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Department of Climate Change

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006

Energy
(Stationary sources)

National Greenhouse Gas Inventory Committee

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http://www.climatechange.gov.au/inventory.

The Intergovernmental Panel on Climate Change *Guidelines for National Greenhouse Gas Inventories* are at:

http://www.ipcc-nggip.iges.or.jp.

Suggestions and comments would be appreciated. They should be addressed to the Manager, Australian National Greenhouse Gas Inventory, Emissions Analysis Team, Department of Climate Change or sent to ageis@climatechange.gov.au.

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FOREWORD

This inventory methodology workbook presents the Australian methodology to estimate greenhouse gas emissions and sinks for stationary sources in the energy sector. It is part of a series that includes:

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Energy (Stationary Sources)

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Energy (Transport)

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Energy (Fugitive Fuel Emissions)

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Industrial Processes

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Solvents

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Agriculture

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Land use, land use change and forestry

Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Waste

The methodology in this workbook was developed with input from researchers and other experts specialising in greenhouse gas emissions from the energy sector and is based on the methodology first presented in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook for Fuel Combustion Activities (Stationary Sources),* National Greenhouse Gas Inventory Committee, Workbooks 1.0 (1994) and 1.1 (1998), Canberra. Contributors to the development of the original methodology are listed in those Workbooks. The revised format of the 2002 Methodology Workbook was provided by Energy Strategies Pty Ltd (Dr Hugh Saddler and David Brunoro) and George Wilkenfeld and Associates Pty Ltd (Dr George Wilkenfeld).

The development of Australia's inventory methodologies and the compilation of Australia's national inventories are guided by the National Greenhouse Gas Inventory Committee, comprising representatives of the Australian, State and Territory governments.

ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ADO	Automotive Diesel Oil
ANZSIC	Australia and New Zealand Standard Industrial Classification
ASIC	Australian Standard Industrial Classification
BTX	Benzene, toluene, xylene
UNFCCC	United Nations Framework Convention on Climate Change
GCV	Gross Calorific Value
HHV	Higher heating value
IDF	Industrial Diesel Fuel
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquid Petroleum Gas
NGGI	National Greenhouse Gas Inventory
NMVOC	Non Methane Volatile Organic Compounds

UNITS

The units mainly used in this workbook include joules (J), watts (W), grams (g) and litres (l), together with their multiples. Standard metric prefixes used in this workbook are:

kilo (k)	=	10^3 (thousand)
mega (M)	=	10^6 (million)
giga (G)	=	10^9 (billion)
tera (T)	=	10^{12}
peta (P)	=	10^{15}

One gigagram (Gg) equals one thousand tonnes, or one kilotonne (kt). One million tonnes or one megatonne (Mt) is equal to one thousand gigagrams. One kilogram per gigajoule (kg/GJ)is equal to one gigagram per petajoule (Gg/PJ).

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INTRODUCTION

Australia's national greenhouse gas inventory is prepared annually by the Department of Climate Change in accordance with both the IPCC *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (IPCC 1997) and the *IPCC Good Practice Guidance* (IPCC 2000) and taking into account Australian conditions. Documenting the methods used in the estimation of emissions for the inventory enhances transparency and improves the comparability of estimates with those reported in the inventories produced by other countries.

The methods and emission factors used by Australia to estimate annual emissions of greenhouse gases from stationary sources within the energy sector are documented in this workbook. It covers the UNFCCC reporting categories *Electricity production (1A1a), Petroleum refining (1A1b), Manufacture of solid fuels and other energy industries (1A1c),* the combustion of fuels used by *Manufacturing Industries and Construction (1A2), Other Sectors (1A4) and Other (1A5).*

The focus of this workbook is on the emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x), carbon monoxide (CO), and non methane volatile organic compounds (NMVOCs) from the purposeful combustion of fuels to provide useful energy.

This workbook is one of three workbooks for the Energy sector. The estimation of greenhouse gas emissions associated with fuel production processes other than combustion are covered in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Energy, (Fugitive Fuel Emissions)* and the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Energy, (Transport)* workbooks.

Emissions of CO_2 result from the oxidation of carbon contained in the fuel. The other gases are produced by incomplete combustion of the fuel and/or side reactions in the combustion process. In terms of the total national inventory of greenhouse gas emissions, stationary fuel combustion is a very major source of CO_2, but a relatively minor source of most of the other gases.

Fuels covered include:

- coal
- fuels derived from coal, including coke, brown coal briquettes and coke oven gas
- petroleum products
- natural gas
- town gas

All greenhouse gas emissions resulting from combustion of these fuels in stationary equipment are included in this workbook.

Fuels derived from biomass, including fuel wood and bagasse, account for a significant quantity of energy used in Australia. The IPCC guidelines require that CO_2 emissions from biomass be reported, but not included in national total CO_2 emissions. However, emissions of other direct and indirect greenhouse gases from biomass combustion are to be included, and these may be significant because of poor combustion conditions in the equipment in which much biomass is used, e.g. open fireplaces.

Emissions from fuel used in mobile equipment such as tractors, earth moving equipment and forklifts, are also included in this workbook. All emissions from transport, including international bunkers, are reported under UNFCCC category 1.A.3*, (Transport)*.

General approach

The IPCC guidelines recommend the use of two different approaches for estimating emissions of CO_2. They are termed respectively the IPCC Reference Approach, which is a Tier 1 or "top-down" method, and the Tier 2/3 or "bottom-up" method. The latter provides more detail about emission processes and sources, and is likely to be more accurate, but requires more detailed information about national energy use. Australia does have the requisite information by sector, fuel type and technology and in some cases at a plant specific level. The IPCC requires that all countries using this approach also report the results of using the Reference Approach, and reconcile the two.

The Reference Approach is based on accounting for carbon in fossil fuels supplied to the economy. It therefore only requires information about production, net imports/exports and stock changes of coal, petroleum and natural gas. No attention is paid to the way the fuel is actually used in the economy. By contrast, the sectoral or "bottom-up" approach is based on accounting in detail for carbon in fossil fuels actually used in the various sectors of the economy, and summing the emissions across all sectors. Under both approaches, adjustments have to be made for carbon contained in fossil fuels which is converted to products where it is stored or sequestered for long periods. Such products include bitumen, plastics and other petrochemicals.

As previously noted, emissions of non-CO_2 gases depend on the nature of the combustion process from which they are emitted, ie they depend on the type of fuel using technology or equipment. Consequently, estimation of emissions of these gases can only be made, at least with any degree of precision, by using the Tier 2 or "bottom-up" approach.

Table 1: Summary of estimation methods and emission factors

Greenhouse gas source and sink categories	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1A1a Public electricity	T2	CS	T2	CS	T2	CS
1A1b Petroleum refining	T2	CS	T2	CS	T2	CS
1A1c Manufacture of Solid Fuels	T2	CS	T2	CS	T2	CS
1A2a Iron and Steel	T2	CS	T2	CS	T2	CS
1A2b Non-Ferrous Metals	T2	CS	T2	CS	T2	CS
1A2c Chemicals	T2	CS	T2	CS	T2	CS
1A2d Pulp, Paper and Print	T2	CS	T2	CS	T2	CS
1A2e Food Processing, Beverages and Tobacco	T2	CS	T2	CS	T2	CS
1A2f Other	T2	CS	T2	CS	T2	CS
1A4a Commercial//Institutional	T2	CS	T2	CS	T2	CS
1A4b Residential	T1, T2	CS	T2	CS	T2	CS
1A4c Agriculture, Forestry and Fisheries	T2	CS	T2	CS	T2	CS
1A5 Other	T1, T2	CS	T2	CS	T2	CS

Notes: T1 = Tier 1. T2 = Tier 2. T3 = Tier 3. CS= Country-specific. D= IPCC default. The distinction between Tier 1 methods and those of Tiers 2 and 3 rests mainly on the reliance of the first on widely available fuel supply data which, by its nature, takes no account of the combustion technology to which the fuel is delivered. Distinguishing between Tiers 2 and 3 is less easily done as there is a steadily increasing degree of refinement and detail. Tier 2 methods may be regarded as those dividing fuel consumption on the basis of sample or engineering knowledge between technology types which are sufficiently homogenous to permit the use of representative emission factors. Tier 3 methods generally estimate emissions from activity figures (kilometre travelled or tonne-kilometre carried, not fuel consumption) and specific fuel efficiency or fuel rates or, alternatively using an emission factor expressed directly in terms of a unit of activity (IPCC 1997, page 1.47).

The IPCC guidelines (1997) specify the following steps in calculating CO_2 emissions from fuel use:

1. Estimate consumption of each fuel in material (mass/volume) units,
2. Convert to standard energy units (TJ),
3. Multiply by carbon emission factor (tC/TJ) for each fuel,
4. Subtract quantity of carbon stored,
5. Correct for incomplete combustion of carbon, by multiplying by an oxidation factor,
6. Convert emissions calculated as carbon to full molecular weight of CO_2.

In general terms, the first two steps constitute the specification of activity levels, while steps three to six lead to calculation of emissions. The factor used in step 3 is termed the carbon emission factor; the factor used in step 5 is termed the oxidation factor. Step 6 involves multiplication by the ratio of the molecular weight of CO_2 to the atomic weight of carbon (44.001/12.011, or approximately 44/12).

This general approach applies to both the default (Reference Approach) and to the Sectoral Tier 2 methods. Under the latter approach, the above steps are applied to each economic sector, at whatever level of sectoral disaggregation the data allow. It should be noted

that CO_2 emission factors as defined in step 3 above are based on the assumption that all carbon in the fuel which is oxidised is oxidised to CO_2, and are therefore dependent only on the carbon content of the fuel, and are independent of technology. It is for this reason that the Reference Approach, which requires no information about how fuel is actually used, is feasible. However, it should be noted that oxidation factors, particularly for coal, are technology dependent, at least to some extent, and hence will vary from sector to sector of the economy, depending on the mix of fuel using equipment in the sector.

The method used in this workbook to compile the Australian inventory on a sector by sector basis departs from the six steps above in several minor ways, while retaining the general approach:

- All Australian energy statistics at the detailed level are presented in standard energy units (PJ), so the first two steps are combined,
- CO_2, rather than carbon, emission factors are used, so steps 3 and 6 are combined,
- Different units (PJ, Mg and Gg) are used.

One consequence of combining steps 3 and 6 is that sequestered carbon must be converted to equivalent CO_2 in order to be deducted from the inventory.

The calculation used for each fuel, *j*, in each economic sector, *i*, may be specified by the following algorithm.

$$E_{ijc} = (F_{ij} \times EF_{jc} \times P_{ij} /100) - S_{ij} \times 44/12 \quad (1)$$

Where E_{ijc} is the amount of CO_2 emitted from fuel *j* in economic sector *i* (in Gg),
F_{ij} is the amount of fuel *j* combusted in sector *i* (in PJ),
EF_{jc} is the CO_2 emission factor (in Gg CO_2/PJ) for fuel *j*,
P_j is the oxidation factor (in percent) of fuel *j*, and
S_{ij} is the amount of carbon sourced from fuel *j* which is stored in sector *i* (in Gg).

In all Australian national energy statistics, the specific energy content of fuels, and hence energy consumption by each sector of the economy, are expressed in terms of gross calorific value (GCV). These energy estimates are the most transparent, consistent and reliable available and, hence, the CO_2 emission factors are also expressed in terms of GCV.

For all other direct and indirect greenhouse gases the main calculation steps used in this workbook are:

1. Estimate consumption of each fuel type in each economic sector in standard energy units (PJ)
2. Multiply by technology weighted emission factor (Gg/PJ) for each fuel type used in each sector.

For these gases, emission factors are highly technology dependent, and hence it is important to determine the shares of total energy use by each fuel type in each sector attributable to each type of equipment used in the sector. These shares are then used to calculate technology weighted emission factors for each greenhouse gas, for each sector and fuel type.

This calculation may be specified by the following algorithm

$$E_{ijk} = F_{ij} \times EF_{ijk} \qquad (2)$$

Where E_{ijk} is the amount greenhouse gas k emitted from combustion of fuel type j, in economic sector i (in Gg);
F_{ij} is the amount of fuel type j combusted in sector i (in PJ);
E_{ijk} is the technology weighted emission factor (in Gg/PJ) for greenhouse gas k, from fuel type j in sector i.

For both CO_2 and non-CO_2 gases, total national emissions are calculated by summing across all fuels and all economic sectors the estimated emissions from each fuel in each economic sector.

Activity data

For many years the Australian Bureau of Agricultural and Resource Economics (ABARE), and predecessor organisations, have compiled statistics of Australian energy use by economic sector and fuel. These statistics are compiled from an annual fuel and electricity survey conducted by the Bureau supplemented by a variety of other sources of information. The statistics provide a comprehensive and detailed "bottom-up" quantification of energy use in Australia. They are reconciled with "top-down" statistics of all major fuels in Australia, collected from the suppliers of those fuels, ie the coal, oil, gas and electricity industries.

The data are presented in common energy units (PJ), which means that they are in the form required to be used in the above algorithms. ABARE provides State breakdowns of energy consumption, but for the purpose of compiling the National Greenhouse Gas Inventory only the aggregate national statistics are used.

ABARE have also collected statistics of energy use by equipment (technology) type. These have been used to compile the technology weighted sectoral emission factors for non-CO_2 greenhouse gases (see below).

The economic sectors for which separate emission estimates are made using the procedures described in this workbook are shown in Table 2 in terms of the Australia New Zealand Standard Industrial Classification (ANZSIC).

Table 2: Relationship between IPCC source categories and ANZSIC sectors

IPCC Source Category		ANZSIC Subdivision/Group/Class			
		Division	Subdivision	Group/Class	Description
1 Energy Industries	a Electricity and heat production [a]	D Electricity, Gas and Water Supply	36	361	Electricity supply
	b Petroleum refining	C Manufacturing	25	251	Petroleum refining
	c Solid fuel transformation and other energy industries	B Mining	11		Coal mining (incl. briquette production)
		B Mining	12		Oil and gas extraction (incl. gas processing and LNG production)
		C Manufacturing	27	2711 (part)	Coke ovens associated with Basic iron and steel manufacturing
		D Electricity, Gas and Water Supply	36	362	Gas supply
		I Transport and Storage	65	6501 (part)	Pipeline transport of gas
2 Manufacturing Industries and Construction	f Other (part)	B Mining	13, 14, 15		Metal ore mining, Other mining, Services to mining
	e Food Processing, Beverages and Tobacco	C Manufacturing	21		Food, beverages, tobacco manufacturing
	f Other (part) (all other manuf.)		22		Textiles, clothing , footwear and leather manufacturing
	d Pulp, Paper and Print		23		Wood and paper product manufacturing.
	d Pulp, Paper and Print		24		Printing, publishing and recorded media
	c Chemicals		25	252	Petroleum and coal product manufacturing
	c Chemicals		25	253	Basic chemical manufacturing
	c Chemicals		25	254	Other chemical product manufacturing
	c Chemicals		25	255	Rubber product manufacturing
	c Chemicals		25	256	Plastic product manufacturing
	f Other (part) (non-metallic mineral products)		26	261	Glass and glass product manufacturing
	f Other (part)		26	262	Ceramic product manufacturing
	f Other (part		26	263	Cement, lime, plaster and concrete product manufacturing
	f Other (part)		26	264	Non-metallic mineral product manufacturing n.e.c.
	a Iron and Steel		27	271	Iron and steel manufacturing (excl. Coke ovens)
	b Non-Ferrous Metals		27	272	Basic non-ferrous metal manufacturing
	f Other (part) (all other manuf.)		27	273, 274, 275, 276	All other metal product manufacturing
	f Other (part)		28		Machinery and equipment manufacturing
	f Other (part)		29		Other manufacturing
	f Other (part)	E Construction	41, 42		Construction

IPCC Source Category		ANZSIC Subdivision/Group/Class			
		Division	Subdivision	Group/Class	Description
4 Other Sectors	a Commercial, Institutional		37		Water supply, sewerage and drainage services
		Division F	45, 46, 47		Wholesale trade
		Division G	51, 52, 53		Retail trade
		Division H	57		Accommodation, cafes and restaurants
		Division I Transport and Storage	66		Services to transport
		Division I Transport and Storage	67		Storage
		Division J	71		Communication services
		Division K	73, 74, 75		Finance and insurance
		Division L	77, 78		Property and business services
		Division M	81, 82		Government administration and defence
		Division N	84		Education
		Division O	86, 87		Health and community services
		Division P	91, 92, 93		Cultural and recreational services
		Division Q	95, 96		Personal and other services
	b Residential				Residential
	c Agriculture, forestry, and fishing		01		Agriculture
			02		Services to agriculture, hunting and trapping
			03		Forestry and logging
			04		Commercial fishing
5 Other					Combustion of solvents, lubricants and greases Military transport

Note: *(a)* Electricity and heat production comprises emissions from facilities whose primary purpose is generating electricity for sale to third parties. Emissions from facilities that generate electricity wholly or partly for their own use are assigned to the sector where they were generated if the main activity of the facility is not electricity generation. There is no public generation of distributed heat in Australia.

Several adjustments to the ABARE statistics are required in order to:

- break down energy consumption into sub-sectors where this is required to match emission factor data, but is not done by ABARE,
- identify and allow for stored carbon,
- remove non-energy fuel used in industrial processes such as coke used in the iron and steel industry, natural gas in ammonia production and petroleum coke in the carbon anodes used for aluminium production,
- remove fugitive emission sources such as gas leakage from the gas distribution system and flaring in petroleum refining.

Emission Factors for CO_2

Under the IPCC methodology, CO_2 emission factors depend only on the chemical composition of the fossil fuel concerned. For fuels having well defined and/or stable chemical composition, CO_2 emission factors can therefore be specified with considerable accuracy. This is the case for natural gas and for petroleum products, with the exception of fuel oil, which may vary considerably in composition. All updated emission factors are contained in Table 3. Emission factors were estimated as follows.

Coal and Coke

Coals, even of the same general type, vary in their composition of both combustible components (carbon, volatiles) and non-combustible components (ash, moisture). CO_2 emission factors for coal used by the electricity industry are requested directly from operational organisations of major power stations connected to the main transmission grids and power stations not connected to the main transmission grids but operated by the same organisations. These emission factors are shown in Appendix A. After the electricity industry, the largest user of coal in Australia is the steel industry. The steel industry has provided a representative CO_2 emission factor of 91.8 Gg/PJ for black coal used in iron/steel/coke production (L.Leung, BHP 2001, Pers comm). Industry has also advised representative emission factors for the combustion of coke. Other major users of coal in the non-ferrous metals and cement industries have advised that the "other industry" default value for coal shown in Table 3 is acceptable.

Coal By-Products

It is assumed that wherever coal by-products are used as a fuel, except in the Food, Beverages and Tobacco, Basic Chemicals and the Petroleum and Coal Products sectors (ANZSIC Codes 21, 253 & 252), the emission factor is the same as for coke oven gas. The coke oven gas emission factor has been advised by the steel industry to be 37 Gg/PJ (Deslandes and Kingston 1997). The steel industry has also advised that for its own inventory purposes it uses emission factors for coal tar and BTX (standing for Benzine, toluene, xylene) of 81.8 and 80.4 Gg/PJ respectively (Deslandes and Kingston 1997). In this workbook a value of 81.0 Gg/PJ is used for coal by-products used in the Basic Chemicals and the Petroleum and Coal Products sector. This is an approximate average of the two factors provided as there is insufficient information for greater accuracy. It should be noted that the effect of this factor is reduced due to the assumed sequestration of over 75% of the coal by-products listed as consumed by ABARE.

Refined Petroleum Products

Australian oil tends to be of the light crude variety and the petroleum products produced by Australian refineries reflect the characteristics of these supplies. The country-specific emission factors for marketable petroleum products for this inventory are taken from GHD 2006, which reports the results of a review of Australian petroleum products. A representative value to be used for fuel oil, derived from IPCC 1997, was confirmed by discussion with Nabalco (J. Bawdin, pers. comm.), one of the largest industrial users of fuel oil in Australia, and Shell (J. Le Cornu, pers. comm.).

Other Petroleum Products

In the sectors, Basic Chemicals (ANZSIC Group 253), Oil and Gas Mining (ANZSIC Subdivision 12) and Basic Non-Ferrous Metals (ANZSIC Group 272), after excluding petroleum coke from the latter sector, petroleum products nec consists largely of naphtha. The emission factor for naphtha (IPCC 1997), is therefore used in these sectors. For all other sectors in which petroleum products nec appears as a fuel type, an emission factor of 68.6 Gg CO_2/PJ, as advised by ABARE, was used. Recycled tyres are combusted for energy within Cement, Lime, Plaster and Concrete (ANZSIC Group 263). An emission factor of 81.6 Gg CO_2/PJ was sourced from the US Energy Information Administration (GHD 2006b).

Solvents, Lubricants, Greases and Bitumen

Australian information on CO_2 emission factors for these products is not available. Default IPCC values of 69.6 Gg/PJ for lubricants and greases and 76.7 Gg/PJ for bitumen have therefore been used (IPCC, 2006). In this workbook, solvents have been given the same emission factor as naphtha, i.e. 69.7 Gg/PJ [1].

Natural Gas

A national emission factor has been estimated for natural gas for each year, using data on the composition of natural gas in each pipeline system, as published by the Australian Gas Association (various years), weighted by the volumes of gas consumed from each pipeline system (see Appendix B).

The CO_2 emission factor for natural gas varies slightly between States, depending on the composition of the gas supplied to energy users in the State, which in turn depends on the characteristics of natural gas in the fields from which supply is sourced. In these circumstances, use of a single national weighted average emission factor for all natural gas will not introduce errors at the level of aggregate national Energy sector emissions. All emission estimates for natural gas are therefore based on national consumption data and national emission factors, except for gas used for electricity generation, where data from individual generators are used where available.

The use of coal seam gas in Australia is restricted to electricity generation (1.A.1.a). Emission factors from coal seam gas are individually estimated for major individual power stations. When individual power station data are unavailable the national CO2 emission factor for natural gas is used.

[1] Petroleum derived solvents are low boiling point crude oil fractions, e.g. white sprit which is virtually identical to Naphtha.

An additional adjustment is made for natural gas used by the chemical industry, because this includes both natural gas and the separate ethane supply, used as feedstock. The CO_2 emission factor used for the NGGI was derived based on data within the ASHRAE Handbook Fundamentals and is 56.5 Gg CO_2/PJ [2]. Ethane is the main source of feedstock and fuel supply for the petrochemical industry in Victoria, which is the location for a large proportion for the total Australian petrochemical industry. In the absence of information about the composition and quantities of natural gas used by the chemical industry in each State, an Australian average emission factor is used for all "natural gas" used by the basic chemicals sector.

Town Gas

Town gas, which is a minor source of emissions, is given the same emission factor as LPG, on the assumption that, in the manufacture of town gas, both carbon content and energy content is reduced in the same proportion, meaning that the carbon emission factor is unchanged.

Biomass Fuels

Emissions of CO_2 from biomass fuels are not included in the national inventory totals, but are required to be reported as a memo item. The CO_2 emission factors for bagasse and wood/woodwaste combusted in commercial and residential sectors are listed in Table 3. A detailed explanation of residential wood heater emission factors is provided (see page 17).

[2] Emission factor derived from: 2001 ASHRAE Handbook Fundamentals Inch-Pound Edition, The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2001,ISBN 1-883413-87-7 (pages18.3 and 37.1). i.e. Higher Heating Value * unit conversion factor* (44/12)*1000. Higher Heating Value = 22,323 Btu/lb, Unit conversion: 1BTU/lb=2.326KJ/kg

Table 3: Emission factors for CO_2 2006

Fuel Type	Fuel	CO_2 emission factor (Gg CO_2/PJ)
Coal derived Fuels	Coal used in public electricity generation [a]	86.2 - 96.4
	Coal used in steel industry [m]	91.8
	Black coal used by other industry [a]	90.0
	Brown coal used by industry [a]	94.6
	Coke [b]	119.5
	Coal by-products (coke oven gas) [b]	37.0
	Coal by-products (coal tar and BTX) [b]	81.0
	Brown coal briquettes [a]	95.0
Petroleum Fuels	LPG [c]	60.2
	Naphtha [l]	69.7
	Automotive gasoline [c]	67.4
	Aviation gasoline [c]	67.0
	Lighting Kerosene [c]	68.9
	Aviation turbine fuel [c]	69.6
	Power Kerosene [c]	68.9
	Heating oil [c]	69.5
	ADO [c]	69.9
	IDF [c]	69.9
	Petroleum products nec [d]	68.6
	Fuel oil [e]	73.6
	Solvents [l]	69.7
	Lubricants and greases [e]	69.6
	Recycled tyres [k]	81.6
	Bitumen [e]	76.7
Gases	Natural gas (including coal seam gas) [f]	51.4
	Natural gas (Basic chemicals sector) [f]	51.4
	Ethane [g]	56.5
	Town gas [c]	60.2
Biomass Fuels	Wood and wood waste [h]	94.0
	Wood for Residential subsector [i]	77.5
	Bagasse [e]	95.0
	Ethanol [e]	67.3

Sources: a GWA 2007. b Deslandes & Kingston 1997. c GHD 2006a. d ABARE. e IPCC 2006. f Australian Gas Association 2001. g ASHRAE 2001. h Todd 1993. i Todd 2005.. k GHD 2006b, l IPCC 1997. m L.Leung BHP 2001

Note: All emission factors expressed in terms of energy measured as gross calorific equivalents (GCV) and do not include the effects of oxidation.

Oxidation Factors for CO_2

The oxidation factor is defined as the proportion of carbon contained in a fuel which is oxidised to CO_2. One minus this factor is the proportion of carbon (on a mass basis) that is stored in solid products such as ash, soot and chimney build-up. It should be noted that the IPCC (1997) states that "a large portion" of the carbon initially deposited in solid products "oxidises in the atmosphere shortly after combustion". Oxidation factors used in this workbook are shown in Table 4: Oxidation factors for CO_2 (non-electricity).

Table 4: Oxidation factors for CO_2 (non-electricity)

Fuel	Utilisation category	Oxidation factor
Black Coal	All Categories	98.0%[(a)]
Brown Coal	All Categories	98.0%[(a)]
Coal By-products	Other than Basic Chemicals and Petroleum and Coal Products nec	99.5%
	Basic Chemicals and Petroleum and Coal Products nec	99.0%
Coke	All Categories	98.0%[(a)]
Petroleum	All Categories	99.0%[(a)]
Gas	All Categories	99.5%[(a)]
Biomass	Residential	100%
	All Other Categories	98.0%

Sources: (a) IPCC (1997, Volume 3)

The oxidation factors listed for coal by-products are a result of the assumption that in all relevant sub-categories, other than Basic Chemicals and Petroleum and Coal Products nec, coal by-products are gaseous fuels. Hence consumption of coal by-products in these categories has an identical oxidation factor to that used for natural gas. Within the Basic Chemicals and Petroleum and Coal Products nec sub-categories the assumption is that the fuel is either BTX or coal tar and hence the IPCC default petroleum factor has been applied.

The oxidation factor for combustion of biomass for Residential is combined with the associated CO_2 emission factor, and is therefore effectively 100%. The oxidation applied to the combustion of biomass has been set at 98.0% for all other sub-categories.

Non-CO_2 Emission Factors

In addition to emissions of CO_2, the combustion of fuel in stationary sources results in the emission of CH_4, N_2O, NO_X, CO, and NMVOCs. The magnitude of emissions per unit of fuel consumed is dependent on a large number of factors including fuel type, equipment design and emission control technology. Therefore the development of non-CO_2 emission factors for use within the NGGI is inherently more complex and more uncertain than the development of CO_2 emission factors.

IPCC (1997, Volume 3) has documented default non- CO_2 emission factors for a range of fuels and equipment types. It is important to note that the IPCC default emission factors relate to uncontrolled emissions from various source categories. Correction factors are available to account for the presence of emission control technology. However, such corrections require a detailed knowledge of individual industrial premises and consequently cannot be reasonably applied to national-level inventories. The use of age cohort as a proxy for the presence of control technology, as is done in *Australian Methodology for the Estimation of Greenhouse Emissions and Sinks 2006: Energy (Transport)* is not generally feasible in this workbook because of the great diversity of equipment types and vintages. However, specified individual emission factors have been used for major power stations (see Appendix A).

In Australia, emissions from stationary fuel combustion sources are controlled to varying degrees. The emission factors for uncontrolled fuel combustion sources, which must be used in the absence of reliable information on the equipment in use, means that the Australian inventories may overestimate some non-CO_2 emissions.

Emission factors various equipment types, for non-CO_2 greenhouse gases are summarised in Table 5: Equipment type emission factors for non-CO_2 greenhouse gases (Mg/PJ). Calculation details of the non-CO_2 sector specific factors are provided in Derivation of non-CO_2 emission factors (Appendix B) and the resulting weighted emission factors by sector are reported in the sectoral discussion below.

It is assumed that N_2O emission factors are dependent on fuel type only. Although data is available from a number of sources on N_2O emission factors according to equipment and coal type, IEA Coal Research (1993) report that with the exception of fluidised bed technology, the variations in measured N_2O concentrations between boilers cannot be attributed either to differences in boiler type (e.g. tangentially-fired), boiler size, boiler load or combustion modifications (e.g. low NO_X burners).

Table 5: Equipment type emission factors for non-CO_2 greenhouse gases (Mg/PJ)

	Sector	Fuel	Equipment type	CH_4	N_2O	NO_x	CO	NMVOC
Electricity Generation/Utility								
1		Natural Gas	Boiler	0.1	0.1	226	16	0.6
2		Residual Oil	Boiler	0.8	0.6	186	14	2.1
3		Distillate Oil	Boiler	0.04	0.6	64	13	1.4
4		Black Coal	Tangentially Fired	0.9	0.8	306	11	1.7
5		Black Coal	Pulverised Wall	0.9	0.8	462	11	1.7
6		Brown Coal	Tangentially Fired	0.9	1.4	136	17	1.7
4		Natural Gas	Turbine	8.0	0.1	190	46	2.4
7		Natural Gas	Internal Combustion	240	0.1	1,331	340	80
8		Fuel Oil	Internal Combustion	4.0	0.6	1,322	349	45
9		Diesel	Internal Combustion	4.0	0.6	1,322	349	45
Other Energy Transformation and Industrial								
10		Natural Gas	Boiler	1.2	0.1	58	14	1.1
11		Residual Oil	Boiler	2.8	0.6	154	14	0.8
12		Distillate Oil	Boiler	0.1	0.6	53	13	0.5
13		Black Coal	Boiler	1.3	0.8	287	105	1.0
14		Wood	Boiler	4.2	4.1	75	680	6.8
15		Bagasse	Boiler	10	4.1	84	1,625	16.3
16		Natural Gas	Kiln	1.0	0.1	1,010	75	1.1
17		Fuel Oil	Kiln	1.0	0.6	502	75	0.8
18		Black Coal	Kiln	1.0	0.8	502	75	1.0
19		Black Coal	Coke Oven	1.0	0.8	287	201	1.0
20		Natural Gas	Dryer	1.0	0.1	58	10	1.1
21		Fuel Oil	Dryer	1.0	0.6	160	15	0.8
22		Black Coal	Dryer	1.0	0.8	215	170	1.7
Commercial								
23		Natural Gas	Boiler	1.1	0.1	41	8.5	2.2
24		Residual Oil	Boiler	1.3	0.6	154	14	3.2
25		Distillate Oil	Boiler	0.6	0.6	53	13	0.9
26		Black Coal	Boiler	1.3	0.8	157	126	1.0
27		Wood	Boiler	3.4	4.1	19	330	5.6
Residential								
28		Natural Gas	Heater	1.6	0.1	39	16	3.1
29		Black Coal	Hot Water Heater	105	0.8	190	5,753	209
32		LPG	Furnace	0.8	0.1	67	7.9	1.6
33		Distillate Oil	Furnace	4.7	0.6	48	13	1.9
General								
34		Gas	Miscellaneous	1.1	0.1	41	8.5	2.2
35		Oil	Miscellaneous	1.3	0.6	154	14	3.2
36		Black Coal	Miscellaneous	1.3	0.8	157	126	1.0

Sources: See Appendix C Table 100 Calculation of emission factors for non-CO_2 greenhouse gases on pp112-114.

Weighted sectorial non-CO_2 emission factors

The published *ABARE Energy Supply and Demand Statistics* fuel consumption data are not in a form that allows the above data on emission factors by equipment and fuel type to be used directly, since the data are primarily arranged by sector of economic activity, rather than equipment type. A separate analysis of the data is therefore commissioned from ABARE, based on the quantities of energy used by each type of equipment, disaggregated by ANZSIC Group and by major fuel type (coal, oil, gas, biomass). These data are used to compile a set of weighted emission factors for each type of fuel used in each economic sector, accurately reflecting the mix of equipment types in which that fuel is used in that sector. The methodology of calculating these factors is discussed in detail in *Workbook 1.1 1998* (Section 2.6.2 page 31).

ABARE has collected information not only on the quantities of each type of energy used by the surveyed enterprises, but also on the type of equipment in which the fuel was used, making use of a large number of different equipment categories. This information is collected for ANZSIC Divisions B (Mining), C (Manufacturing) and D (Electricity, Gas, Water), as shown in Table 2. These Divisions account for the greater part of all non-transport combustion of fuels.

The many equipment categories reported in the ABARE survey were grouped into the equipment types listed in Table 5, using, as far as possible, the same criteria as in the original sources for the Table. Fuels were also grouped into five main types: coal and coke, wood, bagasse, liquid fuels and gaseous fuels. ABARE then undertook an analysis of its data to reveal, for each nominated equipment category in each economic sector, a breakdown of energy use by fuel typein 1987-88 and 1993-94.

For each of the two years, the results of this analysis were compared with the total energy consumption reported for the corresponding fuel type in that sector. It was found that in some cases the quantity of fuel use calculated in this way was less than the total quantity reported, suggesting a certain amount of under-reporting of the energy use by equipment types. In these cases, the required adjustment was made by increasing the share of each equipment type used in the sector by the same proportion, until the shares summed to one across each fuel type in each sector.

Equal weight was given to each of the two year's data, in order to obtain a single set of weighted values which could reasonably be considered to be representative of the whole period covered by the inventories[31].
For the other economic sectors, not covered by the above analysis, fuel use by equipment type and emission factors for equipment types were estimated as follows:

- For Division A (Agriculture, Forestry, Fishing), it was assumed that all diesel is used in mobile equipment, for which the emission factors are reported in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Energy (Transport)*. It is assumed that the small quantities of other fossil fuels consumed in Division A are used in the agricultural industry, in miscellaneous small combustion equipment.

[3] The shares of a particular equipment and fuel type combination seldom differed by more than 10 percentage points between the two years.

- For Division E (Construction), emission factors for mobile equipment are as reported in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006: Energy (Transport)*.
- For Divisions F, H, I, J, K and L, it was assumed that all fuel combustion occurs in miscellaneous small combustion equipment.
- For sectors 65 and 67, it was assumed that consumption of gaseous fuels occurs in gas turbines (used to power compressors in gas transmission and distribution systems) and all consumption of liquid fuels occurs in mobile equipment.
- For the Residential sector, it was assumed that all combustion of coal, liquid fuels and gas occurs in miscellaneous residential combustion equipment.
- The final step in the computation was to apply the equipment type shares as weights to the respective emission factors for the various equipment types, for each fuel in each sector, and sum across the equipment types. This procedure resulted in a set of emission factors for each fuel type in each economic sector, appropriately weighted by the mix of equipment types in which that fuel is used in that sector. Application of these weighted emission factors to the relevant energy consumption data for each inventory year will yield a relatively reliable estimate of non-CO2 emissions from each sector.

This procedure was not used for sector 361, public electricity generation. Instead, the respective electricity generation enterprises are asked to provide relevant operating data for their respective power stations.

SO_2 Emission Factors

All fossil fuels contain sulphur compounds in varying amounts. A great variety of different compounds may be found and consequently sulphur content is always measured in terms of the mass of elemental sulphur, usually as a mass percentage. Under normal combustion conditions with excess air, it can be assumed that all sulphur is oxidised to SO_2. Therefore, it is possible to use a set of standard SO_2 emission factors for the various fuels, just as is done for CO_2.

Data on emission factors was obtained from the following sources:

- for petroleum products — Australian Institute of Petroleum and the Department of the Environment and Water Resources,
- for natural gas and LPG — Australian Gas Association,
- for coal (default values) — Department of Primary Industries and Energy.

Table 6: SO_2 emission factors

Fuel	SO_2 emission factors (Gg SO_2/PJ)
Black coal	0.37
Brown coal	0.15
LPG	0.0023
Aviation gasoline	0.0057
Motor spirit	0.0057
Kerosene	0.057
Heating oil	0.057
ADO	0.057
IDF	0.057
Fuel oil	1.282
Natural gas	0.0023

The above factors were multiplied by the quantity of each fuel type used in each economic sector, as specified in the ABARE statistics, to estimate SO_2 emissions from all sectors except for public electricity generation and petroleum refining.

For the public electricity industry, SO_2 emission factors for the coal used vary significantly between power stations, depending on the coal used, just as CO_2 emission factors also vary depending on the characteristics of the coal used. Most power stations are required to monitor and report their SO_2 emissions to the pollution control authority in their respective State. For these reasons, specific SO_2 emission data were obtained from each power station operator (see Appendix A).

Within the petroleum refining sub-category the SO_2 emissions are not directly calculated but are sourced from the National Pollutant Inventory Database.

Residential - Biomass Combustion (1.A.4)

The Residential sector also includes specific treatment of the use of firewood and also in the combustion of fuels in mobile equipment such as lawnmowers.

This category is characterised by the use of wood in residential woodheaters. Emissions are modeled using an advanced tier 2 approach which takes into account factors such as wood heater technology and replacement of older models, user operation and Australian wood.

The estimation of emissions from residential firewood use requires a more complex approach to the estimation of emissions from fossil fuels reflecting information on heater design (technology type) and the operation of wood-burning appliances,which influences the mix of emissions per kilogram of firewood consumed.

The proportion of Australian households choosing firewood as their main heating fuel peaked in the early 1990s and has decreased slowly since then. New appliances, with lower emissions of some greenhouse gas species, came on the market in the early 1990s and they have gradually been replacing older, non-certified heater models. Poor user behaviour, which significantly increases emissions of pollutants, has been the target of education campaigns and, in the past few years, programs have been aimed specifically at households with excessive visible smoke. This has led to improved appliance use.

The residential wood heater methodology has been developed for Australian conditions (see Todd 2003, and updated with Todd 2005), and incorporates factors such as appliance type and certification, wood type and moisture content and user behaviour. The composition of gaseous and particulate emissions when burning eucalypt firewood in typical Australian appliances is based on Gras (2002). A schematic diagram showing the methodology process is shown in Figure 3.10, and is also summarised in the algorithm below:

$$E_{k,n} = F_n \times S \times W \times fn_k \{\sum_l PEF_n\}$$

Where:
- $E_{k,n}$ = emission of greenhouse gas k in year n
- F_n = amount of fuel combusted (i.e. firewood use) in year n
- S = softwood use correction factor
- W = wet wood correction factor
- fn_k = formula linking the greenhouse gas emission factor for gas k to the particulate emission factor.
- PEF_n = weighted particulate emission factor for year n, which is summed over the mix of appliances and operator behaviour for that year, with l = 1 to 8
  - l(1) certified woodheater correctly operated
  - l(2) certified woodheater carelessly operated
  - l(3) certified woodheater very badly operated
  - l(4) non-certified woodheater correctly operated
  - l(5) non-certified woodheater carelessly operated
  - l(6) non-certified woodheater very badly operated
  - l(7) masonry open fireplace
  - l(8) factory built (metal) open fireplace

Description of factors

Certified and non-certified heater

- **Emission factors**

A base methane emission factor for certified woodheaters of 261.3 Mg/PJ has been developed by Todd (2005). It has been derived from a large database on particulate emissions from heaters meeting the requirements of Australian Standard AS4013. Over 250 different heater models have been tested at the two NATA certified (National Association of Testing Authorities) laboratories in Australia, producing a database of over 2250 individual emission tests (heaters must have three repeat tests at each of high,

medium and low burn rates).

A base methane emission factor of 461.3 Mg/PJ has been applied to non-certified heaters, through the application of a factor of 1.77 to the certified woodheater emission factor. Todd (2005) based this approach on comparisons between US emission tests of non-certified heaters (referred to as 'Pre-Phase I Non-Catalytic Heaters' in US literature) and certified heaters (referred to as Phase II Non-Catalytic Heaters) (US EPA 1996). The Australian emission test for woodheaters has differences to the US test (both in test fuel, and testing procedure); however, the Australian Standard was cross-checked with two models of heater that had passed both the US (Phase II) and found to be generally similar. Thus the US ratio has been applied to Australian heaters.

- **Mix of certified and non-certified heaters and open fireplaces**

A survey of households in 2000, carried out as part of the CSIRO study (Gras, 2002), found that 40% of heaters were less than 6 years old (i.e. installed in 1994 or later). Taking into account the number of open fireplaces also in use (derived by Todd 2005 from a 1999 ABS survey), certified woodheaters accounted for 30.6% of all wood-burning appliances in 2000. The population of certified woodheaters has been decreased linearly to 1994, where it is zero (Todd 2005).

Operator behaviour

- **Emission factors**

Three operator classifications have been adopted for these calculations.

a) 'Good' operation means a certified heater will perform as it did in the laboratory test.

b) 'Careless' operation (or poor operation) refers to operators who pay some attention to heater performance, but are not well enough informed. A survey in Tasmania (Todd 2000) suggested at least half the heater owners fall into this category. Careless operation has been assigned emission factors 1.5 times greater than for good operators, applying to both certified and non-certified heaters (expert judgement by Todd 2005).

c) 'Very poor' operation refers to heater operators that regularly run the heater with a slow, smouldering fire. Todd (2000) indicates 10% of households with woodheaters are in this category. The increase in emissions compared to a well-operated heater has been set at a factor of 4 based on a small number of laboratory tests (Todd 2005).

Proportion of well/poorly operated woodheaters

The proportion of good, careless and very poor woodheater operators for 2000 was set by Todd (2005) at 0.4/0.5/0.1 respectively. This is based on surveys in 1999 and 1997 that showed most households thought they operated their heaters correctly, but more detailed questioning showed that few did everything correctly. National TV campaigns (in 1997 'Breathe the Benefits') and a wide range of other education campaigns at state level suggest user behaviour has improved over time, Therefore Todd (2005) has used 0.7 (i.e. 70%) for 1990 as the proportion of heaters used carelessly.

The very poor operation grouping represents those heaters that regularly emit copious quantities of visible smoke. A 1999 Hobart survey, and feedback from local government officers involved in wood-smoke reduction programs in all states, suggest that about 10% of chimneys/flues smoke excessively. Todd (2005) has allowed for a continuous improvement over the time series, setting 1990 at 0.2, ie (20%) of heaters smoked excessively.

Open fireplaces

- **Emission factors**

No emission testing of masonry open fireplaces has been carried out in Australia. The US (US EPA 1996) value for the particulate emission factor for masonry open fireplaces (17.3g/kg) has been used by Todd (2005) to derive a base methane emission factor of 1365.8 Mg/PJ. Even though the wood species used in Australia are different from the US, this is unlikely to have a significant effect on emission factors. The CSIRO tests provide particulate emission factor of 2.3g/kg for factory-built open fireplace (sometimes referred to as heat-recovery fireplaces) This is used by Todd (2005) to derive a base methane emission factor of 181.6 Mg/PJ. It is assumed that the operator of an open fireplace has little impact on the emissions (on average) and so no correction factors for careless or very poor operation have been used (Todd 2005).

- **Proportion of open fireplaces**

The proportion of open fireplaces in use is based on the same CSIRO survey and a 1999 ABS survey (Todd 2005).

Softwood fuel and wet wood

- **Emission factors**

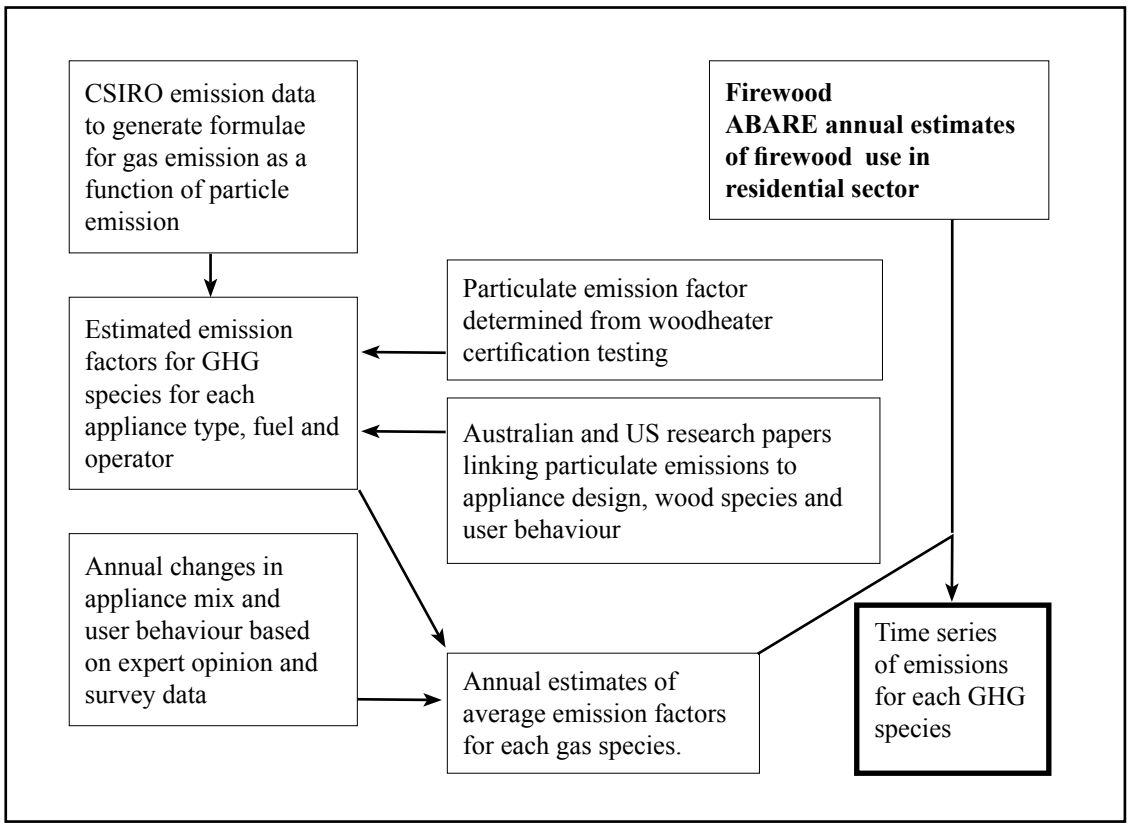
The use of wet firewood is often cited as one of the main reasons for high emissions from woodheaters. However, the CSIRO study, and other Australian studies (e.g. Todd et al. 1989a) have consistently shown that only very wet wood (i.e. unseasoned) influences emissions. High burn-rate tests carried out by the CSIRO have shown that very wet wood (moisture greater than 30%) leads to an increase in emissions by a factor of 3.5 (Todd 2005).

The use of softwood fuel in the CSIRO testing led to a large increase in emissions (by a factor of about 3.5). However, other comparative tests of hardwood and softwood emissions (Todd 1991) have shown smaller increases. Therefore, Todd (2005) has adopted a factor of 2.

- **Proportion of wet wood and softwood**

The 4% proportion of households using very wet wood (>30% moisture, wet weight basis) is taken from a Hobart survey (Todd 2001). The proportion of softwood used as firewood is based on several surveys (Todd et al. 1989b, Driscoll et al. 2000, Gras 2002) that consistently show around 5% of firewood consumed is softwood.

Figure 1. Schematic diagram of the methodology process for estimation of emissions from woodheaters



The resulting emissions factor trends are shown below in Table 7. With Australian standards for woodheater emissions introduced in 1992, there has been an increasing uptake of certified heaters at the expense of older, non-compliant heaters, as well as open fireplaces. Together with improving user operation, these factors work to produce an overall trend for the more complete and efficient combustion of fuelwood. This is borne out in the increasing CO2 emission factor (ie more carbon is oxidised under improved combustion conditions) and decreasing methane emission factor. As a result, the implied methane emission factor varies between 1100 Mg/PJ in 1990 and 714 Mg/PJ in 2005. This range is consistent with the 2006 IPCC defaults for residential methane emission factors for woodstoves (Vol 2, Table 2.9), taking in account the inherent uncertainty of residential combustion methane emission factors of 50 to 150% (IPCC 2006: Vol 2, Table 2.12).

Table 7: Residential biomass emission factors

Inventory year	Greenhouse gas emission factor (Mg/PJ)						
	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
1990	70374	1100.1	2.3	11751.6	16.9	1393.5	1.05
1991	70423	1097.4	2.3	11731.9	16.9	1390.1	1.05
1992	70473	1094.7	2.3	11712.3	17.0	1386.7	1.05
1993	70935	1069.7	2.3	11528.9	17.3	1355.0	1.05
1994	71615	1032.9	2.2	11258.9	17.8	1308.4	1.05
1995	72253	998.4	2.2	11005.7	18.3	1264.6	1.05
1996	72892	963.8	2.1	10752.3	18.7	1220.8	1.05
1997	73517	930.0	2.1	10504.2	19.2	1178.0	1.05
1998	74455	879.3	2.0	10132.1	19.9	1113.7	1.05
1999	75364	830.0	2.0	9771.2	20.5	1051.4	1.05
2000	76245	782.4	1.9	9421.7	21.1	991.0	1.05
2001	76561	765.2	1.9	9296.0	21.4	969.3	1.05
2002	76877	748.2	1.9	9170.7	21.6	947.7	1.05
2003	77191	731.1	1.9	9045.9	21.8	926.1	1.05
2004	77505	714.2	1.9	8921.6	22.1	904.6	1.05
2005	77505	714.2	1.9	8921.6	22.1	904.6	1.05
2006	77505	714.2	1.9	8921.6	22.1	904.6	1.05

1.A.1 Energy Industries

1.A.1.a Electricity and Heat Production (ANZSIC Group 361)

This sector contains the generation of electricity for supply to the grid (whether the power stations are owned by public or private corporations) and also the generation of electricity at mines, mineral processing and manufacturing sites, where data are available on the electricity generated and fuels consumed. Where it is not possible to identify the quantity of fuel consumed – for example, in electricity generation at industrial sites, the fuel consumed and the associated emissions are allocated to the industry involved and hence not included in the emissions for this sub-category. Public heat production without electricity generation refers mainly to the activity of district heating, which does not occur in Australia at present.

The fundamental reporting unit in this sector is the individual power station. Emissions from each large power station (over about 0.5 PJ fuel use) are calculated separately, using specific activity data and specific emission factors where possible. Inferred activity data and default emission factors are used only where specific data are unavailable. Smaller power stations, under 0.5PJ annual fuel use, of similar technology and fuel type (e.g. natural gas-fired turbine generators) may be grouped for the purpose of calculating emissions, using aggregated activity data and default emission factors.

Data Sources

Unlike other fuel combustion sectors, where activity data are supplied by ABARE and unchanging default emission factors are used, the activity data and emission factors for power generation can come from a variety of sources, and emission factors – especially for coal – are likely to change from year to year. Requests are made directly to the operational organisations for historical data on the operation of major power stations connected to the main transmissions grids and power stations not connected to the main transmission grids but operated by the same organisations. The energy use of the power stations for which data were not obtained directly, non-reporting organisations of the major power stations and those not connected to the main transmission grids which are operated by other organisations, is inferred from the difference between the total of reported values and ABARE Energy Supply and Demand Statistics for ANZSIC class 361. In some years the coverage of the survey returns from individual power stations of a certain fuel type are comprehensive which displaces the necessity of using the fuel data in ABARE's energy statistics for ANZSIC class 361 in calculations.

Fuels and technology types

Most large power stations use a main fuel (eg coal) and a secondary fuel that may be used only at start-up (eg fuel oil). Some large power stations use a third fuel type as well, to supplement the main fuel during normal operation. It is necessary to calculate emissions from each fuel using activity data and appropriate emission factors.

Energy consumption and emission factors are tested by major coal power stations and the majority of these power stations report annually to the Department of Climate Change under the Generator Efficiency Standards programme. Estimates are made in accordance with Australian Standard 4264, which provides guidance on the design and operation

of sampling systems and Australian Standard 1038.1g, which provides coal analysis, verification and reporting practices.

Using carbon, ash and carbon in ash data, the emission factor for CO_2 (kg CO_2/PJ) from coal combustion including oxidation is calculated by coal generators using equations the two equations listed below.

$$EF_{CO_2} = \left[\left(\frac{C_{ar}}{100} - \frac{C_a \times A_{ar}}{(100 - C_a) \times 100} \right) \times \frac{44}{12} \right] / ECi$$

Where C_{ar} = carbon in fuel, % as-received or as-fired
A_{ar} = ash in fuel, % as-received or as-fired
C_a = carbon in ash, % as-sampled (weighted average of fly ash and furnace ash)
EC_i is the energy content of the fuel in PJ

$$C_{ar} = C_{daf} \times \left(\frac{100 - M_r - A_{ar}}{100} \right)$$

Where C_{daf} = carbon in coal, mass % dry ash-free basis
M_{ar} = total moisture, mass % as-received or as-fired
A_{ar} = Ash, mass % as-received or as-fired

The oxidation factors and the emissions factors are linked in that some power station operators report CO_2 emission factors based on analysis which includes accounting for carbon in ash as a result of incomplete combustion. In such cases applying the default oxidation factor of 98% for electricity generation coal would double-count the effect of incomplete combustion, so an oxidation factor of 100% is used.

Using the reported data on emission factors, oxidation factors and fuel consumption, CO_2 emissions are calculated for the main fuel, and for the secondary and tertiary fuels (if present) using the formula below.

Gg of CO_2 = (A1 x B1 x C1) + (A2 x B2 x C2) + (A3 x B3 x C3) (1.A.1.a_1)

Where Variables A_{1-3} = Activity data of main, secondary and tertiary fuels respectively
Variables B_{1-3} = Oxidation factors of main, secondary and tertiary fuels respectively
Variables C_{1-3} = Emissions factors of main, secondary and tertiary fuels respectively

Appendix A lists the emission factors and oxidation factors for major thermal power stations from 1990 to the present.

For other power stations, CO_2 emissions are calculated as:

Gg of CO_2 = (A4 x B4 x C4)	(1.A.1.a_2)

Variables A4 = Activity data (PJ of fuel consumed in current year),
Variables B4 = Oxidation factor,
Variables C4 = Emissions factor.

Variable A is inferred from the difference between the total of reported values and ABARE Energy Supply and Demand Statistics for ANZSIC class 361. Variable A for other power stations consists of the sum of many smaller generators and no data is reported within the inventory for this activity. Where the main, secondary or tertiary fuel is renewable, the associated CO_2 emissions are not included in the inventory, but are separately reported.

Non-CO_2 emissions

Non-CO_2 emissions are calculated for the main fuel, and for the secondary and tertiary fuels of power stations (if present) in the form of:

Gg of E_i = Sum (A_j x EF_{ik})/1000	(1.A.1.a_3)

Where E_i = emissions of gas I,
A_j = Activity data of power station j,
EF_{ik} = emission factors for relevant gases i and fuel k.

1.A.1.b Petroleum Refining (ANZSIC Group 251)

There are two main fuel categories reported by ABARE for this sub-sector, those being Petroleum Products nec and Natural Gas.

In the case of Petroleum Products nec:

$$\text{Gg of } CO_2 = (A - D) \times B \times C \qquad (1.A.1b\_1)$$

In the case of Natural Gas:

$$\text{Gg of } CO_2 = A \times B \times C \qquad (1.A.1b\_2)$$

Definition and relevant data for variables A, B & C are contained within Table 8 below. In Equation (1.A.1b_1), the variable D represents the quantity of energy considered to be flared and/or vented and is therefore accounted for in the Fugitive Fuel Emissions sector.

Table 8: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Petroleum Products nec		99.0	68.6
Natural Gas		99.5	51.4

Source: Tables 3,4.

For non-carbon dioxide emissions, in the case of Petroleum Products nec, for all gases except SO_2:

$$\text{Mg of } E = (A - D) \times F \qquad (1.A.1.b\_3)$$

In the case of Natural Gas:

$$\text{Mg of } E = A \times F \qquad (1.A.1.b\_4)$$

Where A is activity and F is given in Table 9. In Equation (1.A.1b_3), the variable D represents the quantity of energy considered to be flared and/or vented and is therefore accounted for in the Fugitive Fuel Emissions sector.

Table 9: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Petroleum Products nec	0.8	0.6	54.0	383.8	0.8	NA
Natural Gas	1.1	0.1	56.6	722.9	1.1	NA

Source: Tables 5, 6.

ABARE statistics for this sector show refinery feedstock, i.e. essentially crude oil, as the major input, together with other, undefined, petroleum products. The various market petroleum products are shown as energy outputs. The total energy content of the products produced by the sector is less than the energy content of the petroleum input, the difference being energy consumed by the refining processes (distillation, cracking etc.). The fuel from which this energy is derived is obtained from the crude oil input and is referred to as refinery fuel.

ABARE statistics show the consumption of refinery fuel, which is specified as the fuel type "Petroleum Products nec". Some natural gas is also consumed in refineries, and separately reported in the ABARE statistics. The apparent consumption of petroleum energy is reduced by the quantity of energy flared and is set at 0.6% of refinery throughput (GHD 2006b). This adjustment is necessary to prevent double counting of emissions, since venting and flaring are accounted under 1.B *Fugitive Fuel Emissions*.

One of the functions of petroleum refining is processing to reduce or remove sulphur compounds contained in crude oil (termed desulphurisation). While most of the sulphur extracted is contained in by-products or solid waste products, some is emitted to the atmosphere as SO_2. All Australian oil refineries are required, by the environmental legislation of the States in which they operate, to monitor and report SO_2 emissions, though the precise form of reporting varies from State to State. Data on the quantities emitted, which depend on operational details at individual refineries, is currently obtained from the National Pollutant Inventory database (NPI)[4]. This methodology is only applicable from 1999 onward, as the data are not available from this source for earlier years. Prior to this methodology being applied the estimates were sourced from the Australian Institute of Petroleum.

[4] Department of the Environment and Water Resources, Australia, http://www.npi.gov.au

1.A.1.c Manufacture of Solid Fuels and Other Energy Industries

This sub-sector consists of six ANZSIC sectors, these being:

- Coke Oven Operation (ANZSIC Class 2711, part),
- Briquette Manufacture (ANZSIC Class 1102, part),
- Coal Mining (ANZSIC Subdivision 11, remainder),
- Oil and Gas Extraction (ANZSIC Subdivision 12),
- Other Transport, assumed to be gas pipeline transport (ANZSIC Subdivision 65),
- Gas Supply (ANZSIC Group 362).

Each sector is examined individually below.

Coke Oven Operation (ANZSIC Class 2711, part)

This sub-sector is effectively a subset of the Iron & Steel sub-sector but is considered an energy transformation industry and hence must be reported separately under current IPCC methodology. As this sub-sector is both a consumer of black coal and coal by-products, and a producer of coke and coal by-products, consideration needs to be made of the actual fuel consumption within the sector and hence the emissions attributable to this sub-sector.

There are three fuel categories to be considered in this sub-sector, those being Black Coal, Coal By-Products and Fuel Oil.

In the case of Black Coal:

$$\text{Gg of } CO_2 = (A - D - G) \times B \times C \qquad (1.A.1.c\_1)$$

In the case of Coal By-Products and Fuel Oil:

$$\text{Gg of } CO_2 = A \times B \times C \qquad (1.A.1.c\_2)$$

Where Variable A = In Equation (1.A.1.c_1), activity B and C are given in Table 10. ,
Variable D = the coke 'derived fuels produced',
Variable G = the coal by-products 'derived fuels produced'.

Table 10: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black Coal		98.0	90.0
Coal By-Products		99.5	37.0
Fuel Oil		99.0	73.6

Source: Tables 3, 4.

For non carbon dioxide emissions, in the case of Black Coal:

$$\text{Mg of E} = (A - D - G) \times F \qquad (1.A.1.c\_3)$$

In the case of Coal By-Products and Fuel Oil:

$$\text{Mg of E} = A \times F \qquad (1.A.1.c\_4)$$

Where A= activity, F is given in Table 11. Variables D and G are as above.

Table 11: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black Coal	1.0	0.8	201.0	287.0	1.0	370.0
Coal By-Products[(a)]	1.0	0.8	36.7	287.0	1.0	370.0
Fuel Oil	1.0	0.6	75.0	502.0	0.9	1390.0

Source: Tables 5, 6. (a) Assumed to be coke oven gas.

Briquette Manufacture (ANZSIC Class 1103, part)

This sub-sector makes up part of the Coal Mining sector (ANZSIC Subdivision 11) which is discussed in the following section. The Briquette Manufacturing industry 'consumes' Brown Coal and outputs the 'derived fuels produced' of Brown Coal Briquettes.

$$\text{Gg of } CO_2 = (A - D) \times B \times C \qquad (1.A.1.c\_5)$$

In Equation (1.A.1c_5), variable D represents the 'derived fuels produced' of Brown Coal Briquettes, as reported by ABARE.

Table 12: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Brown Coal		98.0	94.6

Source: Tables 3,4.

For non-carbon dioxide emissions, in the case of Brown Coal:

Mg of E = (A - D) x F	(1.A.1.c_6)

Variable D represents the 'derived fuels produced' of Brown Coal Briquettes, as reported by ABARE.

Table 13: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Brown Coal	1.3	0.8	105.0	287.0	1.0	150.0

Source: Tables 5,6.

Coal Mining (ANZSIC Subdivision 11, remainder)

This sub-sector excludes Briquette Manufacturing (which forms part of ANZSIC Class 1102).

Gg of CO_2 = A x B x C	(1.A.1c_7)

Table 14: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	59.4
ADO		99.0	69.9
Fuel Oil		99.0	73.6

Source: Tables 3,4.

For non carbon dioxide emissions:

Mg of E = A x F	(1.A.1c_8)

Where A is the Activity data and F is given in Table 15.

Table 15: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
LPG	0.1	0.6	13.0	154.0	5.0	2.3
ADO	0.1	0.6	13.0	154.0	5.0	85.0
Fuel Oil	0.1	0.6	13.0	154.0	5.0	1390.0

Source: Tables 5,6.

Oil and Gas Extraction (ANZSIC Subdivision 12)

$$\text{Gg of } CO_2 = A \times B \times C \qquad (1.A.1.c\_9)$$

Table 16: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
ADO		99.0	69.9
Petroleum Products nec		99.0	68.6
Natural Gas		99.5	51.4

Source: Tables 3,4.

For non carbon dioxide emissions:

$$\text{Mg of } E = A \times F \qquad (1.A.1.c\_10)$$

Table 17: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH4	N2O	CO	NOx	NMVOC	SO2
LPG	4.0	0.6	349.0	1,322.0	45.0	2.3
ADO	3.8	0.6	254.6	1,234.8	67.4	57.0
Petroleum products nec	4.0	0.6	346.8	1,320.0	45.5	57.0
Natural gas	7.3	0.1	42.7	176.3	2.3	2.3

Source: Tables 5,6.

Other Transport (Natural Gas Transmission)

(ANZSIC Subdivision 65)

The natural gas consumption as listed by ABARE under ANZSIC Subdivisions 65-67 is assumed to be used in gas turbines to drive pipeline compressors, and is thus considered an energy transformation activity. (Emissions from the small amount of other energy used in these Subdivisions are accounted under Commercial/Institutional.)

$$\text{Gg of } CO_2 = A \times B \times C \qquad (1.A.1.c\_11)$$

Table 18: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Natural Gas		99.5	51.4

Source: Tables 3, 4.

For non-carbon dioxide emissions:

$$\text{Mg of } E = A \times F \qquad (1.A.1.c\_12)$$

Table 19: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
LPG	0.6	0.6	13.0	53.0	1.0	2.3
ADO	0.6	0.6	13.0	53.0	0.9	57.0
IDF	0.6	0.6	13.0	53.0	0.9	57.0
Natural gas	7.8	0.1	45.5	187.9	2.4	2.3

Source: Tables 5,6.

Gas Production and Distribution (ANZSIC Group 362)

In the case of Natural Gas:

$$\text{Gg of } CO_2 = (A - (D - A_{LPG}) - G) \times B \times C \qquad (1.A.1.c\_13)$$

In the case of Town Gas:

$$\text{Gg of } CO_2 = A \times B \times C \qquad (1.A.1.c\_14)$$

Where Variable D = Town Gas 'derived fuels produced',
Variable A_{LPG} = the activity level reported for LPG,
Variable G = estimated Gas Leakage.

Table 20: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	NA
Natural Gas		99.5	51.4
Town Gas		99.5	60.2

Source: Tables 3, 4.

For non carbon dioxide emissions

In the case of Natural Gas:

$$\text{Mg of E} = (A - (D - A_{LPG}) - G) \times F \qquad (1.A.1.c\_15)$$

In the case of Town Gas:

$$E(l)_{hijk} = A^{u}_{hijk} \times F(l)^{u}_{hijk} \qquad (1)$$

$$\text{Mg of E} = A \times F \qquad (1.A.1.c\_16)$$

Where Variable D = Town Gas 'derived fuels produced',
Variable A_{LPG} = the activity level reported for LPG,
Variable G = estimated Gas Leakage.

Table 21: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Natural Gas	8.0	0.1	46.0	190.0	2.4	2.3
Town Gas	8.0	0.1	46.0	190.0	2.4	2.3

Source: Tables 5,6.

This sector is also one of the energy transformation industries, manufacturing town gas from both natural gas and LPG. Fuel consumption, as indicated by the *ABARE Energy Supply and Demand Statistics* consists of:

- natural gas and LPG used to make town gas,
- other gas, including both natural gas and town gas, used by the industry for its own purposes,
- gas leakage.

The quantity of town gas produced is shown as an energy output of the sector in the *ABARE Energy Supply and Demand Statistics*. Fuel combusted in the sector was therefore estimated as follows.

It was assumed that all LPG is converted to town gas, and none is combusted in the conversion process. LPG consumption was therefore offset in full against an equal quantity (in terms of energy content) of town gas produced.

The remaining town gas production was subtracted from total natural gas consumption. Gas leakage, reported under 1.B – fugitive fuel emissions - was also subtracted from the remaining net natural gas consumption.

The figure remaining was assumed to be the quantity of natural gas combusted in the sector. In each year, this figure is roughly a quarter of total fuel consumption in the sector as shown in ABARE statistics.

1.A.2 Manufacturing Industries and Construction

This category includes direct emissions from fuel combustion in manufacturing, construction and non-energy mining. This includes both stationary equipment and mobile equipment, such as earth moving and mining equipment. However, it does not fully reflect the greenhouse impact of industry, since the emissions from industrial electricity use are counted separately in Electricity and Heat Production (1A1a).

1.A.2.a Iron and Steel (ANZSIC Group 271)

The methodology of calculation of emissions in the Iron and Steel sub-sector is somewhat more complex than many other sections of the inventory. This complexity arises from a number of factors:

- The operation of Coke Ovens is considered to be an energy transformation industry, and hence must be reported separately to the rest of the iron and steel emissions.
- The production of coke yields a variety of by-products, including coke oven gas, coal tar, BTX and naphthalene, all grouped as a single fuel type "Coal By-Products", but each having quite different calorific values and emission factors. Coke oven gas is used as fuel in coke ovens and adjacent steelworks, while the other products are in general not combusted, but are used as feedstock in the chemical industry.
- Overall, the Coke Ovens sector is a producer of coke, most of which is consumed in the Iron and Steel sector and some of which is exported to other sectors (and other countries).
- The operation of blast furnaces to produce pig iron also produces yet another coal by-product, blast furnace gas, which is a low calorific value fuel consisting mainly of CO (and atmospheric nitrogen), used elsewhere in the steelworks. For the purpose of calculating CO_2 emissions, production and subsequent combustion of blast furnace gas is ignored, and it is assumed that all coal and coke used in the iron and steel industry undergoes complete oxidation to CO_2, apart from the small adjustments resulting from application of oxidation factors and a further allowance for carbon sequestered in steel.
- The use of coke, as well as natural gas in hot briquetted iron production is regarded primarily as a chemical process rather than fuel combustion under IPCC reporting guidelines. Consumption and emissions are therefore reported under the Industrial Processes sector rather than the Energy sector.
- Post 2001, steel producers have fed pulverised black coal direct into blast furnaces. This is currently counted as a fuel input within the Energy sector.

Gg of CO_2 = (A x B x C	1.A.2.a_1

Table 22: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Coal by-products		99.5	37.0
LPG		99.0	60.2
Fuel oil		99.0	73.6
Natural gas		99.5	51.4

Source: Tables 3,4.

For non carbon dioxide emissions:

Mg of E = (A x F)	1.A.2.a_3

Table 23: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.1	0.8	82.2	450.5	1.0	370.0
Coal byproducts	1.1	0.1	36.7	274.0	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	22.0	0.5	5,465.0	437.0	409.0	2.3
ADO	2.5	0.5	175.5	553.6	43.3	57.0
Fuel oil	0.4	0.5	34.7	256.6	0.9	1,282.1
Natural gas	0.9	0.1	68.2	914.6	1.1	2.3
Town gas	0.9	0.1	68.2	914.6	1.1	2.3

Source: Tables 5, 6.

Although Coke Ovens (ANZSIC code 2711) are in operation in the Iron and Steel industry, they are considered an energy transformation industry under the IPCC methodology. Therefore Coke Ovens must be separated from the other parts of the iron and steel industry, so that it can be reported under IPCC category 1.A.1.c. This separation is also required by the standard national energy balance tables used by the International Energy Agency; for Australia these tables are prepared by ABARE.

The statistics show that production of both coke and coal by-products exceed consumption within the sectors, i.e. the iron and steel industry as a whole is a net producer of coke and coal by-products. Only the net consumption is used to estimate emissions from the Iron and Steel sector. Some of the remaining production may appear elsewhere in the national inventory if it is consumed as fuel by other industries in Australia, in which case the emissions are allocated to the consuming industry.

Production consumed elsewhere includes some coke (though in most years the majority of surplus coke produced by the industry is exported from Australia), and surplus coal by-products, most of which are consumed by the Coal and Petroleum Products sector. It is assumed that exported coal by-products consist of coal tar and BTX, i.e. it is assumed that all coke oven gas is consumed within either the coke oven operation or the iron and steel sectors.

1.A.2.b Non-Ferrous Metals (ANZSIC Group 272)

In the case of the fuel Petroleum Products nec:

Gg of CO_2 = (A-D) x B x C Equation (1)	1.A.2.b_1

For all other fuels in this sector:

Gg of CO_2 = A x B x C Equation (2)	1.A.2.b_2

Where variable D is the quantity of petroleum coke consumed in this sector, as advised by ABARE special analysis.

Table 24: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Coke		98.0	119.5
Wood, wood waste[(a)]		98.0	94.0
Power kerosene		99.0	69.7
Ado		99.0	69.7
Fuel oil		99.0	73.6
Petroleum products nec		99.0	66.0
Natural gas		99.5	51.4

Source Tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.B_3

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 25: Non-CO2 emission factors below. Variable D is the quantity of petroleum coke consumed in this sector, as advised by industry.

Table 25: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.2	0.8	103.6	316.9	1.0	370.0
Coke	1.2	0.8	103.6	316.9	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	8.5	0.6	1,798.9	340.4	133.2	2.3
Power kerosene	2.0	0.6	38.5	294.0	0.8	57.0
ADO	5.2	0.6	341.0	906.7	93.0	57.0
IDF	2.0	0.6	38.5	294.0	0.8	57.0
Fuel oil	2.0	0.6	38.5	294.0	0.8	1,282.1
Petroleum products nec	2.0	0.6	38.5	294.0	0.8	57.0
Natural gas	1.1	0.1	43.6	519.2	1.1	2.3

Source: Tables 3, 4.

ABARE advised that consumption of petroleum products nec (meaning other, unspecified petroleum products "not elsewhere counted") in this sector includes petroleum coke used to make carbon anodes for aluminium production. CO_2 emitted from oxidation of carbon anodes in aluminium smelters is accounted in UNFCCC category 2.C.3. The quantity of petroleum coke consumed in this sector, as advised by industry each year, was therefore subtracted from total consumption of petroleum products nec, in order to eliminate double counting. It is assumed that remaining consumption of Petroleum Products nec consists of naphtha. Likewise, the use of black coal in the production of synthetic rutile is also regarded as an industrial process, and is therefore deducted from ABARE black coal consumption.

1.A.2.c Chemicals (ANZSIC Subdivision 25)

This sub-sector spans five ANZSIC classes:

- Petroleum and coal product manufacturing (ANZSIC Group 252),
- Basic chemical manufacturing (ANZSIC Group 253),
- Other chemical product manufacturing (ANZSIC Group 254),
- Rubber product manufacturing (ANZSIC Group 255),
- Plastic product manufacturing (ANZSIC Group 256).

The Chemicals sector (ANZSIC Subdivision 25) is a major energy user. Most of the energy is used by the Petroleum and Coal Product Manufacturing and Basic Chemical Manufacturing sub-categories. Energy use in these two sub-categories is separately reported at the national level.

The calculation of emissions in the Chemicals sector must identify and allow for carbon stored in products. Sequestration takes place in the Petroleum and Coal Product Manufacturing (ANZSIC Group 252) and Chemical Manufacturing (ANZSIC Group 253) sub-categories, where fossil fuels are used as feedstock. These two sub-categories are examined individually below. Groups 254-256: Other chemicals, rubber and plastic products are aggregated.

Petroleum and Coal Product Manufacturing (ANZSIC Group 252)

Coal by-products constitute the largest fuel input to this sector. It is assumed that these consist of coal tar and BTX and that, in the absence of specific information about this industry sector in Australia, 75% of this fuel is sequestered in long lived coal products, following the default assumption of the IPCC Methodology.

For coal by-products:

$$\text{Gg of } CO_2 = A \times (1 - 0.75) \times B \times C \qquad 1.A.2.c\_1$$

For all other fuels in this sector:

$$\text{Gg of } CO_2 = A \times B \times C \qquad 1.A.2.c\_2$$

Definition and relevant data for variables A, B & C are contained within Table 26 below.

Table 26: Activity levels and emission factor values - CO_2

Fuel type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Coal by-products		99.0	81.0
Brown coal briquettes		98.0	95.0
LPG		99.0	60.2
Lighting kerosene		99.0	68.9
ADO		99.0	69.9
IDF		99.0	69.9
Fuel oil		99.0	73.6
Natural gas		99.5	51.4

Source: Tables 3, 4.

For non carbon dioxide emissions:

$$\text{Mg of } E = A \times F \qquad 1.A.2.c\_3$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 27 below.

Table 27: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Brown coal	1.0	1.4	77.1	488.5	1.0	150.0
Coal byproducts	1.0	0.8	77.1	488.5	1.0	370.0
Brown coal briquettes	1.0	0.8	77.1	488.5	1.0	150.0
LPG	1.5	0.6	294.5	281.9	20.2	2.3
Lighting kerosene	0.5	0.6	34.5	274.1	0.7	57.0
ADO	4.4	0.6	301.1	823.0	81.2	57.0
IDF	0.5	0.6	34.5	274.1	0.7	57.0
Fuel oil	0.5	0.6	34.5	274.1	0.7	1,282.1
Natural gas	1.1	0.1	21.3	199.0	1.1	2.3

Source: Tables 5, 6.

Basic Chemical Manufacturing (ANZSIC Group 253)

This sub-category includes the major bulk chemical manufacturing enterprises, producing fertilisers, other nitrogenous chemicals, polymer resins (plastics) and carbon black. The fossil fuel feedstocks used include natural gas (methane), ethane, propane, butane, propylene and naphtha. The plastics and carbon black produced by this sub-category contain carbon derived from these feedstocks. The *ABARE Energy Supply and Demand Statistics* do not detail the quantity of each fuel which is used a feedstock, therefore it is required that assumptions be made to estimate these quantities. Currently data is sourced annually in a commercial-in-confidence basis by the Stationary Energy consultants by each related company.

Natural gas used for ammonia production is recognised by the UNFCCC reporting guidelines as an industrial process, and is therefore deducted from ABARE natural gas fuel consumption and reported in the Industrial Processes sector. Likewise, the use of petroleum coke as a reductant in titanium dioxide production is also regarded as an industrial process.

For each fuel and sequestration feedstock pair:

$$\text{Gg of } CO_2 = A \times B \times C - (D \times 44/12) \qquad 1.A.2.c\_4$$

For all other fuels in this sector:

$$\text{Gg of } CO_2 = A \times B \times C \qquad 1.A.2.c\_5$$

Definition and relevant data for variables A, B & C are contained within Table 28 below.

In Equation (1.A.2.c_4) variable D is the amount of carbon contained in products. Several feedstocks are used within this sub-category; these include natural gas (methane), ethane, LPG (propane and butane), propylene and naphtha. These feedstocks are grouped together for subtraction from the consumption data listed in the ABARE Energy Demand and Supply Statistics. Methane and ethane are grouped together and subtracted from Natural Gas consumption (i.e. producing a fuel and sequestration feedstock pair). LPG, propylene and naphtha are grouped for sequestration from the petroleum products emissions (hence producing another fuel and sequestration feedstock pair).

In Equation (1.A.2.c_4) the ratio of 44/12 is the carbon to CO_2 conversion factor. Hence the bracketed term represents the CO_2 sequestered in products, where variable D is the amount of carbon contained in products. The quantities of carbon estimated to be contained in these products varies each year, depending on quantity and quality of feedstocks as well as the production quantities of the related products.

Table 28: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Coke		98.0	119.5
Coal by-products		99.5	81.0
Brown coal briquettes		98.0	95.0
LPG		99.0	60.2
ADO		99.0	69.9
Petroleum products nec		99.0	68.6
Natural gas		99.5	51.4

Source: Tables 3, 4.

For non-carbon dioxide emissions

For each fuel & sequestration feedstock:

$$\text{Mg of E} = (A \times F) - (G \times F) \qquad 1.A.2.c\_6$$

For all other fuels in this sector:

$$\text{Mg of E} = A \times F \qquad 1.A.2.c\_7$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 29 below. Variable G, as used in Equation (1.A.2.c_6) is the amount of feedstock sequestered.

Table 29: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Coke	1.3	0.8	105.0	287.0	1.0	370.0
Coal byproducts	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	5.8	0.6	1,303.1	487.0	93.9	2.3
ADO	1.0	0.6	77.0	505.0	1.6	57.0
IDF	1.0	0.6	75.0	501.7	0.9	57.0
Fuel oil	1.0	0.6	75.0	501.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	75.0	501.7	0.9	57.0
Natural gas	1.1	0.1	41.8	492.6	1.1	2.3
Town gas	1.1	0.1	41.8	492.6	1.1	2.3
Less SEQUESTERED						
from ethane	1.1	0.1	41.8	492.6	1.1	2.3
from petroleum products	1.0	0.6	75.0	501.7	0.9	57.0

Source: Tables 5, 6.

Complexity arises in chemical manufacturing because fossil fuels are used both as feedstocks and a source of energy. In some processes and establishments the uses are relatively distinct, e.g. fuel used in a boiler plant is separately identifiable, but in other processes and establishments chemical syntheses and energy supply are intimately linked, and the separation can only be made by means of an overall mass balance for the establishment concerned.

In compiling the inventory, the first objective is to determine in which chemical products fossil carbon will be sequestered from the atmosphere for a significant period of time, and to then quantify the mass of carbon, sourced from fossil fuel inputs, which leaves the industry in the form of those chemical products. Fossil fuels used as feedstocks in the Basic Chemical Manufacturing industry include natural gas (methane), ethane, LPG (propane and butane), Gas Oil/ADO, propylene and naphtha. Ethane, propane and butane may be either "naturally occurring", i.e. sourced directly from oil and gas fields, or derived from crude oil as by-products of refining. In Australia, all ethane is derived from naturally occurring sources, while both naturally occurring and ex-refinery propane and butane are used. Propylene and naphtha are refinery products.

ABARE statistics include ethane within the reported total natural gas consumption, after appropriately adjusting for the different energy content of ethane. They group propane and butane together as LPG and they group propylene and naphtha as petroleum products nec.

For the purposes both of compiling the inventory and of accurately identifying energy use in the Basic Chemicals Manufacturing sub-sector, the energy intensive parts of the

industry can be allocated to two components:

- synthetic resins (polymers),
- nitrogenous fertilisers and other nitrogenous products.

A third component, carbon black manufacture, uses relatively large quantities of fossil fuel as a source of carbon, but very little energy. A fourth, methanol, was not manufactured in Australia prior to 1996..

Synthetic resins

Because the balance between combustion and storage in products varies greatly between chemical plants, depending on the production processes involved and the configuration of the particular plant, the quantity of feedstock supplied to chemical plants is not a useful indication of the quantity of stored carbon. The only reliable guidance comes from the quantities of chemical products produced. The major products in which fossil carbon is sequestered include polyethylene, polypropylene, synthetic rubber and styrene. Other bulk plastics are made in Australia from imported monomers, e.g. PVC made from imported vinyl chloride monomer. Such imported monomers contain large quantities of fossil carbon, but since this has not been derived form primary fossil fuels (crude oil, petroleum products and natural gas) produced in or imported to Australia, this carbon is not an offset against Australia's fossil CO_2 emissions.

The IPCC Methodology assumes that default fractions of specified fossil fuel products, e.g. ethane, naphtha, are sequestered. Actual production figures are provided by the companies making the products concerned. This is feasible, because the number of companies is relatively small. The analysis is nevertheless relatively complex, because most products are derived from several different feedstocks. The data used in making these estimates is contained in Table 30 and Table 31.

Nitrogenous products

The principal carbon containing products of this industry are urea and CO_2. In compiling the inventory it is assumed that the principal use of urea is as a fertiliser and that it is rapidly hydrolysed, following application. Similarly, it is assumed that uses of CO_2 result in it being quickly released to the atmosphere. Thus it is assumed for both products that the carbon is not stored, but rapidly released to the atmosphere as CO_2, and that no adjustment to fossil fuel consumption figures is needed for the NGGI.

Carbon black

Carbon black is produced in Australia by partial oxidation of petroleum feedstocks and used in a variety of long lived products, including tyres.

Sequestration Estimation Methodology and Data

The general methodology and underlying data used in estimating sequestration levels (variable D in Equation (1.A.2.c_4) and variable G in Equation (1.A.2.c_6)) is detailed below.

1. Feedstock and production activity data (in kilotonnes (kt)) is sourced on a company-by-company basis for the relevant inventory year. Where data is unattainable it is estimated by expert judgement by the Stationary Energy consultants[51] based on the available information and a general understanding of the industry operation as a whole.
2. The quantity of carbon contained in each of the relevant products (variable D in Equation (1)) is then estimated based on the assumed carbon content of the product.
3. The quantity of carbon contained in the product is equal to the carbon sequested from the feedstock. Hence, the quantity of feedstock sequestered (in kt) is estimated using the assumed carbon content of the related feedstock. This is then converted to energy units (PJ) using the assumed calorific value of the feedstock. This is variable G in Equation (3).
4. Equations (1) and (3) are then applied.

The assumed carbon contents and calorific values applied are listed in Table 30 and Table 31.

Table 30: Feedstock assumptions in basic chemicals

Feedstock	Carbon Faction	Calorific Value (GCV)
Ethane	0.80	(a)
Propylene	0.86	52.2
Naphtha (benzine)	0.84	48.1
Gas oil (ADO)	0.85	45.6
Carbon black feedstock	(a)	(a)

Sources: ABARE and Energy Strategies Analysis.
(a) Data is provided in a confidential manner annually from the relevant companies and hence is not reported here.

Table 31: Product assumptions in basic chemicals

Product	Carbon Faction
Polyethylene	0.86
Polypropylene	0.86
BR / SBR	0.86
Styrene	0.92
Carbon black	1.00

[5] Energy Strategies Pty Ltd

Other Chemicals, Rubber and Plastic Products (ANZSIC Groups 254-256)

Gg of CO_2 = A x B x C	1.A.2.c_8

Definition and relevant data for variables A, B & C are contained within Table 32 below.

Table 32: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
LPG		99.0	60.2
ADO		99.0	69.9
Natural gas		99.5	51.4

Source: Tables 3,4.

For non carbon dioxide emissions

Mg of E = A x F	1.A.2.c_9

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 33 below.

Table 33: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	6.8	0.6	1,581.0	465.8	115.2	2.3
ADO	1.1	0.6	84.6	500.2	5.6	57.0
IDF	0.9	0.6	70.6	477.0	0.9	57.0
Fuel oil	0.9	0.6	70.6	477.0	0.9	1,282.1
Natural gas	1.2	0.1	22.4	190.6	1.1	2.3

Source: Tables 5, 6.

1.A.2.d Pulp, Paper and Print (ANZSIC Subdivisions 23 and 24)

$$\text{Gg of } CO_2 = A \times B \times C \qquad 1.A.2.d\_1$$

Table 34: Emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Wood, wood waste[a]		98.0	94.0
LPG		99.0	60.2
ADO		99.0	69.9
Fuel oil		99.0	73.6
Petroleum products nec		99.0	68.6
Natural gas		99.5	51.4

Source: Tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions.

For non carbon dioxide emissions:

$$\text{Mg of } E = A \times F \qquad 1.A.2.d\_2$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 35.

Table 35: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal	1.3	0.8	105.0	287.0	1.0	150.0
Brown coal briquettes	1.3	1.4	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	1.1	0.6	212.7	165.8	15.5	2.3
Heating oil	0.3	0.6	13.5	155.6	0.6	57.0
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
Fuel oil	0.3	0.6	13.5	155.6	0.6	1,282.1
Petroleum products nec	0.3	0.6	13.5	155.6	0.6	57.0
Natural gas	1.2	0.1	13.8	58.4	1.1	2.3

Source: Tables 5, 6.

1.A.2.e Food Processing, Beverages, Tobacco (ANZSIC Subdivision 21)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.e_1

Definition and relevant data for variables A, B & C are contained within Table 36 below.

Table 36: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Coal by-products(a)		99.5	37.0
Brown coal briquettes		98.0	95.0
Wood, wood waste		98.0	94.0
Bagasse		98.0	91.7
LPG		99.0	60.2
ADO		99.0	69.9
IDF		99.0	69.9
Fuel oil		99.0	73.6
Petroleum products nec		99.0	68.6
Natural gas		99.5	51.4

Source: Tables 3, 4. (a) Assumed to be liquid coke oven products

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.e_2

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 37.

Table 37: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.9	207.1	1.0	370.0
Brown coal	1.3	0.8	105.9	207.1	1.0	150.0
Coal byproducts	1.2	0.1	13.6	42.9	1.1	370.0
Brown coal briquettes	1.3	0.8	105.9	207.1	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
Bagasse	9.3	4.1	1,625.0	84.0	16.3	NA
LPG	0.6	0.6	13.2	154.2	0.6	2.3
ADO	4.9	0.6	329.1	868.2	90.6	57.0
IDF	5.5	0.6	375.5	973.2	103.9	57.0
Fuel oil	0.6	0.6	13.2	154.2	0.6	1,282.1
Petroleum products nec	0.6	0.6	13.2	154.2	0.6	57.0
Natural gas	1.1	0.1	11.0	49.5	1.7	2.3
Town gas	1.2	0.1	13.5	58.0	1.1	2.3

Source: Tables 5, 6.

1.A.2.f Other industry (ANSIC subdivisions 13-15; 27-29; 41 & 42)

This sector contains the four sub-sectors of:

- All Other Manufacturing (ANZSIC Subdivisions 22, 28, 29, Groups 274- 276),
- Construction (ANZSIC Division E),
- Non-Metallic Mineral Products (ANZSIC Subdivision 26),
- Mining (non-energy) (ANZSIC Subdivisions 13, 14 and 15).

Each of the above sub-sectors consists of a number of ANZSIC categories. For completeness data is given to the ANZSIC code level under each sub-sector.

1.A.2.f(i) All Other Manufacturing (ANZSIC Subdivisions 22, 28, 29, Groups 274- 276)

This sub-sector consists of four ANZSIC classes, these being:

- Textile, Clothing, Footwear and Leather (ANZSIC Subdivision 22)
- Other Metal Products (ANZSIC Groups 274-276)
- Machinery and Equipment (ANZSIC Subdivision 28)
- Other Manufacturing (ANZSIC Subdivision 29)

Each ANZSIC class is examined individually below.

Textile, Clothing, Footwear and Leather (ANZSIC Subdivision 22)

CO_2 emission estimates:

$$\text{Gg of } CO_2 = A \times B \times C \qquad 1.A.2.f\_1$$

Definition and relevant data for variables A, B & C are contained within Table 38 below.

Table 38: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Brown coal briquettes		98.0	95.0
LPG		99.0	60.2
ADO		99.0	69.9
Fuel oil		99.0	73.6
Natural gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

$$\text{Mg of } CO_2 = A \times F \qquad 1.A.2.f\_2$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 39 below

Table 39: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	7.5	0.6	1810.1	248.4	135.2	2.3
ADO	0.4	0.6	13.6	155.7	0.6	85.0
Fuel oil	0.4	0.6	13.6	155.7	0.6	1282.1
Natural gas	1.2	0.1	13.7	58.0	1.1	2.3

Source: Tables 3, 4.

Other Metal Products (ANZSIC Groups 274-276)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.f_3

Definition and relevant data for variables A, B & C are contained within Table 40 below.

Table 40: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	60.2
ADO		99.0	69.9
Natural gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_4

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 41 below.

Table 41: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	22.0	0.6	5,465.0	437.0	409.0	2.3
ADO	1.4	0.6	103.6	547.8	10.6	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Town gas	1.0	0.1	70.9	949.5	1.1	2.3

Source: Tables 5, 6.

Machinery and Equipment (ANZSIC Subdivision 28)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.f_5

Definition and relevant data for variables A, B & C are contained within Table 42 below.

Table 42: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Brown coal briquettes		98	95.0
LPG		99	60.2
ADO		99	69.9
Fuel oil		99	73.6
Natural gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_6

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 43 below.

Table 43: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	21.1	0.6	5,242.0	435.6	392.2	2.3
Heating oil	0.7	0.6	57.3	402.6	0.8	57.0
ADO	2.8	0.6	194.3	651.0	44.9	57.0
IDF	0.7	0.6	57.3	402.6	0.8	57.0
Fuel oil	0.7	0.6	57.3	402.6	0.8	1,282.1
Natural gas	1.1	0.1	44.9	542.2	1.1	2.3
Town gas	1.1	0.1	44.9	542.2	1.1	2.3

Source: Tables 5, 6.

Other Manufacturing (ANZSIC Subdivision 29)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.f_7

Definition and relevant data for variables A, B & C are contained within Table 44 below.

Table 44: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Natural gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

$$Mg\ of\ E = A \times F \qquad 1.A.2.f\_8$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 45 below.

Table 45: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	0.2	0.6	20.3	100.6	0.5	2.3
ADO	0.2	0.6	20.3	100.6	0.5	57.0
IDF	0.2	0.6	20.3	100.6	0.5	57.0
Natural gas	1.1	0.1	20.3	189.3	1.1	2.3

Source: Tables 5, 6.

1.A.2.f (ii) Construction (ANZSIC Division E)

CO_2 emission estimates:

$$Gg\ of\ CO_2 = A \times B \times C \qquad 1.A.2.f\_9$$

Definition and relevant data for variables A, B & C are contained within Table 46 below.

Table 46: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	60.2
Lighting kerosene		99.0	68.9
Fuel oil		99.0	73.6
Natural gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_10

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 47 below.

Table 47: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
LPG	1.0	0.6	15.0	160.0	0.3	2.3
Lighting kerosene	1.0	0.6	15.0	160.0	0.3	57.0
ADO	5.7	0.6	389.7	1,005.4	107.9	57.0
Fuel oil	1.0	0.6	15.0	160.0	0.3	1,282.1
Natural gas	1.0	0.1	10.0	58.0	0.3	2.3

Source: Tables 5, 6.

1.A.2.f (iii) Non-metallic Mineral Products (ANZSIC Subdivision 26)

This sub-sector consists of four ANZSIC Groups making up Subdivision 26, these being:

- Glass and Glass Products (ANZSIC Group 261),
- Ceramics (ANZSIC Group 262),
- Cement, Lime, Plaster and Concrete (ANZSIC Group 263),
- Non-Metallic Mineral Products nec (ANZSIC Group 264).

Each ANZSIC Group is examined individually below.

Glass and Glass Products (ANZSIC Group 261)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.f_11

Definition and relevant data for variables A, B & C are contained within Table 48 below.

Table 48: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	60.2
Natural gas		99.5	51.4

Source: Tables 3, 4

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_12

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 49.

Table 49: Non-CO2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
LPG	1.0	0.6	75.0	502.0	0.9	2.3
ADO	1.0	0.6	75.0	502.0	0.9	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Fuel oil	1.0	0.6	75.0	502.0	0.9	1,282.1
Natural gas	1.0	0.1	75.0	1,010.0	1.1	2.3

Source: Tables 5, 6.

Ceramics (ANZSIC Group 262)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.2.f_13

Definition and relevant data for variables A, B & C are contained within Table 50 below.

Table 50: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Brown coal		98.0	94.6
Wood, wood waste[(a)]		98.0	94.0
LPG		99.0	60.2
ADO		99.0	69.9
Fuel oil		99.0	73.6
Petroleum products nec		99.0	68.6
Natural gas		99.5	51.4

Source: tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f.14

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 51 below.

Table 51: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.0	0.8	75.0	502.0	1.0	370.0
Brown coal	1.0	0.8	75.0	502.0	1.0	150.0
Brown coal briquettes	1.0	0.8	75.0	502.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	8.2	0.6	1,932.7	474.1	141.6	2.3
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
IDF	1.0	0.6	73.5	493.7	0.9	57.0
Fuel oil	1.0	0.6	73.5	493.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	73.5	493.7	0.9	57.0
Natural gas	1.0	0.1	74.5	1,002.1	1.1	2.3
Town gas	1.0	0.1	74.5	1,002.1	1.1	2.3

Source: Tables 5, 6.

Cement, Lime, Plaster and Concrete (ANZSIC Group 263)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	Equation (1)	1.A.2.F_15

Definition and relevant data for variables A, B & C are contained within Table 52 below.

Table 52: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Wood, wood waste[(a)]		98.0	94.0
Lighting kerosene		99.0	68.9
Heating oil		99.0	69.5
ADO		99.0	69.9
IDF		99.0	69.9
Fuel oil		99.0	73.6
Petroleum products nec		99.0	68.6
Recycled tyres		99.0	81.6
Solvents		99.0	69.7
Natural gas		99.5	51.4

Source: Tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions.

Non-CO_2 emission estimates:

$$Mg\ of\ E = A \times F \qquad 1.A.2.f\_16$$

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 53 below.

Table 53: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.0	0.8	75.7	500.0	1.0	370.0
Brown coal briquettes	1.0	1.4	75.7	500.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	21.7	0.6	5,398.1	435.6	404.0	2.3
Lighting kerosene	0.9	0.6	43.5	322.8	0.9	57.0
Heating oil	0.9	0.6	43.5	322.8	0.9	57.0
ADO	5.3	0.6	359.9	946.6	98.7	57.0
IDF	0.9	0.6	43.5	322.8	0.9	57.0
Fuel oil	0.9	0.6	43.5	322.8	0.9	1,282.1
Petroleum products nec	0.9	0.6	43.5	322.8	0.9	57.0
Recycled tyres	0.9	0.6	43.5	322.8	0.9	57.0
Solvents	0.9	0.6	43.5	322.8	0.9	57.0
Natural gas	1.0	0.1	61.8	815.5	1.1	2.3

Source: Tables 5, 6.

Non-Metallic Mineral Products nec (ANZSIC Code: 264)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	Equation (1)	1.A.2.f_17

Definition and relevant data for variables A, B & C are contained within Table 54 below.

Table 54: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black Coal		98.0	90.0
Coke		98.0	119.5
LPG		99.0	60.2
ADO		99.0	69.9
Fuel Oil		99.0	73.6
Petroleum Products nec		99.0	68.6
Natural Gas		99.5	51.4

Source: Tables 3, 4.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_18

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 55 below.

Table 55: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.1	0.8	80.0	466.5	1.0	370.0
Coke	1.1	0.8	80.0	466.5	1.0	370.0
LPG	19.7	0.6	4,884.1	441.3	365.1	2.3
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
Fuel oil	0.4	0.6	70.6	477.1	0.9	1,282.1
Petroleum products nec	0.4	0.6	70.6	477.1	0.9	57.0
Natural gas	0.9	0.1	67.8	900.1	1.1	2.3

Source: Tables 5, 6.

1.A.2.f (iv) Mining (non-energy minerals) (ANZSIC Subdivisions 13, 14 and 15)

CO_2 emission estimates:

Gg of CO_2 = A x B x C	Equation (1)	1.A.2.F_19

Definition and relevant data for variables A, B & C are contained within Table 56 below.

Table 56: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Coke		98.0	119.5
Coal by-products[(a)]		99.5	37.0
LPG		99.0	60.2
ADO		99.0	69.9
IDF		99.0	69.9
Fuel oil		99.0	73.6
Natural gas		99.5	51.4

Source: Tables 3, 4. (a) Assumed to be coke oven gas.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.2.f_20

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 57 below.

Table 57: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.0	0.8	78.0	493.0	1.0	370.0
Coke	1.0	0.8	78.0	493.0	1.0	370.0
Coal byproducts	3.9	0.1	28.0	122.6	1.6	370.0
LPG	1.1	0.6	44.8	330.9	0.8	2.3
Aviation turbine fuel	1.1	0.6	44.8	330.9	0.8	8.2
Heating oil	1.1	0.6	44.8	330.9	0.8	57.0
ADO	3.7	0.6	226.2	1,190.4	71.1	57.0
IDF	1.1	0.6	44.8	330.9	0.8	57.0
Fuel oil	0.8	0.6	44.8	330.9	0.8	1,282.1
Petroleum products nec	1.1	0.6	44.8	330.9	0.8	57.0

Source: Tables 5, 6.

1.A.4 Other Sectors

1A.4.a Commercial/Institutional

(ANZSIC Subdivision 37, Water, Sewerage and Drainage; sub-division 62 Railway Transport, sub-divisions 65-67, Other Transport, Services to Transport and Storage; Divisions H,P and Q, Accommodation, Cultural and Personal Services; Division J, Communication Services; Divisions K and L Finance, Insurance, Property and Business Services; Division M Government Administration and Defence; Divisions N and O, Education, Health and Community Services; Divisions F and G, Wholesale and Retail Trade).

Due to the large number of ANZSIC Divisions in this category, activity level data has been aggregated and tabled together with the relevant CO_2 emission factors which are also identical across all ANZSIC Divisions. The noted exception is the oxidation factor for wood for Divisions H, P, and Q - Accommodation, Cultural and Personal Services. For ease of reference, non-CO_2 emission factors have been tabulated together by ANZSIC Division.

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.4.a_1

Definition and relevant data for variables A, B & C are contained within Table 58 below. It should be noted that only the petroleum from sub-divisions 65-67 is included in this category. The natural gas consumption is accounting for within the Other Transport (Natural Gas Transmission) sub-category.

In a similar fashion, only the natural gas consumption from sub-category 62 Railway Transport is included in this category. Any other fuel consumption within sub-category 62 is assumed to be accounted for within the transport inventory.

Table 58: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Brown coal briquettes		98.0	95.0
Wood, wood waste[(a)]		98.0	94.0
LPG		99.0	60.2
Aviation gasoline		99.0	67.0
Aviation turbine fuel		99.0	69.6
Lighting kerosene		99.0	68.9
Heating oil		99.0	69.5
ADO		99.0	69.9
IDF		99.0	69.9
Fuel oil		99.0	73.6
Natural gas		99.5	51.4
Town gas		99.5	60.2

Source: tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.4.A_2

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 59 below.

Table 59: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
37 Water, Sewerage and Drainage						
	0.1	0.6	13.0	154.0	0.5	57.0
	5.7	0.6	390.0	1,006.0	108.0	57.0
	1.2	0.1	14.0	58.0	1.1	2.3
62 Railway Transport						
	1.6	0.1	16.0	39.0	3.1	2.3
65-67 Other Transport, Services and Storage (part)						
	0.6	0.6	13.0	53.0	1.0	2.3
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	57.0
	7.8	0.1	45.5	187.9	2.4	2.3
Div. F, G Wholesale and Retail Trade						
	3.4	4.1	330.0	75.0	5.6	NA
	0.6	0.6	13.1	53.2	0.9	2.3
	0.6	0.6	13.1	53.2	0.9	57.0
	0.6	0.6	13.1	53.2	0.9	57.0
	0.6	0.6	13.1	53.2	0.9	1,282.1
	1.1	0.2	15.6	42.3	2.8	2.3
	1.1	0.2	15.6	42.3	2.8	2.3
Div. H, P, Q Accommodation, Cultural and Personal						
	1.3	0.8	105.0	287.0	1.0	370.0
	3.4	4.1	330.0	19.0	5.6	NA
	0.6	0.6	13.0	53.0	0.9	2.3
	0.6	0.6	13.0	53.0	0.9	8.2
	0.6	0.6	13.0	53.0	0.9	8.2
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	1,282.1
	1.1	0.1	9.7	44.8	2.0	2.3

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Div. J Communication						
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	57.0
	0.6	0.6	13.0	53.0	0.9	1,282.1
	1.1	0.1	8.5	41.0	2.2	2.3
Div. K, L Finance, Insurance, Property and Business						
	1.1	0.1	8.5	41.0	2.2	2.3
Div. M Government Administration and Defence						
	1.3	0.8	105.0	287.0	1.0	370.0
	1.3	0.8	105.0	287.0	1.0	150.0
	4.2	4.1	680.0	75.0	6.8	NA
	0.4	0.6	13.0	84.4	0.8	2.3
	0.4	0.6	13.0	84.4	0.8	57.0
	0.4	0.6	13.0	84.4	0.8	57.0
	0.4	0.6	13.0	84.4	0.8	57.0
	0.4	0.6	13.0	84.4	0.8	1,282.1
	1.1	0.1	10.3	46.6	1.8	2.3
	1.1	0.1	10.3	46.6	1.8	2.3
Div. N, O Education, health and community services						
	1.3	0.8	105.0	287.0	1.0	370.0
	1.3	0.8	105.0	287.0	1.0	150.0
	4.2	4.1	680.0	75.0	6.8	NA
	0.4	0.6	13.0	53.0	0.7	2.3
	0.4	0.6	13.0	53.0	0.7	57.0
	0.4	0.6	13.0	53.0	0.7	57.0
	0.4	0.6	13.0	53.0	0.7	57.0
	0.4	0.6	13.0	53.0	0.7	57.0
	0.4	0.6	13.0	53.0	0.7	1,282.1
	1.1	0.1	10.4	44.8	1.8	2.3
	1.1	0.1	10.4	44.8	1.8	2.3

Source: Tables 5, 6.

1.A.4.b Residential

CO_2 emission estimates:

Gg of CO_2 = A x B x C	1.A.4.b_1

Definition and relevant data for variables A, B & C are contained within Table 60 below. There is no consumption reported for mobile equipment by ABARE for this sector.

Table 60: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Black coal		98.0	90.0
Brown coal briquettes		98.0	95.0
Wood, wood waste[(a)]		100.0	See Table 6a
LPG		99.0	60.2
Lighting kerosene		99.0	68.9
Heating oil		99.0	69.5
ADO		99.0	69.9
Natural gas		99.5	51.4
Town gas		99.5	60.2

Source: Tables 3, 4. (a) CO_2 emissions from biomass sources are not included in Inventory total emissions.

Non-CO_2 emission estimates:

Mg of E = A x F	1.A.4.b_2

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 61 overleaf.

Table 61: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	105.0	0.8	5,753.0	190.0	209.0	370.0
Brown coal briquettes	105.0	0.8	5,753.0	190.0	209.0	150.0
Wood, woodwaste	714.2	1.9	8921.6	22.1	904.6	1.05
LPG	4.7	0.6	13.0	48.0	1.9	2.3
Lighting kerosene	4.7	0.6	13.0	48.0	1.9	57.0
Heating oil	4.7	0.6	13.0	48.0	1.9	57.0
ADO	4.7	0.6	13.0	48.0	1.9	57.0
Natural gas	1.6	0.1	16.0	39.0	3.1	2.3
Town gas	1.6	0.1	16.0	39.0	3.1	2.3

Source: Tables 5, 6.

1.A.4.c Agriculture, Forestry & Fisheries: (ANZSIC Division A)

See Explanatory Notes at the end of this section for a discussion on diesel non-CO_2 emission factors.

CO_2 emission estimates:

Gg of CO_2 = A x B x C	Equation (1)	1.A.4.c_1

Definition and relevant data for variables A, B & C are contained within Table 62 below.

Table 62: Activity levels and emission factor values - CO_2

Fuel Type	A	B	C
	Activity Level (PJ)[(d)]	Oxidation Factor (%)	Emission Factor (Gg/PJ)
LPG		99.0	60.2
ADO		99.0	69.9
Natural gas		99.5	51.4

Source: Tables 3, 4.

NON-CO_2 EMISSION ESTIMATES:

Mg of E = A x F	Equation (2)	1.A.4.c_2

Definition and relevant data for variable F (non-CO_2 emission factors) is contained within Table 63 overleaf.

Table 63: Non-CO_2 emission factors

Fuel Type	F: Emission Factors (Mg/PJ)					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
LPG	1.3	0.6	14.0	154.0	0.5	2.3
Aviation gasoline	8.6	0.6	476.0	1,306.0	163.0	8.2
Power kerosene	1.3	0.6	14.0	154.0	0.5	57.0
Heating oil	1.3	0.6	14.0	154.0	0.5	57.0
ADO	8.6	0.6	476.0	1,306.0	163.0	57.0
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3

Source: Tables 5, 6.

ABARE statistics present a single total figure for diesel fuel consumed in agriculture, fisheries and forestry. However, the types of equipment used by these industries vary quite widely (tractors, log skidders, fishing boats etc.), and therefore emission factors for non-CO_2 gases also vary widely. It is assumed that the agriculture, fisheries and forestry industries account respectively for 77%, 6% and 17% of total diesel fuel consumption by the sector as a whole. This estimate is based on the relative volumes of diesel fuel for which excise rebates were claimed, as advised by the Australian Customs Service, over the period 1988 to 1994 inclusive.

These ratios were applied to emission factors for the different types of diesel engines used in the types of equipment typical of the three sectors, to estimate weighted sectoral emission factors. For the derivation of emission factors for different engine types, see *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006, Energy (Transport).*

1.A.5 OTHER

Lubricants (1.A.5.a)

This sector includes emissions of CO_2 arising from the oxidation of lubricants. Lubricants, together with bitumen and solvents, are non-fuel products of crude oil, which are included in the energy statistics compiled by ABARE. It is assumed that 60% of lubricants are not oxidised during engine operation, i.e. not actually combusted (Australian Institute of Petroleum, pers. comm.). Therefore the stated ABARE consumption of Lubricants and greases is reduced by 60% before emissions are estimated. Emissions of gases other than CO_2 are included with the emissions arising from fuel combustion in the engine type concerned in the relevant sector. Some lubricants may be incinerated subsequent to use. Any emissions from this source are included in the Waste sector.
It is assumed that solvents are either emitted not oxidised, i.e. as NMVOC, in which case they are reported in the Solvents sector of the NGGI, or as CO_2, following incineration, in which case they are reported in the Waste sector.
It is assumed that all fossil carbon in bitumen is sequestered.

CO_2 emission estimates:

$$\text{Gg of } CO_2 = (A \times 0.4) \times B \times C \qquad 1.A.5a\_1$$

Definition and relevant data for variables A, B and C are contained within Table 64.

The constant of 0.4 in Equation (1.A.5.a_1) is the assumed ratio of lubricants actually combusted in engine operation, with 60% assumed to remain unoxidised.

Table 64: Activity levels and emission factor values - CO_2

Fossil Fuel Type	A	B	C
	Activity Level (PJ)	Oxidation Factor (%)	Emission Factor (Gg/PJ)
Lubricants		40.0	73.7

Source: Tables 3, 4.

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Glossary

Activity is in general the same as energy consumption.

Australian New Zealand Standard Industrial Classification (ANZSIC) is the classification system used by the Australian Bureau of Statistics (ABS) for reporting statistics related to economic activity in Australia.

Automotive diesel oil (ADO) is a middle distillate petroleum product used as a fuel in high speed diesel engines. It is mostly consumed in the Road and Rail Transport Sectors and Agriculture, Mining and Construction sectors.

Aviation gasoline (Avgas) is motor spirit specially prepared for aviation piston engines with an octane rating suited to the engine.

Aviation turbine fuel (avtur or jet fuel) is a middle distillate petroleum product used for aviation turbine engines.

Bagasse is the fibrous residue of the sugar cane milling process which is used as a fuel in sugar mills.

Bitumen is a highly viscous hydrocarbon with a colloidal structure obtained as a residue in the distillation of crude oil. It is primarily used in the construction of roads and for roofing material.

Black coal for the purposes of this workbook comprises bituminous and sub-bituminous coals.

Briquettes are a composition fuel manufactured from brown coal which is crushed, dried and moulded under high pressure without the addition of binders.

Brown coal or lignite is a low rank coal having a high volatile matter content and high inherent moisture. Brown coal use in Australia is confined to the State of Victoria and almost exclusively limited to steam raising for electricity generation.

Coal byproducts include coke oven gas, coal tar and BTX (standing for benzene, toluene, xylene), all of which are produced in the coke making process, and blast furnace gas, which is collected from blast furnaces at steelworks. Coal tar and BTX are mainly used as feedstock for producing a variety of chemical products, including coal tar pitch, naphthalene, creosote, carbon black and solvents.

Coke is the solid product obtained from the carbonisation of suitable types of coal at high temperature. It is low in moisture and volatile matter and is mainly used in the iron and steel industry acting as an energy source and chemical agent. Semi-coke or coke obtained by carbonisation at low temperatures is included in this category.

Coke oven gas is a combustible gas obtained as a by-product of coke manufacture; it is used as a fuel in coke ovens and associated iron and steel plants.

Crude oil is a mineral oil consisting of a mixture of hydrocarbons of natural origin, being yellow to black in colour and of variable density and viscosity. It normally includes condensates which are low boiling point hydrocarbons recovered from gaseous hydrocarbons at field processing facilities.

Emission factors are used to indicate the quantity of greenhouse gases emitted due to the combustion of a unit of fuel (measured in energy terms). For instance, if natural gas has a CO_2 emission factor of 51.4 g CO_2/MJ then combustion of 100 PJ of natural gas will produce 5140 Gg of CO_2 (assuming no sequestration of carbon).

Fuel oil covers all residual (heavy) fuel oils including those obtained by blending.

Greenhouse gases for the purposes of this workbook include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). In addition, the photochemically important gases non-methane volatile organic compounds (NMVOC), oxides of nitrogen (NO_x) and carbon monoxide (CO) are also considered. NMVOC, NO_x and CO are not direct greenhouse gases. However, they contribute indirectly to the greenhouse effect by influencing the rate at which ozone and other greenhouse gases are produced and destroyed in the atmosphere.

Gross calorific value (GCV) is the quantity of heat released by unit quantity of fuel, when it is burned completely with oxygen, and the products of combustion are returned to liquid water at ambient temperature (101 kPa and 25^{o}C). GCV is measured per unit mass or unit volume. GCV is also known as higher heating value (HHV).

Industrial diesel fuel (IDF) is a petroleum product primarily consumed in the Rail and Water Transport Sectors.

Kerosene comprises refined petroleum distillate, which is intermediate in volatility between gasoline and gas/diesel oil. It is used as a fuel for heating, lighting and in certain types of internal combustion engines.

Liquefied petroleum gas (LPG) is a light hydrocarbon fraction of the paraffin series. It occurs naturally, associated with crude oil and natural gas in many oil and gas deposits, and is also produced in the course of petroleum refinery processes. LPG consists of propane (C_3H_8) and butane (C_4H_{10}) or a mixture. In Australia, LPG as marketed contains more propane than butane. LPG is used in a variety of sectors, such as for feedstocks in the chemical industry, fuel in motor vehicles and for heating and cooking purposes.

Lubricants are defined as hydrocarbons, rich in paraffin, obtained by vacuum distillation of oil residues, and not used as fuels.

Naphtha is a straight run product of crude oil distillation, comprising the range with boiling points immediately below the kerosene range. Naphtha is mainly used as a feedstock for secondary refining processes to make automotive gasoline, but is also used as a feedstock for the petrochemical industry.

Natural gas for the purposes of this workbook consists primarily of methane (around 90 per cent by volume), with traces of other gaseous hydrocarbons, as well as nitrogen and carbon dioxide) occurring naturally in underground deposits. Production is measured after processing to extract heavier hydrocarbons (comprising LPG and condensate) and impurities, such as sulphur containing compounds and carbon dioxide.

Non-methane volatile organic compounds (NMVOC) for the purpose of this workbook include compounds such as alkanes, alkenes, alkynes and oxygenated organics having two or more carbon atoms but exclude chlorofluorocarbons (CFCs).

Oxidation, in the sense used here, is the process by which fuel is consumed by burning with oxygen.

Oxides of nitrogen (NO_X) for the purpose of this workbook include nitric oxide and nitrogen dioxide but exclude nitrous oxide.

Primary fuels are those forms of energy obtained directly from nature. They can be non-renewable fuels such as coal, uranium, crude oil and condensate, naturally occurring LPG, ethane and natural gas, or conditionally renewable energy sources such as wood, bagasse, hydro electric systems and solar energy.

Petroleum products nec means petroleum products not elsewhere classified in energy consumption statistics. In this workbook it includes naphtha, tar, greases and solvents such as white spirit.

Refinery feedstock is a product or a combination of products derived from crude oil and destined for further processing in the refining industry, other than blending. Feedstocks are transformed into one or more components or finished products. This definition covers products imported for refinery intake and those returned from the petrochemical industry to the refining industry.

Refinery fuel includes all petroleum products used as fuel in operating a refinery.

Town gas includes all manufactured gases that are typically reticulated to consumers. These may include synthetic natural gas, reformed natural gas, tempered LPG and tempered natural gas.

APPENDIX A: EMISSION FACTORS FOR ELECTRICITY

Table 65: CO2 emission factors for thermal power stations in operation: 1989-1996

Power station	State	Fuel	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
			Main fuel	Main fuel	Main fuel	Main fuel	Main fuel	Main fuel	Main fuel
Bayswater	NSW	BC	93.1	91.5	92.1	92.2	90.9	90.9	94.0
Eraring	NSW	BC	91.4	89.6	90.7	91.2	92.3	92.3	90.3
Mt Piper	NSW	BC				89.8	91.7	91.7	88.5
Liddell	NSW	BC	96.3	97.3	98.2	97.9	88.1	88.1	94.5
Munmorah	NSW	BC	93.1	92.1	93.5	92.4	91.9	91.9	89.2
Tallawarra B	NSW	BC	86.6						
Vales Point B	NSW	BC	88.9	94.1	87.8	86.7	88.1	88.1	89.2
Wallerawang C	NSW	BC	88.2	90.3	88.7	88.9	90.4	90.4	88.9
Ashford	NSW	BC	90.0	90.0	90.0	90.0	90.0	90.0	90.0
Hazelwood	VIC	BrC	94.0	94.0	94.0	94.0	94.0	94.0	94.0
Loy Yang A	VIC	BrC	94.4	94.4	94.4	94.4	94.4	94.4	94.4
Loy Yang B	VIC	BrC	94.4	94.4	94.4	94.4	94.4	94.4	93.0
Morwell	VIC	BrC	94.0	94.0	94.0	94.0	94.0	94.0	94.0
Yallourn W	VIC	BrC	98.8	98.8	98.8	98.8	98.8	98.8	98.8
Yallourn	VIC	BrC	98.8	98.8	98.8	98.8	98.8	98.8	98.8
Newport	VIC	NG	51.1	50.9	51.0	51.3	51.0	51.0	51.0
Jeeralang A	VIC	NG	51.1	50.9	51.0	51.3	51.0	51.0	51.0
Jeeralang B	VIC	NG	51.1	50.9	51.0	51.3	51.0	51.0	51.0
Callide	Qld	BC	97.3	97.3	97.3	97.3	97.3	97.3	100.3
Gladstone	Qld	BC	93.4	92.7	92.1	92.1	92.1	92.1	92.1
Stanwell	Qld	BC			97.3	97.3	97.3	97.3	90.9
Swanbank	Qld	BC	87.6	87.7	87.9	87.9	87.9	87.9	84.3
Tarong	Qld	BC	89.4	89.4	89.4	89.4	89.4	89.4	87.5
Collinsville	Qld	BC	89.4	89.4	89.4	89.4	89.4	89.4	89.4
Muja A/B	WA	BC	93.8	93.8	93.8	93.8	93.8	93.8	93.8
Muja C/D	WA	BC	93.8	93.8	93.8	93.8	93.8	93.8	93.8
Bunbury	WA	BC	93.8	93.8	93.8	93.8	93.8	93.8	93.8
Kwinana A	WA	BC	93.8	93.8	93.8	93.8	93.8	93.8	93.8
Kwinana C	WA	BC	93.8	93.8	93.8	93.8	93.8	93.8	93.8
Kwinana B	WA	NG	52.2	51.8	52.1	51.6	51.6	51.6	51.6
Kwinana GT	WA	NG	52.2	51.8	52.1	51.6	51.6	51.6	51.6
Kalgoorlie	WA	FO	69.9	69.9	69.9	69.9	69.9	69.9	69.9
Mungarra	WA	NG	52.2	51.8	52.1	51.6	51.6	51.6	51.6
Pinjarra	WA	NG	52.2	51.8	52.1	51.6	51.6	51.6	51.6
Northern	SA	BC	96.4	96.4	96.4	96.4	96.4	96.4	96.4
Torrens Island	SA	NG	50.9	51.1	51.1	51.4	51.4	51.4	51.4
Channel Island	NT	NG	51.1	51.2	51.5	51.5	51.7	51.7	51.7

Source: Annual Reports of and personal communication from: Austa Electric (formerly Queensland Electricity Commission); Western Power Corporation (formerly State Energy Commission of Western Australia); ETSA Corporation (formerly Electricity Trust of South Australia)

Notes: Abbreviations for fuel types are: BC black coal; BrC brown coal; NG natural gas; FO fuel oil; For fuels not listed, including oil used for boiler start-up, default emission factors from Table 4 are used; For natural gas, values are taken from Appendix A

Table 66: CO_2 emission factors for power stations during 1996-1997 (Gg/PJ)

Power Station	State	Fuel	1997-98	
			Main fuel	Oil
Bayswater (a)	NSW	BC	87.6	68.9
Eraring (a)	NSW	BC	90.3	69.8
Mt Piper (a)	NSW	BC	87.9	68.9
Liddell (a)	NSW	BC	83.9	68.8
Munmorah (a)	NSW	BC	89.5	70.8
Vales Point (a)	NSW	BC	89.2	72.4
Wallerawang (a)	NSW	BC	87.5	70.3
Ashford (a)	NSW	BC	85.9	NA
Hazelwood (b)	VIC	BrC	94.0	80.9
Loy Yang A (a)	VIC	BrC	94.4	80.9
Loy Yang B (a)	VIC	BrC	93.0	80.9
Morwell (a)	VIC	BrC	94.0	80.9
Yallourn (b)	VIC	BrC	98.8	80.9
Newport (a)	VIC	NG	50.9	NA
Jeeralang A (a)	VIC	NG	50.9	NA
Jeeralang B (a)	VIC	NG	50.9	NA
Callide (a)	Qld	BC	94.6	70.1
Gladstone (b)	Qld	BC	92.1	
Stanwell (a)	Qld	BC	90.0	68.4
Swanbank (a)	Qld	BC	83.5	70.1
Tarong (a)	Qld	BC	91.4	70.0
Muja A/B (a)	WA	BC	93.8	
Muja C/D (a)	WA	BC	93.8	
Bunbury (a)	WA	BC	93.8	
Kwinana A (a)	WA	BC	93.8	
Kwinana C (a)	WA	BC	93.8	
Kwinana B (a)	WA	NG	51.6	
Kwinana GT (a)	WA	NG	51.6	
Kalgoorlie (a)	WA	FO	69.9	
Mungarra (a)	WA	NG	51.6	
Pinjar (a)	WA	NG	51.6	
Northern (a)	SA	BC	96.4	
Torrens Island (a)	SA	NG	51.4	
Dry Creek (a)	SA	NG		
Mintaro (a)	SA	NG		
Bell Bay (b)	Tas	FO		
Channel Island (b)	NT	NG	51.7	

Source: (a) Wilkenfeld 2006.
(b) Value from previous year retained as default
Note: Abbreviations for fuel types are: BC black coal, BrC brown coal, NG natural Gas, FO fuel oil

Table 67: CO_2 emission factors for power stations during 1997-1998 (Gg/PJ)

Power Station	State	Fuel	1997-98	
			Main fuel	Oil
Bayswater (a)	NSW	BC	87.6	68.9
Eraring (a)	NSW	BC	90.7	69.8
Mt Piper (a)	NSW	BC	88.4	68.9
Liddell (a)	NSW	BC	87.3	68.8
Munmorah (a)	NSW	BC	89.3	70.9
Vales Point (a)	NSW	BC	89.1	68.8
Wallerawang (a)	NSW	BC	87.5	70.3
Hazelwood (a)	VIC	BrC	92.1	128.0
Loy Yang A (a)	VIC	BrC	92.5	80.9
Loy Yang B (a)	VIC	BrC	93.5	51.0
Morwell (a)	VIC	BrC	92.1	89.0
Yallourn (a)	VIC	BrC	98.8	78.8
Newport (b)	VIC	NG	50.9	NA
Jeeralang (b)	VIC	NG	50.9	NA
Callide (a)	Qld	BC	94.6	70.1
Gladstone (b)	Qld	BC	92.1	
Stanwell (b)	Qld	BC	90.0	68.4
Swanbank (b)	Qld	BC	83.5	70.1
Tarong (b)	Qld	BC	91.4	70.0
Collinsville (b)	Qld	BC	89.4	
Muja A/B (a)	WA	BC	93.8	
Muja C/D (a)	WA	BC	93.8	
Bunbury (a)	WA	BC	93.8	
Kwinana A (a)	WA	BC	93.8	
Kwinana C (a)	WA	BC	93.8	
Kwinana B (a)	WA	NG	51.6	
Kwinana GT (a)	WA	NG	51.8	
Kalgoorlie (a)	WA	FO	69.9	
Mungarra (a)	WA	NG	52.5	
Pinjar (a)	WA	NG	52.5	
Northern (b)	SA	BC	96.4	
Torrens Island (b)	SA	NG	51.4	
Channel Island (b)	NT	NG	51.7	

Source: (a) Wilkenfeld 2006.
(b) Value from previous year retained as default

Note: Abbreviations for fuel types are: BC black coal, BrC brown coal, NG natural Gas, FO fuel oil

Table 68: CO_2 emission factors for power stations during 1998–1999 (Gg/PJ)

Power Station	State	Fuel	1998–99	
			Main fuel	Oil
Bayswater (a)	NSW	BC	86.4	70.4
Eraring (a)	NSW	BC	90.3	69.8
Mt Piper (a)	NSW	BC	88.7	69.6
Liddell (a)	NSW	BC	90.5	69.6
Munmorah (a)	NSW	BC	89.5	71.6
Vales Point (a)	NSW	BC	89.7	69.5
Wallerawang (a)	NSW	BC	86.9	71.0
Hazelwood (a)	VIC	BrC	92.1	128.0
Loy Yang A (a)	VIC	BrC	92.5	80.9
Loy Yang B (a)	VIC	BrC	93.5	51.0
Morwell (a)	VIC	BrC	92.1	87.1
Yallourn (a)	VIC	BrC	98.8	78.8
Newport (b)	VIC	NG	51.0	NA
Jeeralang (b)	VIC	NG	51.0	NA
Callide (b)	Qld	BC	94.6	70.1
Gladstone (b)	Qld	BC	92.1	70.1
Stanwell (a)	Qld	BC	91.3	68.4
Swanbank (b)	Qld	BC	83.5	70.1
Tarong (a)	Qld	BC	88.4	70.0
Collinsville (b)	Qld	BC	89.4	
Mica Creek (a)	Qld	NG	51.2	
Muja A/B (a)	WA	BC	93.8	
Muja C/D (a)	WA	BC	93.8	
Bunbury (a)	WA	BC	93.8	
Kwinana A (a)	WA	BC	93.8	
Kwinana C (a)	WA	BC	93.8	
Collie (a)	WA	BC	93.8	
Kwinana B (a)	WA	NG	51.6	
Kwinana GT (a)	WA	NG	52.5	
Kalgoorlie (a)	WA	FO	69.9	
Mungarra (a)	WA	NG	52.5	
Pinjar (a)	WA	NG	52.5	
TIWest (a)	WA	NG	51.6	
Northern (b)	SA	BC	96.4	
Torrens Island (b)	SA	NG	50.8	
Osborne (a)	SA	NG	50.8	
Channel Island (a)	NT	NG	51.7	

Source: (a) Wilkenfeld 2006.
(b) Value from previous year retained as default
Note: Abbreviations for fuel types are: BC black coal, BrC brown coal, NG natural gas, FO fuel oil

Table 69: CO_2 emission factors and oxidation factors for power stations 1999–2000

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater (a)	NSW	black coal	90.93	73.60	100%
Eraring (a)	NSW	black coal	89.72	73.60	100%
Mt Piper (a)	NSW	black coal	88.83	69.64	100%
Liddell (a)	NSW	black coal	88.88	70.15	100%
Munmorah (a)	NSW	black coal	90.46	71.03	100%
Vales Point (a)	NSW	black coal	91.27	69.48	100%
Wallerawang (a)	NSW	black coal	89.89	71.03	100%
Hazelwood (a)	VIC	brown coal	94.0	128.0	98%
Loy Yang A (a)	VIC	brown coal	92.5	127.5	99%
Loy Yang B (a)	VIC	brown coal	94.4	128.0	99%
Morwell (a)	VIC	brown coal	92.1	98.46	99%
Yallourn (a)	VIC	brown coal	96.8	78.8	99%
Yarra (b)(d)	VIC	natural gas	51.0	NA	99.5%
Jeeralang (b)	VIC	natural gas	50.6	NA	99.5%
Callide (b)	QLD	black coal	94.6	70.1	99%
Gladstone (b)	QLD	black coal	92.1	70.1	99%
Stanwell (a)	QLD	black coal	90.9	68.4	99%
Swanbank (b)	QLD	black coal	83.5	70.1	99%
Tarong (a)	QLD	black coal	89.5	70.0	99%
Collinsville (b)	QLD	black coal	89.4		99%
Mica Creek (a)	QLD	natural gas	51.4		99.5%
Muja A/B (a)	WA	black coal	93.8	73.6	99%
Muja C/D (a)	WA	black coal	93.8	73.6	99%
Bunbury (a) (e)	WA	black coal	93.8		99%
Kwinana A (a)	WA	black coal	93.8		99%
Kwinana C (a)	WA	black coal	93.8		99%
Collie (a)	WA	black coal	93.8	73.6	99%
Kwinana B (a)	WA	natural gas	51.8		99.5%
Kwinana GT (a)	WA	natural gas	52.5		99.5%
Kalgoorlie (a)	WA	distillate oil	69.9		99%
Mungarra (a)	WA	natural gas	52.5		99.5%
Pinjar (a)	WA	natural gas	52.5	69.7	99.5%
TIWest (a)	WA	natural gas	51.8		99.5%
Worsley (a)	WA	natural gas	51.8		99.5%
Northern (b)	SA	black coal	96.4	73.6	99%
Torrens Island (b)	SA	natural gas	50.8	73.6	99.5%
Osborne (a)	SA	natural gas	50.8		99.5%
Ladbroke Grove (a)	SA	natural gas	50.8		99.5%
Bell Bay (b)	TAS	fuel oil	73.6		99%
Channel Island (a)	NT	natural gas	51.4		99.5%

Source: (a) Wilkenfeld 2006; (b) Value from previous year retained as default; (c) May be briquettes, fuel oil, natural gas or a combination; (d) Yarra previously operated as Newport; (e) Bunbury was decommissioned on 30 September 1999.

Table 70: CO_2 emission factors and oxidation factors power stations 2000–2001

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater (a)	NSW	black coal	92.31	73.60	100%
Eraring (a)	NSW	black coal	88.30	73.60	100%
Mt Piper (a)	NSW	black coal	88.72	68.94	100%
Liddell (a)	NSW	black coal	89.70	70.15	100%
Munmorah (a)	NSW	black coal	90.13	70.32	100%
Vales Point (a)	NSW	black coal	89.98	68.79	100%
Wallerawang (a)	NSW	black coal	85.78	68.94	100%
Appin/Tower (a)	NSW	waste gas	51.40	-	99.5%
Smithfield (a)	NSW	natural gas	51.40	-	99.5%
Redbank (a)	NSW	black coal	92.00	73.60	100%
Hazelwood (a)	VIC	brown coal	94.00	-	98%
Loy Yang A (a)	VIC	brown coal	92.50	-	99%
Loy Yang B (a)	VIC	brown coal	94.40	-	99%
Morwell (a)	VIC	brown coal	92.10	78.80	99%
Yallourn (a)	VIC	brown coal	94.27	78.80	99%
Anglesea	VIC	brown coal	98.80	-	99%
Yarra (b)(c)	VIC	natural gas	51.00	-	99.5%
Jeeralang A & B (b)	VIC	natural gas	50.60	78.80	99.5%
Callide (b)	QLD	black coal	94.60	70.10	99%
Gladstone (b)	QLD	black coal	92.10	70.10	99%
Stanwell (b)	QLD	black coal	90.80	44.90	99%
Swanbank (b)	QLD	black coal	83.50	70.10	99%
Tarong (b)	QLD	black coal	89.70	55.30	99%
Mica Creek (b)	QLD	natural gas	51.40	-	99.5%
Muja A/B (a)	WA	black coal	93.80	73.60	99%
Muja C/D (a)	WA	black coal	93.80	73.60	99%
Kwinana A (a)	WA	black coal	93.80	-	99%
Kwinana C (a)	WA	black coal	93.80	-	99%
Collie (a)	WA	black coal	93.80	73.60	99%
Kwinana B (a)	WA	natural gas	51.80	-	99.5%
Kwinana GT (a)	WA	natural gas	52.50	-	99.5%
Kalgoorlie (a)	WA	distillate oil	69.9	-	99%
Mungarra (a)	WA	natural gas	52.50	-	99.5%
Pinjar (a)	WA	natural gas	52.50	69.9	99.5%
TIWest (a)	WA	natural gas	51.80	-	99.5%
Worsley (a)	WA	natural gas	51.80	-	99.5%
Northern (a)	SA	black coal	96.40	73.60	99%
Torrens Island (a)	SA	natural gas	50.80	73.60	99.5%
Osborne (a)	SA	natural gas	50.80	-	99.5%
Ladbroke Grove (a)	SA	natural gas	50.80	-	99.5%
Bell Bay (b)	TAS	fuel oil	73.60	-	99%
Channel Island (a)	NT	natural gas	51.40	-	99.5%

(a) Wilkenfeld 2006.
(b) Value from previous year retained as default
(c) Yarra previously operated as Newport

Table 71: CO_2 emission factors and oxidation factors for power stations 2001–2002

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater	NSW	black coal	92.31	73.67	100%
Eraring	NSW	black coal	88.30	73.60	100%
Mt Piper	NSW	black coal	89.49	73.60	99.5%
Liddell	NSW	black coal	88.28	70.15	100%
Munmorah	NSW	black coal	93.02	73.60	100%
Vales Point	NSW	black coal	94.72	73.60	98.5%
Wallerawang	NSW	black coal	89.27	73.60	97.3%
Appin/Tower	NSW	wastegas	50.80	-	99.5%
Smithfield	NSW	natural gas	50.80	-	99.5%
Redbank	NSW	black coal	86.03	73.60	99.7%
Hazelwood	VIC	brown coal	94.80	-	99.7%
Loy Yang A	VIC	brown coal	87.77	-	99%
Loy Yang B	VIC	brown coal	94.40	-	100%
Morwell	VIC	brown coal	92.35	78.80	99.7%
Yallourn	VIC	brown coal	94.27	78.80	100%
Anglesea	VIC	brown coal	91.53	78.80	100%
Yarra	VIC	natural gas	51.00	-	99.5%
Jeeralang A & B	VIC	natural gas	50.60	78.80	99.5%
Callide	QLD	black coal	96.18	70.10	99.5%
Gladstone	QLD	black coal	92.10	70.10	99%
Stanwell	QLD	black coal	90.80	44.90	99%
Swanbank	QLD	black coal	85.56	70.10	96.5%
Tarong	QLD	black coal	90.14	70.70	99%
Mica Creek	QLD	natural gas	52.20	-	99.5%
Muja A/B	WA	black coal	93.80	73.60	99%
Muja C/D	WA	black coal	93.80	73.60	99%
Kwinana A	WA	black coal	93.80	0.00	99%
Kwinana C	WA	black coal	93.80	0.00	99%
Collie	WA	black coal	93.80	73.60	99%
Kwinana B	WA	natural gas	51.80	-	99.5%
Kwinana GT	WA	natural gas	51.80	-	99.5%
Kalgoorlie	WA	distillate oil	69.90	-	99%
Mungarra	WA	natural gas	52.50	-	99.5%
Pinjar	WA	natural gas	52.50	-	99.5%
TiWest	WA	natural gas	51.80	-	99.5%
Worsley	WA	natural gas	51.80	-	99.5%
Northern/Playford	SA	black coal	96.40	73.60	99%
Torrens Island	SA	natural gas	50.80	73.60	99.5%
Osborne	SA	natural gas	50.80	-	99.5%
Ladbroke Grove	SA	natural gas	50.80	-	99.5%
Bell Bay	TAS	fuel oil	73.60		99.5%
Channel Island	NT	natural gas	51.40	-	99.5%

Source: Personal communication with power station operating companies

Table 72: CO_2 emission factors and oxidation factors for power stations 2002–2003

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater	NSW	black coal	90.71	73.62	100%
Eraring	NSW	black coal	90.65	70.85	99%
Mt Piper	NSW	black coal	89.21	68.92	100%
Liddell	NSW	black coal	89.02	70.16	100%
Munmorah	NSW	black coal	90.19	68.91	100%
Vales Point	NSW	black coal	89.71	68.78	100%
Wallerawang	NSW	black coal	86.86	70.32	100%
Appin/Tower	NSW	wastegas	51.40	-	99.5%
Smithfield	NSW	natural gas	51.40	-	99.5%
Redbank	NSW	black coal	90.18	-	99%
Hazelwood	VIC	brown coal	94.80	-	99.7%
Loy Yang A	VIC	brown coal	93.86	-	99%
Loy Yang B	VIC	brown coal	95.40	-	100%
Morwell	VIC	brown coal	91.29	78.80	99.7%
Yallourn	VIC	brown coal	96.29	73.60	98.8%
Anglesea	VIC	brown coal	91.74	78.80	100%
Yarra	VIC	natural gas	51.00	-	99.5%
Jeeralang A & B	VIC	natural gas	50.60	78.80	99.5%
Callide	QLD	black coal	96.61	69.00	99.5%
Gladstone	QLD	black coal	92.10	70.10	99%
Stanwell	QLD	black coal	90.80	44.90	99%
Swanbank	QLD	black coal	86.50	69.00	98%
Tarong	QLD	black coal	89.45	69.40	99%
Mica Creek	QLD	natural gas	52.06	69.86	99.5%
Muja A/B	WA	black coal	93.80	73.60	99%
Muja C/D	WA	black coal	93.80	73.60	99%
Kwinana A	WA	black coal	93.80	-	99%
Kwinana C	WA	black coal	93.80	-	99%
Collie	WA	black coal	93.80	73.60	99%
Kwinana B	WA	natural gas	51.80	-	99.5%
Kwinana GT	WA	natural gas	51.80	-	99.5%
Kalgoorlie	WA	distillate oil	69.90	-	99%
Mungarra	WA	natural gas	52.50	-	99.5%
Pinjar	WA	natural gas	52.50	-	99.5%
TiWest	WA	natural gas	51.80	-	99.5%
Worsley	WA	natural gas	51.80	-	99.5%
Northern/Playford	SA	black coal	96.40	73.60	99%
Torrens Island	SA	natural gas	51.40	73.60	99.5%
Osborne	SA	natural gas	50.80	-	99.5%
Ladbroke Grove	SA	natural gas	50.80	-	99.5%
Bell Bay	TAS	natural gas	51.80	-	99.5%
Channel Island	NT	natural gas	51.40	-	99.5%

Source: Personal communication with power station operating companies

Table 73: CO_2 emission factors and oxidation factors for power stations 2003–2004

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater	NSW	black coal	94.66	73.30	99.3%
Eraring	NSW	black coal	90.92	70.85	99%
Mt Piper	NSW	black coal	89.44	69.37	100%
Liddell	NSW	black coal	90.50	70.16	100%
Munmorah	NSW	black coal	91.01	68.64	100%
Vales Point	NSW	black coal	90.05	69.48	100%
Wallerawang	NSW	black coal	87.22	70.31	100%
Appin/Tower	NSW	waste gas	51.40	-	99.5%
Smithfield	NSW	natural gas	51.40	-	99.5%
Redbank	NSW	black coal	92.00	-	99%
Hazelwood	VIC	brown coal	94.40	-	99.7%
Loy Yang A	VIC	brown coal	93.76	-	99%
Loy Yang B	VIC	brown coal	92.68	-	100%
Morwell	VIC	brown coal	94.20	68.00	99.7%
Yallourn	VIC	brown coal	96.29	73.60	98.8%
Anglesea	VIC	brown coal	91.51	78.80	99.9%
Yarra	VIC	natural gas	51.00	-	99.5%
Jeeralang A & B	VIC	natural gas	50.60	78.80	99.5%
Callide	QLD	black coal	96.13	69.00	99.5%
Gladstone	QLD	black coal	92.10	70.10	99%
Stanwell	QLD	black coal	90.80	44.90	99%
Swanbank	QLD	black coal	86.50	69.00	98%
Tarong	QLD	black coal	89.64	64.96	98.9%
Mica Creek	QLD	natural gas	52.06	69.90	99.5%
Muja A/B	WA	black coal	93.80	69.70	99%
Muja C/D	WA	black coal	93.80	69.70	99%
Cockburn	WA	natural gas	51.80	-	99.5%
Kwinana A	WA	black coal	93.80	-	99%
Kwinana C	WA	black coal	93.80	-	99%
Collie	WA	black coal	93.80	69.70	99%
Kwinana B	WA	natural gas	51.80	-	99.5%
Kwinana GT	WA	natural gas	51.80	-	99.5%
Kalgoorlie	WA	distillate oil	69.90	-	99%
Mungarra	WA	natural gas	52.50	-	99.5%
Pinjar	WA	natural gas	52.50	-	99.5%
TiWest	WA	natural gas	51.80	-	99.5%
Worsley	WA	natural gas	51.80	-	99.5%
Northern/Playford	SA	black coal	96.40	73.60	99%
Torrens Island	SA	natural gas	51.40	73.60	99.5%
Osborne	SA	natural gas	50.80	-	99.5%
Ladbroke Grove	SA	natural gas	50.80	-	99.5%
Bell Bay	TAS	natural gas	51.80	-	99.5%
Channel Island	NT	natural gas	51.40	-	99.5%

Source: Personal communication with power station operating companies

Table 74: CO_2 emission factors and oxidation factors for power stations 2004–2005

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater	NSW	black coal	91.00	69.61	100%
Eraring	NSW	black coal	90.14	70.97	99%
Mt Piper	NSW	black coal	89.59	70.15	100%
Liddell	NSW	black coal	90.54	70.16	100%
Munmorah	NSW	black coal	89.97	67.69	100%
Vales Point	NSW	black coal	89.31	69.28	100%
Wallerawang	NSW	black coal	87.00	70.31	100%
Appin/Tower	NSW	waste gas	51.88	-	99.5%
Smithfield	NSW	natural gas	51.40	-	99.5%
Redbank	NSW	black coal	92.00	73.60	99%
Hazelwood	VIC	brown coal	93.91	-	99.7%
Loy Yang A	VIC	brown coal	90.33	-	99%
Loy Yang B	VIC	brown coal	93.56	-	100%
Morwell	VIC	brown coal	92.10	68.00	99.7%
Yallourn	VIC	brown coal	95.46	73.60	98.8%
Anglesea	VIC	brown coal	100.92	78.80	99.9%
Yarra	VIC	natural gas	50.60	-	99.5%
Jeeralang A & B	VIC	natural gas	52.60	70.10	99.5%
Callide	QLD	black coal	96.13	69.00	99.0%
Gladstone	QLD	black coal	92.10	70.10	99%
Stanwell	QLD	black coal	93.80	44.90	99%
Swanbank	QLD	black coal	86.50	69.00	99%
Tarong	QLD	black coal	89.44	66.86	98.9%
Mica Creek	QLD	natural gas	52.06	69.90	99.5%
Millmerran	QLD	black coal	87.50	71.10	99.0%
Muja A/B	WA	black coal	93.80	69.70	99%
Muja C/D	WA	black coal	93.80	69.70	99%
Cockburn	WA	natural gas	51.80	69.70	99.5%
Kwinana A	WA	black coal	93.80	-	99%
Kwinana C	WA	black coal	93.80	69.70	99%
Collie	WA	black coal	93.80	69.70	99%
Kwinana B	WA	natural gas	51.80	69.70	99.5%
Kwinana GT	WA	natural gas	51.80	-	99.5%
Kalgoorlie	WA	distillate oil	69.9	-	99%
Mungarra	WA	natural gas	52.50	-	99.5%
Pinjar	WA	natural gas	52.50	-	99.5%
TiWest	WA	natural gas	51.80	-	99.5%
Worsley	WA	natural gas	51.80	-	99.5%
Worsley Alumina	WA	black coal	90.00	-	99.0%
Northern/Playford	SA	black coal	96.40	73.60	99%
Torrens Island	SA	natural gas	51.40	73.60	99.5%
Osborne	SA	natural gas	50.80	-	99.5%
Ladbroke Grove	SA	natural gas	50.80	-	99.5%
Pelican Point	SA	natural gas	53.15	-	99.5%
Bell Bay	TAS	natural gas	51.80	-	99.5%
Channel Island	NT	natural gas	51.40	-	99.5%

Source: Personal communication with power station operating companies

Table 75: CO_2 emission factors and oxidation factors for power stations 2005–2006

Power Station	State	Fuel	Gg CO_2/PJ		Oxidation factor
			Main fuel	Oil	
Bayswater	NSW	black coal	89.1	69.6	100%
Eraring	NSW	black coal	90.2	69.3	98.9%
Mt Piper	NSW	black coal	89.2	69.7	100%
Liddell	NSW	black coal	90.1	70.2	100%
Munmorah	NSW	black coal	89.4	67.4	100%
Vales Point	NSW	black coal	89.0	69.5	100%
Wallerawang	NSW	black coal	86.2	70.3	100%
Appin/Tower	NSW	waste gas	51.8	-	99.5%
Smithfield	NSW	natural gas	51.4	-	99.5%
Redbank	NSW	black coal	92.0	73.6	99%
Hazelwood	VIC	brown coal	94.2	-	99.7%
Loy Yang A	VIC	brown coal	92.3	-	99%
Loy Yang B	VIC	brown coal	93.6	-	100.0%
Morwell	VIC	brown coal	92.0	68.0	99.6%
Yallourn	VIC	brown coal	95.2	73.6	98.8%
Anglesea	VIC	brown coal	91.7	-	99.9%
Yarra	VIC	natural gas	50.6	-	99.5%
Jeeralang A & B	VIC	natural gas	50.6	-	99.5%
Callide	QLD	black coal	96.1	69.0	99%
Gladstone	QLD	black coal	91.8	70.1	99%
Stanwell	QLD	black coal	90.5	69.5	100%
Swanbank	QLD	black coal	86.5	69.0	99%
Tarong	QLD	black coal	91.0	69.4	99%
Mica Creek	QLD	natural gas	52.1	69.9	99.5%
Millmerran	QLD	black coal	89.0	71.1	99%
Muja A/B	WA	black coal	93.8	69.7	99%
Muja C/D	WA	black coal	93.8	69.7	99%
Cockburn	WA	natural gas	51.8	-	99.5%
Kwinana A	WA	black coal	93.8	-	99%
Kwinana C	WA	black coal	93.8	69.7	99%
Collie	WA	black coal	93.8	69.7	99%
Kwinana B	WA	natural gas	51.8	69.7	99.5%
Kwinana GT	WA	natural gas	51.8	-	99.5%
Kalgoorlie	WA	distillate oil	69.9	-	99%
Mungarra	WA	natural gas	52.5	-	99.5%
Pinjar	WA	natural gas	52.5	69.9	99.5%
TiWest	WA	natural gas	51.8	-	99.5%
Worsley	WA	natural gas	51.8	-	99.5%
Northern/Playford	SA	black coal	96.4	73.6	99%
Torrens Island	SA	natural gas	51.4	73.6	99.5%
Osborne	SA	natural gas	50.8	-	99.5%
Ladbroke Grove	SA	natural gas	50.8	-	99.5%
Pelican Point	SA	natural gas	53.1	-	99.5%
Bell Bay	TAS	natural gas	51.8	-	99.5%
Channel Island	NT	natural gas	51.4	-	99.5%

Source: Personal communication with power station operating companies

Table 76: Emission factors for non-CO_2 greenhouse gases, power stations in operation in period 1988-1995.

No.	Power Station	State	Equipment Type	Fuel	Emission Factor (Mg/PJ)				
					CH_4	N_2O^a	NO2	CO	NMVO
1	Bayswater(a)	NSW	PW	BC	0.9	0.8	220	11	1.7
2	Eraring(a)	NSW	PW	BC	0.9	0.8	220	11	1.7
3	Mt Piper (a)	NSW	PW	BC	0.9	0.8	220	11	1.7
4	Liddell (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
5	Munmorah (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
6	Tallawarra A (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
7	Tallawarra B (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
8	Vales Point A (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
9	Vales Point B (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
10	Wallerawang B (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
11	Wallerawang C (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
12	Ashford (b)	NSW	TF	BC	0.9	0.8	260	11	1.7
13	Hazelwood (c)	VIC	TF	BrC	0.5	1.4	151	14	1.7
14	Loy Yang A (c)	VIC	TF	BrC	0.5	1.4	136	18	1.7
15	Loy Yang B (c)	VIC	TF	BrC	0.5	1.4	136	18	1.7
16	Morwell (c)	VIC	TF	BrC	0.5	1.4	151	14	1.7
17	Yallourn W (c)	VIC	TF	BrC	0.5	1.4	106	20	1.7
18	Yallourn (c)	VIC	TF	BrC	0.5	1.4	106	20	1.7
19	Newport (c)	VIC	GB	NG	0.1	0.1	97	35	0.6
20	Jeeralang A (c)	VIC	GT	NG	5.4	0.1	188	29	0.6
21	Jeeralang B (c)	VIC	GT	NG	5.4	0.1	72	29	0.6
22	Callide (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
23	Gladstone (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
24	Stanwell (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
25	Swanbank (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
26	Tarong (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
27	Collinsville (d)	QLD	PW	BC	0.9	0.8	523	11	1.7
28	Muja A/B (e)	WA	PW	BC	0.9	0.8	462	11	1.7
29	Muja C/D (e)	WA	TF	BC	0.9	0.8	306	11	1.7
30	Bunbury (e)	WA	PW	BC	0.9	0.8	462	11	1.7
31	Kwinana A (e)	WA	PW	BC	0.9	0.8	462	11	1.7
32	Kwinana C (e)	WA	TF	BC	0.9	0.8	306	11	1.7
33	Kwinana B (e)	WA	GB	NG	0.1	0.1	226	16	0.6
34	Kwinana GT (e)	WA	GT	NG	8.0	0.1	190	46	2.4
36	Kalgoorlie (e)	WA	GT	FO	4	0.6	1322	349	45

37	Mungarra (e)	WA	GT	NG	8.0	0.1	190	46	2.4
38	Pinjarra (e)	WA	GT	NG	8.0	0.1	190	46	2.4
39	Northern	SA	PW	BC	0.9	1.4	130	17	1.7
40	Torrens Island (h)	SA	GW	NG	0.1	0.1	117	6	0.67
41	Dry Creek (g)	SA	GT	NG	8.0	0.1	383	16	2.47
42	Mintaro (e)	SA	GT	NG	8.0	0.1	190	46	2.4
43	Vales Point A (a)	TAS	Boiler	FO	0.8	0.6	186	14	12.1
44	Wallerawang B (a)	NT	GT	NG	8.0	0.1	190	46	2.4
91	Various		GT	NG	8.0	0.1	190	46	2.47
92	Various		GT	D	4.0	0.6	1322	349	45
93	Various		IC	NG	240	0.1	1331	340	80
94	Various		IC	FO	4.0	0.6	1322	349	45
95	Various		IC	D	4.0	0.6	1322	349	45
96	Various		Boiler	FO	0.8	0.6	186	14	2.1
97	Various (e)		Boiler	D	0.04	0.6	64	13	1.4

Notes and Sources

(a) Default emission factors for CH4, N2O, CO and NMVOC. NSW data for Nox (Pacific Power pers. comm. 1995)
(b) Assume same emission factors as other NSW TF power stations
(c) Data for CH4, Nox, and CO from *Workbook for Fuel Combustion Activities (Stationary Sources)*
(d) Default emission factors for CH4, N2O, CO and NMVOC. Nox data for Swanbank as reported by Australian Environment Council (1988). Assume Nox emission rate for Qld power stations identical to Swanbank.
(e) Default emission factors for all pollutants.
(f) Assume gas turbine equipment type.
(g) Default emission factors for CH4, N2O and NMVOC. Nox and CO data as reported by Australian Environment Council (1988).
(h) Default emission factors for CH4, N2O and NMVOC. Nox and CO data based on weighted anerage emission factors as reported by the Australian Environment Council (1988).
(i) One sixth of installed capacity is Combined Cycle.

D Distillate
BC Black Coal
BrC Brown Coal
FO Fuel Oil
GB Gas Boiler
GT Gas Turbine
IC Internal Combustion.
NG Natural Gas.
N/AV Not Available
PW Pulverised Wall
TF Tangentially Fired.

Table 77: Emission factors for non-CO_2 greenhouse gases for thermal power stations during 1995-1996 (Mg/PJ)

No.	Power station	State	Equipment Type	Fuel	Emission Factor (Mg/PJ)				
					CH_4	N_2O	NO_x	CO	NMVOC
1	Bayswater [a]	NSW	PW	BC	0.9	0.8	220	11	1.7
2	Eraring [a]	NSW	PW	BC	0.9	0.8	220	11	1.7
3	Mt Piper [a]	NSW	PW	BC	0.9	0.8	220	11	1.7
4	Liddell [a]	NSW	TF	BC	0.9	0.8	260	11	1.7
5	Munmorah [a]	NSW	TF	BC	0.9	0.8	221	11	1.7
9	Vales Point B [a]	NSW	TF	BC	0.9	0.8	260	11	1.7
11	Wallerawang C [a]	NSW	TF	BC	0.9	0.8	260	11	1.7
12	Ashford [b]	NSW	TF	BC	0.9	0.8	260	11	1.7
13	Hazelwood [c]	VIC	TF	BrC	0.5	1.4	151	14	1.7
14	Loy Yang A [c]	VIC	TF	BrC	0.5	1.4	136	18	1.7
15	Loy Yang B [c]	VIC	TF	BrC	0.5	1.4	136	18	1.7
16	Morwell [c]	VIC	TF	BrC	0.5	1.4	151	14	1.7
17	Yallourn W [c]	VIC	TF	BrC	0.5	1.4	106	20	1.7
18	Yallourn [c]	VIC	TF	BrC	0.5	1.4	106	20	1.7
19	Newport [c]	VIC	GB	NG	0.1	0.1	97	35	0.6
20	Jeeralang A [c]	VIC	GT	NG	5.4	0.1	188	29	0.6
21	Jeeralang B [c]	VIC	GT	NG	5.4	0.1	72	29	0.6
22	Callide [d]	QLD	PW	BC	0.9	0.8	473	11	1.7
23	Gladstone [d]	QLD	PW	BC	0.9	0.8	523	11	1.7
24	Stanwell [d]	QLD	PW	BC	0.9	0.8	302	11	1.7
25	Swanbank [d]	QLD	PW	BC	0.9	0.8	258	11	1.7
26	Tarong [d]	QLD	PW	BC	0.9	0.8	356	11	1.7
27	Collinsville [d]	QLD	PW	BC	0.9	0.8	523	11	1.7
28	Muja A/B [e]	WA	PW	BC	0.9	0.8	462	11	1.7
29	Muja C/D [e]	WA	TF	BC	0.9	0.8	306	11	1.7
30	Bunbury [e]	WA	PW	BC	0.9	0.8	462	11	1.7
31	Kwinana A [e]	WA	PW	BC	0.9	0.8	320	11	1.7
32	Kwinana C [e]	WA	TF	BC	0.9	0.8	258	11	1.7
33	Kwinana B [e]	WA	GB	NG	0.1	0.1	226	16	0.6
34	Kwinana GT [e]	WA	GT	NG	8.0	0.1	190	46	2.4
36	Kalgoorlie [e]	WA	GT	FO	4	0.6	1322	349	45
37	Mungarra [e]	WA	GT	NG	8.0	0.1	190	46	2.4
38	Pinjarra [e]	WA	GT	NG	8.0	0.1	190	46	2.4
39	Northern	SA	PW	BC	0.9	1.4	136	17	1.7
40	Torrens Island [h]	SA	GB	NG	0.1	0.1	117	6	0.6

No.	Power station	State	Equipment Type	Fuel	Emission Factor (Mg/PJ)				
					CH_4	N_2O	NO_x	CO	NMVOC
41	Dry Creek [g]	SA	GT	NG	8.0	0.1	383	16	2.4
42	Mintaro [e]	SA	GT	NG	8.0	0.1	190	46	2.4
43	Bell Bay	TAS	Boiler	FO	0.8	0.6	186	14	2.1
44	Channel Island [e,i]	NT	GT	NG	8.0	0.1	190	46	2.4
91	Various [e]		GT	NG	8.0	0.1	190	46	2.4
92	Various [e]		GT	Distillate	4.0	0.6	1322	349	45
93	Various [e]		IC	NG	240	0.1	1331	340	80
94	Various [e]		IC	FO	4.0	0.6	1322	349	45
95	Various [e]		IC	Distillate	4.0	0.6	1322	349	45
96	Various [e]		Boiler	FO	0.8	0.6	186	14	2.1
97	Various [e]		Boiler	Distillate	0.04	0.6	64	13	1.4

Notes and sources

[a] Default emission factors for CH_4, N_2O, CO and NMVOC. NSW data for NO_x (Pacific Power pers. comm. 1995).
[b] Assume same emission factors as other NSW TF power stations.
[c] Data for CH_4, NO_x, and CO from Workbook for *Fuel Combustion Activities (Stationary Sources) 1.0* 1994. Default emission factors for N_2O and NMVOC.
[d] Default emission factors for CH_4, N_2O, CO and NMVOC. NO_x data for Callide, Stanwell, Swanbank and Tarong provided by Austa Electric. Assume NO_x emission rate for Gladstone and Collinsville same as in previous years.
[e] Default emission factors for all pollutants.
[f] Assume gas turbine equipment type.
[g] Default emission factors for CH_4, N_2O, and NMVOC. NO_x and CO data as reported by Australian Environment Council (1988).
[h] Default emission factors for CH_4, N_2O, and NMVOC. NO_x and CO data based on weighted average emission factors as reported by the Australian Environment Council (1988).
[i] One sixth of installed capacity is Combined Cycle.
BC Black Coal.
BrC Brown Coal.
FO Fuel Oil.
GB Gas Boiler.
GT Gas Turbine.
IC Internal Combustion.
NG Natural Gas.
N/AV Not Available.
PW Pulverised Wall.
TF Tangentially Fired.

Table 78: **Emission factors for non-CO_2 greenhouse gases for major thermal power stations in operation 1996-1997 (Mg/PJ)**

No.	Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ				
					CH_4	N_2O	NO_x	CO	NMVOC
1	Bayswater (a)	NSW	PW	BC	0.9	0.8	220	11	1.7
2	Eraring (a)	NSW	PW	BC	0.9	0.8	220	11	1.7
3	Mt Piper (a)	NSW	PW	BC	0.9	0.8	220	11	1.7
4	Liddell (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
5	Munmorah (a)	NSW	TF	BC	0.9	0.8	221	11	1.7
6	Vales Point (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
7	Wallerawang (a)	NSW	TF	BC	0.9	0.8	260	11	1.7
8	Ashford (b)	NSW	TF	BC	0.9	0.8	260	11	1.7
9	Hazelwood (b)	VIC	TF	BrC	0.5	1.4	151	14	1.7
10	Loy Yang A (a)	VIC	TF	BrC	0.5	1.4	136	18	1.7
11	Loy Yang B (a)	VIC	TF	BrC	0.5	1.4	136	18	1.7
12	Morwell (a)	VIC	TF	BrC	0.5	1.4	151	14	1.7
13	Yallourn (b)	VIC	TF	BrC	0.5	1.4	106	20	1.7
14	Newport (a)	VIC	GB	NG	0.1	0.1	97	35	0.6
15	Jeeralang A (a)	VIC	GT	NG	5.4	0.1	188	29	0.6
16	Jeeralang B (a)	VIC	GT	NG	5.4	0.1	72	29	0.6
17	Callide (a)	QLD	PW	BC	0.9	0.8	469	11	1.7
18	Gladstone (b)	QLD	PW	BC	0.9	0.8	523	11	1.7
19	Stanwell (a)	QLD	PW	BC	0.9	0.8	286	11	1.7
20	Swanbank (a)	QLD	PW	BC	0.9	0.8	127	11	1.7
21	Tarong (a)	QLD	PW	BC	0.9	0.8	345	11	1.7
22	Muja A/B (b)	WA	PW	BC	0.9	0.8	462	11	1.7
23	Muja C/D (b)	WA	TF	BC	0.9	0.8	306	11	1.7
24	Bunbury (b)	WA	PW	BC	0.9	0.8	462	11	1.7
25	Kwinana A (b)	WA	PW	BC	1.0	0.3	320	11	1.0
26	Kwinana C (b)	WA	TF	BC	1.0	0.3	258	11	1.0
27	Kwinana B (b)	WA	GB	NG	0.1	0.1	226	16	0.6
28	Kwinana GT (b)	WA	GT	NG	8.0	0.1	190	46	2.4
30	Kalgoorlie (b)	WA	GT	FO	4	0.6	1322	349	45
31	Mungarra (b)	WA	GT	NG	8.0	0.1	190	46	2.4
32	Pinjar (b)	WA	GT	NG	8.0	0.1	190	46	2.4
33	Northern (a)	SA	PW	BC	0.9	1.4	136	17	1.7
34	Torrens Island (a)	SA	GB	NG	0.1	0.1	117	6	0.6
35	Dry Creek (b)	SA	GT	NG	8.0	0.1	383	16	2.4
36	Mintaro (b)	SA	GT	NG	8.0	0.1	190	46	2.4
37	Bell Bay (b)	TAS	Boiler	FO	0.8	0.6	186	14	2.1
40	Channel Island (b,c)	NT	GT	NG	8.0	0.1	190	46	2.4

Source: (a) Wilkenfeld 2006.
(b) Value from previous year retained as default
(c) One sixth of installed capacity is Combined Cycle.

Notes: Abbreviations for fuel types are: BC Black Coal, BrC Brown Coal, FO Fuel Oil, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion., NG Natural Gas, N/AV Not Available, PW Pulverised Wall and TF Tangentially Fired.

Table 79: **Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 1997-1998 (Mg/PJ)**

Power Station	State	Equipment Type	Fuel	Emission Factor Mg/PJ				
				CH_4	N_2O	NO_x	CO	NMVOC
Bayswater	NSW	PW	BC	0.9	0.8	220	11	1.7
Eraring	NSW	PW	BC	0.9	0.8	220	11	1.7
Mt Piper	NSW	PW	BC	0.9	0.8	220	11	1.7
Liddell	NSW	TF	BC	0.9	0.8	260	11	1.7
Munmorah	NSW	TF	BC	0.9	0.8	221	11	1.7
Vales Point	NSW	TF	BC	0.9	0.8	260	11	1.7
Wallerawang	NSW	TF	BC	0.9	0.8	260	11	1.7
Hazelwood	VIC	TF	BrC	0.5	1.4	151	14	1.7
Loy Yang A	VIC	TF	BrC	0.5	1.4	136	18	1.7
Loy Yang B (a)	VIC	TF	BrC	0.5	1.4	136	12	1.7
Morwell	VIC	TF	BrC	0.5	1.4	151	14	1.7
Yallourn	VIC	TF	BrC	0.5	1.4	106	20	1.7
Newport	VIC	GB	NG	0.1	0.1	97	35	0.6
Jeeralang A	VIC	GT	NG	5.4	0.1	188	29	0.6
Jeeralang B	VIC	GT	NG	5.4	0.1	72	29	0.6
Callide	QLD	PW	BC	0.9	0.8	469	11	1.7
Gladstone	QLD	PW	BC	0.9	0.8	523	11	1.7
Stanwell	QLD	PW	BC	0.9	0.8	286	11	1.7
Swanbank	QLD	PW	BC	0.9	0.8	127	11	1.7
Tarong	QLD	PW	BC	0.9	0.8	345	11	1.7
Muja A/B	WA	PW	BC	0.9	0.8	462	11	1.7
Muja C/D	WA	TF	BC	0.9	0.8	306	11	1.7
Bunbury	WA	PW	BC	0.9	0.8	462	11	1.7
Kwinana A	WA	PW	BC	1.0	0.3	320	11	1.0
Kwinana C	WA	TF	BC	1.0	0.3	258	11	1.0
Kwinana B	WA	GB	NG	0.1	0.1	226	16	0.6
Kwinana GT	WA	GT	NG	8.0	0.1	190	46	2.4
Kalgoorlie	WA	GT	FO	4	0.6	1322	349	45
Mungarra	WA	GT	NG	8.0	0.1	190	46	2.4
Pinjar	WA	GT	NG	8.0	0.1	190	46	2.4
Northern	SA	PW	BC	0.9	1.4	136	17	1.7
Torrens Island	SA	GB	NG	0.1	0.1	117	6	0.6
Bell Bay	TAS	Boiler	FO	0.8	0.6	186	14	2.1
Channel Island	NT	GT	NG	8.0	0.1	190	46	2.4

Source: (a) One or more factors changed from previous year.
Notes: Abbreviations for fuel types are: BC Black Coal, BrC Brown Coal, FO Fuel Oil, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion., NG Natural Gas, N/AV Not Available, PW Pulverised Wall and TF Tangentially Fired.

Table 80: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 1998–1999 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission Factor Mg/PJ				
				CH_4	N_2O	NO_x	CO	NMVOC
Bayswater	NSW	PW	BC	0.9	0.8	220	11	1.7
Eraring	NSW	PW	BC	0.9	0.8	220	11	1.7
Mt Piper	NSW	PW	BC	0.9	0.8	220	11	1.7
Liddell	NSW	TF	BC	0.9	0.8	260	11	1.7
Munmorah	NSW	TF	BC	0.9	0.8	221	11	1.7
Vales Point	NSW	TF	BC	0.9	0.8	260	11	1.7
Wallerawang	NSW	TF	BC	0.9	0.8	260	11	1.7
Hazelwood	VIC	TF	BrC	0.5	1.4	151	14	1.7
Loy Yang A	VIC	TF	BrC	0.5	1.4	136	18	1.7
Loy Yang B [a]	VIC	TF	BrC	0.7	1.4	136	12	1.7
Morwell	VIC	TF	BrC	0.5	1.4	151	14	1.7
Yallourn	VIC	TF	BrC	0.5	1.4	106	20	1.7
Newport	VIC	GB	NG	0.1	0.1	97	35	0.6
Jeeralang A	VIC	GT	NG	5.4	0.1	188	29	0.6
Jeeralang B	VIC	GT	NG	5.4	0.1	72	29	0.6
Callide	QLD	PW	BC	0.9	0.8	469	11	1.7
Gladstone	QLD	PW	BC	0.9	0.8	523	11	1.7
Stanwell	QLD	PW	BC	0.9	0.8	286	11	1.7
Swanbank	QLD	PW	BC	0.9	0.8	127	11	1.7
Tarong	QLD	PW	BC	0.9	0.8	345	11	1.7
Mica Creek [a]	QLD	GT	NG	8.0	0.1	190.0	46.0	2.4
Muja A/B	WA	PW	BC	0.9	0.8	462	11	1.7
Muja C/D	WA	TF	BC	0.9	0.8	306	11	1.7
Bunbury	WA	PW	BC	0.9	0.8	462	11	1.7
Kwinana A	WA	PW	BC	1.0	0.3	320	11	1.0
Kwinana C	WA	TF	BC	1.0	0.3	258	11	1.0
Collie [a]	PW	TF	BC	0.9	0.8	462.0	11.0	1.7
Kwinana B	WA	GB	NG	0.1	0.1	226	16	0.6
Kwinana GT	WA	GT	NG	8.0	0.1	190	46	2.4
Kalgoorlie	WA	GT	FO	4	0.6	1322	349	45
Mungarra	WA	GT	NG	8.0	0.1	190	46	2.4
Pinjar	WA	GT	NG	8.0	0.1	190	46	2.4
TIWest [a]	WA	GT	NG	8.0	0.1	190.0	46.0	2.4
Northern	SA	PW	BC	0.9	1.4	136	17	1.7
Torrens Island	SA	GB	NG	0.1	0.1	117	6	0.6
Osborne [a]	SA	GT	NG	8.0	0.1	190.0	46.0	2.4
Bell Bay	TAS	Boiler	FO	0.8	0.6	186	14	2.1
Channel Island	NT	GT	NG	8.0	0.1	190	46	2.4

Source: (a) One or more factors changed from previous year.
Notes: Abbreviations for fuel types and equipment types are: BC black coal, BrC brown coal, FO fuel oil, GB gas boiler, GT gas turbine, IC internal combustion, NG natural gas, PW pulverised wall, and TF tangentially fired.

Table 81: Emission factors for non-CO2 greenhouse gases for main fuel used in major thermal power stations in operation 1999-2000 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ				
				CH_4	N_2O	NO_x	CO	NMVOC
Bayswater	NSW	PW	black coal	0.9	0.8	220	11	1.7
Eraring	NSW	PW	black coal	0.9	0.8	220	11	1.7
Mt Piper	NSW	PW	black coal	0.9	0.8	220	11	1.7
Liddell	NSW	TF	black coal	0.9	0.8	260	11	1.7
Munmorah	NSW	TF	black coal	0.9	0.8	221	11	1.7
Vales Point	NSW	TF	black coal	0.9	0.8	260	11	1.7
Wallerawang	NSW	TF	black coal	0.9	0.8	260	11	1.7
Hazelwood	VIC	TF	brown coal	0.5	1.4	151	14	1.7
Loy Yang A	VIC	TF	brown coal	0.5	1.4	136	18	1.7
Loy Yang B (a)	VIC	TF	brown coal	0.7	1.4	136	11.7	1.7
Morwell	VIC	TF	brown coal	0.5	1.4	151	14	1.7
Yallourn	VIC	TF	brown coal	0.5	1.4	106	20	1.7
Yarra (b)	VIC	GB	natural gas	0.1	0.1	97	35	0.6
Jeeralang A	VIC	GT	natural gas	5.4	0.1	188	29	0.6
Jeeralang B	VIC	GT	natural gas	5.4	0.1	72	29	0.6
Callide	QLD	PW	black coal	0.9	0.8	469	11	1.7
Gladstone	QLD	PW	black coal	0.9	0.8	523	11	1.7
Stanwell (a)	QLD	PW	black coal	0.7	0.8	343	9	1.7
Swanbank	QLD	PW	black coal	0.9	0.8	127	11	1.7
Tarong (a)	QLD	PW	black coal	0.9	0.8	363	13	1.7
Mica Creek	QLD	GT	natural gas	8.0	0.1	190	46	2.4
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7
Bunbury (c)	WA	PW	black coal	0.9	0.8	462	11	1.7
Kwinana A	WA	PW	black coal	1.0	0.3	320	11	1.0
Kwinana C	WA	TF	black coal	1.0	0.3	258	11	1.0
Collie (a)	WA	PW	black coal	0.9	0.8	462	11	1.7
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4
Worsley (a)	WA	GT	natural gas	0.1	0.1	226	16	0.6
Northern	SA	PW	black coal	0.9	1.4	136	17	1.7
Torrens Island	SA	GB	natural gas	0.1	0.1	117	6	0.6
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4
Ladbroke Grove (a)	SA	GT	natural gas	8.0	0.1	190	46	2.4
Bell Bay	TAS	Boiler	fuel oil	0.8	0.6	186	14	2.1
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4

Source: (a) One or more factors changed from previous year, or new power station added
(b) Yarra previously operated as Newport. (c) Bunbury was decommissioned on 30 September 1999.

Notes: Abbreviations for equipment types are: GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 82: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2000–2001 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	220	11	1.7	370
Eraring	NSW	PW	black coal	0.9	0.8	220	11	1.7	370
Mt Piper	NSW	PW	black coal	0.9	0.8	220	11	1.7	370
Liddell	NSW	TF	black coal	0.9	0.8	260	11	1.7	370
Munmorah	NSW	TF	black coal	0.9	0.8	221	11	1.7	370
Vales Point	NSW	TF	black coal	0.9	0.8	260	11	1.7	370
Wallerawang	NSW	TF	black coal	0.9	0.8	260	11	1.7	370
Hazelwood	VIC	TF	brown coal	0.5	1.4	151	14	1.7	150
Loy Yang A	VIC	TF	brown coal	0.5	1.4	136	18	1.7	150
Loy Yang B	VIC	TF	brown coal	0.7	1.4	136	11.7	1.7	509
Morwell	VIC	TF	brown coal	0.5	1.4	151	14	1.7	150
Yallourn	VIC	TF	brown coal	0.5	1.4	106	20	1.7	150
Yarra (b)	VIC	GB	natural gas	0.1	0.1	97	35	0.6	150
Jeeralang A&B (a)	VIC	GT	natural gas	5.4	0.1	130	29	0.6	2.3
Callide	QLD	PW	black coal	0.9	0.8	469	11	1.7	370
Gladstone	QLD	PW	black coal	0.9	0.8	523	11	1.7	370
Stanwell	QLD	PW	black coal	0.7	0.8	316	9	1.7	377
Swanbank	QLD	PW	black coal	0.9	0.8	127	11	1.7	370
Tarong (a)	QLD	PW	black coal	0.9	0.8	411	13	1.7	261
Mica Creek	QLD	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	370
Kwinana A	WA	PW	black coal	1.0	0.3	320	11	1.0	370
Kwinana C	WA	TF	black coal	1.0	0.3	258	11	1.0	370
Collie (a)	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Worsley	WA	GT	natural gas	0.1	0.1	226	16	0.6	2.3
Northern	SA	PW	black coal	0.9	1.4	136	17	1.7	150
Torrens Island	SA	GB	natural gas	0.1	0.1	117	6	0.6	2.3
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Ladbroke Grove	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Bell Bay	TAS	Boiler	fuel oil	0.8	0.6	186	14	2.1	1,390
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4	2.3

(a) One or more factors changed from previous year, or new power station added
(b) Yarra previously operated as Newport
Notes: Abbreviations for equipment types are: GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 83: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2001-2002 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	220	11	1.7	370.0
Eraring	NSW	PW	black coal	0.9	0.8	220	11	1.7	370.0
Mt Piper	NSW	PW	black coal	0.9	0.8	220	11	1.7	370.0
Liddell	NSW	TF	black coal	0.9	0.8	260	11	1.7	370.0
Munmorah	NSW	TF	black coal	0.9	0.8	221	11	1.7	370.0
Vales Point	NSW	TF	black coal	0.9	0.8	260	11	1.7	370.0
Wallerawang	NSW	TF	black coal	0.9	0.8	260	11	1.7	370.0
Appin/Tower	NSW	IC	waste gas	240.0	0.1	1331	340	80.0	2.3
Smithfield	NSW	CCGT	natural gas	0.1	0.1	190	46	2.4	2.3
Redbank	NSW	FB	black coal	0.9	0.8	260	11	1.7	370.0
Hazelwood	VIC	TF	brown coal	0.5	1.4	136	14	1.7	58.8
Loy Yang A	VIC	TF	brown coal	0.9	1.4	134	9	1.7	249.0
Loy Yang B	VIC	TF	brown coal	0.7	1.4	0	17.0	1.7	217.0
Morwell	VIC	TF	brown coal	0.7	1.4	151	14	1.7	196.0
Yallourn	VIC	TF	brown coal	0.5	1.4	71	70	2.2	97.7
Anglesea	VIC	TF	brown coal	0.9	1.4	227	3	1.3	237.0
Yarra	VIC	GB	natural gas	0.1	0.1	97	35	0.6	150.0
Jeeralang A & B	VIC	GT	natural gas	5.4	0.1	130	29	0.6	2.3
Callide	QLD	PW	black coal	0.7	0.8	385	11	1.7	155.1
Gladstone	QLD	PW	black coal	0.9	0.8	523	11	1.7	370.0
Stanwell	QLD	PW	black coal	0.7	0.8	316	9	1.7	377.0
Swanbank	QLD	PW	black coal	0.7	0.8	268	11	1.7	364.1
Tarong	QLD	PW	black coal	0.9	0.8	462	11	1.7	370.0
Mica Creek	QLD	GT	natural gas	4.6	0.1	143	33	1.6	0.2
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	629.4
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	629.4
Kwinana A	WA	PW	black coal	1.0	0.3	320	11	1.0	629.4
Kwinana C	WA	TF	black coal	1.0	0.3	258	11	1.0	629.4
Collie	WA	PW	black coal	0.9	0.8	462	11	1.7	629.4
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	3.9
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Worsley	WA	GT	natural gas	0.1	0.1	226	16	0.6	3.9
Northern/Playford	SA	PW	black coal	0.9	1.4	136	17	1.7	150.0
Torrens Island	SA	GB	natural gas	0.1	0.1	117	6	0.6	2.3
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Ladbroke Grove	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Bell Bay	TAS	Boiler	fuel oil	0.8	0.6	186	14	2.1	1390.0
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4	2.3

Source: Personal communication with power station operating companies
Notes: Abbreviations for equipment types are: CCGT Combined Cycle Gas Turbine, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 84: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2002-2003 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	243	11	1.7	527.9
Eraring	NSW	PW	black coal	0.9	0.8	241	11	1.7	335.6
Mt Piper	NSW	PW	black coal	0.7	0.8	303	11	1.7	425.0
Liddell	NSW	TF	black coal	0.9	0.8	306	11	1.7	370.0
Munmorah	NSW	TF	black coal	0.7	0.8	237	11	1.7	245.0
Vales Point	NSW	TF	black coal	0.7	0.8	225	11	1.7	314.0
Wallerawang	NSW	TF	black coal	0.7	0.8	206	11	1.7	473.0
Appin/Tower	NSW	IC	waste gas	240.0	0.1	1331	340	80.0	2.3
Smithfield	NSW	CCGT	natural gas	8.0	0.1	190	46	2.4	2.3
Redbank	NSW	FB	black coal	0.9	0.8	39	11	1.7	168.1
Hazelwood	VIC	TF	brown coal	0.5	1.4	136	17	1.7	54.9
Loy Yang A	VIC	TF	brown coal	0.9	1.4	178	6	1.7	251.9
Loy Yang B	VIC	TF	brown coal	0.7	1.4	136	17.0	1.7	337.3
Morwell	VIC	TF	brown coal	0.7	1.4	151	14	2.0	161.0
Yallourn	VIC	TF	brown coal	0.5	1.4	78	43	0.0	108.5
Anglesea	VIC	TF	brown coal	0.9	1.4	227	3	1.3	2382.0
Yarra	VIC	GB	natural gas	0.1	0.1	97	35	0.6	150.0
Jeeralang A & B	VIC	GT	natural gas	5.4	0.1	130	29	0.6	2.3
Callide	QLD	PW	black coal	0.9	0.8	380	11	0.6	170.0
Gladstone	QLD	PW	black coal	0.9	0.8	523	11	1.7	370.0
Stanwell	QLD	PW	black coal	0.7	0.8	316	9	1.7	377.0
Swanbank	QLD	PW	black coal	0.9	0.8	245	5	0.6	395.0
Tarong	QLD	PW	black coal	0.9	0.8	462	11	1.7	370.0
Mica Creek	QLD	GT	natural gas	4.8	0.1	149	4	1.7	0.1
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	629.4
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	629.4
Kwinana A	WA	PW	black coal	1.0	0.3	320	11	1.0	629.4
Kwinana C	WA	TF	black coal	1.0	0.3	258	11	1.0	629.4
Collie	WA	PW	black coal	0.9	0.8	462	11	1.7	629.4
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	3.9
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Worsley	WA	GT	natural gas	0.1	0.1	226	16	0.6	3.9
Northern/Playford	SA	PW	black coal	0.9	1.4	136	17	1.7	150.0
Torrens Island	SA	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Ladbroke Grove	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Bell Bay	TAS	GT	natural gas	0.1	0.1	226	16	0.6	3.9
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4	2.3

Source: Personal communication with power station operating companies
Notes: Abbreviations for equipment types are: CCGT Combined Cycle Gas Turbine, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 85: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2003-2004 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	215	11	1.7	565.8
Eraring	NSW	PW	black coal	0.9	0.8	241	11	1.7	335.6
Mt Piper	NSW	PW	black coal	0.7	0.8	306	11	1.7	439.0
Liddell	NSW	TF	black coal	0.9	0.8	306	11	1.7	370.0
Munmorah	NSW	TF	black coal	0.7	0.8	190	11	1.7	260.3
Vales Point	NSW	TF	black coal	0.7	0.8	236	11	1.7	330.0
Wallerawang	NSW	TF	black coal	0.7	0.8	203	11	1.7	443.0
Appin/Tower	NSW	IC	waste gas	236.4	0.1	346	304	80.0	2.3
Smithfield	NSW	CCGT	natural gas	8.0	0.1	23	46	2.4	2.3
Redbank	NSW	FB	black coal	0.9	0.8	55	11	1.7	175.4
Hazelwood	VIC	TF	brown coal	0.5	1.4	136	17	1.7	62.0
Loy Yang A	VIC	TF	brown coal	0.9	1.4	145	4	1.7	259.5
Loy Yang B	VIC	TF	brown coal	0.7	1.4	136	17.0	1.7	310.5
Morwell	VIC	TF	brown coal	0.9	1.4	136	17	1.7	150.0
Yallourn	VIC	TF	brown coal	0.5	1.4	81	55	0.0	113.3
Anglesea	VIC	TF	brown coal	0.9	1.4	213	5	1.6	2453.0
Yarra	VIC	GB	natural gas	0.1	0.1	97	35	0.6	150.0
Jeeralang A & B	VIC	GT	natural gas	5.4	0.1	130	29	0.6	2.3
Callide	QLD	PW	black coal	0.9	0.8	380	11	0.6	170.0
Gladstone	QLD	PW	black coal	0.9	0.8	523	11	1.7	370.0
Stanwell	QLD	PW	black coal	0.7	0.8	316	9	1.7	377.0
Swanbank	QLD	PW	black coal	0.9	0.8	245	5	0.6	395.0
Tarong	QLD	PW	black coal	0.9	0.8	378	12	1.5	231.8
Mica Creek	QLD	GT	natural gas	0.1	0.1	32	1	0.6	0.1
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	370.0
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	370.0
Cockburn	WA	CCGT	natural gas	8.0	0.1	39	10	2.4	2.3
Kwinana A	WA	PW	black coal	0.9	0.8	306	11	1.7	370.0
Kwinana C	WA	TF	black coal	0.9	0.8	306	11	1.7	370.0
Collie	WA	PW	black coal	0.9	0.8	462	11	1.7	370.0
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4	3.9
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Worsley	WA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Northern/Playford	SA	PW	black coal	0.9	1.4	136	17	1.7	150.0
Torrens Island	SA	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Ladbroke Grove	SA	GT	natural gas	8.0	0.1	190	46	2.4	2.3
Bell Bay	TAS	GT	natural gas	0.1	0.1	226	16	0.6	3.9
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4	2.3

Source: Personal communication with power station operating companies;
Abbreviations for equipment types are: CCGT Combined Cycle Gas Turbine, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 86: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2004-2005 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	178	11	1.7	413
Eraring	NSW	PW	black coal	0.9	0.8	243	11	1.7	312
Mt Piper	NSW	PW	black coal	0.7	0.8	280	11	1.7	434
Liddell	NSW	TF	black coal	0.9	0.8	306	11	1.7	370
Munmorah	NSW	TF	black coal	0.7	0.8	188	11	1.7	287
Vales Point	NSW	TF	black coal	0.7	0.8	239	11	1.7	343
Wallerawang	NSW	TF	black coal	0.7	0.8	217	11	1.7	434
Appin/Tower	NSW	IC	waste gas	240.0	0.1	870	340	80.0	2
Smithfield	NSW	CCGT	natural gas	8.0	0.1	23	46	2.4	2
Redbank	NSW	FB	black coal	0.9	0.8	55	11	1.7	175
Hazelwood	Vic	TF	brown coal	0.5	1.4	136	17	1.7	68
Loy Yang A	Vic	TF	brown coal	0.9	1.4	162	10	1.7	285
Loy Yang B	Vic	TF	brown coal	0.7	1.4	136	17	1.7	439
Morwell	Vic	TF	brown coal	0.9	1.4	136	17	1.7	150
Yallourn	Vic	TF	brown coal	0.5	1.4	85	73	0.0	64
Anglesea	Vic	TF	brown coal	0.9	1.4	233	5	1.6	2409
Yarra	Vic	GB	natural gas	0.1	0.1	226	16	0.6	2
Jeeralang A & B	Vic	GT	natural gas	8.0	0.1	190	46	2.4	2
Callide	Qld	PW	black coal	0.9	0.8	380	11	0.6	170
Gladstone	Qld	PW	black coal	0.9	0.8	523	11	1.7	370
Stanwell	Qld	PW	black coal	0.7	0.8	316	9	1.7	377
Swanbank	Qld	PW	black coal	0.9	0.8	245	5	0.6	395
Tarong	Qld	PW	black coal	0.9	0.8	379	11	1.7	236
Mica Creek	Qld	GT	natural gas	0.1	0.1	32	1	0.6	0
Millmerran	Qld	PW	black coal	0.9	0.8	97	11	1.7	370
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	370
Cockburn	WA	CC	natural gas	8.0	0.1	39	10	2.4	2
Kwinana A	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Kwinana C	WA	TF	black coal	0.9	0.8	306	11	1.7	370
Collie	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	2
Kwinana GT	WA	GT	natural gas	8.0	0.1	190	46	2.4	4
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8.0	0.1	190	46	2.4	2
Pinjar	WA	GT	natural gas	8.0	0.1	190	46	2.4	2
TiWest	WA	GT	natural gas	8.0	0.1	190	46	2.4	2
Worsley	WA	GT	natural gas	8.0	0.1	190	46	2.4	2
Worsley Alumina	WA	GB	black coal	0.9	0.8	462	11	1.7	370
Northern/Playford	SA	PW	black coal	0.9	1.4	136	17	1.7	150
Torrens Island	SA	GB	natural gas	0.1	0.1	226	16	0.6	2
Osborne	SA	GT	natural gas	8.0	0.1	190	46	2.4	2
Ladbroke Grove	SA	GT	natural gas	8.0	0.1	190	46	2.4	2
Pelican Point	SA	GT	natural gas	0.1	0.1	190	46	2.4	2
Bell Bay	Tas	GT	natural gas	0.1	0.1	226	16	0.6	4
Channel Island	NT	GT	natural gas	8.0	0.1	190	46	2.4	2

Source: Personal communication with power station operating companies;
Notes: Abbreviations for equipment types are: CCGT Combined Cycle Gas Turbine, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

Table 87: Emission factors for non-CO_2 greenhouse gases for main fuel used in major thermal power stations in operation 2005-2006 (Mg/PJ)

Power Station	State	Equipment Type	Fuel	Emission factor Mg/PJ					
				CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Bayswater	NSW	PW	black coal	0.9	0.8	238	11	1.7	538
Eraring	NSW	PW	black coal	0.9	0.8	248	11	1.7	281
Mt Piper	NSW	PW	black coal	0.7	0.8	301	11	1.7	437
Liddell	NSW	TF	black coal	0.9	0.8	306	11	1.7	370
Munmorah	NSW	TF	black coal	0.7	0.8	201	11	1.7	274
Vales Point	NSW	TF	black coal	0.7	0.8	199	11	1.7	298
Wallerawang	NSW	TF	black coal	0.7	0.8	260	11	1.7	438
Appin/Tower	NSW	IC	waste gas	240	0.1	945	340	80.0	2.3
Smithfield	NSW	CCGT	natural gas	8	0.1	23	46	2.4	2.3
Redbank	NSW	FB	black coal	0.9	0.8	54.6	11	1.7	175
Hazelwood	Vic	TF	brown coal	0.5	1.4	136	17	1.7	69.5
Loy Yang A	Vic	TF	brown coal	0.9	1.1	161	13	1.7	332
Loy Yang B	Vic	TF	brown coal	0.5	1.4	136	1.7	150.0	303
Morwell	Vic	TF	brown coal	0.9	1.4	136	17	1.7	150
Yallourn	Vic	TF	brown coal	0.5	1.4	85	79	0.0	61.5
Anglesea	Vic	TF	brown coal	0.9	1.4	230	3.4	1.4	2423
Yarra	Vic	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Jeeralang A & B	Vic	GT	natural gas	8	0.1	190	46	2.4	2.3
Callide	Qld	PW	black coal	0.9	0.8	380	11	0.6	170
Gladstone	Qld	PW	black coal	0.9	0.8	523	11	1.7	370
Stanwell	Qld	PW	black coal	0.9	0.8	400	11	1.7	370
Swanbank	Qld	PW	black coal	0.9	0.8	245	5	0.6	395
Tarong	Qld	PW	black coal	0.9	0.8	459	11	1.7	249
Collinsville	Qld	PW	black coal	0.9	0.8	523	11	1.7	370
Mica Creek	Qld	GT	natural gas	0.1	0.1	32.0	1.4	0.6	0.1
Millmerran	Qld	PW	black coal	0.9	0.8	96.6	11	1.7	370
Muja A/B	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Muja C/D	WA	TF	black coal	0.9	0.8	306	11	1.7	370
Cockburn	WA	CC	natural gas	8	0.1	39	9.5	2.4	2.3
Kwinana A	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Kwinana C	WA	TF	black coal	0.9	0.8	306	11	1.7	370
Collie	WA	PW	black coal	0.9	0.8	462	11	1.7	370
Kwinana B	WA	GB	natural gas	0.1	0.1	226	16	0.6	2.3
Kwinana GT	WA	GT	natural gas	8	0.1	190	46	2.4	2.3
Kalgoorlie	WA	GT	distillate oil	4	0.6	1322	349	45	85
Mungarra	WA	GT	natural gas	8	0.1	190	46	2.4	2.3
Pinjar	WA	GT	natural gas	8	0.1	190	46	2.4	2.3
TiWest	WA	GT	natural gas	8	0.1	190	46	2.4	2.3
Worsley	WA	GT	natural gas	8	0.1	190	46	2.4	2.3
Northern/Playford	SA	PW	black coal	0.9	1.4	136	17	1.7	150
Torrens Island	SA	GB	natural gas	0.1	0.0	226	16	0.6	2.3
Osborne	SA	GT	natural gas	8	0.1	190	46	2.4	2.3
Ladbroke Grove	SA	GT	natural gas	8	0.1	190	46	2.4	2.3
Pelican Point	SA	GT	natural gas	0.1	0.1	190	46	2.4	2.3
Bell Bay	Tas	GT	natural gas	0.1	0.1	226	16	0.6	3.9
Channel Island	NT	GT	natural gas	8	0.1	190	46	2.4	2.3

Source: Personal communication with power station operating companies;
Notes: Abbreviations for equipment types are: CCGT Combined Cycle Gas Turbine, GB Gas Boiler, GT Gas Turbine, IC Internal Combustion, PW Pulverised Wall and TF Tangentially Fired.

APPENDIX B EMISSION FACTORS FOR NATURAL GAS

Table 88: Natural gas composition and emission factors, 1989–90

Note	Pipeline		Longford Melbourne (Victoria)	Moomba Sydney, Adelaide (NSW, SA)	Roma Brisbane (Qld)	Dampier Perth (WA)	Dongarra Perth (WA)	Amadeus Darwin (NT)	Australia (weighted average) (W)
	Methane	% of natural gas by volume P_{pc}	91.0	92.8	88.2	87.2	92.5	83.5	
	Ethane		5.4	4.7	6.9	5.9	1.6	9.2	
	Propane		0.7	0.1	0.5	2.2	0.5	2.1	
(1)	butane		0.1	0.0	0.3	0.7	0.2	0.6	
	pentane		0.0	0.0	0.1	0.0	0.1	0.2	
	Hexane		0.0	0.1	0.1	0.0	0.1	0.1	
	CO_2		2.0	1.4	0.7	3.2	2.9	0.1	
(2)	MJ/m^3	E_p	38.7	38.2	39.0	39.8	37.0	40.9	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1978.1	1944.6	1981.8	2076.8	1898.1	2089.8	
(4)	kg CO_2/GJ (combustion)	F_p	51.1	50.9	50.8	52.2	51.3	51.1	51.3
(5)	Total State consumption (PJ)		259.2	211.1	22.0	183.3	183.3	12.5	
(6)	Pipeline consumption (PJ)	S_p	259.2	211.1	13.2	175.0	8.4	12.5	
	% total State sales		100%	100%	60%	95%	5%	100%	
	Weighted state average: kg CO_2/GJ (combustion)					52.1			

Table 89: Natural gas composition and emission factors, 1990–91

Note	Pipeline		Longford Melbourne (Victoria)	Moomba Sydney, Adelaide (NSW, SA)	Roma Brisbane (Qld)	Denison Trough Gladstone (WA)	Dampier Perth (WA)	Dongarra Perth (WA)	Amadeus Darwin (NT)	Australia (weighted average) (*W*)
	Methane	% of natural gas by volume P_{pc}	91.2	89.8	89.9	88.7	87.8	92.5	84.5	
	Ethane		5.5	7.2	6.3	4.5	5.2	1.6	9.2	
	Propane		0.4	0.2	0.5	1.2	2.1	0.5	1.9	
(1)	Butane		0.0	0.0	0.2	0.3	0.7	0.2	0.6	
	Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.2	
	Hexane		0.0	0.0	0.0	0.1	0.0	0.1	0.1	
	CO_2		2.1	1.8	0.6	1.7	3.0	2.9	0.0	
(2)	MJ/m^3	E_p	38.6	38.8	39.2	38.9	39.6	37.0	40.9	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1963.2	1983.7	1970.7	1959.5	2052.6	1898.1	2095.4	
(4)	kg CO_2/GJ (combustion)	F_p	50.9	51.1	50.3	50.4	51.8	51.3	51.2	51.2
(5)	Total State consumption (PJ)		231.1	193.1	37.0	37.0	181.3	181.3	13.2	
(6)	Pipeline consumption (PJ)	S_p	231.1	193.1	22.2	14.8	173.8	7.5	13.2	
	% total State sales		100%	100%	60%	40%	96%	4%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.3		51.8			

Table 90: Natural gas composition and emission factors, 1991-92

Note	Pipeline		Longford - Melbourne (Victoria)	Moomba - Sydney, Adelaide (NSW, SA)	Roma - Brisbane (Qld)	Denison Trough - Gladstone (Qld)	Dampier - Perth (WA)	Dongarra - Perth (WA)	Amadeus - Darwin (NT)	Australia (weighted average) (W)
	Methane	% of natural gas by volume P_{pc}	91.2	89.8	89.1	89.0	88.1	92.3	82.0	
	Ethane		5.0	7.2	6.4	5.0	5.2	1.8	9.6	
	Propane		0.6	0.2	0.5	1.0	2.1	0.5	2.3	
(1)	Butane		0.1	0.0	0.3	0.5	0.7	0.2	0.7	
	Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.2	
	Hexane		0.0	0.0	0.0	0.1	0.0	0.1	0.1	
	CO_2		2.1	1.8	0.7	1.4	2.7	3.3	0.1	
(2)	MJ/m^3	E_p	38.5	38.8	39.1	38.9	39.4	37.0	40.7	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1963.2	1983.7	1968.8	1981.8	2052.6	1909.3	2095.4	
(4)	kg CO_2/GJ (combustion)	F_p	51.0	51.1	50.4	50.9	52.1	51.6	51.5	51.3
(5)	Total State consumption (PJ)		239.1	197.8	39.1	39.1	189.0	189.0	13.6	
(6)	Pipeline consumption (PJ)	S_p	239.1	197.8	23.5	15.6	181.5	7.5	13.6	
	% total State sales		100%	100%	60%	40%	96%	4%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.6		52.1			

Table 91: Natural gas composition and emission factors, 1992-93

Note	Pipeline		Longford - Melbourne (Victoria)	Moomba - Sydney, Adelaide (NSW, SA)	Roma - Brisbane (Qld)	Denison Trough - Gladstone (Qld)	Dampier - Perth (WA)	Dongarra - Perth (WA)	Amadeus - Darwin (NT)	Australia (weighted average) (W)
	Methane	% of natural gas by volume P_{pc}	91.0	88.5	89.1	89.9	88.1	93.2	82.0	
	Ethane		5.1	8.0	6.4	4.1	5.2	1.9	9.6	
	Propane		0.8	0.1	0.5	1.1	2.0	0.4	2.3	
(1)	Butane		0.1	0.0	0.3	0.4	0.7	0.2	0.7	
	Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.2	
	Hexane		0.0	0.0	0.0	0.1	0.0	0.3	0.1	
	CO_2		2.1	2.4	0.7	1.5	2.6	2.6	0.1	
(2)	MJ/m^3	E_p	38.5	38.8	39.1	38.6	39.6	37.5	40.7	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1974.4	1994.9	1968.8	1965.1	2045.1	1933.5	2095.4	
(4)	kg CO_2/GJ (combustion)	F_p	51.3	51.4	50.4	50.9	51.6	51.6	51.5	51.4
(5)	Total State consumption (PJ)		245.7	200.8	39.4	39.4	207.0	207.0	13.8	
(6)	Pipeline consumption (PJ)	S_p	245.7	200.8	23.6	15.8	199.5	7.5	13.8	
	% total State sales		100%	100%	60%	40%	96%	4%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.6		51.6			

Table 92: Natural gas composition and emission factors, 1993-94

Note	Pipeline		Longford - Melbourne (Victoria)	Moomba - Sydney, Adelaide (NSW, SA)	Roma - Brisbane (Qld)	Denison Trough - Gladstone (Qld)	Dampier - Perth (WA)	Dongarra - Perth (WA)	Amadeus - Darwin (NT)	Australia (weighted average) (W)
	Methane	% of natural gas by volume P_{pc}	91.2	88.5	88.5	88.5	88.1	92.8	80.9	
	Ethane		5.1	8.0	5.7	4.8	5.3	2.0	10.4	
	Propane		0.5	0.2	0.6	1.2	2.0	0.4	2.5	
(1)	Butane		0.1	0.0	0.3	0.5	0.7	0.2	1.0	
	Pentane		0.0	0.0	0.1	0.2	0.0	0.1	0.4	
	Hexane		0.0	0.0	0.1	0.2	0.0	0.1	0.2	
	CO_2		2.2	2.1	0.7	1.5	2.6	3.3	0.0	
(2)	MJ/m^3	E_p	38.5	38.8	38.5	39.0	39.7	37.5	41.9	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1963.2	1994.9	1948.4	1998.6	2048.8	1920.4	2166.1	
(4)	kg CO_2/GJ (combustion)	F_p	51.0	51.4	50.6	51.2	51.6	51.2	51.7	51.3
(5)	Total State consumption (PJ)		232.5	210.6	43.8	43.8	232.8	232.8	13.7	
(6)	Pipeline consumption (PJ)	S_p	232.5	210.6	26.3	17.5	225.3	7.5	13.7	
	% total State sales		100%	100%	60%	40%	97%	3%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.9		51.6			

Table 93: Natural gas composition and emission factors, 1994-95

Note	Pipeline		Longford - Melbourne (Victoria)	Moomba - Sydney, Adelaide (NSW, SA)	Roma - Brisbane (Qld)	Denison Trough - Gladstone (Qld)	Dampier - Perth (WA)	Dongarra - Perth (WA)	Amadeus - Darwin (NT)	Australia (weighted average) (7)
	Methane	% of natural gas by volume P_{pc}	91.5	88.0	88.5	89.4	84.0	92.1	79.1	
	Ethane		5.0	8.4	6.4	4.3	6.7	2.2	10.2	
	Propane		0.6	0.2	0.7	1.2	3.4	0.6	2.8	
(1)	Butane		0.1	0.0	0.3	0.2	1.2	0.2	0.9	
	Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.2	
	Hexane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
	CO_2		1.9	2.2	0.8	1.5	2.7	3.4	0.1	
(2)	MJ/m^3	E_p	38.6	38.8	38.9	38.6	40.9	37.5	40.8	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1965.1	2002.3	1981.8	1953.9	2141.9	1927.9	2106.5	
(4)	kg CO_2/GJ (combustion)	F_p	50.9	51.6	50.9	50.6	52.4	51.4	51.6	51. 6 *W*
*	State use in gas processing		20.3	20.5	4.9		71.4			
(5)	State sales to end users		217.6	187.0	38.9		189.9		15.1	
(6)	Total State consumption (PJ)		237.9	207.5	43.8	43.8	261.3	261.3	15.1	
	Pipeline consumption (PJ)	S_p	237.9	207.5	26.3	17.5	247.9	13.4	15.1	
	% total State sales		100%	100%	60%	40%	95%	5%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.8		52.3			

New notes: * Data on State use in gas processing is taken from ABARE.

Table 94: Natural gas composition and emission factors, 1995-96 (combustion)

Note	Pipeline		Longford Melbourne (Victoria)	Moomba Sydney, Adelaide (NSW, SA)	Roma Brisbane (Qld)	Denison Trough Gladstone (Qld)	Dampier Perth (WA)	Dongarra Perth (WA)	Amadeus Darwin (NT)	Australia (weighted average) (7)
	Methane	% of natural gas by volume P_{pc}	91.1	88.0	88.3	90.2	84.5	90.9	77.1	
	Ethane		5.1	8.4	6.8	3.6	6.7	2.9	10.7	
	Propane		0.7	0.2	0.8	1.2	3.1	0.9	3.1	
(1)	Butane		0.1	0.0	0.3	0.3	1.2	0.3	0.3	
	Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
	Hexane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
	CO_2		1.9	2.2	0.6	1.6	2.6	3.4	0.0	
(2)	MJ/m^3	E_p	38.7	38.8	39.3	38.7	40.7	37.8	40.9	
(3)	g CO_2/m^3 of natl gas burnt	M_p	1967.0	2002.3	1994.9	1952.1	2132.6	1955.8	2048.8	
(4)	kg CO_2/GJ (combustion)	F_p	50.9	51.6	50.8	50.4	52.4	51.7	50.1	51.6 W
*	State use in gas processing		19.7	8.6	4.0		97.3			
(5)	State sales to end users		214.2	178.1	38.1		190.5		16.4	
(6)	Total State consumption (PJ)		233.9	186.7	42.1	42.1	287.8	287.8	16.7	
	Pipeline consumption (PJ)	S_p	233.9	186.7	25.3	16.8	274.4	13.4	16.7	
	% total State sales		100%	100%	60%	40%	95%	5%	100%	
	Weighted state average: kg CO_2/GJ (combustion)				50.6		52.4			

Notes: * Data on State use in gas processing is taken from ABARE.

Table 95: Natural gas composition and emission factors, 1996-97 (combustion)

Pipeline		Longford - Melbourne (Victoria)	Moomba - Sydney, Adelaide (NSW, SA)	Roma - Brisbane (Qld)	Denison Trough - Gladstone (Qld)	Dampier - Perth (WA)	Dongarra - Perth (WA)	Amadeus - Darwin (NT)	Australia (weighted average)(7)
Methane	% of natural gas by volume P_{pc}	91.2	90.6	87.6	89.4	84.3	92.4	77.8	
Ethane		5.2	6.7	7.3	4.3	7.3	2.1	10.5	
Propane		0.6	0.1	1.0	1.1	3.1	0.5	3.0	
Butane		0.1	0.0	0.2	0.3	1.2	0.2	0.9	
Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.3	
Hexane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
CO_2		2.2	1.6	0.9	1.5	2.7	3.4	0.1	
MJ/m^3	E_p	38.6	38.8	39.5	38.7	41.1	37.3	40.9	39.6
g $CO2/m^3$ of natl gas burnt	M_p	1972.5	1970.7	2009.8	1955.8	2153.0	1924.2	2114.0	
kg CO_2/GJ (combustion)	F_p	51.1	50.8	50.9	50.5	52.4	51.6	51.7	51.5 W
State use in gas processing		34.0	11.0	3.6		75.6		0.2	
State sales to end users		190.6	175.9	38.3		203.0		16.5	
Total State consumption (PJ)		224.6	186.9	41.9	41.9	278.6	278.6	16.7	
Pipeline consumption (PJ)	S_p	224.6	186.9	25.1	16.8	265.2	13.4	16.7	
% total State sales		100%	100%	60%	40%	95%	5%	100%	
Weighted state average: kg CO_2/GJ (combustion)				50.7		52.3			

Note: Data on State use in gas processing is taken from AGA Table 2.8

Table 96: Natural gas composition and emission factors, 1997–98 (combustion)

Pipeline		Longford Melbourne (Victoria)	Moomba Sydney, Adelaide (NSW, SA)	Roma Brisbane (Qld)	Denison Trough Gladstone (Qld)	Dampier Perth (WA)	Dongarra Perth (WA)	Amadeus Darwin (NT)	Australia (weighted average) (7)
Methane	% of natural gas by volume P_{pc}	91.6	89.9	88.5	90.0	85.8	91.8	78.2	
Ethane		5.0	7.2	6.1	3.7	6.0	2.3	10.2	
Propane		0.4	0.1	1.4	1.1	2.7	0.5	2.8	
Butane		0.1	0.0	0.5	0.2	0.8	0.2	0.9	
Pentane		0.0	0.0	0.1	0.1	0.1	0.1	0.2	
Hexane		0.0	0.0	0.1	0.1	0.0	0.1	0.2	
CO_2		2.1	1.6	1.2	1.7	2.1	3.5	0.0	
MJ/m^3	E_p	38.5	38.9	39.7	38.6	40.8	37.4	40.6	39.5
g CO_2/m^3 of natl gas burnt	M_p								
kg CO_2/GJ (combustion)	F_p	1959.5	1976.3	2032.1	1940.9	2078.6	1922.3	2099.1	
State use in gas processing		50.9	50.8	51.2	50.3	50.9	51.4	51.7	50.9 W
State sales to end users									
Total State consumption (PJ)		190.5	189.5	51.7		235.3		21.6	
Pipeline consumption (PJ)	S_p	190.5	189.5	51.7	51.7	235.3	235.3	21.6	
% total State sales		190.5	189.5	31.0	20.7	222.6	12.7	21.6	689
Weighted state average:		100%	100%	60%	40%	95%	5%	100%	
kg CO_2/GJ (combustion)				50.8		51.0			

Table 97: Natural gas composition and emission factors, 1998–99

Pipeline		Longford Melbourne (Victoria)	Moomba Sydney, Adelaide (NSW, SA)	Roma Brisbane (Qld)	Denison Trough Gladstone (Qld)	Dampier Perth (WA)	Dongarra Perth (WA)	Amadeus Darwin (NT)	Australia (weighted average) (7)
Methane	% of natural gas by volume P_{pc}	91.6	89.9	90.4	91.5	84.3	92.7	75.8	
Ethane		5.2	7.2	5.7	2.5	7.2	3.0	10.9	
Propane		0.7	0.1	1.2	0.9	3.1	0.9	3.3	
Butane		0.1	0.0	0.4	0.2	1.0	0.3	1.1	
Pentane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
Hexane		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
CO_2		1.6	1.6	2.0	1.3	2.3	2.3	0.0	
MJ/m^3	E_p	38.9	38.9	39.3	37.9	40.8	38.4	40.7	39.7
g CO_2/m^3 of natural gas burnt	M_p	1974.4	1976.3	2048.8	1905.6	2127.0	1972.5	2102.8	
kg CO_2/GJ (combustion)	F_p	50.8	50.8	52.1	50.3	52.1	51.4	51.7	51.4 W
State use in gas processing		34.1	5.5	4.8		75.2		0.6	
State sales to end users		181.3	184.7	109.0		273.0		28.0	
Total State consumption (PJ)		215.4	190.2	113.8	113.8	348.2	348.2	28.6	
Pipeline consumption (PJ)	S_p	215.4	190.2	68.3	45.5	339.9	8.3	28.6	896
% total State sales		100%	100%	60%	40%	98%	2%	100%	
Weighted state average: kg CO_2/GJ (combustion)				51.4		52.1			

Table 98: Natural Gas Composition and Emission Factors, 1999–2000

Pipeline		Longford, Melbourne (Victoria)	Moomba, Sydney, Adelaide (NSW, SA)	Roma, Brisbane (Qld)	Denison Trough, Gladstone (Qld)	Dampier, Perth (WA)	Dongarra, Perth (WA)	Amadeus, Darwin (NT)	Australia (weighted average)
Methane [a]	% of natural gas by volume	90.1	89.9	88.8	90.8	83.9	91.1	75.7	
Ethane [a]		5.8	7.2	6.5	3.2	7.2	2.9	10.7	
Propane [a]		1.1	0.1	1.5	1.0	3.1	0.9	3.3	
Butane [a]		0.2	0.0	0.5	0.2	1.0	0.3	1.1	
Pentane [a]		0.0	0.0	0.1	0.1	0.1	0.1	0.3	
Hexane [a]		0.0	0.0	0.1	0.1	0.0	0.1	0.1	
CO2 [a]		1.9	1.6	1.8	1.5	2.3	3.0	0.0	
MJ/m^3		39.3	38.9	40.1	38.3	40.8	38.0	40.7	39.8
g CO_2/m^3 of natl gas burnt		2004.2	1976.3	2069.3	1927.9	2128.9	1952.1	2112.1	
kg CO_2/GJ (combustion)		51.0	50.8	51.6	50.3	52.2	51.4	51.9	51.4
State use in gas processing (PJ)		35.2	19.3	4.7		67.5		0.6	
State sales to end users (PJ)		192.9	198.6	80.6		257.8		26.2	
Total State consumption (PJ)		228.1	217.9	85.3		325.3		26.8	883
Pipeline consumption (PJ)		228.1	217.9	51.2	34.1	315.3	10.0	26.8	883
% total State sales		100%	100%	60%	40%	97%	3%	100%	
Weighted state average: kg CO_2/GJ (combustion)				51.1		52.2			

Table 99. Natural gas CO_2 emission factors, 2000 to 2006[a]

Pipeline	Combustion (kg CO_2/GJ)	Weighted state average (QLD, WA):
Longford, Melbourne (Victoria)	51.0	
Moomba, Sydney, Adelaide (NSW, SA)	50.8	
Roma, Brisbane (Qld)	51.6	51.1
Denison Trough, Gladstone (Qld)	50.3	
Dampier, Perth (WA)	52.2	52.2
Dongarra, Perth (WA)	51.4	
Amadeus, Darwin (NT)	51.9	
Australia (weighted average)	51.4	

(a) In previous years, emission factors for both combustion and fugitive natural gas emissions have been calculated from pipeline gas composition data, published by the Australian Gas Association. However, as from 2001 the Association no longer collect this data from its members. Approaches made directly to the major natural gas producers and suppliers throughout Australia where unsuccessful with the exception of one major supplier in WA. As no other sources of 2001 data were available, it was assumed that all natural gas emission factors for 2001 onwards were unchanged from 2000.

APPENDIX C:
ESTIMATION OF NON–CARBON DIOXIDE EMISSION FACTORS

NON CO_2 EMISSION FACTORS: 1999 TO PRESENT

Table 100: 1990 to present equipment weighted sectorial emission factors for non-CO_2 gases

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Agriculture, forestry, fishing						
LPG	1.3	0.6	14.0	154.0	0.5	2.3
Aviation gasoline	8.6	0.6	476.0	1,306.0	163.0	8.2
Power kerosene	1.3	0.6	14.0	154.0	0.5	57.0
Heating oil	1.3	0.6	14.0	154.0	0.5	57.0
ADO	8.6	0.6	476.0	1,306.0	163.0	57.0
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
11 Coal mining						
Black coal	1.1	1.4	97.1	154.0	1.0	370.0
LPG	0.1	0.6	13.0	154.0	5.0	2.3
ADO	3.6	0.6	221.4	1,166.3	70.0	57.0
Fuel oil	0.1	0.6	13.0	154.0	5.0	1,282.1
1103 Briquette manufacturing						
Brown coal	1.3	0.8	105.0	287.0	1.0	150.0
12 Oil and gas mining						
LPG	4.0	0.6	349.0	1,322.0	45.0	2.3
ADO	3.8	0.6	254.6	1,234.8	67.4	57.0
Petroleum products nec	4.0	0.6	346.8	1,320.0	45.5	57.0
Natural gas	7.3	0.1	42.7	176.3	2.3	2.3
14 All other mining						
Black coal	1.0	0.8	78.0	493.0	1.0	370.0
Coke	1.0	0.8	78.0	493.0	1.0	370.0
Coal byproducts	3.9	0.1	28.0	122.6	1.6	370.0
LPG	1.1	0.6	44.8	330.9	0.8	2.3
Aviation turbine fuel	1.1	0.6	44.8	330.9	0.8	8.2
Heating oil	1.1	0.6	44.8	330.9	0.8	57.0
ADO	3.7	0.6	226.2	1,190.4	71.1	57.0
IDF	1.1	0.6	44.8	330.9	0.8	57.0
Fuel oil	0.8	0.6	44.8	330.9	0.8	1,282.1
Petroleum products nec	1.1	0.6	44.8	330.9	0.8	57.0
Natural gas	1.1	0.1	14.0	86.2	1.1	2.3
21 Food, beverages, tobacco						
Black coal	1.3	0.8	105.9	207.1	1.0	370.0
Brown coal	1.3	0.8	105.9	207.1	1.0	150.0
Coal byproducts	1.2	0.1	13.6	42.9	1.1	370.0
Brown coal briquettes	1.3	0.8	105.9	207.1	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
Bagasse	9.3	4.1	1,625.0	84.0	16.3	NA
LPG	0.6	0.6	13.2	154.2	0.6	2.3
ADO	4.9	0.6	329.1	868.2	90.6	57.0
IDF	5.5	0.6	375.5	973.2	103.9	57.0
Fuel oil	0.6	0.6	13.2	154.2	0.6	1,282.1
Petroleum products nec	0.6	0.6	13.2	154.2	0.6	57.0

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Natural gas	1.1	0.1	11.0	49.5	1.7	2.3
Town gas	1.2	0.1	13.5	58.0	1.1	2.3
22 Textile, clothing, footwear and leather						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	7.5	0.6	1,810.1	248.4	135.2	2.3
ADO	0.4	0.6	13.6	155.7	0.6	57.0
IDF	0.4	0.6	13.6	155.7	0.6	57.0
Fuel oil	0.4	0.6	13.6	155.7	0.6	1,282.1
Petroleum products nec	0.4	0.6	13.6	155.7	0.6	57.0
Natural gas	1.2	0.1	13.7	58.0	1.1	2.3
Town gas	1.2	0.1	13.7	58.0	1.1	2.3
23–24 Wood, paper and printing						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal	1.3	0.8	105.0	287.0	1.0	150.0
Brown coal briquettes	1.3	1.4	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	1.1	0.6	212.7	165.8	15.5	2.3
Heating oil	0.3	0.6	13.5	155.6	0.6	57.0
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
Fuel oil	0.3	0.6	13.5	155.6	0.6	1,282.1
Petroleum products nec	0.3	0.6	13.5	155.6	0.6	57.0
Natural gas	1.2	0.1	13.8	58.4	1.1	2.3
253 Basic chemicals						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Coke	1.3	0.8	105.0	287.0	1.0	370.0
Coal byproducts	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	5.8	0.6	1,303.1	487.0	93.9	2.3
ADO	1.0	0.6	77.0	505.0	1.6	57.0
IDF	1.0	0.6	75.0	501.7	0.9	57.0
Fuel oil	1.0	0.6	75.0	501.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	75.0	501.7	0.9	57.0
Natural gas	1.1	0.1	41.8	492.6	1.1	2.3
Town gas	1.1	0.1	41.8	492.6	1.1	2.3
LESS SEQUESTERED						
from ethane	1.1	0.1	41.8	492.6	1.1	2.3
from petroleum products	1.0	0.6	75.0	501.7	0.9	57.0
254–256 Other chemicals, rubber and plastic						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	6.8	0.6	1,581.0	465.8	115.2	2.3
ADO	1.1	0.6	84.6	500.2	5.6	57.0
IDF	0.9	0.6	70.6	477.0	0.9	57.0
Fuel oil	0.9	0.6	70.6	477.0	0.9	1,282.1
Natural gas	1.2	0.1	22.4	190.6	1.1	2.3
251 Petroleum refining						
Petroleum products nec	0.8	0.6	54.0	383.8	0.8	NA
Natural gas	1.1	0.1	56.6	722.9	1.1	NA

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
252 Petroleum and coal products nec						
Brown coal	1.0	1.4	77.1	488.5	1.0	150.0
Coal byproducts	1.0	0.8	77.1	488.5	1.0	370.0
Brown coal briquettes	1.0	0.8	77.1	488.5	1.0	150.0
LPG	1.5	0.6	294.5	281.9	20.2	2.3
Lighting kerosene	0.5	0.6	34.5	274.1	0.7	57.0
ADO	4.4	0.6	301.1	823.0	81.2	57.0
IDF	0.5	0.6	34.5	274.1	0.7	57.0
Fuel oil	0.5	0.6	34.5	274.1	0.7	1,282.1
Natural gas	1.1	0.1	21.3	199.0	1.1	2.3
261 Glass and glass products						
LPG	1.0	0.6	75.0	502.0	0.9	2.3
ADO	1.0	0.6	75.0	502.0	0.9	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Fuel oil	1.0	0.6	75.0	502.0	0.9	1,282.1
Natural gas	1.0	0.1	75.0	1,010.0	1.1	2.3
262 Ceramics						
Black coal	1.0	0.8	75.0	502.0	1.0	370.0
Brown coal	1.0	0.8	75.0	502.0	1.0	150.0
Brown coal briquettes	1.0	0.8	75.0	502.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	8.2	0.6	1,932.7	474.1	141.6	2.3
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
IDF	1.0	0.6	73.5	493.7	0.9	57.0
Fuel oil	1.0	0.6	73.5	493.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	73.5	493.7	0.9	57.0
Natural gas	1.0	0.1	74.5	1,002.1	1.1	2.3
Town gas	1.0	0.1	74.5	1,002.1	1.1	2.3
263 Cement, lime, plaster and concrete						
Black coal	1.0	0.8	75.7	500.0	1.0	370.0
Brown coal briquettes	1.0	1.4	75.7	500.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	21.7	0.6	5,398.1	435.6	404.0	2.3
Lighting kerosene	0.9	0.6	43.5	322.8	0.9	57.0
Heating oil	0.9	0.6	43.5	322.8	0.9	57.0
ADO	5.3	0.6	359.9	946.6	98.7	57.0
IDF	0.9	0.6	43.5	322.8	0.9	57.0
Fuel oil	0.9	0.6	43.5	322.8	0.9	1,282.1
Petroleum products nec	0.9	0.6	43.5	322.8	0.9	57.0
Solvents	0.9	0.6	43.5	322.8	0.9	57.0
Natural gas	1.0	0.1	61.8	815.5	1.1	2.3
264 Non-metallic mineral products nec						
Black coal	1.1	0.8	80.0	466.5	1.0	370.0
Coke	1.1	0.8	80.0	466.5	1.0	370.0
LPG	19.7	0.6	4,884.1	441.3	365.1	2.3
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
Fuel oil	0.4	0.6	70.6	477.1	0.9	1,282.1
Petroleum products nec	0.4	0.6	70.6	477.1	0.9	57.0
Natural gas	0.9	0.1	67.8	900.1	1.1	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
2711 & 2520 (parts) Coke Ovens						
Black coal	1.0	0.8	201.0	287.0	1.0	370.0
Coal byproducts	1.0	0.8	36.7	287.0	1.0	370.0
Fuel oil	1.0	0.6	75.0	502.0	0.9	1,282.1
2711 (part) Rest of Basic Iron and Steel						
Black coal	1.1	0.8	82.2	450.5	1.0	370.0
Coke	1.1	0.8	82.2	450.5	1.0	370.0
Coal byproducts	1.1	0.1	36.7	274.0	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	22.0	0.5	5,465.0	437.0	409.0	2.3
ADO	2.5	0.5	175.5	553.6	43.3	57.0
Fuel oil	0.4	0.5	34.7	256.6	0.9	1,282.1
Natural gas	0.9	0.1	68.2	914.6	1.1	2.3
Town gas	0.9	0.1	68.2	914.6	1.1	2.3
272–273 Basic non-ferrous metals						
Black coal	1.2	0.8	103.6	316.9	1.0	370.0
Coke	1.2	0.8	103.6	316.9	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	8.5	0.6	1,798.9	340.4	133.2	2.3
Power kerosene	2.0	0.6	38.5	294.0	0.8	57.0
ADO	5.2	0.6	341.0	906.7	93.0	57.0
IDF	2.0	0.6	38.5	294.0	0.8	57.0
Fuel oil	2.0	0.6	38.5	294.0	0.8	1,282.1
Petroleum products nec	2.0	0.6	38.5	294.0	0.8	57.0
Natural gas	1.1	0.1	43.6	519.2	1.1	2.3
274–276 Other metal products						
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	22.0	0.6	5,465.0	437.0	409.0	2.3
ADO	1.4	0.6	103.6	547.8	10.6	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Town gas	1.0	0.1	70.9	949.5	1.1	2.3
28 Machinery and equipment						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	21.1	0.6	5,242.0	435.6	392.2	2.3
Heating oil	0.7	0.6	57.3	402.6	0.8	57.0
ADO	2.8	0.6	194.3	651.0	44.9	57.0
IDF	0.7	0.6	57.3	402.6	0.8	57.0
Fuel oil	0.7	0.6	57.3	402.6	0.8	1,282.1
Natural gas	1.1	0.1	44.9	542.2	1.1	2.3
Town gas	1.1	0.1	44.9	542.2	1.1	2.3
29 Other manufacturing						
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	0.2	0.6	20.3	100.6	0.5	2.3
ADO	0.2	0.6	20.3	100.6	0.5	57.0
IDF	0.2	0.6	20.3	100.6	0.5	57.0
Natural gas	1.1	0.1	20.3	189.3	1.1	2.3
362 Gas production and distribution						
Natural gas	8.0	0.1	46.0	190.0	2.4	2.3
Town gas	8.0	0.1	46.0	190.0	2.4	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
37 Water, sewerage and drainage						
Lighting kerosene	0.1	0.6	13.0	154.0	0.5	57.0
ADO	5.7	0.6	390.0	1,006.0	108.0	57.0
Natural gas	1.2	0.1	14.0	58.0	1.1	2.3
Div. E Construction						
LPG	1.0	0.6	15.0	160.0	0.3	2.3
Lighting kerosene	1.0	0.6	15.0	160.0	0.3	57.0
ADO	5.7	0.6	389.7	1,005.4	107.9	57.0
Fuel oil	1.0	0.6	15.0	160.0	0.3	1,282.1
Natural gas	1.0	0.1	10.0	58.0	0.3	2.3
Div.F,G Wholesale and Retail Trade						
Wood, woodwaste	3.4	4.1	330.0	75.0	5.6	NA
LPG	0.6	0.6	13.1	53.2	0.9	2.3
ADO	0.6	0.6	13.1	53.2	0.9	57.0
IDF	0.6	0.6	13.1	53.2	0.9	57.0
Fuel oil	0.6	0.6	13.1	53.2	0.9	1,282.1
Natural gas	1.1	0.2	15.6	42.3	2.8	2.3
Town gas	1.1	0.2	15.6	42.3	2.8	2.3
62 Railway transport						
Natural gas	1.6	0.1	16.0	39.0	3.1	2.3
65–67 Other Transport, services and storage						
LPG	0.6	0.6	13.0	53.0	1.0	2.3
ADO	0.6	0.6	13.0	53.0	0.9	57.0
IDF	0.6	0.6	13.0	53.0	0.9	57.0
Natural gas	7.8	0.1	45.5	187.9	2.4	2.3
Div. J Communication						
Heating oil	0.6	0.6	13.0	53.0	0.9	57.0
ADO	0.6	0.6	13.0	53.0	0.9	57.0
IDF	0.6	0.6	13.0	53.0	0.9	57.0
Fuel oil	0.6	0.6	13.0	53.0	0.9	1,282.1
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Div. K,L Finance, insurance, property and busines						
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Div. M Government administration and defence						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.4	0.6	13.0	84.4	0.8	2.3
Heating oil	0.4	0.6	13.0	84.4	0.8	57.0
ADO	0.4	0.6	13.0	84.4	0.8	57.0
IDF	0.4	0.6	13.0	84.4	0.8	57.0
Fuel oil	0.4	0.6	13.0	84.4	0.8	1,282.1
Natural gas	1.1	0.1	10.3	46.6	1.8	2.3
Town gas	1.1	0.1	10.3	46.6	1.8	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Div. N,O Education, health and community services						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.4	0.6	13.0	53.0	0.7	2.3
Lighting kerosene	0.4	0.6	13.0	53.0	0.7	57.0
Heating oil	0.4	0.6	13.0	53.0	0.7	57.0
ADO	0.4	0.6	13.0	53.0	0.7	57.0
IDF	0.4	0.6	13.0	53.0	0.7	57.0
Fuel oil	0.4	0.6	13.0	53.0	0.7	1,282.1
Natural gas	1.1	0.1	10.4	44.8	1.8	2.3
Town gas	1.1	0.1	10.4	44.8	1.8	2.3
Div. H,P,Q Accommodation, cultural and personal						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Wood, woodwaste	3.4	4.1	330.0	19.0	5.6	NA
LPG	0.6	0.6	13.0	53.0	0.9	2.3
Aviation gasoline	0.6	0.6	13.0	53.0	0.9	8.2
Aviation turbine fuel	0.6	0.6	13.0	53.0	0.9	8.2
Heating oil	0.6	0.6	13.0	53.0	0.9	57.0
ADO	0.6	0.6	13.0	53.0	0.9	57.0
Fuel oil	0.6	0.6	13.0	53.0	0.9	1,282.1
Natural gas	1.1	0.1	9.7	44.8	2.0	2.3
Residential						
Black coal	105.0	0.8	5,753.0	190.0	209.0	370.0
Brown coal briquettes	105.0	0.8	5,753.0	190.0	209.0	150.0
Wood, woodwaste [(a)]						
LPG	4.7	0.6	13.0	48.0	1.9	2.3
Lighting kerosene	4.7	0.6	13.0	48.0	1.9	57.0
Heating oil	4.7	0.6	13.0	48.0	1.9	57.0
ADO	4.7	0.6	13.0	48.0	1.9	57.0
Natural gas	1.6	0.1	16.0	39.0	3.1	2.3
Town gas	1.6	0.1	16.0	39.0	3.1	2.3

(a) See Table 6a

Non CO_2 Emission Factors: 1997 to 1998

Table 101: 1997-1998 equipment weighted sectorial emission factors for non-CO_2 gases

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Agriculture, forestry, fishing						
LPG	1.3	0.6	14.0	154.0	0.5	2.3
Aviation gasoline	1.3	0.6	14.0	154.0	0.5	8.2
Power kerosene	1.3	0.6	14.0	154.0	0.5	57.0
Heating oil	1.3	0.6	14.0	154.0	0.5	57.0
ADO	1.3	0.6	14.0	154.0	0.5	57.0
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
11 Coal mining						
Black coal	1.1	1.4	97.1	154.0	1.0	370.0
LPG	0.1	0.6	13.0	154.0	5.0	2.3
ADO	0.1	0.6	13.0	154.0	5.0	57.0
Fuel oil	0.1	0.6	13.0	154.0	5.0	1,282.1
1103 Briquette manufacturing						
Brown coal	1.3	0.8	105.0	287.0	1.0	150.0
12 Oil and gas mining						
LPG	4.0	0.6	349.0	1,322.0	45.0	2.3
ADO	4.0	0.6	349.0	1,322.0	45.0	57.0
Petroleum products nec	4.0	0.6	349.0	1,322.0	45.0	57.0
Natural gas	7.3	0.1	42.7	176.3	2.3	2.3
14 All other mining						
Black coal	1.0	0.8	78.0	493.0	1.0	370.0
Coke	1.0	0.8	78.0	493.0	1.0	370.0
Coal byproducts	3.9	0.1	28.0	122.6	1.6	370.0
LPG	1.1	0.6	44.8	330.9	0.8	2.3
Aviation turbine fuel	1.1	0.6	44.8	330.9	0.8	8.2
Heating oil	1.1	0.6	44.8	330.9	0.8	57.0
ADO	0.8	0.6	44.8	330.9	0.8	57.0
IDF	1.1	0.6	44.8	330.9	0.8	57.0
Fuel oil	0.8	0.6	44.8	330.9	0.8	1,282.1
Petroleum products nec	1.1	0.6	44.8	330.9	0.8	57.0
Natural gas	1.1	0.1	14.0	86.2	1.1	2.3
21 Food, beverages, tobacco						
Black coal	1.3	0.8	105.9	207.1	1.0	370.0
Brown coal	1.3	0.8	105.9	207.1	1.0	150.0
Coal byproducts	1.2	0.1	13.6	42.9	1.1	370.0
Brown coal briquettes	1.3	0.8	105.9	207.1	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
Bagasse	9.3	4.1	1,625.0	84.0	16.3	NA
LPG	0.6	0.6	13.2	154.2	0.6	2.3
ADO	0.6	0.6	13.2	154.2	0.6	57.0
IDF	0.6	0.6	13.2	154.2	0.6	57.0
Fuel oil	0.6	0.6	13.2	154.2	0.6	1,282.1
Petroleum products nec	0.6	0.6	13.2	154.2	0.6	57.0
Natural gas	1.2	0.1	13.5	58.0	1.1	2.3
Town gas	1.2	0.1	13.5	58.0	1.1	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
22 Textile, clothing, footwear and leather						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	0.4	0.6	13.6	155.7	0.6	2.3
ADO	0.4	0.6	13.6	155.7	0.6	57.0
IDF	0.4	0.6	13.6	155.7	0.6	57.0
Fuel oil	0.4	0.6	13.6	155.7	0.6	1,282.1
Petroleum products nec	0.4	0.6	13.6	155.7	0.6	57.0
Natural gas	1.2	0.1	13.7	58.0	1.1	2.3
Town gas	1.2	0.1	13.7	58.0	1.1	2.3
23–24 Wood, paper and printing						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal	1.3	0.8	105.0	287.0	1.0	150.0
Brown coal briquettes	1.3	1.4	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.3	0.6	13.5	155.6	0.6	2.3
Heating oil	0.3	0.6	13.5	155.6	0.6	57.0
ADO	0.3	0.6	13.5	155.6	0.6	57.0
Fuel oil	0.3	0.6	13.5	155.6	0.6	1,282.1
Petroleum products nec	0.3	0.6	13.5	155.6	0.6	57.0
Natural gas	1.2	0.1	13.8	58.4	1.1	2.3
253 Basic chemicals						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Coke	1.3	0.8	105.0	287.0	1.0	370.0
Coal byproducts	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	1.0	0.6	75.0	501.7	0.9	2.3
ADO	1.0	0.6	75.0	501.7	0.9	57.0
IDF	1.0	0.6	75.0	501.7	0.9	57.0
Fuel oil	1.0	0.6	75.0	501.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	75.0	501.7	0.9	57.0
Natural gas	1.1	0.1	41.8	492.6	1.1	2.3
Town gas	1.1	0.1	41.8	492.6	1.1	2.3
LESS SEQUESTERED						
from ethane	1.1	0.1	41.8	492.6	1.1	2.3
from petroleum products	1.0	0.6	75.0	501.7	0.9	57.0
254–256 Other chemicals, rubber and plastic						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	0.9	0.6	70.6	477.0	0.9	2.3
ADO	0.9	0.6	70.6	477.0	0.9	57.0
IDF	0.9	0.6	70.6	477.0	0.9	57.0
Fuel oil	0.9	0.6	70.6	477.0	0.9	1,282.1
Natural gas	1.2	0.1	22.4	190.6	1.1	2.3
251 Petroleum refining						
Petroleum products nec	0.8	0.6	54.0	383.8	0.8	NA
Natural gas	1.1	0.1	56.6	722.9	1.1	NA
252 Petroleum and coal products nec						
Brown coal	1.0	1.4	77.1	488.5	1.0	150.0
Coal byproducts	1.0	0.8	77.1	488.5	1.0	370.0
Brown coal briquettes	1.0	0.8	77.1	488.5	1.0	150.0
LPG	0.5	0.6	34.5	274.1	0.7	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Lighting kerosene	0.5	0.6	34.5	274.1	0.7	57.0
ADO	0.5	0.6	34.5	274.1	0.7	57.0
IDF	0.5	0.6	34.5	274.1	0.7	57.0
Fuel oil	0.5	0.6	34.5	274.1	0.7	1,282.1
Natural gas	1.1	0.1	21.3	199.0	1.1	2.3
261 Glass and glass products						
LPG	1.0	0.6	75.0	502.0	0.9	2.3
ADO	1.0	0.6	75.0	502.0	0.9	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Fuel oil	1.0	0.6	75.0	502.0	0.9	1,282.1
Natural gas	1.0	0.1	75.0	1,010.0	1.1	2.3
262 Ceramics						
Black coal	1.0	0.8	75.0	502.0	1.0	370.0
Brown coal	1.0	0.8	75.0	502.0	1.0	150.0
Brown coal briquettes	1.0	0.8	75.0	502.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	1.0	0.6	73.5	493.7	0.9	2.3
ADO	1.0	0.6	73.5	493.7	0.9	57.0
IDF	1.0	0.6	73.5	493.7	0.9	57.0
Fuel oil	1.0	0.6	73.5	493.7	0.9	1,282.1
Petroleum products nec	1.0	0.6	73.5	493.7	0.9	57.0
Natural gas	1.0	0.1	74.5	1,002.1	1.1	2.3
Town gas	1.0	0.1	74.5	1,002.1	1.1	2.3
263 Cement, lime, plaster and concrete						
Black coal	1.0	0.8	75.7	500.0	1.0	370.0
Brown coal briquettes	1.0	1.4	75.7	500.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.9	0.6	43.5	322.8	0.9	2.3
Lighting kerosene	0.9	0.6	43.5	322.8	0.9	57.0
Heating oil	0.9	0.6	43.5	322.8	0.9	57.0
ADO	0.9	0.6	43.5	322.8	0.9	57.0
IDF	0.9	0.6	43.5	322.8	0.9	57.0
Fuel oil	0.9	0.6	43.5	322.8	0.9	1,282.1
Petroleum products nec	0.9	0.6	43.5	322.8	0.9	57.0
Solvents	0.9	0.6	43.5	322.8	0.9	57.0
Natural gas	1.0	0.1	61.8	815.5	1.1	2.3
264 Non-metallic mineral products nec						
Black coal	1.1	0.8	80.0	466.5	1.0	370.0
Coke	1.1	0.8	80.0	466.5	1.0	370.0
LPG	0.4	0.6	70.6	477.1	0.9	2.3
ADO	0.4	0.6	70.6	477.1	0.9	57.0
Fuel oil	0.4	0.6	70.6	477.1	0.9	1,282.1
Petroleum products nec	0.4	0.6	70.6	477.1	0.9	57.0
Natural gas	0.9	0.1	67.8	900.1	1.1	2.3
2711 & 2520 (parts) Coke Ovens						
Black coal	1.0	0.8	201.0	287.0	1.0	370.0
Coal byproducts	1.0	0.8	36.7	287.0	1.0	370.0
Fuel oil	1.0	0.6	75.0	502.0	0.9	1,282.1
2711 (part) Rest of Basic Iron and Steel						

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Black coal	1.1	0.8	82.2	450.5	1.0	370.0
Coke	1.1	0.8	82.2	450.5	1.0	370.0
Coal byproducts	1.1	0.1	36.7	274.0	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.4	0.5	34.7	256.6	0.9	2.3
ADO	0.4	0.5	34.7	256.6	0.9	57.0
Fuel oil	0.4	0.5	34.7	256.6	0.9	1,282.1
Natural gas	0.9	0.1	68.2	914.6	1.1	2.3
Town gas	0.9	0.1	68.2	914.6	1.1	2.3
272–273 Basic non-ferrous metals						
Black coal	1.2	0.8	103.6	316.9	1.0	370.0
Coke	1.2	0.8	103.6	316.9	1.0	370.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	2.0	0.6	38.5	294.0	0.8	2.3
Power kerosene	2.0	0.6	38.5	294.0	0.8	57.0
ADO	2.0	0.6	38.5	294.0	0.8	57.0
IDF	2.0	0.6	38.5	294.0	0.8	57.0
Fuel oil	2.0	0.6	38.5	294.0	0.8	1,282.1
Petroleum products nec	2.0	0.6	38.5	294.0	0.8	57.0
Natural gas	1.1	0.1	43.6	519.2	1.1	2.3
274–276 Other metal products						
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	1.0	0.6	75.0	502.0	0.9	2.3
ADO	1.0	0.6	75.0	502.0	0.9	57.0
IDF	1.0	0.6	75.0	502.0	0.9	57.0
Natural gas	1.0	0.1	70.9	949.5	1.1	2.3
Town gas	1.0	0.1	70.9	949.5	1.1	2.3
28 Machinery and equipment						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
LPG	0.7	0.6	57.3	402.6	0.8	2.3
Heating oil	0.7	0.6	57.3	402.6	0.8	57.0
ADO	0.7	0.6	57.3	402.6	0.8	57.0
IDF	0.7	0.6	57.3	402.6	0.8	57.0
Fuel oil	0.7	0.6	57.3	402.6	0.8	1,282.1
Natural gas	1.1	0.1	44.9	542.2	1.1	2.3
Town gas	1.1	0.1	44.9	542.2	1.1	2.3
29 Other manufacturing						
Black coal	1.3	0.8	105.0	157.0	1.0	370.0
LPG	0.2	0.6	20.3	100.6	0.5	2.3
ADO	0.2	0.6	20.3	100.6	0.5	57.0
IDF	0.2	0.6	20.3	100.6	0.5	57.0
Natural gas	1.1	0.1	20.3	189.3	1.1	2.3
362 Gas production and distribution						
Natural gas	8.0	0.1	46.0	190.0	2.4	2.3
Town gas	8.0	0.1	46.0	190.0	2.4	2.3
37 Water, sewerage and drainage						
Lighting kerosene	0.1	0.6	13.0	154.0	0.5	57.0
ADO	0.1	0.6	13.0	154.0	0.5	57.0
Natural gas	1.2	0.1	14.0	58.0	1.1	2.3
Div. E Construction						
LPG	1.0	0.6	15.0	160.0	0.3	2.3

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Lighting kerosene	1.0	0.6	15.0	160.0	0.3	57.0
ADO	1.0	0.6	15.0	160.0	0.3	57.0
Fuel oil	1.0	0.6	15.0	160.0	0.3	1,282.1
Natural gas	1.0	0.1	10.0	58.0	0.3	2.3
Div.F,G Wholesale and Retail Trade						
Wood, woodwaste	3.4	4.1	330.0	75.0	5.6	NA
LPG	0.6	0.6	13.1	53.2	0.9	2.3
ADO	0.6	0.6	13.1	53.2	0.9	57.0
IDF	0.6	0.6	13.1	53.2	0.9	57.0
Fuel oil	0.6	0.6	13.1	53.2	0.9	1,282.1
Natural gas	1.1	0.2	15.6	42.3	2.8	2.3
Town gas	1.1	0.2	15.6	42.3	2.8	2.3
62 Railway transport						
Natural gas	1.6	0.1	16.0	39.0	3.1	2.3
65–67 Other Transport, services and storage						
LPG	0.6	0.6	13.0	53.0	1.0	2.3
ADO	0.6	0.6	13.0	53.0	0.9	57.0
IDF	0.6	0.6	13.0	53.0	0.9	57.0
Natural gas	8.0	0.1	46.0	190.0	2.4	2.3
Div. J Communication						
Heating oil	0.6	0.6	13.0	53.0	0.9	57.0
ADO	0.6	0.6	13.0	53.0	0.9	57.0
IDF	0.6	0.6	13.0	53.0	0.9	57.0
Fuel oil	0.6	0.6	13.0	53.0	0.9	1,282.1
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Div. K,L Finance, insurance, property and busines						
Natural gas	1.1	0.1	8.5	41.0	2.2	2.3
Div. M Government administration and defence						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.4	0.6	13.0	84.4	0.8	2.3
Heating oil	0.4	0.6	13.0	84.4	0.8	57.0
ADO	0.4	0.6	13.0	84.4	0.8	57.0
IDF	0.4	0.6	13.0	84.4	0.8	57.0
Fuel oil	0.4	0.6	13.0	84.4	0.8	1,282.1
Natural gas	1.1	0.1	10.3	46.6	1.8	2.3
Town gas	1.1	0.1	10.3	46.6	1.8	2.3
Div. N,O Education, health and community services						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0
Brown coal briquettes	1.3	0.8	105.0	287.0	1.0	150.0
Wood, woodwaste	4.2	4.1	680.0	75.0	6.8	NA
LPG	0.4	0.6	13.0	53.0	0.7	2.3
Lighting kerosene	0.4	0.6	13.0	53.0	0.7	57.0
Heating oil	0.4	0.6	13.0	53.0	0.7	57.0
ADO	0.4	0.6	13.0	53.0	0.7	57.0
IDF	0.4	0.6	13.0	53.0	0.7	57.0
Fuel oil	0.4	0.6	13.0	53.0	0.7	1,282.1
Natural gas	1.1	0.1	10.4	44.8	1.8	2.3
Town gas	1.1	0.1	10.4	44.8	1.8	2.3
Div. H,P,Q Accommodation, cultural and personal						
Black coal	1.3	0.8	105.0	287.0	1.0	370.0

Category—Fuel	Equipment Weighted Emission Factor Mg/PJ					
	CH_4	N_2O	CO	NO_x	NMVOC	SO_2
Wood, woodwaste	3.4	4.1	330.0	19.0	5.6	NA
LPG	0.6	0.6	13.0	53.0	0.9	2.3
Aviation gasoline	0.6	0.6	13.0	53.0	0.9	8.2
Aviation turbine fuel	0.6	0.6	13.0	53.0	0.9	8.2
Heating oil	0.6	0.6	13.0	53.0	0.9	57.0
ADO	0.6	0.6	13.0	53.0	0.9	57.0
Fuel oil	0.6	0.6	13.0	53.0	0.9	1,282.1
Natural gas	1.1	0.1	9.7	44.8	2.0	2.3
Residential						
Black coal	105.0	0.8	5,753.0	190.0	209.0	370.0
Brown coal briquettes	105.0	0.8	5,753.0	190.0	209.0	150.0
Wood, woodwaste*						
LPG	4.7	0.6	13.0	48.0	1.9	2.3
Lighting kerosene	4.7	0.6	13.0	48.0	1.9	57.0
Heating oil	4.7	0.6	13.0	48.0	1.9	57.0
ADO	4.7	0.6	13.0	48.0	1.9	57.0
Natural gas	1.6	0.1	16.0	39.0	3.1	2.3
Town gas	1.6	0.1	16.0	39.0	3.1	2.3

* See Table 6a for Residential biomass emission factors.

Non CO_2 Emission Factors: 1990 to 1996

Table 102: 1990 to 1996 equipment weighted sectorial emission factors for non-CO_2 gases (Stationary)

ECONOMIC SECTOR	CH_4 factor	N_2O factor	NO_x factor	CO factor	NMVOC factor
Agriculture, Forestry and Fishing					
Oil	1.3	0.6	154.0	14.0	3.2
Gas	1.1	0.1	41.0	8.5	2.2
Div. B Mining					
Coal and coke	1.1	1.4	319	97.1	1.0
Oil	1.1	0.6	400	72.2	5.0
Gas	3.9	0.1	123	28.0	1.6
21 Food, Beverages, Tobacco					
Coal and coke	1.3	1.4	180	106	1.0
Wood	4.2	4.1	75.0	680	6.8
Bagasse	4.3	4.1	84.0	1625	16.3
Oil	0.4	0.6	75	13.6	0.6
Gas	1.2	0.1	42.9	13.6	1.1
23-24 Textiles, Clothing, Footwear					
Coal and coke	1.3	1.4	157	105	1.0
Oil	0.2	0.6	69	12.9	0.5
Gas	1.2	0.1	47.2	14.0	1.1
25 Wood & Wood Products					
Coal and coke	1.3	1.4	157	105	1.0
Wood and bagasse	4.2	4.1	75.0	680	6.8
Oil	0.7	0.6	138	16.7	0.8
Gas	1.1	0.1	51.3	11.6	1.1
26 Paper & Paper Products					
Coal and coke	1.3	1.4	232	105	1.0
Wood and bagasse	4.2	4.1	75.0	680	6.8
Oil	1.7	0.6	142	14.2	0.8
Gas	1.2	0.1	74.0	15.5	1.1
275 Basic Chemicals					
Coal and coke	1.3	1.4	231	105	1.0
Oil	1.3	0.0	285.4	41.2	0.8
Gas	1.1	0.1	484	41.5	1.1
276 Other Chemical Products					
Coal and coke	1.3	1.4	157	105	1.0
Oil	0.1	0.6	53	13.0	0.5
Gas	1.2	0.1	41.4	13.9	1.1
277 Petroleum Refining					
Oil	1.1	0.6	317	47.3	0.8
Gas	1.2	0.1	600	49.3	1.1
278 Petroleum & Coal Products					
Coal and coke	1.3	1.4	157	105.0	1.0
Oil	0.5	0.6	173	27.6	0.7
Gas	1.1	0.1	268	27.1	1.1
285 Glass & Glass Products					
Oil	1.0	0.6	485	72.7	0.9
Gas	1.0	0.1	1009	74.9	1.1
286 Clay Products					
Coal and coke	1.0	1.4	502	75.0	1.0
Wood and bagasse	4.2	4.1	75	680.0	6.8

ECONOMIC SECTOR	CH_4 factor	N_2O factor	NO_x factor	CO factor	NMVOC factor
Oil	1.0	0.6	492	73.3	0.9
Gas	1.0	0.1	998	74.2	1.1
287 Cement & Concrete Products					
Coal and coke	1.0	1.4	501	75.2	1.0
Wood and bagasse	4.2	4.1	75.0	680	6.8
Oil	0.8	0.6	282.4	39.4	0.8
Gas	1.0	0.1	956	71.4	1.1
288 Other Non-Metallic Mineral Products					
Coal and coke	1.1	1.4	349	88.3	1.0
Oil	0.7	0.6	358	55.1	0.8
Gas	1.0	0.1	621	49.0	1.1
294 Basic Iron and Steel					
Coal and coke	0.8	1.4	420	109	1.0
Wood and bagasse	4.2	4.1	75.0	680	6.8
Oil	0.1	0.4	57	11.3	0.3
Gas	0.9	0.1	274	36.7	0.9
295-6 Basic Non-ferrous Metals					
Coal and coke	1.2	1.4	322	103	1.0
Oil	1.6	0.6	347	48.8	0.8
Gas	1.1	0.1	446	38.9	1.1
31 Fabricated Metal Products					
Coal and coke	1.3	1.4	157	105	1.0
Oil	0.5	0.6	251	40.3	0.7
Gas	1.2	0.1	82.7	16.6	1.1
32 Transport Equipment					
Coal and coke	1.3	1.4	192	102	1.0
Oil	0.3	0.6	171	29.3	0.6
Gas	1.2	0.1	140	20.7	1.1
33 Other Machinery & Equipment					
Coal and coke	1.3	1.4	157	105	1.0
Oil	0.5	0.6	130	18.8	0.7
Gas	1.2	0.1	147	20.4	1.1
34 Miscellaneous Manufacturing					
Coal and coke	1.3	1.4	157	105	1.0
Oil	0.2	0.6	101	19.6	0.5
Gas	1.2	0.1	135	19.7	1.1
3612 Private Electricity Generation					
Coal and coke	0.9	1.4	306	11	1.7
Oil	3.8	0.6	1248	329	42.4
Gas	3.4	0.1	201	27.9	1.3
362 Gas Production & Distribution					
Gas	7.5	0.1	178.7	43.6	2.3
37 Water, Sewerage & Drainage					
Oil	0.1	0.6	53.0	13.0	0.5
Gas	1.2	0.1	41.0	14.0	1.1
Div. E Construction					
Gas	1.2	0.1	41.0	14.0	1.1
Div. F Wholesale & Retail Trade					
Wood and bagasse	3.4	4.1	19.0	330.0	5.6
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
55-58 Other Transport, Services & Storage					
Gas	8.0	0.1	190.0	46.0	2.4

ECONOMIC SECTOR	CH_4 factor	N_2O factor	NO_x factor	CO factor	NMVOC factor
Div. H Communication					
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
Div. I Finance & Business Services					
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
Div. J Public Administration					
Coal and coke	1.3	1.4	225.0	126.0	1.0
Wood and bagasse	3.4	4.1	19.0	330.0	5.6
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
Div. K Community Services					
Coal and coke	1.3	1.4	225.0	126.0	1.0
Wood and bagasse	3.4	4.1	19.0	330.0	5.6
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
Div. L Recreation & Other Services					
Coal and coke	1.3	1.4	225.0	126.0	1.0
Wood and bagasse	3.4	4.1	19.0	330.0	5.6
Oil	0.6	0.6	53.0	13.0	0.9
Gas	1.1	0.1	41.0	8.5	2.2
Residential					
Coal and coke	105.0	1.4	190.0	5753.0	209.0
[1]Wood and bagasse					
Oil	4.7	0.6	48.0	13.0	1.9
Gas	1.6	0.1	39.0	16.0	3.1

Derivation of non-CO_2 emission factors

Table 103: Calculation of emission factors for non-CO_2 greenhouse gases

				Emission Factors (Mass/Mass or Volume or Energy)						Conversion Factors		Emission Factors (Mass/Gross Energy Use)				
	Sector	Fuel	Equipment	CH_4	N_2O^a	NO_X	CO	NMVOC	Units	Value	Units	CH_4	N_2O^a	NO_X	CO	NMVOC
												Mg/PJ				
	Electricity Generation/Utility															
1		Natural Gas	Boiler[b]	4.8		8,800	640	23.24	kg/106m3	38.9	MJ/m3	0.1	0.1	226	16	0.6
2		Residual Oil	Boiler[c]	0.034		8	0.6	0.091	kg/103L	42.9	MJ/L	0.8	0.6	186	14	2.1
3		Distillate Oil	Boiler[d]	0.002		3	0.6	0.06	kg/103L	45.6	MJ/L	0.04	0.6	64	13	1.4
4		Black Coal	Tangentially Fired[e]	0.02		7.2	0.25	0.04	kg/t	23.5	GJ/t	0.9	0.8	306	11	1.7
5		Black Coal	Pulverised Wall[f]	0.02		10.85	0.25	0.04	kg/t	23.5	GJ/t	0.9	0.8	462	11	1.7
6		Brown Coal	Tangentially Fired[g]									0.9	1.4	136	17	1.7
4		Natural Gas	Turbine[h]	7.95		190	46	2.37	ng/J	1.0		8.0	0.1	190	46	2.4
7		Natural Gas	Internal Combustion[i]	240		1,331	340	80	ng/J	1.0		240	0.1	1,331	340	80
8		Fuel Oil	Internal Combustion[j]	4		1,322	349	45	ng/J	1.0		4.0	0.6	1,322	349	45
9		Diesel	Internal Combustion[k]	4		1,322	349	45	ng/J	1.0		4.0	0.6	1,322	349	45
	Other Energy Transformation and Industrial															
10		Natural Gas	Boiler[l]	47.8		2,240	560	44.16	kg/106m3	38.9	MJ/m3	1.2	0.1	58	14	1.1
11		Residual Oil	Boiler[m]	0.12		6.6	0.6	0.034	kg/103L	42.9	MJ/L	2.8	0.6	154	14	0.8
12		Distillate Oil	Boiler[n]	0.006		2.4	0.6	0.024	kg/103L	45.6	MJ/L	0.1	0.6	53	13	0.5
13		Black Coal	Boiler[o]	0.03		6.85	2.5	0.025	kg/t	23.9	GJ/t	1.3	0.8	287	105	1.0
14		Wood	Boiler[p]	0.042		0.75	6.8	0.068	kg/t	10.0	GJ/t	4.2	4.1	75	680	6.8
15		Bagasse	Boiler [q]									10.0	4.1	84	1,625	16.3
16		Natural Gas	Kiln[r]									1.0	0.1	1,010	75	1.1
17		Fuel Oil	Kiln[r]									1.0	0.6	502	75	0.8
18		Black Coal	Kiln[r]									1.0	0.8	502	75	1.0
19		Black Coal	Coke Oven[r]									1.0	0.8	287	201	1.0

				Emission Factors (Mass/Mass or Volume or Energy)						Conversion Factors		Emission Factors (Mass/Gross Energy Use)				
				CH_4	N_2O^a	NO_X	CO	NMVOC	Units	Value	Units	CH_4	N_2O^a	NO_X	CO	NMVOC
	Sector	Fuel	Equipment									Mg/PJ				
20		Natural Gas	Dryer[r]									1.0	0.1	58	10	1.1
21		Fuel Oil	Dryer[r]									1.0	0.6	160	15	0.8
22		Black Coal	Dryer[r]									1.0	0.8	215	170	1.7
	Commercial															
23		Natural Gas	Boiler[s]	43.5		1,600	330	84.48	kg/106m3	38.9	MJ/m3	1.1	0.1	41	8.5	2.2
24		Residual Oil	Boiler[t]	0.057		6.6	0.6	0.136	kg/103L	42.9	MJ/L	1.3	0.6	154	14	3.2
25		Distillate Oil	Boiler[u]	0.026		2.4	0.6	0.041	kg/103L	45.6	MJ/L	0.6	0.6	53	13	0.9
26		Black Coal	Boiler[v]	0.03		3.75	3	0.025	kg/t	23.9	GJ/t	1.3	0.8	157	126	1.0
27		Wood	Boiler[w]	0.034		0.19	3.3	0.056	kg/t	10.0	GJ/t	3.4	4.1	19	330	5.6
	Residential															
28		Natural Gas	Heater[x]	61.2		1,500	640	118.8	kg/106m3	38.9	MJ/m3	1.6	0.1	39	16	3.1
29		Black Coal	Hot Water Heater[y]	2.5		4.55	137.5	5	kg/t	23.9	GJ/t	105	0.8	190	5,753	209
30		Wood	Fireplace[z]	43.5		1.3	126.3	71.0	kg/t	16.2	GJ/t	2,686	4.1	80	7,796	4,382
31		Wood	Stove[aa]	2.4		1.4	115.4	21.9	kg/t	16.2	GJ/t	148	4.1	86	7,123	1,352
32		LPG	Furnace[ab]	0.02		1.7	0.2	0.04	kg/103L	25.3	MJ/L	0.8	0.1	67	7.9	1.6
33		Distillate Oil	Furnace[ac]	0.214		2.2	0.6	0.085	kg/103L	45.6	MJ/L	4.7	0.6	48	13	1.9
	General															
34		Gas	Miscellaneous [ad]									1.1	0.1	41	8.5	2.2
35		Oil	Miscellaneous [ad]									1.3	0.6	154	14	3.2
36		Black Coal	Miscellaneous [ad]									1.3	0.8	157	126	1.0

SOURCES:

IPCC (1997, Volume 3) Assume value is independent of equipment category, i.e. fuel dependent only (0.1, 0.6, 0.8 and 4.1 Mg/PJ for natural gas, oil, coal and wood combustion, respectively).

[a]

[b] USEPA (1995) Pg 1.4-4 to 1.4-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from natural gas fired utility/large industrial boilers (>29 MW).

[c] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from residual oil (No. 4 - 6) fired utility boilers (normal firing).

[d] Distillate oil fired utility boiler data not available. Assume emissions equal those of residual oil fired utility boiler scaled by relative emissions of industrial boiler category (USEPA, 1986, Pg 1.3-2) .

[e] USEPA (1995) Pg 1.1-6 and 1.1-22. Uncontrolled emissions for pulverised coal fired dry bottom configuration (tangentially fired boiler).

[f] USEPA (1995) Pg 1.1-6 and 1.1-22. Uncontrolled emissions for pulverised coal fired dry bottom configuration.

[g] Assume CH4 and NMVOC emission factors identical to black coal combustion. CO and NOx emission factors based on average of SECV data (1994). N2O emission rate based on mid-range value as reported by IEA Coal Research (1993).

[h] USEPA (1995) Pg 3.1-3 and 3.1-5. Uncontrolled emissions of CO and NOx for large stationary natural gas turbines. NMVOC and CH4 emissions estimated from ratio of NMHC and CH4, respectively: to Total Organic Compounds for selective catalytic reduction controlled turbines.

[i] USEPA (1995) Pg 3.4-3. Assume dual fuel emission factors.

[j] USEPA (1995) Pg 3.4-3. Assume diesel emission factors.

[k] USEPA (1995) Pg 3.4-3.

[l] USEPA (1995) Pg 1.4-4 to 1.4-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from natural gas fired “small industrial” boilers (3-29 MW).

[m] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from residual oil fired industrial boilers.

[n] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from distillate oil fired industrial boilers.

[o] USEPA (1995) Pg 1.1-6 and 1.1-22. Uncontrolled emissions for spreader stoker firing configuration.

[p] USEPA (1995) Pg 1.6-6 to 1.6-7. Uncontrolled emissions from wood waste combustion in stoker boiler. Assume wood moisture content of 50% as recommended by USEPA. Assume CH4/TOC as for [z].

[q] IPCC (1997a) data for NOx and CO converted to gross calorific equivalent by dividing by 1.05. CH4 and NMVOC emission rates estimated by scaling relative to wood boiler data (see [p]).

[s] USEPA (1995) Pg 1.4-4 to 1.4-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from natural gas fired “commercial” boilers (0.1-2.9 MW).

[t] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from residual oil (No. 5 and 6) fired commercial boilers (0.1-2.9 MW).

[u] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from distillate oil fired commercial boilers (0.1-2.9 MW).

[v] USEPA (1995) Pg 1.1-6 and 1.1-23. Uncontrolled emissions for overfeed stoker firing configuration.

[w] USEPA (1995) Pg 1.6-6 to 1.6-7. Uncontrolled emissions from wood waste combustion in Dutch oven boiler. Assume wood moisture content of 50% as recommended by USEPA. Assume CH4/TOC as for [z].

[x] USEPA (1995) Pg 1.4-4 to 1.4-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from natural gas fired residential furnaces (< 0.1 MW).

[y] USEPA (1995) Pg 1.1-7 and 1.1-23. Uncontrolled emissions for hand fired units.

[z] USEPA (1995) Pg 1.9-3. Assume CH4 constitutes 38% of total organic emissions for fireplace (USEPA recommendation for wood combustion).

[aa] USEPA (1995) Pg 1.10-3. Assume CH4 constitutes 38% of total organic emissions for fireplace (USEPA recommendation for wood combustion).

[ab] USEPA (1995) Assume propane combustion (commercial boiler) and CH4 to constitute 34% of total organic emissions (as recommended by USEPA for residential gas fired furnace).

[ac] USEPA (1995) Pg 1.3-2 to 1.3-6. Uncontrolled emissions of CO, NOx, NMVOC and CH4 from distillate oil fired residential furnace (< 0.1 MW).

[ad] Assume emission factors for commercial boilers (0.1 - 2.9 MW).

(Footnotes) 1 See Table 6a for Residential biomass emission factors.