial accuracy of the data obtained. However, unless there are good reasons for believing that there are distinct differences in activity levels between these sub-regions, this approach is not recommended as it effectively amounts to treating each sub-region as a discrete area for survey, each requiring a similar level of sampling. This would obviously result in a significant increase in survey costs. Also, given the uncertainties in the survey process and emissions estimation, the resulting improvements in spatial accuracy may be difficult to justify.

4 Design of Questionnaire

The survey questions should be developed by the jurisdiction, and discussed and refined with the firm. Questionnaires and covering letters used in other jurisdictions (as described above) provide a useful starting point, as they are the product of a series of lessons learnt over the last decade about domestic activity surveys.

It is recommended that the temptation to ask for data that is unlikely to be used should be resisted, including information on attitudes and opinions, as the shorter and simpler the questionnaire, the better the response rate is likely to be.

It should also be recognised that if relevant aggregated data is already available (e.g. data on overall domestic gas consumption may be available from gas retailers), there is little point in asking households for this information, as its accuracy would almost certainly be reduced.

5 Use of Mail Surveys

The nature of the data required for emissions inventories lends itself very well to a mail survey, as potential respondents may need to spend a little time in developing accurate responses (e.g. by discussing questions with other household members, checking equipment details, etc). Allowing surveys to be completed over a few days is therefore likely to produce more accurate responses.

While telephone or door-to-door survey methods produce quicker results, it is difficult to achieve response rates comparable with mail surveys without repeated call-backs to households, and hence comparatively high costs. Also, mail surveys are considered to be more suited to the gathering of factual information, whereas phone or door-to-door methods are usually better for gathering information on opinions and attitudes.

6 Use of Stationery of Jurisdiction

The use of Government stationery (preferable signed by a Government official) is considered to be a significant factor in obtaining good response rates.

7 Response Rates

For mail surveys of this type response rates are generally 50 to 55%, with the initial mail-out generating around 30% of returns and the follow-up a further 20%.

With these types of response rates, a sample size of 600 (i.e. about 300 returns) results in a sampling error of only about 5.6% at 95% probability. Increasing the sample size to 1000 only reduces the error to 4.4%.

Questionnaires could be numbered, allowing identification of households which have submitted returns and elimination of them from the second mail-out. However, this reduces confidentiality and may discourage reporting of activities which may not be strictly legal or acceptable (e.g. waste incineration). It is therefore considered preferable for the second mail-out to include the full initial sample. The initial covering letter should therefore make it clear that this process is being followed to ensure confidentiality, and apologise in advance to people who return their questionnaires quickly.

8 Checking of Returns

Returns should be forwarded in the first instance to the jurisdiction, as there are benefits in an initial technical check of returns prior to data entry. This increases data quality, and allows obviously conflicting, inaccurate or incomplete responses to be removed. This can be done progressively as returns are received, thereby not delaying the overall process.