Emissions Estimation Technique Manual

for

Aggregated Emissions from Domestic Gaseous Fuel Burning

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EMISSIONS ESTIMATION TECHNIQUE MANUAL: AGGREGATED EMISSIONS FROM DOMESTIC GASEOUS 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.

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

This manual provides guidance on the estimation of aggregated emissions from the domestic burning of gaseous fuels, including natural gas, town gas and liquefied petroleum gas (LPG). As these fuels are widely used throughout the country in domestic applications, their consumption can make a significant contribution to regional emissions.

2.1 NPI Substances

Table 1 lists those substances in Table 2 to Annex A of the NEPM which are emitted by domestic gaseous fuel burning.

Table 1: NPI Substances Emitted by Domestic Gaseous Fuel Burning.

Arsenic and compounds	Manganese and compounds
Benzene	Mercury and compounds
Beryllium and compounds	Nickel and compounds
Cadmium and compounds	Oxides of nitrogen
Chromium (VI) compounds	Particulate matter ≤10μm (PM10)
Carbon monoxide	Polycyclic aromatic hydrocarbons
Cobalt and compounds	Selenium and compounds
Copper and compounds	Sulphur dioxide
Cyclohexane	Toluene
Formaldehyde	Total volatile organic compounds
n-Hexane	Zinc and compounds
Lead and compounds	

2.2 Emission Sources and Related Processes

Domestic gaseous fuel burning is undertaken for cooking, space heating and hot water heating. Natural gas and town gas supplies are limited by the extent of the reticulation system whilst LPG for domestic applications (primarily propane) is supplied in the form of large, portable gas bottles.

Town gas is usually supplied by a reticulated gas system that is not connected to a larger regional or statewide natural gas supply. Town gas systems often serve only a small area around a population centre and may utilise a number of different types of gases.

Emissions are dependent on the amount and type of the gaseous fuel burnt, and also on the temperature and efficiency of combustion, but these latter influencing factors are not directly considered in the EETs.

2.3 Emission Controls

There are no emission controls to factor into the EETs.

Industrial gaseous fuel burning practices often incorporate emission controls such as flue gas recirculation and special burners to control the emission of oxides of nitrogen. However, this technology is not used in domestic applications and is not considered in the EETs.

3.0 Emissions Estimation Techniques

The information required to estimate emissions from domestic gaseous fuel burning is as follows:

- the amount of each fuel type burnt in domestic applications in the airshed or jurisdiction; and
- the density or energy content of each fuel type.

3.1 Approaches Employed

3.1.1 Determination of Gaseous Fuel Consumed

Fuel Consumption

Information on domestic fuel consumption may be available from local natural gas, town gas and LPG distributors in an airshed or jurisdiction. It is desirable to contact all gas distribution companies that operate within the airshed of interest to ensure that all gas consumption is accounted for in estimating emissions.

If domestic gas usage data are not available from local gas distributors, information on the amounts of natural gas, town gas and LPG consumed in domestic appliances across individual jurisdictions is available from the Australian Bureau of Agriculture and Resource Economics (ABARE). Alternatively, data for domestic gas use may be sought from the Australian Gas Association (AGA).

Data from both of these alternative sources must be scaled down from jurisdiction to airshed level, based on the population fraction and taking into account the availability of each fuel type in the airshed. If information on the availability of fuel types is not obtainable, simple scaling according to population should be undertaken.

Energy Contents

Gas consumption data should be requested in volume units for the estimation of emissions. If usage data are provided in tonnes, the fuel density should be requested to converted it to a volume basis. If information on gas use is reported as petajoules (PJ), it must also be converted to volume.

If data on local energy contents cannot be obtained, Table 2 lists typical energy contents of fuels used in Australia.

The types and amounts of town gas used in an airshed should be available from local gas distributors. Alternatively, a breakdown of the proportion of each type of town gas used in various jurisdictions is available from ABARE.

Once the total annual domestic energy consumption and energy content of each type of fuel used within an airshed are known, the total volume of each fuel consumed for domestic purposes can be calculated from Equation 1.

Table 2: Typical Energy Content of Gaseous Fuels around Australia

Type of Fuel	Energy Content[a]
Natural Gas	
Victoria	38.8 MJ m^{-3}
Queensland	38.5 MJ m^{-3}
South Australia and New South Wales	38.9 MJ m^{-3}
Western Australia	39.6 MJ m^{-3}
Northern Territory	40.7 MJ m^{-3}
Town gas	
Synthetic natural gas	39.0 MJ m^{-3}
Reformed gas	20.0 MJ m^{-3}
Tempered LPG[b]	25.0 MJ m^{-3}
Tempered natural gas	25.0 MJ m^{-3}
LPG	25.3 MJ L^{-1}

[a] ABARE (1999).

[b] Tempered LPG is supplied via a reticulation system in the form of a gas, and should not be confused with LPG which is supplied as a bottled liquid.

Equation 1: Calculation of annual volumes of gaseous fuels burnt in domestic applications in an airshed (based on energy consumption data)

$$V_i = E_i / (Q_i * F_i)$$

where

V_i = Volume of fuel type i consumed domestically in an airshed, 10^6 m^3 yr^{-1} (or 10^3 L for LPG)

E_i = Domestic energy consumption for fuel type i in an airshed, PJ yr^{-1}

Q_i = Energy content of fuel type i, MJ m^{-3} (or MJ L^{-1} for LPG)

F_i = Conversion factor: 10^{-3} (for natural gas and town gas) or 10^{-6} (for LPG)

If specific information on the use of each form of town gas within an airshed is not known, then ABARE information on the typical proportions of usage for each town gas type in a jurisdiction should be used. From these typical proportions, an estimate of the total volume of town gas used can be calculated using Equation 2.

Equation 2: Calculation of annual volume of town gas burnt in domestic applications in an airshed (where specific usage data are not available)

$$V_{TG} = E_{TG} * 10^3 * \sum_i (P_{TGi} / Q_{TGi})$$

where

V_{TG} = Total annual volume of town gas used in an airshed, 10^6 m^3 yr^{-1}

E_{TG} = Total domestic energy consumption for town gas in an airshed, PJ yr^{-1}

Q_{TGi} = Energy content of town gas type i, MJ m^{-3}

P_{TGi} = Proportion of town gas usage across the jurisdiction for town gas type i

3.1.2 Determination of Emissions of NPI Substances

Once the volume of each fuel burnt in domestic applications in an airshed has been estimated, the annual emissions of each NPI substance for that fuel type can be calculated using Equation 3.

Emission factors for town gas are not available and are assumed to be the same as for natural gas.

Equation 3: Calculation of annual airshed emissions of an NPI substance from combustion of particular fuel type

$$E_{ij} = EF_{ij} * V_i$$

where

E_{ij} = Total annual emissions of substance j in the airshed from fuel type i, kg yr^{-1}

EF_{ij} = Emission factor for substance j from fuel type i, kg 10^{-6} m^{-3} (or kg 10^{-3} L^{-1} for LPG)

V_i = Volume of fuel type i consumed annually in airshed, 10^6 m^3 yr^{-1} (or 10^3 L yr^{-1} for LPG)

3.2 Spatial Surrogates and Spatial Allocation

Supply of natural gas and town gas is reliant on reticulation systems which have definite boundaries. Annual emissions from use of these fuels should therefore be spatially allocated according to the population distribution *within these reticulation areas*.

If gas usage data can be acquired on the basis of postcode or some other area basis, it is a relatively easy task to allocate emissions to their correct grid cells (see Equation 4 below). If ABARE data are used, it is necessary to obtain information on the boundaries of the reticulation areas from local gas suppliers or the AGA, and to determine the postcodes (or other appropriate area units) which receive gas supplies. If no spatial data are available, or if it is known that the reticulation system covers the whole airshed, emissions from natural gas and town gas can be allocated according to population alone (see Equation 5).

LPG sales data are generally available from distribution companies by postcode, which can be used for spatial allocation of emissions. If this information is not available, LPG emissions can also be spatially allocated according to the population within the airshed.

The Australian Bureau of Statistics collects population data by Collection District (CD). This data can be converted to population by grid cells using a program or Geographic Information System (GIS). If spatial distribution information is provided by gas suppliers on a postcode basis, emissions in a grid cell can be calculated using Equation 4. Use of a GIS is recommended in applying Equation 4, as it can accurately calculate the proportion of a postcode region's population that is present in a grid cell.

Equation 4: Estimating emissions of an NPI substance in a grid cell for a fuel type (based on gas usage data provided on a postcode basis)

$$E_{ijk} = \left(E_{ij} / V_i\right) * \sum_p \left(P_{kp} / P_p\right) * V_{ip}$$

where

E_{ijk}	=	Annual emissions of substance j from fuel type i in grid cell k, kg yr^{-1}
E_{ij}	=	Total annual airshed emissions of substance j from fuel type i, kg yr^{-1}
P_{kp}	=	Population of postcode region p in grid cell k
P_p	=	Total population of postcode region p
V_{ip}	=	Volume of fuel type i used in postcode region p, 10^6 m^3 yr^{-1} (or 10^3 L yr^{-1} for LPG)
V_i	=	Total volume of fuel type i use in the airshed, 10^6 m^3 yr^{-1} (or 10^3 L yr^{-1} for LPG)

Energy consumption data for postcode regions and the airshed may be used instead of data on fuel usage.

Equation 5: Estimating emissions of an NPI substance in a grid cell for a fuel type (based on population alone)

$$E_{ijk} = E_{ij} * (P_k / P)$$

where

P_k = Population in grid cell k
P = Total population of the airshed

3.3 Emission Factors

Emission factors for use in determining aggregate emissions from domestic gaseous fuel burning are provided in Table 3.

Table 3: Emission Factors for Domestic Gaseous Fuel Burning

NPI Substance	Natural Gas[a] (kg 10^{-6} m^{-3})	LPG[b] (kg 10^{-3} L^{-1})
Arsenic and compounds	3.20×10^{-3}	
Benzene	3.36×10^{-2}	2.66×10^{-3} [c]
Beryllium and compounds	9.6×10^{-5} [d]	
Cadmium and compounds	1.76×10^{-2}	
Chromium (VI) compounds	2.24×10^{-2}	2.64×10^{-4} [e]
Carbon monoxide	640	0.228
Cobalt and compounds	1.34×10^{-3}	9.60×10^{-4} [e]
Copper and compounds	1.36×10^{-2}	2.40×10^{-5} [e]
Cyclohexane	1.74[c]	7.13×10^{-4} [c]
Formaldehyde	1.20	6.28×10^{-3} [c]
n-Hexane	28.8	7.38×10^{-4} [c]
Lead and compounds	8.0×10^{-3}	2.40×10^{-5} [e]
Manganese and compounds	6.08×10^{-3}	2.40×10^{-5} [e]
Mercury and compounds	4.16×10^{-3}	
Nickel and compounds	3.36×10^{-2}	2.64×10^{-4} [e]
Oxides of nitrogen	1500	1.68
Particulate matter ≤10µm	122	4.80×10^{-2}
Polycyclic aromatic hydrocarbons	1.1×10^{-2}	
Selenium and compounds	1.92×10^{-4} [d]	2.64×10^{-4} [e]
Sulphur dioxide	8.36[f]	9.45×10^{-9} [g]
Toluene	5.4×10^{-2}	1.34×10^{-3} [c]
Total volatile organic compounds	88.0	3.60×10^{-2}
Zinc and compounds	4.64×10^{-1}	2.64×10^{-4} [e]

[a] USEPA (1998) unless otherwise specified.
[b] USEPA (1996) unless otherwise specified.
[c] CARB (1991).
[d] Emission factors based on 50% of USEPA (1998) method detection limit.
[e] USEPA (1992).
[f] Based on 2.09 times the typical Victorian sulfur content of 4 mg m^{-3} (EA 1999). Indicative sulphur content data for other jurisdictions may also be used.

[g] Based on 0.00021 times the Australian average sulfur content for LPG of 0.045 g m^{-3} (EA 1999).

3.4 Sample Calculations

The data in Tables 4, 5 and 6 will be used in the sample calculations.

Table 4: Sample Energy Consumption Data

Energy Consumption in an Airshed by Fuel Type	
Fuel Type	**Amount (PJ)**
LPG	2
Natural Gas	25
Town Gas	3

Table 5: Sample Data on Town Gas Usage

Proportion of Different Types of Town Gas Used in a Jurisdiction	
Town Gas Type	**Proportion (%)**
Synthetic Natural Gas	90
Reformed Gas	10
Tempered LPG	0
Tempered Natural Gas	0

Table 6: Sample Data for Notional Postcode Regions

Postcode Region	Population in Postcode Region	Portion of Postcode Region Population in Grid Cell k	Annual LPG Usage in Postcode Region (10^3 L yr^{-1})
P1	45 000	20 000	580
P2	38 000	8 000	220

Example 1: Calculation of annual volumes of gaseous fuels burnt in an airshed (based on energy consumption data)

Using Equation 1 for natural gas and LPG, the sample data from Table 4, the energy content from Table 2 for LPG, and an assumed energy content of natural gas in the jurisdiction of 40.0 MJ m^{-3}

$$V_i = E_i / (Q_i * F_i)$$

$$V_{naturalgas} = 25 / (40.0 * 10^{-3})$$
$$= (6.25 * 10^2)\ 10^6\ m^3\ yr^{-1}$$

$$V_{LPG} = 2 / (25.3 * 10^{-6})$$
$$= (7.91 * 10^4)\ 10^3\ L\ yr^{-1}$$

For the following example involving town gas, Equation 2 is used because usage data are only provided as an overall figure (not for each type of town gas), but estimates of typical proportions of usage of each town gas type in the jurisdiction are available.

Example 2: Calculation of annual volume of town gas burnt in an airshed (where specific usage data are not available)

Using Equation 2, the data from Table 5, and the energy content data from Table 2 for the two town gas types

$$V_{TG} = E_{TG} * 10^3 * \sum_i (P_{TGi} / Q_{TGi})$$

V_{TG} = $3 * 10^3 [0.90 / (39.0 * 10^{-3}) + 0.10 / (20.0 * 10^{-3})]$
= $84.2\ 10^6\ m^3\ yr^{-1}$

Example 3: Calculation of annual airshed emissions of PM10 from combustion of gaseous fuels

Using Equation 3, the emission factors from Table 3 (assuming the same EF for town gas as natural gas), and the results of Examples 1 and 2

$$E_{ij} = EF_{ij} * V_i$$

$E_{naturalgas,PM10}$ = $122 * 6.25 * 10^2$
= $7.63 * 10^4$ kg yr^{-1}

$E_{towngas,PM10}$ = $122 * 84.2$
= $1.03 * 10^4$ kg yr^{-1}

$E_{LPG,PM10}$ = $4.80 * 10^{-2} * 7.91 * 10^4$
= $3.79 * 10^3$ kg yr^{-1}

Example 4: Estimating PM10 emissions in a grid cell from LPG usage (based on usage data provided on a postcode basis)

Using Equation 4, the results for LPG from Examples 1 and 3, and the sample data from Table 6

$$E_{ijk} = (E_{ij} / V_i) * \sum_p (P_{kp} / P_p) * V_{ip}$$

$E_{LPG,PM10,cell}$ = $(E_{LPG,PM10} / V_{LPG}) * [(P_{P1/cell} / P_{P1}) * V_{LPG,P1} + (P_{P2/cell} / P_{P2}) * V_{LPG,P2}]$
= $3.79 * 10^3 / (7.91 * 10^4) * [(20000 / 45000) * 580 + (8000 / 38000) * 220]$
= 14.6 kg yr^{-1}

4.0 Uncertainty Analysis

In the following analysis 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 on domestic gas usage from local gas distributors should be of high reliability. ABARE and AGA data are considered to be of medium reliability as they are based on gas consumption data provided by gas suppliers and LPG distributors at a jurisdiction (rather than airshed) level.

4.2 Reliability of Emission Factors

Natural Gas Emission Factors

Most of the emission factors for natural gas combustion are based on AP-42 data (USEPA 1998) for uncontrolled residential gas burning. The factors for CO, NO_x, SO_2, benzene and formaldehyde are considered to be of high reliability.

The remaining factors are considered to have medium reliability, with the exception of factors for compounds of arsenic, beryllium, selenium, zinc and polycyclic aromatic hydrocarbons which are considered to have low reliability. The factor for cyclohexane is sourced from CARB and is also considered to be of relatively low reliability.

Town Gas Emission Factors

There are no emission factors available for town gas, and the factors for natural gas are recommended for use in this EET manual. As these emission factors are not specific to each (or, indeed, any) form of town gas, the reliability for all factors is considered to be lower than those for natural gas. Thus, the factors for CO, NO_x, SO_2, benzene and formaldehyde are considered to be of medium reliability, while the reliability of the remaining factors is considered to be low.

LPG Emission Factors

The LPG emission factors for CO, NO_x, SO_2, VOC and PM10 are based on the emission factors for uncontrolled commercial boilers in AP-42 (USEPA 1996). These factors are considered to be of medium reliability. The remaining factors are based on speciation calculations by USEPA, and are considered to have low reliability.

4.3 Problems and Issues Encountered

Data availability is the primary problem that limits the accuracy of the results obtainable with these EETs. Most of the emission factors are based on USEPA data and may not be very relevant to appliances used in Australia.

4.4 Recommendations for Further Work

Specific emissions tests on Australian appliances using Australian gaseous fuels would allow more accurate emission factors to be developed.

Some manufacturers are developing the use of emission control technology such as low NO_x burners for application in domestic appliances. While this technology is not common at this stage in Australia, its development should be monitored as a significant change in technology will require a review of emission factors.

5.0 Glossary of Terms and Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
AGA	Australian Gas Association
CARB	California Air Resources Board
CO	Carbon monoxide
EA	Environment Australia
EET	Emissions estimation technique
EPAV	Environment Protection Authority of Victoria
GIS	Geographic information system
LPG	Liquefied petroleum gas
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO_x	Oxides of nitrogen
NPI	National Pollutant Inventory
PM10	Particulate matter less than or equal to 10 μm
PJ	Petajoules
SO_2	Sulphur dioxide
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

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