Emissions Estimation Technique Manual

for

Aggregated Emissions from Barbeques

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EMISSIONS ESTIMATION TECHNIQUE MANUAL:
AGGREGATED EMISSIONS FROM BARBEQUES

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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.

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 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

Domestic barbeques in Australia are generally fuelled by either barbeque fuel, briquettes, firewood or liquefied petroleum gas (LPG). This manual provides guidance on estimating aggregate emissions from barbeques using barbeque fuel, briquettes and firewood. Emissions from LPG barbeques are covered in the EET manual for Aggregated Emissions from Domestic Gaseous Fuel Burning.

Barbeques are not major contributors to area-based emissions. However, they may contribute significantly to PM10 emissions, mostly as a result of firewood use.

2.1 NPI Substances

Table 1 lists those substances in Table 2 to Annex A of the NEPM which are emitted by domestic barbeques. As emissions vary with the type of fuel used, some of these substances are not emitted by particular fuel types.

Table 1: NPI Substances Emitted by Domestic Barbeques

Acetaldehyde	n-Hexane
Acetone	Lead and compounds
Antimony and compounds	Manganese and compounds
Arsenic and compounds	Mercury and compounds
Benzene	Methyl ethyl ketone
Beryllium and compounds	Nickel and compounds
1,3-Butadiene	Oxides of nitrogen
Cadmium and compounds	Particulate matter ≤ 10 μm (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

2.2 Emission Sources and Related Processes

Emissions from barbeques arise from the direct burning of fuel to provide heat for cooking. The types and quantities of the substances emitted will vary with the type of fuel used.

Emissions for wood fuel barbeques are calculated from the quantity of wood burnt, using emission factors for open fireplaces.

The EET for barbeque fuel and briquettes is also based on fuel consumption, and uses the same emission factors as those for combustion of brown coal in

hand-fed stoves. The factor for sulphur dioxide has been adjusted for local fuel content. Because the emission factors are the same for both fuel types, they are treated as a single fuel type in the EET.

There are also emissions from the product being cooked, both directly and from the burning of dripping fats. However, the EET only addresses emissions from fuel combustion. Emissions from the product are not included.

2.3 Emission Controls

There are no controls on emissions from barbeques.

Jurisdictional controls can be applied to the use of barbeques in times of poor air quality or elevated fire risk, although the former has not been implemented in Australia. Controls might also be required for an individual appliance if its operation is causing a nuisance.

The use of barbeques is quite seasonal, and may also vary significantly with time of day and day of the week. Although it is possible to estimate seasonal and temporal variations, the NPI only requires reporting of annual aggregated emissions.

3.0 Emissions Estimation Techniques

The information required to calculate aggregated emissions from domestic barbeques is as follows:

- the amount of each type of fuel consumed in barbeques in the relevant jurisdiction or airshed; and
- the distribution of households or population by ABS Collection District.

3.1 Approaches Employed

3.1.1 Amount of Each Type of Fuel Consumed

The preferred methodology for obtaining information about fuel consumption in barbeques 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 sub-regional differences, while for a smaller region a single sample may be sufficient. Appendix A provides guidelines for the design and conduct of domestic surveys.

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, default figures of 600 kg m^{3} for hardwoods and 345 kg m^{-3} for softwoods may be used (QDEH 1998).

The amount of each fuel type consumed in barbeques in a airshed can be calculated using Equation 1.

Equation 1: Calculation of amount of solid fuel consumed in the airshed (using domestic survey results)

$$F_s = F_{hs} * (H_{hs} / 100) * P$$

where

F_s	=	Total annual consumption of fuel type s in barbeques, kg yr^{-1}
F_{hs}	=	Average annual household consumption of fuel type s in barbeques, kg yr^{-1}
H_{hs}	=	Percentage of households using fuel type s in barbeques
P	=	Number of households in the airshed

An alternative methodology for obtaining information on the amount of wood used in barbeques would be to use consumption data from the national survey conducted by Forestry Technical Services and University of Tasmania

(DPIE 1989). Wood consumed for cooking would be assumed to be used for barbeques. State fuel usage would need to be scaled down to consumption at airshed level using Equation 2.

Equation 2: Calculation of amount of wood consumed in the airshed (using DPIE data)

$$F_w = F_{wj} * (N_a / N_j)$$

where

F_w	=	Total wood consumption in barbeques in the airshed, kg yr^{-1}
F_{wj}	=	Total wood consumption in barbeques in the jurisdiction, kg yr^{-1}
N_a	=	Number of households (or population) in airshed
N_j	=	Number of households (or population) in jurisdiction

Information on barbeque fuel and briquette usage in an airshed may be available from fuel suppliers. Alternatively, ABARE publishes data on residential wood and briquette use for Australia in petajoules (PJ). This can be converted to mass by using the energy contents data in Table 2. Mass consumption figures also need to be scaled down to airshed level, and usage in barbeques then needs to be distinguished from heating uses to avoid double counting. To make this distinction the amount of fuel used in barbeques can be derived from the data in Table 3, if more specific data are not available. ABARE does not specifically record barbeque fuel usage.

Equation 3: Calculation of amount of solid fuel consumed in the airshed (using ABARE data)

$$F_s = (F_{As} / E_s) * (N_a / N_j) * B_s$$

where

F_s	=	Total annual consumption of fuel type s in barbeques in the airshed, kg yr^{-1}
F_{As}	=	Total Australian residential energy consumption for fuel type s, PJ
E_s	=	Energy content of fuel type s, PJ kg^{-1}
N_a	=	Number of households (or population) in airshed
N_j	=	Number of households (or population) in Australia
B_s	=	Proportion of total fuel type s used in barbeques

Table 2: Energy Contents of Wood and Briquettes

Fuel	Energy Content (PJ kg^{-1})[a]
Wood	$1.62 * 10^{-8}$
Briquette	$2.21 * 10^{-8}$

[a] ABARE (1999).

Table 3: Default Percentages of Total State Consumption of Wood, Barbeque Fuel and Briquettes for Heating and Barbeques[a]

Jurisdiction	Heating	Barbeques
Australian Capital Territory	97	3
New South Wales	94.5	5.5
Northern Territory	81.5[b]	18.5[b]
Queensland	91	9
South Australia	98	2
Tasmania	94	6
Victoria	96	4
Western Australia	97.5	2.5

[b] Derived from (DPIE 1989).
[c] No data available, so Australian average figure is used.

3.1.2 Emissions of Each NPI Substance for Each Fuel Type

Once the annual consumption of each fuel type in an airshed has been derived, the annual emission of each NPI substance from barbeques using that fuel type can be calculated from Equation 4. Then total emissions of a substance from all barbeques using solid fuel can be calculated by summing the estimates for wood and barbeque.

Equation 4: Calculation of total annual emissions

$$E_{is} = F_s * EF_{is} * 10^{-3} \quad (4.1)$$

where

E_{is} = Total annual airshed emissions of substance i from barbeques using fuel type s, kg yr^{-1}

F_s = Total annual airshed consumption of fuel type s in barbeques, kg yr^{-1}

EF_{is} = Emission factor for substance i from barbeques burning fuel type s, g kg^{-1}

then

$$E_i = E_{i,wood} + E_{i,BBQfuel/briquettes} \quad (4.2)$$

where

E_i = Total annual airshed emissions of substance i from barbeques, kg yr^{-1}

$E_{i,wood}$ = Total annual airshed emissions of substance i from barbeques using wood, kg yr^{-1}

$E_{i,BBQfuel/briquettes}$ = Total annual airshed emissions of substance i from barbeques using barbeque fuel or briquettes, kg yr^{-1}

3.2 Spatial Surrogates and Spatial Allocation

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

The ABS collects household and population 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 5.

Equation 5: Allocating emissions to grid cells

$$E_{ij} = E_i * (P_j / P_a)$$

where

E_{ij} = Annual emissions of substance i in grid cell j, kg yr^{-1}

E_i = Total annual airshed emissions of substance i, kg yr^{-1}

P_j = Number of households (or population) in grid cell j

P_a = Number of households (or population) in the airshed

3.3 Emission Factors

Emission factors for barbeques burning wood and barbeque fuel/briquettes are presented in Table 4.

Table 4: Emission Factors for Solid Fuel Combustion

NPI Substance	Emission Factor (g kg^{-1})[a]	
	Wood Burning	**Barbeque Fuel or Briquettes**
Acetaldehyde	8.87 [b]	2.85×10^{-4}
Acetone	6.56 [b]	-
Antimony and compounds	1.13×10^{-4} [c]	-
Arsenic and compounds	7.52×10^{-5} [c]	9.5×10^{-5}
Benzene	-	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]	3.55×10^{-5}
Chromium (VI) compounds	-	1.4×10^{-2}
Carbon disulphide	-	6.5×10^{-5}
Carbon monoxide	126.3	138
Cobalt and compounds	1.88×10^{-5} [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]	1.2×10^{-4}
n-Hexane	-	3.35×10^{-5}
Lead and compounds	3.01×10^{-4} [c]	4.45×10^{-3}
Manganese and compounds	5.45×10^{-4} [c]	1.8×10^{-3}
Mercury and compounds	-	6.5×10^{-5}
Methyl ethyl ketone	-	1.95×10^{-4}
Nickel and compounds	-	1.3×10^{-4}
Oxides of nitrogen	1.3	4.55
Particulate matter ≤ 10 μm	17.3	3.1
Phenol	-	8.0×10^{-6}
Polycyclic aromatic hydrocarbons	8.0×10^{-4}	1.12×10^{-3}
Selenium and compounds	1.88×10^{-5} [c]	6.5×10^{-4}
Sulphur dioxide	0.20	3.1 [e]
Styrene	0.175 [d]	1.25×10^{-5}
Tetrachloroethylene	-	2.15×10^{-5}
Toluene	2.39 [b]	1.2×10^{-4}
Total volatile organic compounds	114.5	5
Xylenes	1.45 [b]	1.85×10^{-5}
Zinc and compounds	0.0139 [c]	-

[a] USEPA (1995), unless otherwise specified.
[b] CARB (1991a).
[c] CARB (1991b).
[d] EPAV (1996).
[e] 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. The notional domestic survey data in Table 5 will also be employed in the sample calculations.

Table 5: Domestic Survey Data Used in Sample Calculations

	Firewood	Barbeque Fuel and Briquettes	LPG
% of households with barbeque type	25	30	35
Average fuel consumption (kg household^{-1} yr^{-1})	20	25	10

Example 1: Calculation of airshed fuel consumption from domestic survey results

Total annual fuel consumption in barbeques in the airshed can be calculated from Equation 1

$$F_s = F_{hs} * (H_{hs} / 100) * P$$

$$F_{wood} = 20 * (25 / 100) * 2 * 10^5$$
$$= 1 * 10^6 \text{ kg yr}^{-1}$$

$$F_{BBQfuel/briquettes} = 25 * (30 / 100) * 2 * 10^5$$
$$= 1.5 * 10^6 \text{ kg yr}^{-1}$$

Example 2: Calculation of airshed fuel consumption using ABARE data

If total annual Australian energy consumption for domestic wood combustion is estimated by ABARE as 9.5 PJ, 7% of which is consumed by barbeques in an airshed with 200,000 households, and there are 8 million households in Australia, total annual consumption of wood in barbeques in the airshed can be estimated from Equation 3 and the heat content data for wood in Table 2

$$F_s = (F_{As} / E_s) * (N_a / N_j) * B_s$$
$$= [9.5 / (1.62 * 10^{-8})] * [2 * 10^5 / (8 * 10^6)] * 7 * 10^{-2}$$
$$= 1.03 * 10^6 \text{ kg yr}^{-1}$$

Example 3: Calculation of airshed emissions of PM10

Using the results from Example 1 and the emission factor from Table 4, total annual airshed emissions of PM10 from solid fuel barbeques can be calculated from Equations 4.1 and 4.2

$$E_{is} = F_s * EF_{is} * 10^{-3}$$

$$E_{PM10,wood} = 1 * 10^6 * 17.3 * 10^{-3}$$

$$= 1.73 * 10^4 \text{ kg yr}^{-1}$$

$$E_{PM10,BBQfuel/briquettes}$$

$$= 1.5 * 10^6 * 1.15 * 10^{-3}$$

$$= 1.73 * 10^3 \text{ kg yr}^{-1}$$

then total PM10 emissions from barbeques in the airshed using solid fuels can be calculated from

$$E_i = E_{i,wood} + E_{i,BBQfuel/briquettes}$$

$$E_{PM10} = E_{PM10,wood} + E_{PM10,BBQfuel/briquettes}$$

$$= 1.73 * 10^4 + 1.73 * 10^3$$

$$= 1.90 * 10^4 \text{ kg yr}^{-1}$$

4.0 Uncertainty Analysis

In the following discussion, the reliability of various data and estimation techniques are classified into 3 levels: high (with an uncertainty of 20% or less), medium (between 20% and 80%) and low (greater than 80%).

4.1 Data Reliability

Data from domestic surveys should be of high reliability, provided appropriate care is taken in their design and conduct. Guidelines for domestic surveys are contained in Appendix A.

Wood consumption data from DPIE must be scaled down from jurisdiction to airshed level and those from ABARE from national to airshed level. In both cases, wood consumption needs to be allocated to use in barbeques as opposed to heating and the split is based on households rather than on consumption. The use of data from DPIE or ABARE is hence of low reliability.

Barbeque fuel and briquette consumption data obtained from suppliers are usually of high reliability. Using data from ABARE for briquette consumption is of low reliability, as the data must be scaled from national to airshed level and then distributed between barbeque and heating uses. This split is based on household rather than on consumption, and is derived from the split reported in DPIE 1989 for wood fuel use. ABARE does not have data on barbeque fuels and the use of ABARE data alone will underestimate emissions from barbeques.

4.2 Reliability of Emission Factors

4.2.1 Emission Factors for Firewood

Emission factors for carbon monoxide, sulphur dioxide, oxides of nitrogen, total volatile organic compounds and PM10 are from USEPA AP-42 open fire emissions. These factors were obviously not developed for barbeques or for Australian fuels, and so are considered to have low reliability.

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

4.2.2 Emission Factors for Barbeque Fuel and Briquettes

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

4.3 Problems and Issues Encountered

The main problems with the EETs proposed in this manual are the relatively low levels of confidence in the emissions factors. In particular, the proposed factors have not been developed for either barbeques or the Australian applications.

Also, the EETs in this manual only deal with emissions from combustion of fuel. Emissions from the product being cooked, either directly or from the effect of fat dripping onto the burning fuel, are not covered in this EET.

4.4 Recommendations for Further Work

Further investigation and development of emission factors for local fuels used in Australian barbeques would improve the accuracy of emissions estimates.

The emission factors for barbeques are linked to those for domestic solid fuel combustion for heating purposes. Any advances in the quality of factors used in that manual would also benefit the EETs in this manual.

5.0 Glossary of Terms and Abbreviations

ABS	Australian Bureau of Statistics
AE	Aggregated emissions
ABARE	Australian Bureau of Agricultural and Resource Economics
CARB	California Air Resources Board
CD	Collection District
DPIE	Department of Primary Industry and Energy
EET	Emissions estimation technique
EF	Emission factor
EPAV	Environment Protection Authority of Victoria
LPG	Liquefied petroleum gas
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
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

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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 USEPA 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 checking 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.