Australian Government

Australian Greenhouse Office

NATIONAL GREENHOUSE GAS INVENTORY 2002

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http://www.greenhouse.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, International Land and Analysis Division, Australian Greenhouse Office, GPO Box 621, Canberra ACT 2601.

April 2004

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Australia is committed, as a party to UNFCCC, to updating and publishing annual national greenhouse gas inventories. Inventories have been produced each year from 1990 to 2002 inclusive.

The 2002 inventory has been compiled using the methods described in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002* series. These are available from the Australian Greenhouse Office website. In line with international good practice guidelines, the methodologies used to estimate Australia's national inventory have been improved over time and will continue to be refined as new information emerges and as international practice evolves.

Emissions Estimates for 2002: Kyoto Accounting

For 2002, Australia's net greenhouse gas emissions were estimated to be 550.1 Mt carbon dioxide-equivalent. This amounts to a 1.5% increase on net emissions in 2001, largely reflecting increases in emissions from the energy sector (both stationary energy (1.3%) and transport (2.5%)) and from industrial processes (2.5%). Australia's net emissions in 2002 were 1.3% above 1990 levels.

The combined *energy* subsectors (*stationary energy*, *transport* and *fugitive emissions* from fossil fuel extraction and distribution) were the largest source of net national emissions, contributing 67.5% of the total. This proportion, while significant, is nonetheless less than in many countries due to the relatively large contribution from the *agriculture* (19.2%) and *land use, land use change* and *forestry* sectors (5.3%) to Australia's inventory. Other relatively minor sources include emissions from *industrial processes*, such as from the manufacture of mineral products, and emissions from *waste disposal*.

Emissions Estimates for 2002: UNFCCC Accounting

Under the accounting provisions of the UNFCCC, which are broader in scope than those of the Kyoto Protocol, Australia's net emissions increased by 2.2% in 2002 to 539.2 Mt. By comparison, net emissions in 1990 were 515.9 Mt.

ACKNOWLEDGEMENTS

The following have contributed to the preparation of the 2002 inventory:

SECTOR CONSULTANTS

Sector	Consultant	Organisation
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[1] Commonwealth Scientific and Industrial Research Organisation.

General Notes

Units

The units mainly used in this inventory are joules (J), grams (g), tonnes (t), metres (m) and litres (l), together with their multiples. Standard metric prefixes used in this inventory are:

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

Emissions are generally expressed in gigagrams (Gg) in the Inventory tables, as called for under international guidelines, and in megatonnes (Mt) in the text of the inventory report:

gigagram (Gg) = 1,000 tonnes = 1 kilotonne (kt)
megatonne (Mt) = 1,000,000 tonnes = 1,000 Gg.

Gases

CF_4	perfluoromethane (a perfluorocarbon)
C_2F_6	perfluoroethane (a perfluorocarbon)
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
HFCs	hydrofluorocarbons
N_2O	nitrous oxide
NMVOC	non-methane volatile organic compounds
NO_x	oxides of nitrogen
PFCs	perfluorocarbons
SF_6	sulphur hexafluoride
SO_2	sulphur dioxide.

Global Warming Potentials

$CO_2 = 1$	HFC-23 = 11,700
$CH_4 = 21$	HFC-125 = 2,800
$N_2O = 310$	HFC-134a = 1,300
$CF_4 = 6,500$	HFC-143a =3,800
$C_2F_6 = 9,200$	$SF_6 = 23,900$.

Conversion Factors

From element basis to molecular mass	**From molecular mass to element basis**
$C \rightarrow CO_2$: x 44/12 = 3.67	$CO_2 \rightarrow C$: x 12/44 = 0.27
$C \rightarrow CH_4$: x 16/12 = 1.33	$CH_4 \rightarrow C$: x 12/16 = 0.75
$N \rightarrow N_2O$: x 44/28 = 1.57	$N_2O \rightarrow N$: x 28/44 = 0.64.

Indicators

In the tables, the following standard indicators are used:

NO (not occurring) when the activity or process does not occur in Australia

NA (not applicable) when the activity occurs in Australia but the nature of the process does not result in emissions or removals

NE (not estimated) where it is known that the activity occurs in Australia but there are no data or methodology available to derive an estimate of emissions

IE (included elsewhere) where emissions or removals are estimated but included elsewhere in the inventory (Summary Table 9 of the Common Reporting Format tables details the source category where these emissions or removals are reported)

C (confidential) where reporting at a disaggregated level could lead to the disclosure of confidential information.

Shading in cells indicates that there cannot be a value in that cell, because of the nature of the process or because of the Intergovernmental Panel on Climate Change (IPCC) reporting instructions for National Greenhouse Gas Inventories (IPCC 1997).

UNFCCC or Kyoto Reporting

In general, the estimates presented relate to the accounting provisions of both the Kyoto Protocol and the UNFCCC. However, the estimates from the *land use, land use change and forestry* sector differ under each of the two accounting approaches and, as appropriate, the applicable accounting provision has been identified. Identification of the accounting approach has also been made at the aggregate emission level.

PART A

2002
NATIONAL GREENHOUSE GAS INVENTORY REPORT

CHAPTER 1
INTRODUCTION

Australia's *National Greenhouse Gas Inventory 2002* has the dual purpose of providing estimates of Australia's net greenhouse gas emissions for the United Nations Framework Convention on Climate Change (UNFCCC) and of tracking Australia's progress towards its internationally agreed target of limiting emissions to 108% of 1990 levels over the period 2008–2012.

The Australian Greenhouse Office is the agency responsible for coordinating Australia's greenhouse gas inventory activities. Representatives of the Australian, state and territory governments—constituting the National Greenhouse Gas Inventory Committee—jointly guide the preparation and review of Australia's National Greenhouse Gas Inventory.

Australia's 2002 *National Greenhouse Gas Inventory* has been compiled in accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* and UNFCCC reporting guidelines on annual inventories. In addition, the principles of the Intergovernmental Panel on Climate Change (IPCC), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), have been applied in the preparation of this inventory, with the aim of ensuring that the estimates of emissions are accurate, transparent, consistent through time and comparable with those produced in the inventories of other countries.

The 2002 National Greenhouse Gas Inventory Report is presented in Part A. It provides background on the inventory preparation process and an overview of Australia's total net emissions in 2002; identifies trends in emissions between 1990 and 2002 for each of the sectors and for the main greenhouse gases; and discusses data quality, as required by international guidelines.

The UNFCCC Common Reporting Format tables and appendix tables are presented in Part B. The tables include revised emissions estimates for the years 1990 to 2001, reflecting end-of-series averaging effects, some revised data and the inclusion of minor additional sources in the industrial processes sector.

The emissions trends tables according to the Kyoto accounting provisions are presented in Part C.

GASES

The Australian *National Greenhouse Gas Inventory* covers the major greenhouse gases—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). Also covered are the indirect greenhouse gases—carbon monoxide (CO), oxides of nitrogen (NO_X), and non-methane volatile organic compounds (NMVOCs). Sulphur dioxide (SO_2), an aerosol precursor, is also included because emissions of this gas influence global warming.

Only greenhouse gas emissions from sources and removals by sinks resulting from human (anthropogenic) activities have been estimated and included in the inventory. Natural processes are outside the scope of the inventory.

The National Greenhouse Gas Inventory Report presents emissions for each gas as carbon dioxide equivalents (CO_2-e). As greenhouse gases vary in their radiative activity and in their atmospheric residence time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared. The conversion of emission data to CO_2-e is done using the concept of global warming potentials (GWPs).

GWPs represent the relative warming effect (i.e. cumulative radiative forcing[2]) of a unit mass of the gas when compared with the same mass of CO_2 over a specific period. The CO_2-e emissions are calculated by multiplying the mass of emissions of each gas by the appropriate GWP. Aggregate emissions are then obtained by summing the emissions of various greenhouse gases.

GWPs are revised from time to time as knowledge about the influence of different gases and processes on climate change increases. GWPs also vary with the time horizon being considered—by international agreement the 100-year horizon is used in policy analyses. To be consistent with the Kyoto and UNFCCC reporting requirements, the 100-year GWPs contained in the 1995 IPCC *Second Assessment Report* (IPCC 1996) are used in this document (e.g. 1 for CO_2, 21 for CH_4, 310 for N_2O, 6,500 for the PFC tetrafluoromethane (CF_4), 9,200 for the PFC hexafluoroethane (C_2F_6), and 23,900 for SF_6).

The indirect effects of a number of gases (e.g. CO, NO_X, and NMVOCs) cannot currently be characterised and these gases do not have GWPs. In accordance with the UNFCCC reporting guidelines, gases that do not have GWPs are reported but they are not included in the inventory total.

SECTORS

National greenhouse gas inventory sources and sink categories have been grouped under six sectors that have been defined by the IPCC. These represent the main human activities that contribute to the release or capture of greenhouse gases into or from the atmosphere:

1. Energy
2. Industrial processes
3. Solvent and other product use
4. Agriculture
5. Land use change and forestry (or land use, land use change and forestry under Kyoto accounting)
6. Waste.

At various places in the inventory, sectors are disaggregated to subsectors (e.g. 1.A. *Fuel combustion*, or 4.D. *Agricultural soils*), and sometimes more detailed disaggregations are provided (e.g. 1.A.3.b. *Road transportation*). There is no correspondence between the level of disaggregation and the scale of greenhouse gas emissions.

[2] Radiative forcing is a change in the energy balance of the global Earth-atmosphere system.

Reporting Year

For the large part, the Australian inventory is compiled on an Australian fiscal year basis as key data sources such as the national energy statistics are collected on this basis. The year 2002 refers to the Australian fiscal year from 1 July 2001 to 30 June 2002, and a similar format is used for other years. Time series consistency is maintained.

Relationship between Inventory Rules for the UNFCCC and the Kyoto Protocol

Separate estimates of Australia's net emissions have been compiled according to the inventory reporting requirements of the UNFCCC and of those applying under the Kyoto Protocol.

The UNFCCC requires parties to report on all anthropogenic (human-induced) emissions of greenhouse gases and removals from sinks where adequate data are available. That is, the UNFCCC provides for comprehensive reporting of greenhouse gas sources, sectors and sinks.

The reporting requirements of the Kyoto Protocol have a more limited scope.

First, inventories prepared under the Kyoto guidelines require reporting of anthropogenic emissions of the six greenhouse gases or groups of gases where GWPs are available (CO_2, CH_4, N_2O, PFCs, HFCs and SF_6) across all sectors. Indirect gases without GWPs, such as CO, are not reported.

Second, the Kyoto Protocol makes provision for countries to choose whether 1990 or 1995 is used as the base year for the synthetic gases (HFCs, PFCs, SF_6), whereas under the UNFCCC emissions of the synthetic gases should be included for all years of the inventory.

Third, the accounting rules for the *land use, land use change and forestry* sector, as set out in Article 3.3 of the Kyoto Protocol, provide for developed countries to account for only a limited set of forestry activities—namely afforestation, reforestation, and deforestation activities that have taken place on land, but only since 1990. Under Article 3.4, countries may elect (for 2008–12) to apply any or all defined additional sinks activities. These are defined as revegetation, forest management (capped), cropland management and grazing land management.

The Kyoto Protocol also establishes a specific approach for the calculation of developed countries' base year estimates in the *land use, land use change and forestry* sector, which in turn provides the basis for a component of each country's 'assigned amount'. Article 3.7 states that countries with a net source of emissions from the *land use change and forestry* sector in 1990 should include emissions from land use change in the baseline used for calculating their assigned amounts. In fact, as this sector was a net source in 1990, the operation of this provision requires Australia to report land use change emissions in the base year, 1990, and for all other years. Consequently, and unlike other *land use change and forestry* activities, the estimates of Australia's emissions from *land use change* (called *deforestation* under the Kyoto protocol) are the same under the accounting provisions of both the UNFCCC and Kyoto Protocol in all years.

1.1 Methodologies

Methodology

Greenhouse gas emissions are generated from a large number of processes and from a range of often diffuse sources. Emissions are not usually monitored directly but are generally estimated through the application of models and methodologies that link emissions to data on observable activities. The Australian methodology for estimating greenhouse gas emissions and sinks uses a combination of country-specific and IPCC methodologies and emission factors (see Summary Table 3 in Part B). Australia predominantly uses Tier 2 approaches to estimating emissions.[3] These methods are consistent with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1997) and are comparable with international practice.

The Australian methodologies have been documented in a series of workbooks to ensure transparency. The 2002 inventory relies on the inventory methodology in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002*, which provides an edited compilation of the methodologies described in Workbooks 1.1 to 8.1 (NGGIC 1998a-h), Workbook 4.2 (NGGIC 1997a) and Workbook 6.2 (NGGIC 2003)[4], and the methodology supplements published with the 1995, 1996, 1997, 1998, 1999 and 2000 inventories (NGGIC 1997b, 1998 and 1999; AGO 2000, 2001 and 2002a).

Emissions from the *forest and grassland conversion* subsector (5B) of *land use change and forestry* are estimated by the National Carbon Accounting System. The National Carbon Accounting System is a model-based accounting system providing a Tier 3 approach under the international guidelines. The methodology is summarised in *Greenhouse Gas Emissions from Land Use Change in Australia: an Integrated Application of the National Carbon Accounting System* (AGO 2002b) and *Greenhouse Gas Emissions from Land Use Change in Australia: Results of the National Carbon Accounting System* (AGO 2003).

A summary of key emission factors is provided each year in the Australian Greenhouse Office (AGO) Factors and Methods Workbook and is available, along with a compilation of the current methodology for each sector, from the AGO website at <http://www.greenhouse.gov.au>.

1.2 Planned Improvements

In line with the international guidelines for the preparation of the national greenhouse gas inventory, the methodologies used to estimate greenhouse emissions have been refined as new information emerges. The need for refinement arises from the range and complexity of greenhouse gas emission processes, the need to improve understanding of some of the relationships between activities and emissions through empirical research (especially in processes outside fossil fuel combustion) and the need to enhance data collection procedures. Future refinements will be informed by the ongoing technical review of sectoral methodologies and data sources undertaken by the Australian Greenhouse Office as part of Australia's efforts to comply with inventory good practice.

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[3] An explanation of the 'Tier' concept is provided in the Glossary.

[4] Note that the numbering of the workbooks does not correspond with the numbering of the IPCC categories.

Priorities for the inventory development process will be informed by analysis of key sources and key trends; by analysis of the level of uncertainty surrounding existing emission estimates; and the comments received from previous international reviews of Australia's inventory.

KEY SOURCE ANALYSIS

The *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, the IPCC *Good Practice* report) introduces the concept of 'key source categories' for prioritising the inventory development process.

A key source category has a significant influence on a country's total inventory of direct greenhouse gases in terms of absolute level of emissions, the trend in emissions, or both. Australia has identified the key sources for the inventory using the Tier 1[5] level and trend assessments as recommended in the IPCC *Good Practice* report. This approach identifies sources that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms.

Australia has identified 43 key sources through the level assessment, with an additional three categories identified through the trends assessment. *Public electricity* (solid fuel), *enteric fermentation* (cattle), *forest and grassland conversion* (CO_2) and *road transportation* (passenger cars) are the most significant of the key source categories—contributing 52.2% of emissions. More details are provided in Chapter 5.

UNCERTAINTY

The IPCC *Good Practice* report also encourages publication of uncertainty levels attached to the emission estimates of the various components of the inventory, with the aim of informing directions for future methodological development of the inventory. Managing these uncertainties, and reducing them over time, is recognised by the IPCC *Good Practice* report as an important element of inventory preparation and development.

Australia first published quantitative analyses of uncertainty for a limited number of sources and gases in the 1998 inventory (AGO 2000). The objective has been to undertake detailed quantitative uncertainty analyses for all sources and gases for which it is reasonable to do so and for which probability distributions can be sensibly characterised. The estimates of uncertainty vary from sector to sector and process to process. As is the case with most national inventories, the estimates with lowest uncertainty are produced for the energy sector, where data is easily obtained and where the relationships between the consumption of fossil fuels and emissions are consistent and well understood. In other sectors, such as agriculture, uncertainties are higher because the relationships between activities and emissions are biological in nature and dependent on a range of factors such as climatic conditions and because the emission sources are diffuse and often mobile.

The results of the analysis of the uncertainty attached to Australia's emission estimates are presented in Chapter 5. These estimates show that the uncertainty ranges for the various components of the Australian inventory are largely consistent with the typical uncertainty ranges expected for each sector, as identified in the IPCC *Good Practice* report.

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[5] An explanation of the 'Tier' concept is provided in the Glossary.

Responses to UNFCCC Inventory Reviews

In 2001, Australia's 1998 inventory (AGO 2000) underwent both an individual in-country review and a centralised review. One of the key recommendations in relation to the *industrial processes* sector was that emissions from coke used in iron and steel production (previously accounted for under *stationary energy*) should be transferred to *industrial processes*. This change has now been made.

The UNFCCC Expert Review Team also requested that the methodology of the sinks associated with alumina production and soda ash production be reviewed. The reporting of these sinks has been retained whilst the topic continues to be investigated.

1.3 Data and Quality Issues

The data for the estimates provided in this report are mostly derived from published sources, principally from the Australian Bureau of Agricultural and Resource Economics and from the Australian Bureau of Statistics. Specific survey data were collected, however, in the sectors of electricity generation, industrial processes, fugitives and wastes.

The IPCC *Good Practice* Tier 1[6] general inventory level quality control procedures were conducted for all sectors and focused on key source categories. This included systematic checks for transcription and computational errors, and documentation, archiving and reporting procedures. The 2002 inventory emission estimates, activity data and emission factors were compared with those of the previous year and any significant deviations were analysed. In future, commencing with the 2003 inventory, the emission estimates will be prepared using an integrated Australian Greenhouse Emissions Information System, developed by the Australian Greenhouse Office, that will improve the quality and efficiency of the compilation and reporting of emissions estimates.

The Australian methodologies were developed by a series of expert working groups and have been reviewed by a wide range of technical experts in research institutions, governments and industry as well as by community groups. Subsequent revisions to the methodologies have been published with past inventory reports. In future, in order to maintain high levels of transparency for the Australian inventory, consolidated and up-to-date sets of Australia's current methodologies and emission factors will be incorporated into a series of sectoral methodological workbooks and, along with the AGO Emission Factors and Methods Workbook, will be made available from the Australian Greenhouse Office website (hard copy publication of methodologies will cease).

Development of this inventory has been guided by an intergovernmental committee, including the state and territory governments. The inventory report is distributed to other Australian government departments and agencies and relevant state experts through the National Greenhouse Gas Inventory Committee for review prior to submission.

Changes since the 2001 Inventory

Several changes in methodology and improvements in data have been introduced for the 2002 Inventory, which have been specified in the sectoral discussions provided in Chapter 3. These changes require emissions estimates for 1990 to 2001 to be recalculated so as to maintain time

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[6] An explanation of the 'Tier' concept is provided in the Glossary.

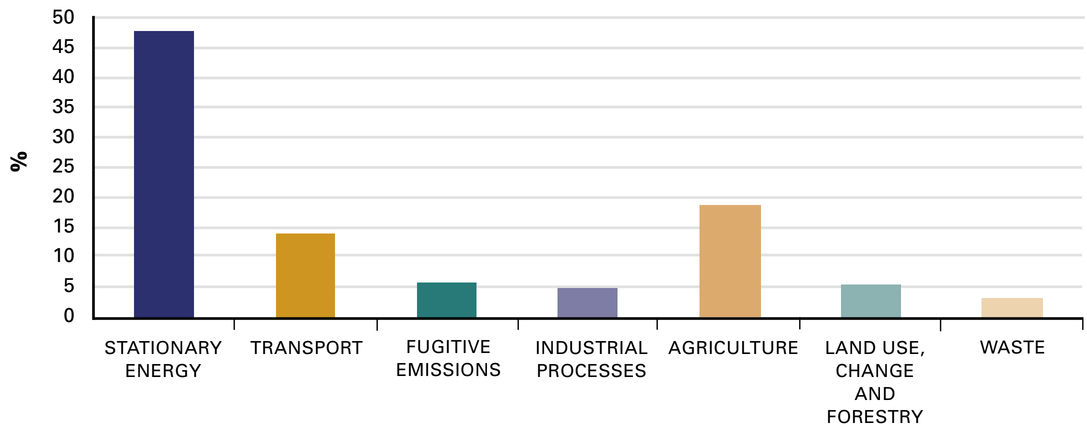
series consistency in emissions trends reported in the inventory. The net effect of the revisions is reported in Chapter 4. A full set of revised estimates for the years 1990 to 2001, which supersedes all previously published estimates of emissions for 1990 to 2001, is included in appendix Table 6—Summary Table 1A for 1990 to 2001. Emission estimates in the current inventory will not necessarily be consistent with the corresponding values of previous inventories, or with analyses based on such inventories.

CHAPTER 2
AUSTRALIA'S NET GREENHOUSE GAS EMISSIONS

2.1 EMISSIONS IN 2002

In 2002, Australia's net greenhouse gas emissions using the Kyoto accounting provisions were 550.1 million tonnes (Mt), CO_2-equivalent (CO_2-e). The combined *energy* sectors were the largest source of greenhouse gas emissions comprising 67.5% (371.4 Mt CO_2-e) of emissions (Figure 1). This proportion is less than in many countries, however, due to the relatively large contribution from the *agriculture* (19.2%) and *land use, land use change and forestry* sectors (5.3%) to Australia's inventory. Other relatively minor sources include emissions from *industrial processes*, such as from the manufacture of mineral products, and emissions from *waste disposal*.

Figure 1. Contribution to total net CO_2-e emissions by sector (Kyoto accounting), 2002



The national emissions from the *energy* sector (including *stationary energy*, *transport* and *fugitive* emissions) comprise mainly emissions of carbon dioxide (Table 2). Consequently, at the level of individual greenhouse gases, the energy sector is the major contributor to carbon dioxide emissions at 88.5% (340.1 Mt). *Agriculture* is the main contributor of methane (62.9%, 3.7 Mt) and nitrous oxide (81.9%, 0.1 Mt) emissions.

Table 1. Australian net greenhouse gas emissions by sector (Kyoto accounting), 2002

Sector and Subsector	CO_2		CH_4		N_2O		CO_2-e	
	Mt	%	Mt	%	Mt	%	Mt	%
1 All energy (combustion + fugitive)	340.1		1.23		0.02		371.4	
Stationary energy	259.6	67.5	0.1	1.2	0.003	2.7	261.9	47.6
Transport	74.1	19.3	0.03	0.5	0.01	12.8	79.2	14.4
Fugitive emissions from fuel	6.5	1.7	1.1	19.3	0.0001	0.1	30.2	5.5
2 Industrial processes	18.3	4.8	0.003	0.1	0.0	0.1	26.4	4.8
3 Solvent and other product use[(a)]	NA	NA	NA	NA	NA	NA	NA	NA
4 Agriculture	NA	NA	3.7	62.9	0.092	81.9	105.6	19.2
5 Land use, land use change and forestry	26.2	6.8	0.1	2.2	0.0	0.9	29.2	5.3
6 Waste	0.0	0.0	0.8	13.9	0.002	1.6	17.6	3.2
Total net emissions	384.6	100.0	5.8	100.0	0.11	100.0	550.1	100.0

(a) No emissions are included because all emissions from the sector are NMVOCs, which are not assigned a GWP. Details of these emissions are provided in the tables for solvent and other product use in Part B.

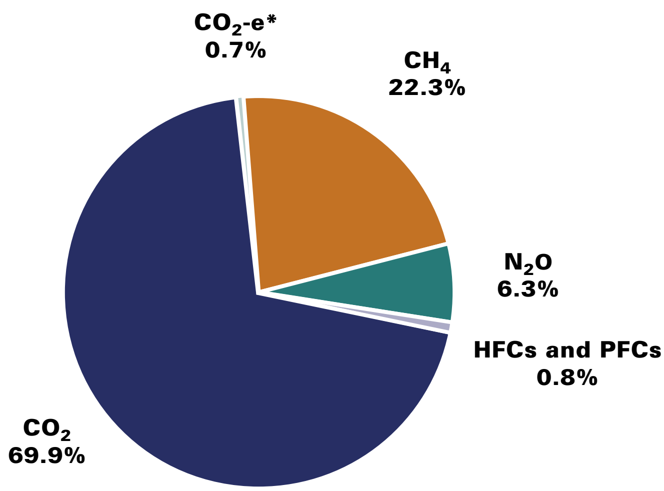
Carbon dioxide is the most important of the greenhouse gases in Australia's inventory with a share of 69.9% (384.6 Mt) of the total CO_2-e emissions, followed by methane, which comprises 22.3% (122.6 Mt CO_2-e). The remaining gases make up 7.8% (42.8 Mt CO_2-e) of Australia's greenhouse gas emissions.

Table 2. Australian net greenhouse gas emissions by gas, 2002

Greenhouse gas	Mt	GWP	Mt CO_2-e	% of total
Kyoto accounting				
CO_2	384.6	1	384.6	69.9
CH_4	5.8	21	122.6	22.3
N_2O	0.1	310	34.9	6.3
HFCs	(b)	>1,300	2.7	0.5
PFCs	(c)	>6,500	1.5	0.3
SF_6	NE	23,900	NE	NA
CO_2-e(a)	C	1	3.7(a)	0.7
Total CO_2-e	NA	NA	550.1	100.0
UNFCCC accounting				
CO_2	371.6	1	371.6	68.9
CH_4	5.9	21	124.3	23.1
N_2O	0.1	310	35.3	6.5
HFCs	(b)	(b)	2.7	0.5
PFCs	(c)	(c)	1.5	0.3
SF_6	NE	23,900	NE	NA
CO_2-e(a)	C	1	3.7(a)	0.7
NO_x	3.2	NA	NA	NA
CO	28.0	NA	NA	NA
NMVOC	2.1	NA	NA	NA
SO_2	2.3	NA	NA	NA
Total CO_2-e	NA	NA	539.2	100.0

Notes: (a) Includes confidential data on nitric acid, ammonia and magnesia production and soda ash production and use.
(b) HFC-23 (GWP = 11,700), HFC-125 (GWP = 2,800), HFC-134a (GWP= 1,300) and HFC-143a (GWP = 3,800).
(c) CF_4 (GWP = 6,500) and C_2F_6 (GWP = 9,200).

Figure 2. Contribution to total net CO_2-e emissions by gas (Kyoto accounting), 2002



*Includes confidential N_2O and CO_2 emissions from nitric acid, ammonia and magnesia production and soda ash production and use.

INDIRECT GREENHOUSE GASES

The indirect greenhouse gases NO_x, CO, NMVOC and SO_2 are reported under the UNFCCC guidelines, but as they have not been allocated global warming potentials they are not included within Australia's total aggregated emissions. The estimated emissions from these gases are shown in Table 4, but where the other greenhouses gases have been converted into CO_2-equivalents, the CO_2-equivalents for these gases are shown as NA (not applicable). Compared with 1990, there has been an increase in the emissions of NO_x CO and SO_2 (0.9 Mt (39%), 5.8 Mt (26%) and 0.7 Mt (76%) respectively) while NMVOC emissions have decreased by 0.3 Mt (12%).

2.2 EMISSION TRENDS

KYOTO ACCOUNTING

Under the Kyoto accounting rules, Australia's net emissions in 2002 were 550.1 Mt, an increase of 8.2 Mt or 1.5% over net emissions recorded in 2001. Contributing sectors to the growth in emissions over this period included increases in *stationary energy* (1.3%), transport (2.5%), *industrial processes* (2.5%), *land use, land use change and forestry* (12.6%[7]) and aspects of *agriculture* such as *savanna burning*. *Fugitive* emissions from fossil fuel extraction and distribution decreased by 6.3%.

Net emissions in 2002 were 1.3% above 1990 levels (Figure 3). The largest sectoral increase in greenhouse gas emissions over the 1990 to 2002 period, of 34.0% (66.5 Mt CO_2-e), occurred in the *stationary energy* sector, driven in part by increasing population and numbers of households. *Transport* is the next largest growth sector with an increase of 27.8% (17.2 Mt CO_2-e). The main driver for the increase in *transport* emissions is continuing growth in the ownership of private vehicles. Offsetting growth in these sectors has been a strong decline in emissions from the *land use, land use change and forestry* sector. Trends in emissions from each sector are discussed further in Chapter 3.

Of the individual greenhouse gases, net emissions of carbon dioxide decreased by 1.9% between 1990 and 2002. Methane emissions increased by 1.6%; nitrous oxide emissions increased by 47.9%; HFC emissions increased by 143.7%; and PFC and sulphur hexafluoride emissions fell by 61.7%. Annual emissions of each gas and from each sector for the years 1990 to 2002 are reported in Part C.

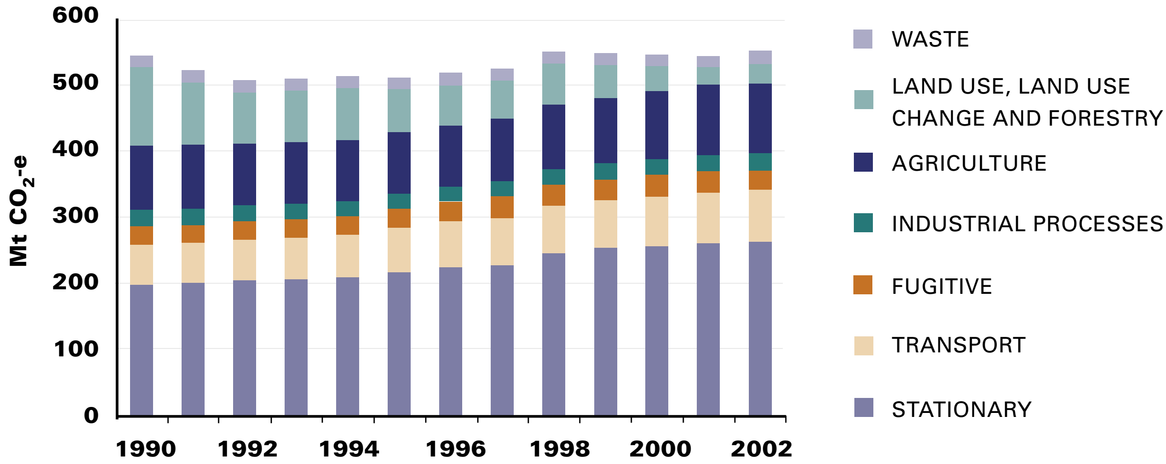
[7] This is based on interim estimates for both 2002 and 2001—see Section 3.4.

Table 3. Change in total net CO_2-e emissions by gas (Kyoto accounting), 1990–2002

Greenhouse gases	1990 Mt CO_2-e	2002 Mt CO_2-e	1990 % of Total	2002 % of Total	Changes Mt	% Change in emissions
CO_2	392.1	384.6	72.2	69.9	-7.4	-1.9
CH_4	120.7	122.6	22.2	22.3	1.9	1.6
N_2O	23.6	34.9	4.3	6.3	11.3	47.9
HFCs	1.1	2.7	0.2	0.5	1.6	143.7
PFCs and SF_6	3.9	1.5	0.7	0.3	-2.4	-61.7
CO_2-e [(a)]	1.7	3.7	0.3	0.7	2.0	115.3
Total CO_2-e	543.2	550.1	100.0	100.0	7.0	1.3

(a) Includes confidential CO_2 and N_2O data from nitric acid, ammonia and magnesia production and soda ash production and use.

Figure 3. Trends in CO_2-e emissions and removals by sector (Kyoto accounting), 1990–2002



UNFCCC Accounting

Under the inventory accounting rules for the UNFCCC, net national emissions in 2002 were 539.2 Mt CO_2-e, compared with 527.7 Mt CO_2-e in 2001 and 515.8 Mt CO_2-e in 1990. The estimated total is less than the national estimate under the Kyoto accounting provisions by 12 Mt CO_2-e because of the inclusion of additional sink or emission removal categories in the *land use change and forestry* sector. Annual emissions of each gas and from each sector for the years 1990 to 2002 are reported in Common Reporting Format Table 10 (*see* Part B).

Greenhouse Gas Emissions Intensity

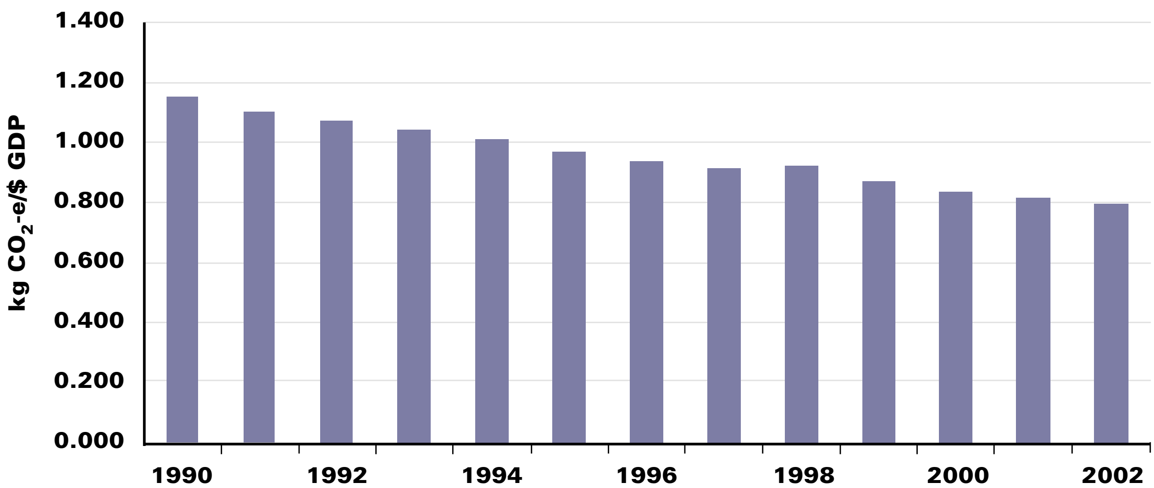
The greenhouse gas emissions intensity of the Australian economy has declined relative to 1990. Emissions per dollar of GDP were 31.1% lower in 2002 than in 1990 (Figure 4).[8] The falling trend in emissions per unit of GDP reflects both the result of specific emissions management actions across sectors and structural changes in the economy. Some of the decline relates specifically to outcomes in certain sectors. In particular, the decline in emissions from the *land use* sector contributes around one-third of the decrease in emissions

[8] In 2000–01 Australian dollars, emissions intensity fell from 1.1 to 0.8 kg CO_2-e per dollar of GDP.

intensity while the changing mix of production within the livestock industries in *agriculture* has limited emissions growth in that sector over the last 12 years. Some part of the decline is due to structural changes in the economy—whereas gross value added from the services sector was 47% higher in 2001 than in 1990, it was 18% higher from the more energy intensive *manufacturing* sector.

Australia has reduced its emissions when expressed in per capita terms over the period of 1990 to 2002 by 12.5% from 31.8 tonnes CO_2-e in 1990 to 27.8 tonnes in 2002. Australia's per capita emission level reflects a number of factors: (i) the dominance of the use of coal as a fuel in the electricity industry where, by contrast, there is no nuclear power produced and hydro-electric power options are limited; (ii) the presence of net emissions from the *land use, land use change and forestry* sector; and (iii) the impact of international trade patterns, which result in the production in Australia of many goods with high associated emission levels—that is, resource and agricultural products—that are destined for export and consumption in other countries.

Figure 4. Greenhouse gas emissions per dollar of GDP, 1990–2002



CHAPTER 3
EMISSIONS BY SECTOR

3.1 ENERGY

Total emissions from the *energy* sector for 2002 were estimated to be 371.4 Mt CO_2-e (Table 5). *Energy industries* were the main contributor, accounting for 53.8% of emissions from the *energy* sector. Other significant contributors to total *energy* emissions were *transport* (21.3%), and *manufacturing industries and construction* (11.7%).

Table 4. Energy sector CO_2-e emissions, 2002

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)				% Total net national emissions
	CO_2	CH_4	N_2O	Total (includes CO_2)	
Total net national emissions (Kyoto)	**384,640**	**122,635**	**34,850**	**550,125**	**100.0**
1 ENERGY	**340,142**	**25,786**	**5,422**	**371,350**	**67.5**
A. Fuel combustion activities (National approach)	**333,680**	**2,079**	**5,396**	**341,155**	**62.0**
1 Energy industries	**198,871**	**193**	**627**	**199,691**	**36.3**
a Electricity and heat production	181,005	164	596	181,765	33.5
b Petroleum refining	6,806	2	17	6,825	1.3
c Manufacture of solid fuels	11,059	27	14	11,101	2.1
2 Manufacturing industries and construction	**43,249**	**48**	**224**	**43,520**	**7.9**
3 Transport	**74,087**	**656**	**4,467**	**79,210**	**14.4**
a Civil aviation	5,780	5	56	5,841	1.1
b Road transportation	64,887	597	4,385	69,869	12.7
c Railways	1,818	2	16	1,836	0.3
d Navigation (domestic)	1,560	52	9	1,622	0.3
e Other transportation	42	0	0	42	0.01
4 Other sectors	**16,043**	**1,180**	**72**	**17,295**	**3.1**
5 Other	**1,431**	**1**	**7**	**1,439**	**0.3**
a Lubricants	644	NA	NA	644	0.1
b Mobile (military)	787	1	7	795	0.2
B. Fugitive emissions from fuels	**6,462**	**23,707**	**26**	**30,196**	**5.5**
1 Solid fuels	NE	17,456	NA	17,456	3.2
2 Oil and natural gas	6,462	6,251	26	12,739	2.3

Energy sector emissions increased by 29.7% (85.1 Mt) between 1990 and 2002. Emissions from the sector increased by 3.3 Mt (0.9%) from 368.0 Mt in 2001. The main contributor to the increase in emissions was *energy industries*, which contributed an additional 1.7 Mt CO_2-e (49.8%) of the increase.

3.1.1 STATIONARY ENERGY

Stationary energy principally comprises fossil fuel combustion in *electricity and heat production* and *manufacturing and construction industries.* Total estimated emissions from *stationary energy* combustion were 261.9 Mt CO_2-e in 2002, equal to 47.6% of net national emissions.

The *energy industries* subsector includes fuel combustion in electricity generation, petroleum refining, gas production and solid fuel manufacture. *Electricity and heat production* (1.A.1.a) contributed 181.8 Mt CO_2-e or 69.4% of *stationary energy* emissions in 2002. This category includes emissions from electricity generation only because heat production as defined by the IPCC does not occur in Australia. Estimated emissions from the remaining e*nergy industries* subsectors were 17.9 Mt in 2002.

The *manufacturing industries and construction* subsector (1.A.2) emissions were 43.5 CO_2-e in 2002. This subsector includes direct emissions from fuel combustion in manufacturing industries, ferrous and non-ferrous metals production, plastics production, construction and non-energy mining. These calculations do not fully reflect the greenhouse impact of these industries, as the emissions generated from the production of electricity used in these industries are included under electricity and heat production (1.A.1.a).

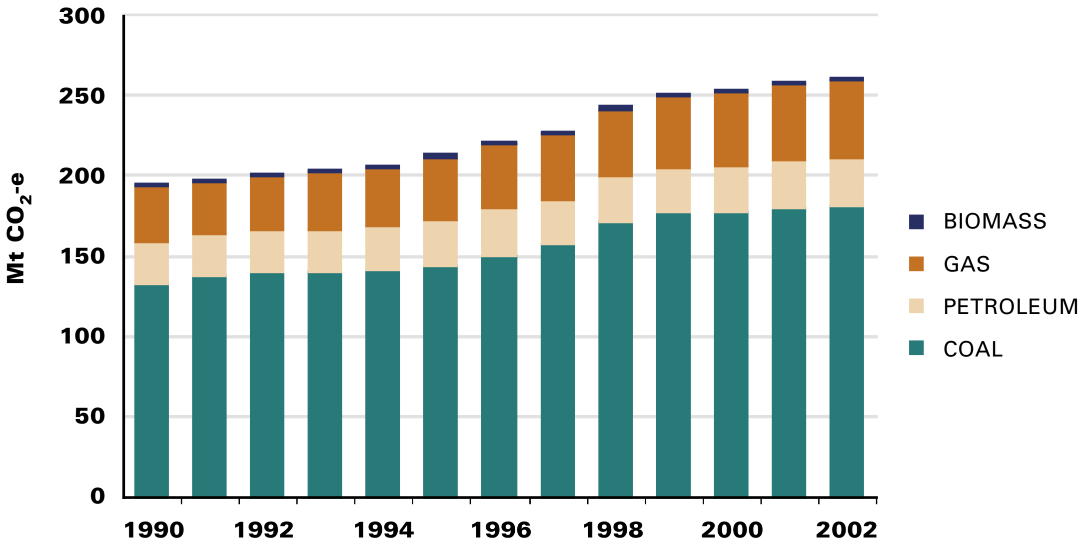
Estimated emissions from *other* sectors (1.A.4) were 17.3 Mt CO_2-e in 2002. This subsector comprises direct fuel combustion in the residential, commercial and institutional sectors, including energy used in mobile equipment in *agriculture*, *forestry* and *fishing* industries. However, as with *manufacturing*, much of the greenhouse impact of these sectors arises from their large consumption of electricity, which is not reflected in this figure alone (reported under 1.A.1.a). *Other* (1.A.5) includes emissions from *lubricants* (0.6 Mt) and *military transport* (0.8 Mt). Emissions from *lubricants* arise from the combustion of engine oil in vehicles.

The use of feedstocks within chemicals production resulted in 1.9 Mt CO_2 being stored in products such as plastics and was therefore deducted from the estimate of emissions from the *energy* sector. A further deduction of 16.3 Mt was made for CO_2 not emitted in the energy sector due to the non-energy use of fuels. Of this, 4.2 Mt CO_2 were stored in products, such as lubricants and bitumen, and 12.1 Mt CO_2 were emissions reported elsewhere in other sectors within the inventory. Coke and natural gas, used as reductants within iron and steel production, were the most significant non-energy uses of fuels, resulting in the reporting of 10.5 Mt CO_2 within the *industrial processes* sector. There is also a small use of fuels in aluminium production and the balance is reported as *fugitive* emissions.

TRENDS

Emissions from *stationary energy* increased by 34.0% (66.4 Mt) between 1990 and 2002, including an increase in emissions from coal combustion of 36.4% (48.5 Mt) in the same period (Figure 5). Although coal accounted for the highest absolute increase in emissions over this period, emissions related to natural gas have shown the largest relative growth, increasing by 43.8% (14.8 Mt) between 1990 and 2002. Emissions from oil increased by 13.9% (3.7 Mt) in the same period. The increase in coal-related emissions accounts for 73.0% of the overall increase in emissions, with gas accounting for 22.3%, oil 5.6% and biomass decreasing 0.8%. Between 2001 and 2002 emissions from *stationary energy* increased by 1.3% (3.4 Mt).

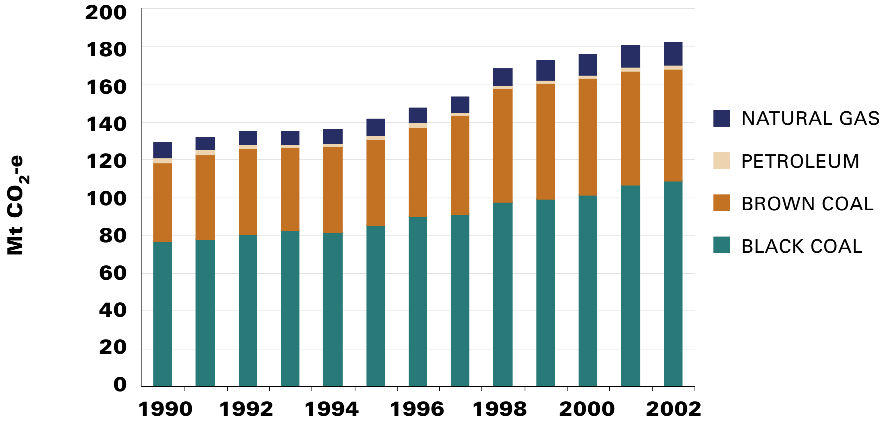
Figure 5. Total CO_2-e emissions from stationary energy combustion by fuel, 1990–2002



Electricity generation emissions increased by 1.3 Mt (0.7%) from 2001 to 2002, and by 52.7 Mt (40.8%) from 1990 to 2002 (Figure 6). The 2001 to 2002 *electricity generation* emissions increase was slightly less than the increase in fuel use. Underpinning these changes were shifts in the fuel mix – although the coal share of total fuel use increased slightly from 87.4% to 87.5%, the share of brown coal of the total coal use declined from 35.8% to 35.0%. Natural gas share of total fuel use declined from 10.8% to 10.6%. These changes in fuel mix drove a 1.3% decrease in overall emissions intensity of electricity consumed, from 0.973 kg CO_2-e/kWh in 2001, to 0.961 kg CO_2-e/kWh for 2002.

Emissions from *stationary energy* subsectors, other than *electricity*, increased by 2.1 Mt (2.7%) between 2001 and 2002, and increased overall by 13.8 Mt (20.8%) from 1990 to 2002. Emissions from the *manufacturing industries and construction* subsector increased 2.9% (1.2 Mt) between 2001 and 2002, and by 15.7% (5.9 Mt) from 1990 to 2002.

Figure 6. CO_2-e emissions from electricity generation by fossil fuels, 1990–2002



Note: the inventory also reports small quantities of biofuel (wood, bagasse and landfill gas) use, but these accounted for less than 0.03% of electricity generation sector emissions.

Methodology

As in previous years, emissions from the *stationary energy* sector's combustion of fossil fuels were estimated using a Tier 2 approach. Country-specific approaches have been used in all cases where they are seen to be more accurate than the IPCC default emission and oxidation factors or methodologies. The sequestration of feedstocks has been accounted for using data obtained directly from various companies or through application of IPCC defaults. Non-CO_2 emission factors have been calculated using a sectoral equipment-weighted average approach.

A full description of the methodologies and emission factors is presented in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Energy (Stationary Sources)* (NGGIC 2004a), which is an edited compilation of the methodologies described in *Fuel Combustion Activities (Stationary Sources)*, Workbook 1.1 (NGGIC 1998a), and the 1995–2002 supplements (NGGIC 1996, 1997b, 1998, 1999; AGO 2000, 2001).

The main source of activity data used for the 2002 inventory report is the national survey of energy consumption by industry sector and fuel type, compiled by the Australian Bureau of Agricultural and Resource Economics (ABARE). The data used for 2002 were modelled estimates using ABARE's *Australian Energy: National and State Projections to 2019–20* (Dickson et al. 2003). Supplementary data is obtained from various other sources including Australian power generator and chemical manufacturing companies, expert consultants, and the Australian Gas Association.

Recalculations since the 2001 Inventory

Previous inventories from 1990 to 1994 were recalculated due to a minor inclusion of incorrect fuels within 1.A.5.a. *Lubricants*. The estimate for 2001 was recalculated due to revised values for brown coal consumption for *electricity generation*. The revision resulted in a reduction in emissions from *electricity production* from 181,420 Gg CO_2-e to 180,470 Gg CO_2-e in 2001.

3.1.2 TRANSPORT

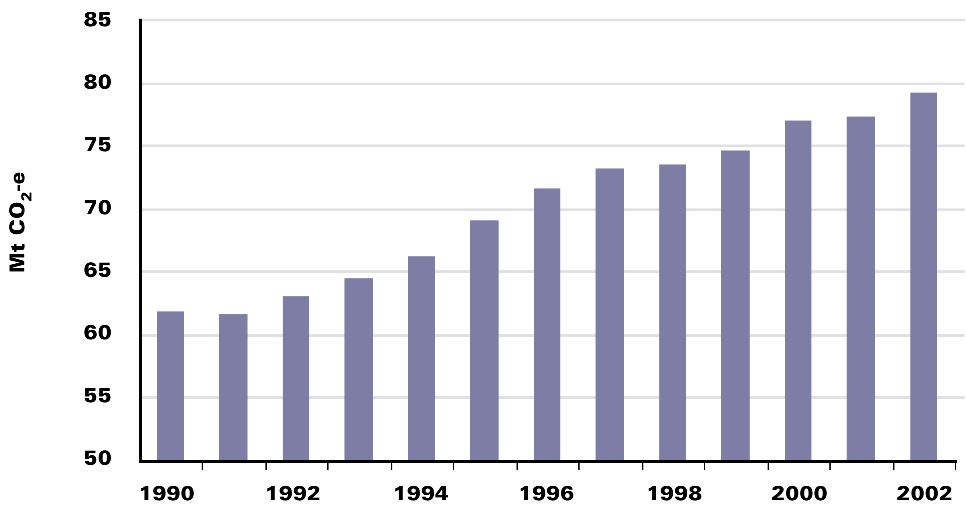
In 2002 *transport* contributed 79.2 Mt CO_2-e or 14.4% of Australia's net emissions. Of these emissions, 88.2% (69.9 Mt) arose from *road transportation*, of which 62.2% (43.5 Mt) were from *passenger cars*. *Domestic aviation* contributed 7.4% (5.8 Mt), *domestic navigation* 2.0% (1.6 Mt), and *railways* 2.3% (1.8 Mt)—not counting the emissions from generating the electricity used by rail, which are included in the *stationary energy* sector emissions.

Fuel used in *international transport* (*international aviation* and *marine 'bunkers'*) is by international agreement reported separately from the national total net emissions. In 2002, international bunker fuels generated 11.2 Mt of emissions.

Trends

Transport emissions increased by 27.8% on the 1990 level, and increased by 2.5% on the 2001 level (Figure 7). Over this period *transport* emissions increased by about 2.1% annually, making this one of the fastest growing source of emissions of the inventory.

Figure 7. Total transport emissions, 1990–2002



Emissions from *road transportation* increased by 27.3% (15.0 Mt) between 1990 and 2002, and increased by 2.5% (1.7 Mt) from 2001 to 2002 (Figure 7). Between 1990 and 2002 emissions from *passenger cars* increased from 34.2 Mt to 43.5 Mt, an increase of 27.1% (9.3 Mt).

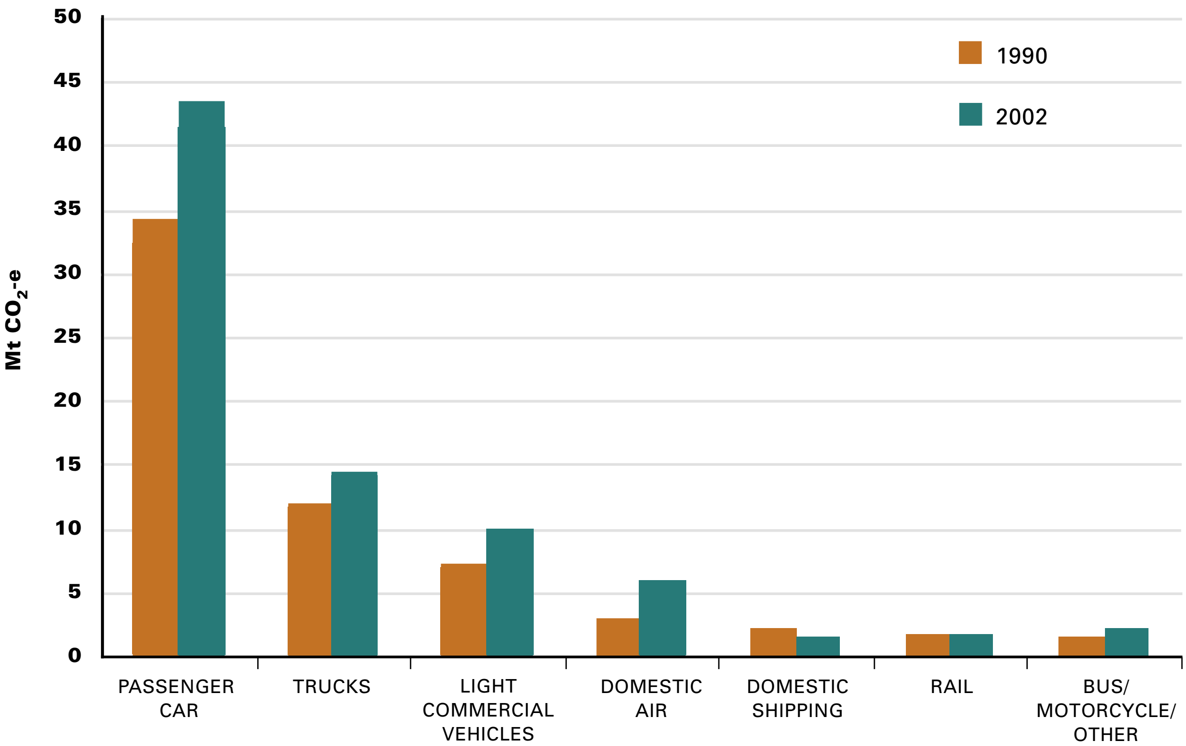
Estimates of *civil aviation* (*domestic air transport*) emissions were 5.5% (0.3 Mt) higher in 2002 than in 2001 and 99.0% (2.9 Mt) higher than the 1990 level.

Emissions from *domestic shipping* (*navigation*) in 2002 were 31.4% (0.74 Mt) lower than in 1990, and 1.6% (0.03 Mt) lower than in 2001. Large year-to-year fluctuations occur in emissions from this subsector and they are driven mostly by changes in activity. A number of factors influence navigation activity including fuel price variations from country to country and the proportion of domestic freight transported by international ships.

Transport emissions are mostly CO_2 (93.5%), with only small amounts of CH_4 (0.8%) and N_2O (5.6%). The proportion of N_2O in *transport* emissions increased from 2.7% in 1990 to

5.6% in 2002. This is due mainly to the increasing proportion of passenger vehicles equipped with three-way catalytic converters.

Figure 8. Comparison of transport emissions by subcategory, 1990–2002



Methodology

The methodologies for estimating CO_2 emissions from *transport* are based on the IPCC Tier 1 approach using country-specific emission factors. Non-CO_2 gas emissions from the *civil aviation* category and *passenger car* subcategory are estimated using the IPCC Tier 2 approach and country-specific emission factors, except for N_2O where IPCC default factors are used. The non-CO_2 emissions from other transport source categories are estimated using the IPCC Tier 1 approach with a mixture of country-specific and international emission factors. A full description of the methodologies and emission factors is presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Energy (Transport)* (NGGIC 2004b), which provides an edited compilation of the methodologies described in the *Workbook for Transport 3.1* (NGGIC 1998b) and the supplements in the 1995, 1996, and 1999 to 2001 inventories (NGGIC 1996, 1997b, 1998; AGO 2001, 2002).

The main sources of data are ABARE's *Australian Energy: National and State Projections to 2019–20* (Dickson et al. 2003); the Department of Industry, Tourism and Resources monthly series *Sales of Petroleum Products by State Marketing Area*, and AVSTATS' *Air Transport Statistics Airport Traffic Data* (DOTARS 2002).

No special methodology is required to disaggregate international and domestic aviation and navigation fuel consumption. In Australia, data on international and domestic fuel consumption are collected separately due to the differential excise tax placed on the fuel. Petroleum companies collect and report these data to the Department of Industry, Tourism and Resources.

Recalculations since the 2001 Inventory

Fuel consumption rates were revised to estimate emissions from the *road transport* subsector. These were obtained from the 2001 *Australian Transport Facts* (ACG 2003) provided to the Australian Transport Energy Data and Analysis Centre.

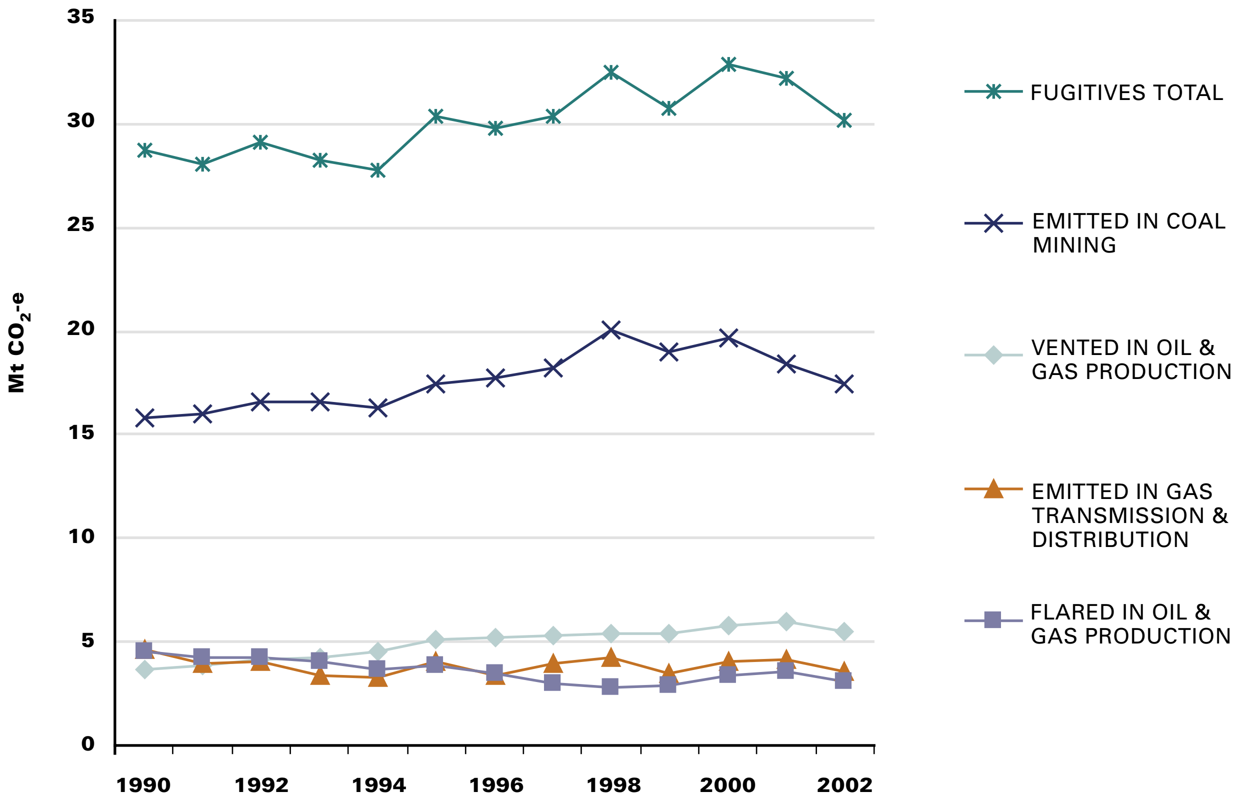
3.1.3 Fugitive Emissions Subsector

Total estimated *fugitive emissions* for 2002 were 30.2 Mt CO_2-e, representing 5.5% of net national emissions. Net *solid fuel* emissions, all of which are associated with coal mining and handling, contributed 57.8% (17.5 Mt) of *fugitive* emissions. *Oil and natural gas production, processing and distribution* account for the remaining 42.8% (12.7 Mt) of *fugitive* emissions.

Trends

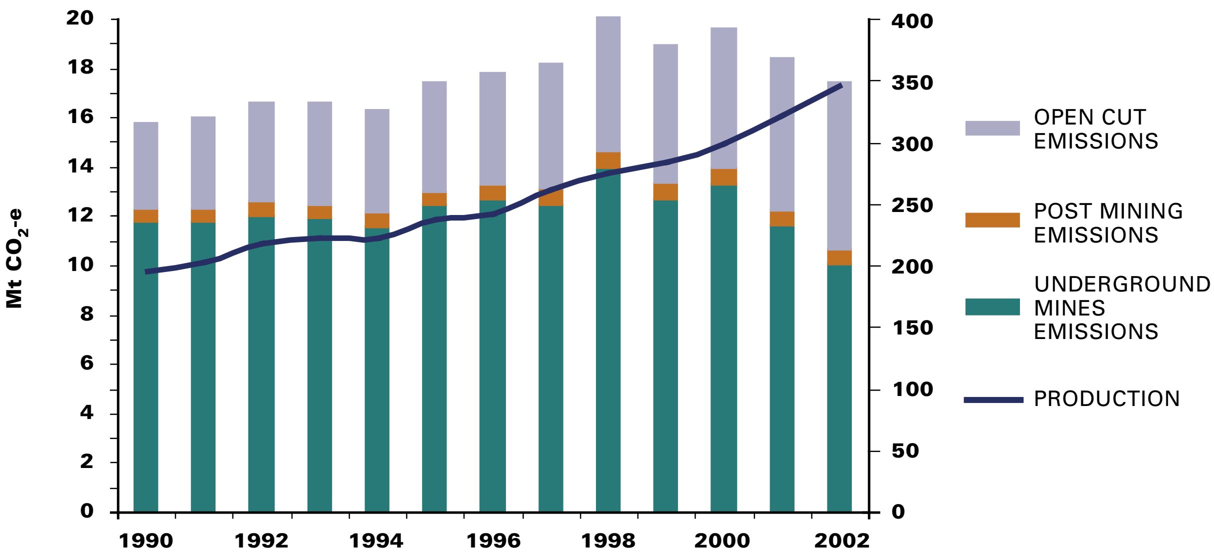
Overall *fugitive* emissions increased by 5.0% (1.4 Mt) between 1990 and 2002, and decreased by 6.3% (2.0 Mt) from 2001 to 2002 (Figure 9). From 2001 to 2002 fugitive emissions from *solid fuels* decreased by 1.0 Mt (5.4%) and *oil and natural gas* emissions decreased by 7.5% (1.0 Mt).

Figure 9. CO_2-e fugitive emissions by category, 1990–2002



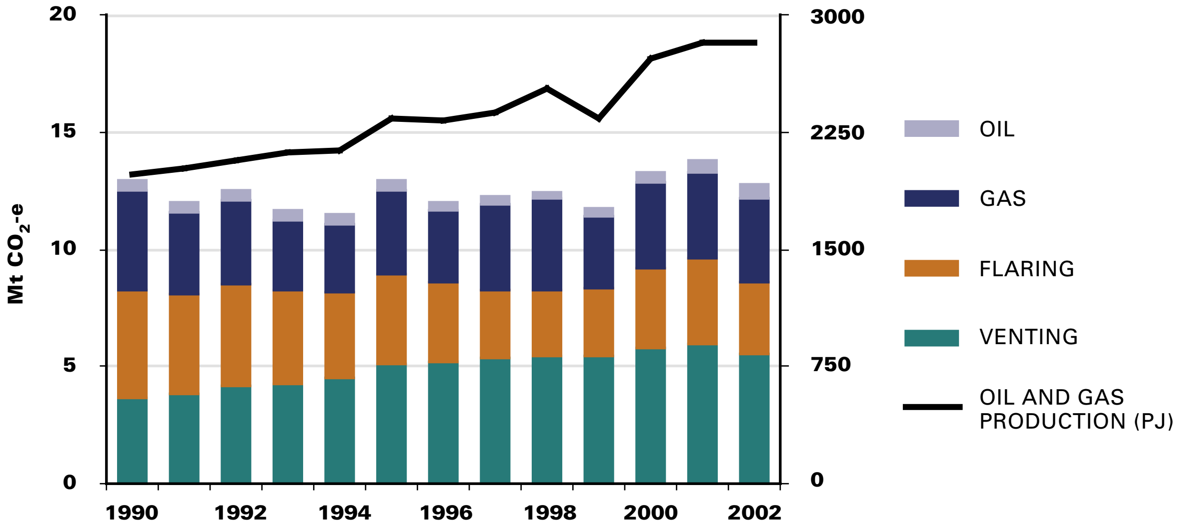
Solid fuel emissions increased by 10.4% (1.6 Mt) between 1990 and 2002. Emissions tend to fluctuate from year to year, depending on the volume of coal mined and the share of gassy underground mines in total production. Emissions from *coal mining* have increased up to 1998, then declined (Figure 10). Mine production of coal has increased from 195 Mt in 1990 to 345 Mt in 2002, an increase of 77%. Since 1990, methane emissions have not grown as fast as activity and, since 1998, there has been a decrease in emissions reflecting a decrease in Class A (gassy) mines and growth in Class B (non-gassy) mines and surface mines. In addition, technologies to recover and utilise or flare CH_4 have been adopted in an increasing number of mines.

Figure 10. Fugitive CO_2-e emissions from coal mining, 1990–2002



Oil and natural gas fugitive emissions decreased by 1.6% (0.2 Mt) between 1990 and 2002 (Figure 11). This compares with a 43% increase in production activity. The small rise in emissions relative to the increase in activity is the result of improvements in gas distribution and a reduction in the emissions from flaring. Between 2001 and 2002, emissions from oil-related activities increased by 8.4% (0.1 Mt) and emissions from gas-related activities decreased by 2.4% (0.1 Mt). Emissions from venting decreased by 7.7% (0.5 Mt) from 2001 to 2002 although, compared with 1990, emissions were higher by 49.2% (1.8 Mt). Flaring-related emissions decreased by 14.5% (0.5 Mt) from 2001 to 2002 consistent with a longer-term trend. Emissions were lower than 1990 levels by 32.5% (1.5 Mt).

Figure 11. Fugitive CO_2-e emissions from oil and gas production, 1990–2002



METHODOLOGY

Methane emissions from *coal mining* are based on a country-specific Tier 2 approach where the emission factors (m^3 CH_4/tonne coal produced) are based on measurement from Australian mines. Emissions from venting and flaring, the other significant emissions source in this sector, are based on emissions estimates reported by the Australian Petroleum Production and Exploration Association. *Flaring* emissions are estimated using country-specific emission factors applied to a measured activity parameter (volume flared). *Venting* emissions are reported from measured data. Emissions from *natural gas* are based on country-specific emission factors and activity data derived from statistics published by the Australian Gas Association. A full description of the methodologies and emission factors is presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Energy (Fugitive Emissions)* (NGGIC 2004c), which provides an edited compilation of the methodologies described in the *Workbook for Fugitive Fuel Emissions 2.1* (NGGIC 1998c) and the supplements in the 1995 to 2001 Inventories (NGGIC 1996, 1997b, 1998, 1999; AGO 2000, 2001, 2002).

The main sources of data are the Australian Petroleum Production and Exploration Association Greenhouse Challenge submissions (<http://www.appea.com.au>), the Australian Gas Association's *Australian Gas Statistics* annual series, and the Department of Industry Tourism and Resources monthly series, *Australian Petroleum Statistics*.

RECALCULATIONS SINCE THE 2001 INVENTORY

Nil.

3.2 INDUSTRIAL PROCESSES

Total net emissions estimated from *industrial processes* were 26.4 Mt CO_2-e in 2002, or 4.8% of net national emissions (Table 5).

Greenhouse gas emissions from *industrial processes* are a by-product of various production processes. For example, high temperature processing of calcium carbonate to produce quicklime gives rise to CO_2 emissions. The main determinant of *industrial processes* emissions from year to year is the quantity of the relevant product that is produced.

Table 5. Industrial processes sector CO_2-e emissions, 2002

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)					%Total net national emissions
	CO_2	CH_4	N_2O	HFC/PFC /SF_6	Total	
Total net national emissions (Kyoto)	384,640	122,635	34,850	4,252	550,125	100.0
2 INDUSTRIAL PROCESSES	**18,297**	**65**	**20**	**4,252**	**26,382**	4.8
A Mineral products	5,180	NE	NE	NA	5,180	0.9
B Chemical industry[(a)]	C	8	C	NA	3,756	0.7
C Metal production	13,118	57	20	1,507	14,702	2.7
D Other production	NE	NA	NA	NA	NE	NA
E Production of halocarbons and sulphur hexafluoride	NO	NO	NO	NO	NO	NA
G Consumption of Halocarbons and sulphur hexafluoride	NA	NA	NA	2,744	2,744	0.5

(a) Includes confidential emissions from soda ash production and use, magnesia production, nitric acid production and ammonia production, and emissions of CH_4 from polymers and other chemicals. Disaggregated emissions are confidential.

Metal production contributed 55.7% (14.7 Mt CO_2-e) of the sector's emissions, *mineral products* contributed 19.6% (5.2 Mt CO_2-e), *chemical industries* contributed 14.2% (3.8 Mt CO_2-e), and the *consumption of halocarbons* (HFCs) contributed 10.4% (2.7 Mt CO_2-e).

Metal production emissions are mostly attributable to iron and steel production with 71.6% (10.5 Mt CO_2-e), and aluminium smelting with 28.4% (4.2 Mt CO_2-e). Cement (clinker) production accounted for 63.5% (3.3 Mt CO_2-e) of emissions from *mineral products*, followed by lime production at 20.8% (1.1 Mt CO_2-e), and limestone and dolomite use at 15.6% (0.8 Mt CO_2-e). Magnesia production data and emissions are confidential and are included with the confidential emissions reported.

Activity data for soda ash production and use, magnesia production, nitric acid production and ammonia production are commercial-in-confidence and due to the direct relationship between activity and emissions, emissions estimates by gas species are also confidential. These emissions are aggregated and reported as CO_2-e emissions. Total emissions from this subsector are 3.7 Mt CO_2-e.

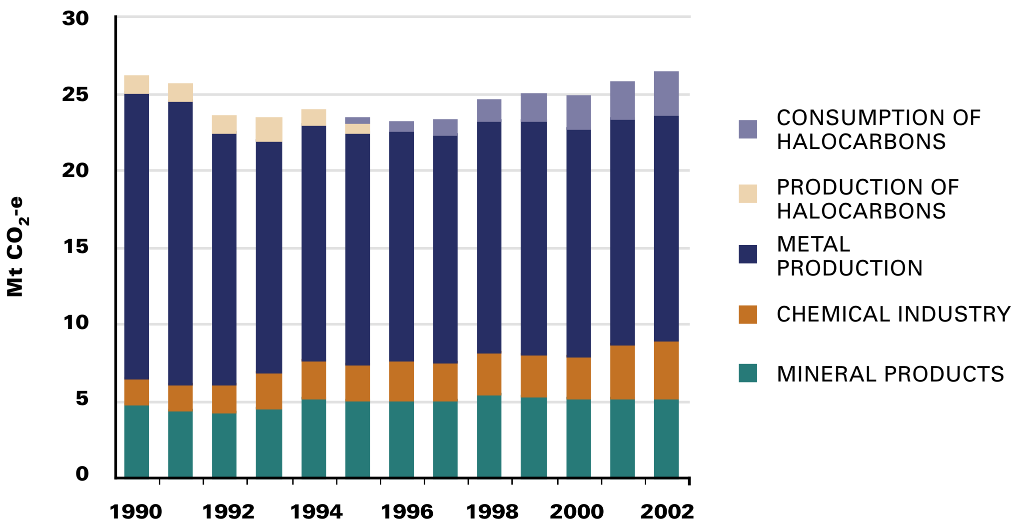
The main gas emitted by *industrial processes* is carbon dioxide, contributing 69.4% (18.3 Mt) of the sector's emissions in 2002. PFCs contributed 5.7% (1.5 Mt), HFCs contributed 10.4% (2.7 Mt), nitrous oxide contributed 0.1% (0.02 Mt), and methane 0.3% (0.06 Mt). CO_2-e emissions from the subsectors where data are confidential contributed 14.2% (3.7 Mt).

Trends

Net emissions from *industrial processes* increased by 0.9% (0.25 Mt CO_2-e) from 1990 to 2002, and increased by 2.5% (0.65 Mt CO_2-e) from 2001 to 2002 (Figure 12).

Net emissions from *mineral products* increased by 8.7% (0.42 Mt CO_2-e) from 1990 to 2002 due to increased production of cement clinker and lime. From 2001 to 2002, net emissions increased by 0.4% (0.02 Mt CO_2-e) as a result of an increase in lime production.

Figure 12. Emissions from industrial processes by subsector, 1990–2002



Net emissions from *metal production* declined by 20.5% (3.8 Mt CO_2-e) from 1990 to 2002 despite an increase of 46.5% in aluminium production. This was due to a 61.7% (2.4 Mt CO_2-e) reduction in perfluorocarbon (PFC) emissions from aluminium smelting as a result of technological improvements in process control and monitoring, and a 26.6% (3.4 Mt CO_2-e) fall in emissions from crude steel production. These reductions have been partly offset by growth in emissions of CO_2 from aluminium production and hot briquetted iron production. From 2001 to 2002, net *metal production* emissions decreased by 0.3% (0.04 Mt CO_2-e).

HCFC-22 was produced in Australia from 1990 to 1995 and the fugitive emissions of HFC-23 from this production peaked at 1.4 Mt CO_2-e in 1993 before declining to zero, in 1996, when HCFC-22 production ceased. The use of HFCs in refrigeration and air conditioning equipment commenced in 1994, and estimated emissions from this source have increased to 2.7 Mt.

Methodology

The methodologies used to estimate emissions associated with each industrial process are consistent with the IPCC approach. Generally the methods involve the product of activity level data (the amount of material produced or consumed) and an associated emission factor per unit of production or consumption. Country-specific emission factors are used where available.

Emissions of HFCs from refrigeration and air conditioning are estimated using equipment based models that are consistent with IPCC Tier 2a methodologies (Burnbank Consulting 2002).

The *Ozone Protection and Synthetic Greenhouse Gas Management Act* (2003) includes provisions for Montreal Protocol industries to report bulk imports of HFCs and PFCs and quantities of HFCs and PFCs in pre-charged equipment. Methodologies are currently being developed to convert these potential data into actual emissions estimates for inclusion in future inventories.

A full description of the methodologies and emission factors is presented in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002*: *Industrial Process Emissions* (NGGIC 2004d), which provides an edited compilation of the *Workbook for Industrial Process Emissions 7.1*.(NGGIC 1998d) and the supplements in the 1995, 1996, 1997, 2000 and 2001 inventories (NGGIC 1996, 1997b, 1998, 1999; AGO 2002).

The main sources of data are the Cement Industry Federation, National Lime Association and the majority of companies involved in lime production, Wesfarmers, Orica (Incitec), Queensland Nitrates, Australian Aluminium Council, BlueScope Steel, OneSteel, Qmag, Causmag, companies producing polymers and other chemicals, and ABARE's *Australian Commodity Statistics 2001* (ABARE 2002b).

Recalculations since the 2001 Inventory

There have been several inclusions of additional sources of emissions since the 2001 inventory. Emissions from magnesia production for the years 1990 to 2002 are included for the first time. Two companies producing magnesia have provided complete time series data. Data are confidential and emissions are included with other confidential emissions. Production data from an additional nitric acid plant, which had not previously been accounted for, has been obtained for all years for which the plant has been in operation. Emissions from polymers and other chemicals have been estimated for the first time in the 2002 inventory. Complete time series data were obtained for the production of butadiene, carbon black, ethyl benzene, ethylene, ethylene oxide, formaldehyde, HDPE, LDPE, LLDPE, propylene, polypropylene, polystyrene, styrene, polyvinyl chloride, and styrene butadiene rubber.

3.3 AGRICULTURE

Agriculture produced an estimated 105.6 Mt CO_2-e emissions or 19.2% of net national emissions in 2002 (Table 6). The *agriculture* sector is the dominant national source of both methane and nitrous oxide—accounting for 62.8% (77.1 Mt CO_2-e) and 82.1% (28.6 Mt CO_2-e) respectively of the net national emissions for these two gases. These emissions principally consisted of methane from *livestock, manure management and savanna burning*, and nitrous oxide from *manure management*, *savanna burning* and *agricultural soils* (the cultivation of agricultural soils, the use of nitrogen fertilisers on crops and improved pastures, and faecal and urine deposition from grazing animals onto pasture).

Greenhouse gas emissions from *livestock,* which is the sum of the *enteric fermentation and manure management* subsectors, declined by 2.8% (1.9 Mt) between 1990 and 2002, including a 0.7% (0.4 Mt) decrease in emissions from 2001 to 2002. In contrast, there has been a 48.7% (12.5 Mt) increase in emissions from the remaining *agriculture* subsectors between 1990 and 2002. The net result of these trends is an increase of 11.1% (10.5 Mt) in greenhouse gas emissions from *agriculture* between 1990 and 2002, and a 0.3% (0.4 Mt) increase from 2001 to 2002.

Table 6. Agriculture sector CO_2-e emissions, 2002

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)				**%Total net national emissions**
	CO_2	CH_4	N_2O	Total	
Total net national emissions (Kyoto)	384,640	122,635	34,850	550,125	100.0
4 AGRICULTURE		**77,115**	**28,529**	**105,644**	**19.2**
A Enteric fermentation		64,230		64,230	11.7
B Manure management		2,006	1,376	3,382	0.6
C Rice cultivation		591		591	0.1
D Agricultural soils		NE	19,471	19,471	3.5
E Prescribed burning of savannas		10,015	7,567	17,583	3.2
F Field burning of agricultural residues		274	114	388	0.1

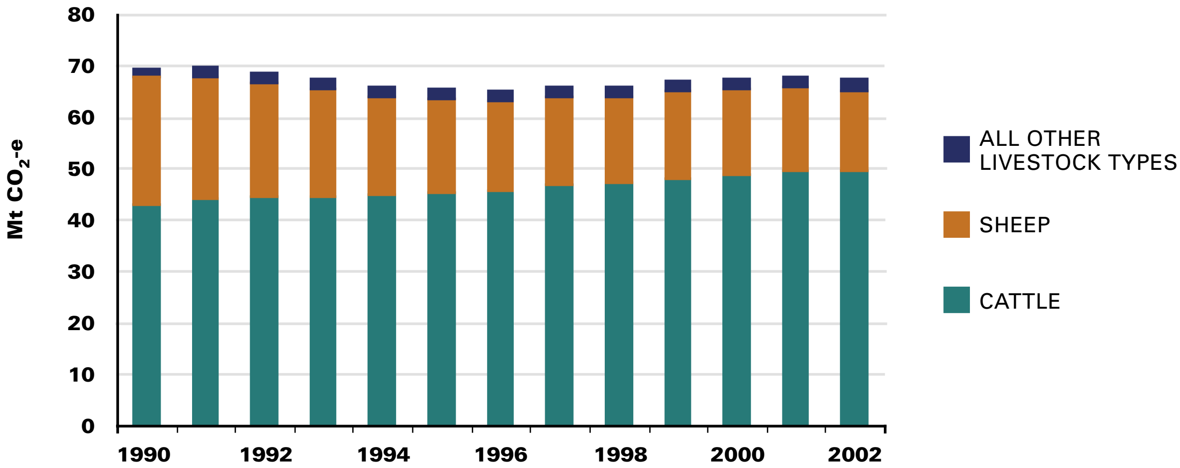
3.3.1 LIVESTOCK

Livestock emissions were 67.6 Mt CO_2-e in 2002, which represents 64.0% of the *agriculture* sector's emissions and 12.3% of net national emissions.

TRENDS

Livestock related emissions in 2002 were 2.8% (1.9 Mt) lower than in 1990 and 0.4 Mt CO_2-e (0.7%) lower than in 2001 (Figure 13). Between 1990 and 2002, cattle numbers have gradually increased from 24.8 million to 27.8 million (12%). This growth in cattle numbers is tending to drive up livestock emissions, particularly as emissions per head from cattle are about 12 times that per head of sheep. Against this trend, sheep numbers, after having peaked in 1990 at 170 million, have declined to 106 million (-38%) in 2002 due largely to reduced returns to the industry. The combined effect of these two trends is that *livestock* emissions peaked in 1991, declined between 1991 and 1996 and have grown steadily since. The slight drop in emissions between 2001 and 2002 is a result of stable cattle numbers and the continuing decline in the sheep population, but it is too early to interpret this as a reversal of the upward trend in light of the widespread drought conditions in this period.

Figure 13. CO_2-e emissions from livestock, 1990–2002



Methodology

Methane emissions from *enteric fermentation* are estimated using a country-specific Tier 2 approach for cattle (dairy, feedlot and free-range), sheep and pigs. These *livestock* classes produce over 99% of the national greenhouse emissions from *livestock*. Emissions are estimated based on feed intake, which is calculated from information on liveweights, liveweight gain, milk or wool production and feed digestibility.

A Tier 1 approach using both country-specific and IPCC default emission factors is used to estimate *enteric* methane emissions for all other livestock classes, such as horses, goats, buffalo, deer, emu and alpaca. These are a small component (less than 1%) of the national *livestock* emissions.

Emissions from *manure management* are calculated using the IPCC Tier 2 approach and they are based on an estimate of the volatile organic fraction of manure, the potential capacity of this material to produce methane, and the fraction of this potential likely to be realised in the management systems used in Australia. Nitrogen excretion in urine and faeces is calculated for cattle and sheep using a simple nitrogen balance technique, whilst swine excretion rates are based on an industry nutrient balance model. Emissions of nitrous oxide are a function of this excretion, the manure management systems used, and the IPCC default emission factors.

A full description of the methodologies and emission factors are presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Agriculture* (NGGIC 2004e), which includes the methodology presented in the *Workbook for Livestock 6.2* (NGGIC 2003).

The main sources of data are: the Australian Bureau of Statistics for most livestock numbers and for wool production, the Australian Lotfeeders Association for feedlot animal numbers (<http://www.lotfeeders.com>), and industry statistics for milk production (<http://www.dairycorp.com.au>).

RECALCULATIONS SINCE THE 2001 INVENTORY

One minor modification was made to methods for the 2002 inventory relating to calculation of numbers of animals on feedlots. Previously numbers of animals were calculated from the numbers of animals on feed from data provided by the Australian Lotfeeders Association (ALFA) following the procedure in the *Workbook for Livestock 6.2* (NGGIC 2003). Since 1998, ALFA have reported animals turned off. This, in combination with the proportion of animals destined for the different markets allows a more direct calculation of the number and characteristics of animals for inventory calculations from 1998 onwards. A 'year-equivalent' is calculated for each market class (i.e. Japan Ox, domestic market) by using the estimated number of days on feed in the feedlot for different market segments.

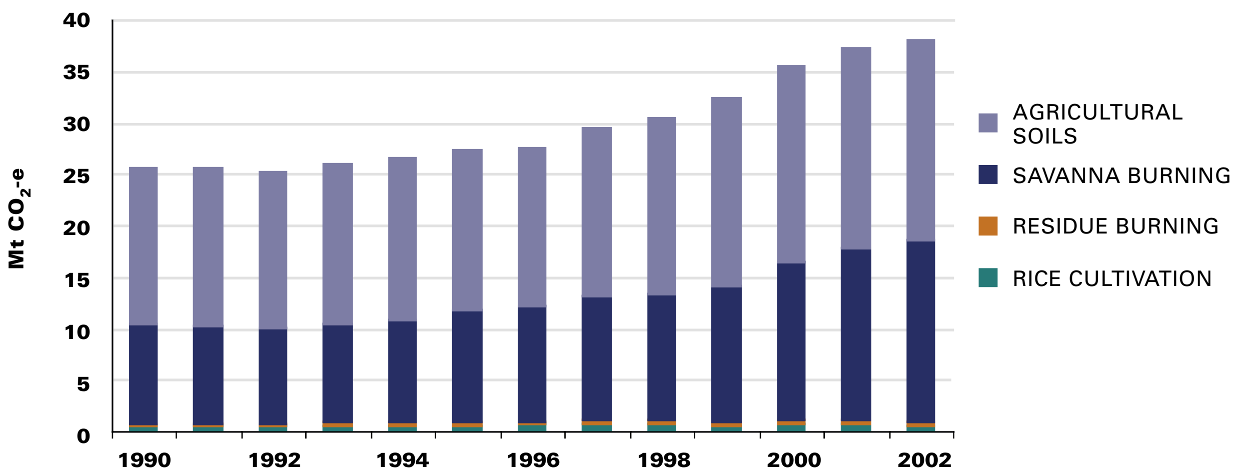
3.3.2 OTHER AGRICULTURE

Total estimated emissions from the *other agriculture* subsectors in 2002 were 38.0 Mt CO_2-e. These include emissions from *rice cultivation* (0.6 Mt), *agricultural soils* (19.5 Mt), *prescribed burning of savannas* (17.6 Mt) and *field burning of agricultural residues* (0.4 Mt) (*see* Table 6).

TRENDS

Emissions from agricultural land cultivation and burning of savanna and crop residues in 2002 were 48.7% (12.5 Mt) higher than in 1990 and 2.2% (0.8 Mt) higher than in 2001. The increase is principally a result of an increase in the reported savanna area burnt, but this is partly offset by the significant reduction in land under rice cultivation because of the prolonged and widespread drought over south-eastern Australia restricting the water available for irrigation.

Figure 14. Total emissions of other agriculture subsectors, 1990–2002



Reported estimates currently indicate an 81.9% (7.9 Mt) increase in emissions *from savanna burning* between the years of 1990 to 2002. However, the methodology for estimating the area burnt by fires is not necessarily consistent throughout this period—satellite imagery has been used exclusively in the later years and only on a limited basis in the early 1990s. The AGO is undertaking a project to develop a consistent time series of fire scar data from satellite images collected in the period of interest to determine the extent to which this apparent growth in emissions is an actual trend or whether to some extent it reflects an artefact of the methodology. Expert opinion is that fires seem to be no more frequent or widespread now than they have been historically.

Emissions from *agricultural soils* in 2002 are 28.6% (4.3 Mt CO_2-e) higher than in 1990. This trend is a result of increased areas under cropping, the increased rate of fertiliser application and increases in the numbers of livestock carried, and particularly free-range cattle.

METHODOLOGY

The methodologies, emission factors and other parameters used to compile emissions from the other (non-livestock) agriculture subsectors are largely country-specific, sourced principally from Australian studies. A full description of the methodologies and emission factors is presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Agriculture* (NGGIC 2004f), which provides an edited compilation of the methodologies described in the *Workbook for Non-Carbon Dioxide Gases from the Biosphere 5.1* (NGGIC 1998f) and the supplements in the 1996, 1997, 1999 and 2000 Inventories (NGGIC 1996, 1998, 1999; AGO 2001, 2002).

Emissions from *rice cultivation* (4.C) are estimated using the IPCC Tier 2 methodology and a country-specific emission factor. The methodologies for *prescribed burning of savannas* (4.E), and *field burning of agricultural residues* (4.F) closely correspond to the IPCC Tier 2 methodologies but with modifications relevant to Australian conditions and the availability of relevant data.

Agricultural soils (4.D) emissions are estimated using country-specific methods and emission factors. The estimated emissions from synthetic fertiliser application, nitrogen input from manure applied to soils and excretion of nitrogen on pasture range and paddock correspond directly to the equivalent IPCC source categories. The emission of N_2O from soil disturbance is a country-specific category that accounts empirically for emissions associated with crop residues, nitrogen fixation, soil cultivation and atmospheric nitrogen deposition. It is defined as the difference between the annual emission rates from crop and pasture soils in the absence of direct inorganic and animal fertiliser application and the N_2O emissions from soils of the pristine ecosystems they replaced. The emission factor for this subsector is derived from Australian field studies in the wheat belt of Western Victoria, and the grazing systems of the Riverina. The *soil disturbance* category includes emissions from a number of IPCC categories; however, there is currently no reliable method to disaggregate them.

The main sources of data are the Australian Bureau of Statistics Agricultural Survey and Agricultural Census, Agricultural Industry Associations (Australian Rice Growers Association, the Australian Canegrowers Association, NSW Canegrowers Association, the Fertiliser Industry Federation of Australia), and the state government authorities responsible for fire control in private land, state forests, crown land, and national parks.

RECALCULATIONS SINCE THE 2001 INVENTORY

Emissions for the most recent year in the *agriculture* sector are recalculated each year due to the recalculation of the three-year average of emissions once the third year of data becomes available. In addition, data for the area of savanna burnt have been reanalysed and revised as a result of overlaps in past analyses of data covering the wet and dry seasons.

3.4 Land Use Change and Forestry

3.4.1 Kyoto Accounting

According to the Kyoto accounting provisions, *land use, land use change and forestry* activities constituted an estimated net source of 29.2 Mt in 2002, representing 5.3% of the net national emissions (Table 7).

For Australia's Kyoto target, the treatment of emissions from land use change activities (deforestation) is the same as reported for inventory accounting under the UNFCCC—*see* subsector 5.B *Forest and grassland conversion* in section 3.4.2.

Under Kyoto accounting, reforestation activities (plantations established since 1990) are estimated to have sequestered approximately 13.0 Mt of CO_2 in 2002, an estimated increase of 1.9 Mt from 2001. Strictly speaking, under Kyoto target rules the greenhouse sinks credits are accounted for in 2008–12 only. However, their inclusion in the 2002 inventory account facilitates an understanding of Australia's emissions trends in relation to the 108% Kyoto target.

Table 7. Land use, land use change and forestry net CO_2-e emissions, 2002 (Kyoto accounting)

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)				%Total net national emissions
	CO_2	CH_4	N_2O	Total	
Total net national emissions (Kyoto)	384,640	122,635	34,850	550,125	100.0
5 LAND USE, LAND USE CHANGE AND FORESTRY[(a)]	**26,185**	**2,651**	**323**	**29,159**	**5.2**
Afforestation and reforestation	–12,979			–12,979	-2.3
Land use change (deforestation)	39,164	2,651	323	42,138	7.5

(a) A negative sign denotes a sink. (b) The results for deforestation for 2000 and 2001 will increase when areas of deforestation are confirmed following the next update of estimates using the National Carbon Accounting System. The 2002 estimate is an average of the 2000 and 2001 estimates.

3.4.2 UNFCCC Accounting

According to the UNFCCC accounting provisions the net emissions from the *land use change and forestry* sector were 18.2 Mt CO_2-e in 2002 (Table 8). The subsectors included in *land use change and forestry* are *changes in forest and other woody biomass stocks* (5A), *forest and grassland conversion* (5B), *CO_2 emissions and removals from soil* (5D) and *other* (5E).

Forest and other woody biomass stocks (5A) comprises emissions and removals from changes in managed native forests, plantations, commercial harvest, and fuelwood consumption. This subsector is estimated to have constituted a net sink of 21.8 Mt CO_2-e in 2002.

Forest and grassland conversion (5B) comprises emissions and removals arising from the removal of forest with a minimum of 20% canopy cover, minimum height of two metres and a minimum area of 0.2 hectares. It includes emissions due to the burning and decay of cleared vegetation and from soil disturbed in the clearing process, and removals due to the subsequent

LAND USE CHANGE AND FORESTRY

regrowth of vegetation. Net emissions from the *forest and grassland conversion* subsector were estimated to be 42.1 Mt CO_2-e in 2002.

CO_2 emissions and removals from soil (5D) comprise removals associated with pasture improvement and minimum tillage (4.2 Mt).

Other (5E) comprises non-CO_2 gas emissions from prescribed burning of forests and wildfire. Estimated emissions for this subsector were 2.1 Mt CO_2-e in 2002.

Table 8. Land use change and forestry net CO_2-e emissions, 2002 (UNFCCC accounting)

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)			
	CO_2	CH_4	N_2O	Total (includes CO_2)
5 LAND USE CHANGE AND FORESTRY[(a)]	**13,113**	**4,302**	**774**	**18,189**
A. Changes in forest and other woody biomass stocks	–21,827			–21,827
B. Forest and grassland conversion	39,164	2,651	323	42,138[(b)]
C. Abandonment of managed lands	NA			NA
D. CO_2 emissions and removals from soil[(c)]	–4,223			–4,223
E. Other[(d)]	NA	1,651	451	2,102

(a) A negative sign denotes a sink. (b) The results for deforestation for 2000 and 2001 will increase when areas of deforestation are confirmed following the next update of estimates using the National Carbon Accounting System. The 2002 estimate is an average of the 2000 and 2001 estimates. (c) Sinks from minimum tillage and pasture improvement. (d) Emissions from wildfires and prescribed burning.

Emission Trends

Emissions from *commercial forest harvesting* increased by 28.8% (10.2 Mt) over the period 1990 to 2002 and by 3.2% (1.4 Mt) between 2001 and 2002. The sink associated with *forest growth* increased by 12.5% (9.0 Mt) from 1990 to 2002, and by 1.5% (1.2 Mt) from 2001 to 2002. The net effect of these changes is a reduction in the *forestry* net sink of 11.3% (2.8 Mt) from 1990 to 2002, including a decrease in the net *forestry* sink of 2.7% (0.6 Mt) between 2001 and 2002.

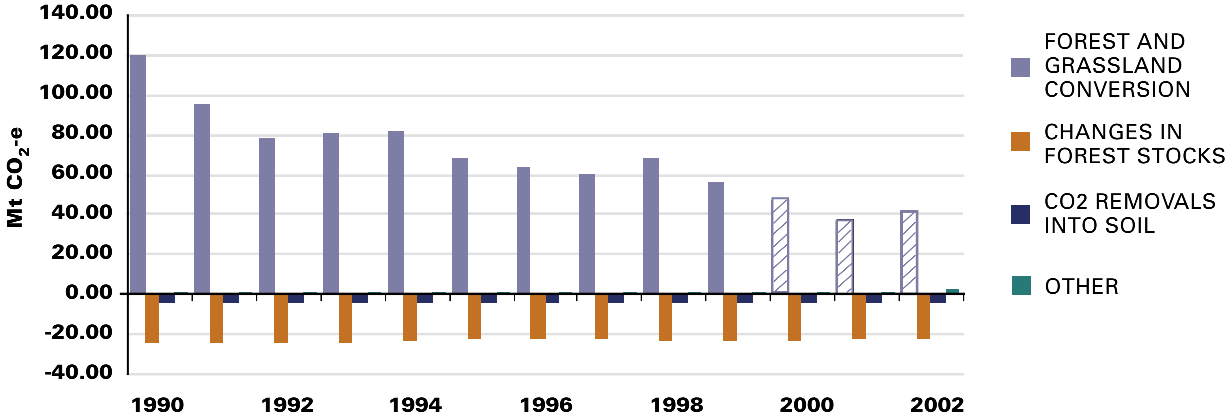
Emissions from the *forest and grassland conversion* subsector, at a preliminary estimate of 42.1 Mt, were 78.3 Mt lower than emissions from this source in 1990. Comparisons with 2001 estimates should be undertaken with caution, as both 2000 and 2001 estimates will be revised for next year's submission. In particular, the results reported for 2000 and 2001 will likely increase when areas of *land use change* are confirmed in the next data update using the National Carbon Accounting System. Nonetheless, it is clear that since 1990 the annual rates of *forest conversion* have decreased substantially with consequent reductions in estimated emissions from burning and decay of above-ground biomass and below-ground carbon. There is also a diminishing effect of extensive past *land use change* on decay of above-ground biomass and below-ground carbon.

There was a 35.7% (0.6 Mt) increase in *prescribed burning and wildfire* emissions between 1990 and 2002 and a 68.4% (0.9 Mt) increase from 2001 to 2002. The 2002 figure is estimated as a ten-year average of the values from 1994 to 2003 inclusive. The average of the 21 years of wildfire data is 0.7 Mt, and individual years have been as low as 0.13 Mt. Significant years were 1991, 2002 and 2003, when emissions were 1.6 Mt, 1.3 Mt and 3.6 Mt respectively. These years represent coincident bad fire seasons in WA, Vic., NSW and the ACT. The 1991 fire year was unusually high (1.6 Mt) and boosted the estimated emissions up to 1999.

No change is recorded in *minimum tillage and pasture improvement* emissions as these estimates rely on limited data that are not frequently updated.

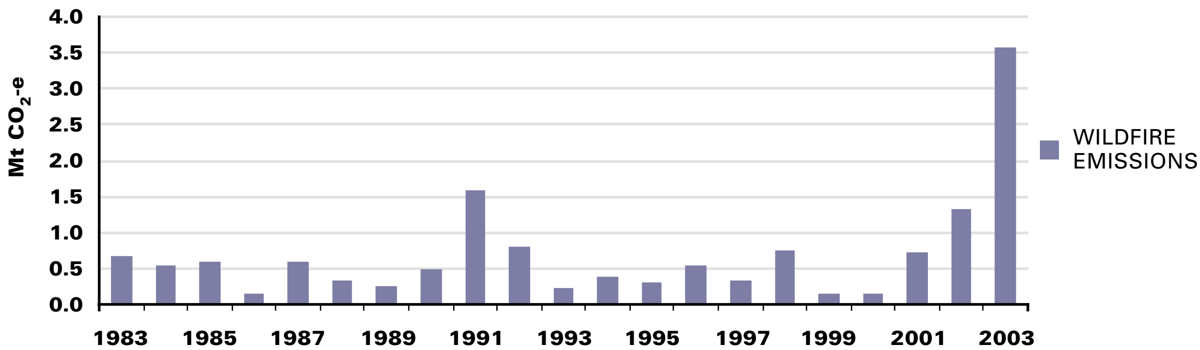
Overall the total *land use change and forestry* emissions declined from 93.1 Mt in 1990 to 18.2 Mt in 2002, representing an 81% decrease.

Figure 15. Total net CO_2-e emissions from land use change and forestry, 1990–2002 (UNFCCC accounting)



Note: The results for forest and grassland conversion (or deforestation as it called for Kyoto accounting) for 2000 and 2001 will increase when areas of deforestation are confirmed following the next update of estimates using the National Carbon Accounting System. The 2002 estimate is an average of the 2000 and 2001 estimates.

Figure 16. Emissions from wildfires, 1990–2002



METHODOLOGY

The methodology, emission factors and other parameters used to compile the *land use change and forestry* estimates are largely country-specific. A full description of the methodology used to estimate CO_2 emissions from 5A, 5D and 5E is presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Land Use Change and Forestry*, which provides an edited compilation of the methodologies described in *Workbook for CO_2 from the Biosphere 4.2* and its 1996 and 1997 supplements (NGGIC 1997a, 1997b 1998).

The CO_2 emissions from 5.B *Forest and grassland conversion* are now estimated using the National Carbon Accounting System. The National Carbon Accounting System is a model-based accounting system supported by resource inventories, field studies and extensive multi-temporal remote sensing methods. The methodology is fully documented (AGO 2002b, 2003) and supersedes that described in Workbook 4.2.

A full description of the methodology used to estimate non-CO_2 emissions from all subsectors is presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Land Use Change and Forestry* (NGGIC 2004g), which provides an edited compilation of methodologies described in the *Workbook for Non-Carbon Dioxide Gases from the Biosphere 5.1* (NGGIC 1998g).

The IPCC Guidelines consider only abandoned lands that are regrowing towards a natural state. *Abandonment of managed lands* (5C) is reported as 'not applicable' as *abandoned lands* in Australia are generally degraded due to problems such as salinity; hence regrowth is negligible.

RECALCULATIONS SINCE THE 2001 INVENTORY

Remote sensing data for 2002 land use change has not yet been fully analysed because of the short period since the completion of previous work (September 2003). To provide an interim estimate of emissions for the 2002 inventory, an average of the 2000 and 2001 estimates has been used. This estimate will be revised next year when the analysis of the National Carbon Accounting System (NCAS) satellite data for the relevant years has been completed.

3.5 Waste

Total estimated *waste* emissions for 2002 were 17.6 Mt CO_2-e, or 3.2% of total net national emissions (Table 9). The majority of these emissions were from *solid waste disposal on land*, contributing 15.7 Mt or 89.0% of *waste* emissions. *Wastewater handling* contributed a further 1.9 Mt (10.9%) of *waste* emissions while *waste incineration* contributed 0.02 Mt (0.1%). *Waste* emissions are predominantly methane-generated from anaerobic decomposition of organic matter. Small amounts of carbon dioxide and nitrous oxide are generated through the incineration of solvents and the decomposition of human wastes respectively.

Table 9. Waste CO_2-e emissions, 2002

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)				**%Total net national emissions**
	CO_2	CH_4	N_2O	Total	
Total net national emissions (Kyoto)	384.6	122.6	34.9	550.1	100.0
6 WASTE	**0.02**	**17.02**	**0.56**	**17.59**	3.2
A. Solid waste disposal on land	NE	15.66	NE	15.66	2.8
B. Wastewater handling	NE	1.36	0.56	1.91	0.3
C. Waste incineration	0.02	NA	NE	0.02	0.003
D. Other waste	NA	NA	NA	NA	NA

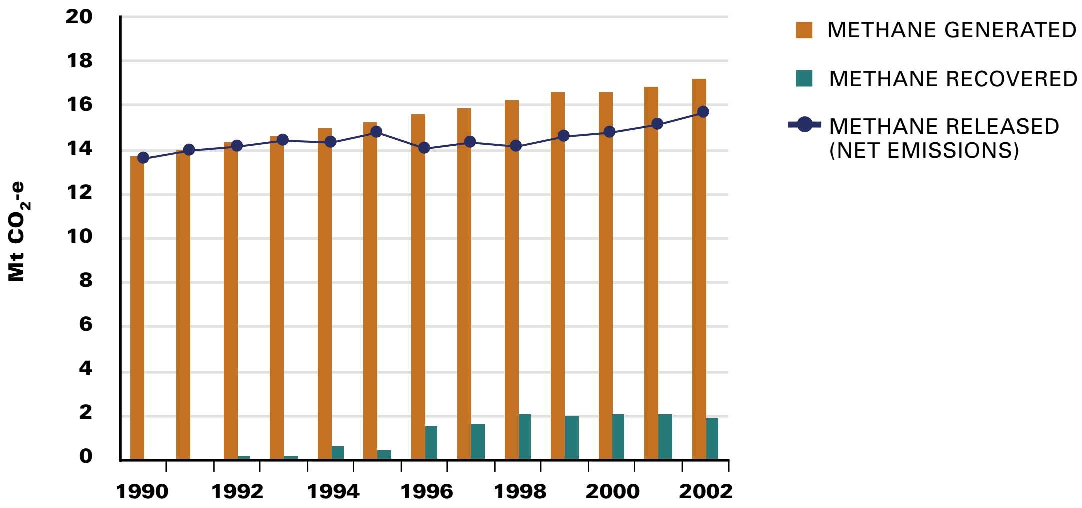
Trends

Waste emissions were 11.5% (2.3 Mt CO_2-e) higher in 2002 than they were in 1990 and 3.1% (0.5 Mt CO_2-e) higher than in 2001.

Emissions from municipal *solid waste disposal on land* increased by 11.2% (2.0 Mt CO_2-e) over the period 1990 to 2002 (Figure 17), and by 3.4% (0.5 Mt CO_2-e) since 2001. This increase can be related to an increase in population and per capita waste disposal. As waste degradation is a slow process, estimates of methane generation for 2002 reflect waste disposal from up to 25 years earlier.

Rates of methane recovery from solid waste have improved substantially since 1993, increasing from a negligible amount to 10.9% (1.9 Mt CO_2-e) of methane in 2002. This increased capture has offset increasing methane generation to some extent and is reflected in the relatively stable emission rates for 1993 to 2002.

Figure 17. Emissions from solid waste disposal on land, 1990–2002



Wastewater handling emissions increased by 13.8% (0.25 Mt CO_2-e) over the period 1990 to 2002, with an increase of 1.2% (0.02 Mt CO_2-e) since 2001. Estimates for *wastewater handling* emissions are based on population changes; hence estimates for methane generation from sewage and recovery from wastewater plants and estimates of nitrous oxide emissions from human sewage increase at the same rate as population growth.

Methodology

Emissions from *solid waste disposal on land* are estimated using a country specific methodology where the quantity of methane released is estimated based on the average quantity of waste landfill in the 25 years prior to the inventory year and the methane potential of landfilled waste. It is equivalent to a Tier 2 approach as defined in the IPCC *Good Practice* report. Data on methane recovered from *solid waste disposal* sites are obtained from the main companies involved in landfill gas recovery projects.

Methane releases and recovery from *wastewater* are estimated using a combination of IPCC and country-specific default values. The methodology is a country-specific equivalent to a Tier 2 methodology. Nitrous oxide emissions are derived using the IPCC default methodology (Tier 1).

A full description of the methodologies and emission factors are presented in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Waste* (NGGIC 2004h), which provides an edited compilation of the methodologies described in *Workbook for Waste Emissions 8.1* (NGGIC 1998h) and the supplements in the 1996, 1998 and 2000 inventories (NGGIC 1996, 1998; AGO 2000).

The main sources of data are demographic data from ABS (2002) and methane recovery data from companies involved in landfill gas recovery projects.

Recalculations since the 2001 Inventory

There were no methodology changes in the *waste* sector; however, the Australian Bureau of Statistics population statistics have been revised and updated for all years back to the 1996–97 financial year. This has resulted in a recalculation of *waste sector* emissions from 1996–97 to the current inventory year.

CHAPTER 4
RECALCULATIONS

4.1 RECALCULATIONS IN THE 1990-2002 TIME SERIES

Estimates of emissions presented in past inventory reports are revised for a number of reasons including end-of-series averaging effects (for the *agriculture* sector), revisions of data, the inclusion of additional sources of data capture or from refinements in the estimation methodology. To ensure the accuracy of the estimates of all years, and to maintain consistency of the series through time, recalculations of past emission estimates are undertaken for all previous years.

Within the 1990–2002 time series there have been a number of items that have led to recalculations being performed. These include the recalculation of emission estimates for *agriculture* for 2001 and 2002 due to averaging effects, the addition of new sources in the *industrial processes* sector for emissions from *magnesia* and *nitric acid* production, and the inclusion of some revised data for the *energy* sector and for *savanna burning*.

The overall effect of the recalculations, under Kyoto accounting provisions, is to increase the 1990 assessment of Australia's greenhouse emissions by 0.1 Mt, and to decrease the 2001 assessment by 0.1% (0.7 Mt)—Table 10. Similar recalculation effects are observed under the accounting provisions of the UNFCCC inventory—Table 11.

Table 10. Previous and latest estimates of emissions, 1990–2001 (Kyoto accounting)

Year	Net Mt CO_2-e emissions			Difference	
	Previously published	Latest estimates		Mt CO_2-e	% of Previous value
1990	543.1	543.2		0.1	0.0
1991	519.7	519.8		0.1	0.0
1992	505.3	505.4		0.1	0.0
1993	508.2	508.9		0.7	0.1
1994	512.6	513.3		0.7	0.1
1995	510.2	511.8		1.6	0.3
1996	515.3	516.1		0.7	0.1
1997	522.3	523.1		0.8	0.1
1998	549.3	550.2		0.9	0.2
1999	546.6	547.2		0.7	0.1
2000	544.9	545.7		0.7	0.1
2001	542.6	542.0		-0.7	-0.1

Table 11. Previous and latest estimates of emissions, 1990–2001 (UNFCCC accounting)

Year	Net Mt CO_2-e emissions			Difference	
	Previously published	Latest estimates		Mt CO_2-e	% of Previous value
1990	515.8	515.9		0.1	0.0
1991	493.5	493.5		0.0	0.0
1992	479.0	479.1		0.1	0.0
1993	482.7	483.4		0.7	0.1
1994	488.4	489.1		0.7	0.2
1995	487.4	489.0		1.6	0.3
1996	493.1	493.8		0.7	0.2
1997	501.3	502.1		0.8	0.2
1998	529.5	530.3		0.9	0.2
1999	527.6	528.2		0.6	0.1
2000	528.7	529.6		0.9	0.2
2001	528.1	527.7		-0.4	-0.1

4.2 Future Recalculations

Australia is currently reviewing the methodologies for estimation of emissions in a number of sectors. The priority of these reviews has been informed by the use of the key source analysis, the relative level of uncertainty of emission estimates and by comments from past international reviews. Estimates under review include those for the *waste* sector and for *savanna burning*. If the methodology is refined in these sectors, recalculations will be required for the entire time series to maintain consistency.

Recalculations may also be necessary following consideration of new data, particularly for recent years. Recalculations could be expected for the 2000 to 2002 estimates of emissions from *land use change*, following completion of analyses of new satellite data, and for the *energy* sector, following analysis of the ABARE Fuel and Energy Survey data for 2002. The *Ozone Protection and Synthetic Greenhouse Gas Management Act 2003* includes provisions for Montreal Protocol industries to report bulk imports of HFCs and PFCs and quantities of HFCs and PFCs in pre-charged equipment. Methodologies are currently being developed to convert this new data source into emissions estimates for inclusion in future inventories.

CHAPTER 5
DATA QUALITY ISSUES AND PLANNED INVENTORY IMPROVEMENTS

Australia is committed to improving the transparency, completeness, consistency, accuracy and comparability of its national greenhouse inventory. In this chapter, a range of data quality issues are addressed, including completeness of the inventory and the estimated uncertainty of emission estimates by sector.

5.1 QUALITY CONTROL

Quality control and verification processes are an important part of the preparation of national greenhouse gas inventories. Processes such as comparisons against IPCC default values, trend analysis, and independent checks have ensured the integrity of data going into and coming out of the inventory preparation process. The procedures adopted for this inventory are consistent with IPCC *Good Practice* Tier 1 on general inventory level quality control. Significant reductions in errors arising from transcription errors, computational errors, modelling and sampling errors have been facilitated through making quality control an integral part of the inventory process.

The Australian Greenhouse Office is currently developing the Australian Greenhouse Emission Information System, including a database of its national greenhouse gas emissions estimates, that will expand the level of automation of data-handling processes and lead to significant improvements in quality control in the preparation of future inventories.

5.2 COMPLETENESS OF AUSTRALIA'S INVENTORY IN 2002

Greenhouse gases emanate from a wide variety of sources and through a large range of processes. For the most part estimates are generated from published sources of activity data. This is true for the most significant component of the inventory—emissions from fossil fuel combustion—where data collection processes are well established for either energy policy or taxation reasons. Where published data are not readily available, such as for some industries in the industrial processes sector, the AGO conducts comprehensive surveys of industry in order to obtain the necessary data.

A few minor sources are not included within the inventory, due to either a lack of available information or methodology. These sources are considered to be insignificant, however, when compared with the inventory as a whole. A full assessment of the completeness of the inventory can be found in Table 9 in Part B.

The assessment of completeness is used to help identify areas where methodologies can be developed, and where additional sources of data may be sought. For this inventory, data from a source from *magnesia production* will be included within the inventory for the first time.

5.3 Key Source Analysis

A *key source category* has a significant influence on a country's total inventory of direct greenhouse gases in terms of absolute level of emissions, the trend in emissions, or both. Australia has identified the key sources for the UNFCCC inventory using the Tier 1 level and trend assessments as recommended in the IPCC *Good Practice* report. This approach identifies sources that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms.

Australia has identified *public electricity* (solid fuel), *enteric fermentation (cattle), forest and grassland conversion* (CO_2) and *road transportation* (passenger cars) as the most significant of the key source categories—on a level basis. On a trends basis, the only difference to the most important four categories is that *enteric fermentation (sheep)* replaces *enteric fermentation (cattle)*.

Table 12. Key source categories for Australia's inventory—level assessment

A		B	C	D	E	F
IPCC source category		Direct greenhouse gas	Base year estimate (Gg)	Current year estimate (Gg)	Level assessment	Cumulative total %
1.A.1.a	Public electricity and heat production—solid fuels	CO_2	118049.2	167377.8	0.3	29.7
4.A.1	Enteric fermentation—cattle	CH_4	42627.5	48316.6	0.1	38.3
5.B	Forest and grassland conversion	CO_2	114192.3	39163.9	0.1	45.3
1.A.3.b.i.	Road transportation—passenger car	CO_2	32392.3	38901.7	0.1	52.2
4.D	Agricultural soils	N_2O	15145.9	19471.1	0.0	55.6
6.A	Solid waste disposal on land	CH_4	13623.3	15659.8	0.0	58.4
4.A.3	Enteric fermentation—sheep	CH_4	24563.2	15646.4	0.0	61.2
1.A.1.a	Public electricity and heat production—gaseous fuels	CO_2	7981.3	11424.4	0.0	63.2
1.B.1.a.i.	Fugitive emissions—underground mines	CH_4	12339.1	10663.3	0.0	65.1
2.C.1	Iron and steel production	CO_2	12644.5	10442.9	0.0	66.9
4.E	Prescribed burning of savannas	CH_4	5507.0	10015.4	0.0	68.7
1.A.3.b.ii.	Road transportation—light trucks	CO_2	7054.5	9678.1	0.0	70.5
1.A.4	Other sectors—gaseous fuels	CO_2	6401.9	9141.0	0.0	72.1
1.A.3.b.iv	Road transportation—heavy duty trucks	CO_2	6055.4	8341.6	0.0	73.6
1.A.1.c	Manufacture of solid fuels and other energy industries—gaseous fuels	CO_2	4596.3	8272.1	0.0	75.0
4.E	Prescribed burning of savannas	N_2O	4160.9	7567.3	0.0	76.4
1.A.2.f	Other—liquid fuels	CO_2	5011.7	7100.3	0.0	77.6
1.B.1.a.ii.	Fugitive emissions—surface mining	CH_4	3477.3	6793.0	0.0	78.8
1.A.4	Other sectors—liquid fuels	CO_2	5500.4	6533.6	0.0	80.0
1.A.2.b	Non-ferrous metals—gaseous fuels	CO_2	4136.6	6465.9	0.0	81.1
1.A.3.b.iii.	Road transportation—medium duty trucks	CO_2	5779.1	5875.8	0.0	82.2
1.A.1.b	Petroleum refining—liquid fuels	CO_2	5192.7	5841.1	0.0	83.2
1.A.3.a	Civil aviation—jet kerosene	CO_2	2626.3	5531.8	0.0	84.2
1.A.2.b	Non-ferrous metals—solid fuels	CO_2	4979.4	5530.2	0.0	85.2
1.A.2.f	Other—gaseous fuels	CO_2	4200.4	4416.3	0.0	86.0
1.A.3.b.i.	Road transportation—passenger car	N_2O	1459.8	4125.8	0.0	86.7
2.B	Chemical industry	CO_2e	1741.0	3748.4	0.0	87.4
1.B.2.c.	Oil and natural gas—venting	CO_2	1966.5	3580.1	0.0	88.0
1.B.2.b.	Oil and natural gas—natural gas	CH_4	4206.1	3560.7	0.0	88.6
1.A.2.c	Chemicals—gaseous fuels	CO_2	2234.6	3490.2	0.0	89.3
2.A.1	Cement production	CO_2	3214.4	3291.2	0.0	89.8
2.F.1	Refrigeration and air conditioning equipment	HFC	0.00	2744.5	0.0	90.3
2.C.3	Aluminium production	CO_2	1826.7	2674.7	0.0	90.8
5.B	Forest and grassland conversion	CH_4	5506.9	2650.9	0.0	91.3
1.A.2.b	Non-ferrous metals—liquid fuels	CO_2	3043.2	2612.0	0.0	91.7
1.A.2.f	Other—solid fuels	CO_2	3033.5	2545.5	0.0	92.2
1.B.2.c.	Oil and natural gas—flaring	CO_2	3601.4	2439.1	0.0	92.6
1.A.1.a	Public electricity and heat production—liquid fuels	CO_2	2641.2	2203.1	0.0	93.0
4.B	Manure management	CH_4	1508.2	2005.8	0.0	93.4
1.A.2.c	Chemicals—liquid fuels	CO_2	2124.3	1980.5	0.0	93.7
1.B.2.c	Oil and natual gas venting	CH_4	1733.9	1940.3	0.0	94.1
1.A.3.b.v	Road transportation—buses	CO_2	1218.3	1849.1	0.0	94.4
1.A.3.c	Railways	CO_2	1723.0	1818.2	0.0	94.7

Table 13. Key source categories for Australia's inventory—trend assessment

A		B	C	D	E	F	G
IPCC source categories		Direct greenhouse gas	Base year estimate	Current year estimate	Trend assessment	% Contribution to trend	Cumulative total of column F %
5.B	Forest and grassland conversion	CO_2	114192.3	39163.9	0.1	0.4	36.5
1.A.1.a	Public electricity and heat production—solid fuels	CO_2	118049.2	167377.8	0.1	0.2	57.2
4.A.3	Enteric fermentation—sheep	CH_4	24563.2	15646.4	0.0	0.0	61.8
1.A.3.b.i.	Road transportation—passenger car	CO_2	32392.3	38901.7	0.0	0.0	64.2
4.E	Prescribed burning of savannas	CH_4	5507.0	10015.4	0.0	0.0	66.2
4.A.1	Enteric fermentation—cattle	CH_4	42627.5	48316.6	0.0	0.0	68.1
4.D	Agricultural soils	N_2O	15145.9	19471.1	0.0	0.0	69.9
1.A.1.c	Manufacture of solid fuels and other energy industries—gaseous fuels	CO_2	4596.3	8272.1	0.0	0.0	71.5
4.E	Prescribed burning of savannas	N_2O	4160.9	7567.3	0.0	0.0	72.9
1.B.1.a.ii.	Fugitive emissions—surface mining	CH_4	3477.3	6793.0	0.0	0.0	74.4
1.A.1.a	Public electricity and heat production —gaseous fuels	CO_2	7981.3	11424.4	0.0	0.0	75.9
5.B	Forest and grassland conversion	CH_4	5507.0	2650.9	0.0	0.0	77.3
1.A.3.a	Civil aviation—jet kerosene	CO_2	2626.3	5531.8	0.0	0.0	78.6
2.F.1	Refrigeration and air conditioning equipment	HFC	0.00	2744.5	0.0	0.0	79.9
2.C.1	Iron and steel production	CO_2	12644.5	10442.9	0.0	0.0	81.1
1.A.3.b.i.	Road transportation—passenger car	N_2O	1459.8	4125.8	0.0	0.0	82.3
2.C.3	Aluminium production	PFC	3938.3	1507.2	0.0	0.0	83.5
1.A.4	Other sectors—gaseous fuels	CO_2	6401.9	9141.0	0.0	0.0	84.6
1.A.3.b.ii.	Road transportation—light trucks	CO_2	7054.5	9678.1	0.0	0.0	85.7
1.A.2.b	Non-ferrous metals—gaseous fuels	CO_2	4136.6	6465.9	0.0	0.0	86.7
1.B.1.a.i.	Fugitive emissions—underground mines	CH_4	12339.1	10663.3	0.0	0.0	87.7
1.A.3.b.iv	Road transportation—heavy duty trucks	CO_2	6055.5	8341.6	0.0	0.0	88.7
2.B	Chemical industry	CO_2-e	1741.0	3748.4	0.0	0.0	89.5
1.A.2.f	Other—liquid fuels	CO_2	5011.7	7100.3	0.0	0.0	90.4
1.B.2.c.	Oil and natual gas—venting	CO_2	1966.5	3580.1	0.0	0.0	91.1
6.A	Solid waste disposal on land	CH_4	13623.3	15659.8	0.0	0.0	91.9
1.B.2.c.	Oil and natural gas—flaring	CO_2	3601.4	2439.1	0.0	0.0	92.4
1.A.2.c	Chemicals—gaseous fuels	CO_2	2234.6	3490.2	0.0	0.0	93.0
1.A.1.c	Manufacture of solid fuels and other energy industries—solid fuels	CO_2	1822.5	1053.8	0.0	0.0	93.4
1.A.4	Other sectors—liquid fuels	CO_2	5500.4	6533.6	0.0	0.0	93.8
4.B	Manure management	N_2O	527.5	1375.8	0.0	0.0	94.1
1.A.3.d.ii	Navigation (domestic)	CO_2	2299.5	1559.9	0.0	0.0	94.5
1.B.2.b.	Oil and natural gas—natural gas	CH_4	4206.1	3560.7	0.0	0.0	94.9

Table 14. Key source categories for Australia's inventory—summary

A		B	C	D	E
IPCC source categories		Direct greenhouse gas	Key source category flag	If column C is yes, criteria for identification	Comments
	Energy				
1.A.1.a	Public electricity and heat production—solid fuels	CO_2	Yes	Level, Trend	
1.A.1.a	Public electricity and heat production—gaseous fuels	CO_2	Yes	Level, Trend	
1.A.1.a	Public electricity and heat production—liquid fuels	CO_2	Yes	Level	
1.A.1.b	Petroleum refining—liquid fuels	CO_2	Yes	Level	
1.A.1.c	Manufacture of solid fuels and other energy industries—gaseous fuels	CO_2	Yes	Level, Trend	
1.A.1.c	Manufacture of solid fuels and other energy industries—solid fuels	CO_2	Yes	Trend	
1.A.2.b	Non-ferrous metals—gaseous fuels	CO_2	Yes	Level, Trend	
1.A.2.b	Non-ferrous metals—solid fuels	CO_2	Yes	Level	
1.A.2.b	Non-ferrous metals—liquid fuels	CO_2	Yes	Level	
1.A.2.c	Chemicals—gaseous fuels	CO_2	Yes	Level, Trend	
1.A.2.c	Chemicals—liquid fuels	CO_2	Yes	Level	
1.A.2.f	Other—liquid fuels	CO_2	Yes	Level, Trend	
1.A.2.f	Other—gaseous fuels	CO_2	Yes	Level	
1.A.2.f	Other—solid fuels	CO_2	Yes	Level	
1.A.3.a	Civil aviation—jet kerosene	CO_2	Yes	Level, Trend	
1.A.3.b.i.	Road transportation—passenger car	CO_2	Yes	Level, Trend	
1.A.3.b.i.	Road transportation—passenger car	N_2O	Yes	Level, Trend	
1.A.3.b.ii.	Road transportation—light trucks	CO_2	Yes	Level, Trend	
1.A.3.b.iii.	Road transportation—heavy duty trucks	CO_2	Yes	Level, Trend	
1.A.3.b.iv	Road transportation—medium duty trucks	CO_2	Yes	Level, Trend	
1.A.3.b.v	Road transportation—buses	CO_2	Yes	Level	
1.A.3.c	Railways	CO_2	Yes	Level	
1.A.3.d.ii	Navigation (domestic)	CO_2	Yes	Level, Trend	
1.A.4	Other sectors—gaseous fuels	CO_2	Yes	Level, Trend	
1.A.4	Other sectors—liquid fuels	CO_2	Yes	Level, Trend	
1.B.1.a.i.	Fugitive emissions—underground mines	CH_4	Yes	Level, Trend	
1.B.1.a.ii.	Fugitive emissions—surface mining	CH_4	Yes	Level, Trend	
1.B.2.b.	Oil and natural gas—natural gas	CH_4	Yes	Level, Trend	
1.B.2.c.	Oil and natural gas—venting	CO_2	Yes	Level, Trend	
1.B.2.c.	Oil and natural gas—flaring	CO_2	Yes	Level, Trend	
1.B.2.c.	Oil and natural gas—venting	CH_4	Yes	Level	
	Industrial processes				
2.A.1	Cement production	CO_2	Yes	Level	
2.B	Chemical industry	CO_2-e	Yes	Level, Trend	
2.C.1	Iron and steel production	CO_2	Yes	Level, Trend	
2.C.3	Aluminium production	CO_2	Yes	Level	
2.C.3	Aluminium production	PFC	Yes	Trend	
2.F.1	Refrigeration and air conditioning equipment	HFC	Yes	Level, Trend	
	Agriculture				
4.A.1	Enteric fermentation—cattle	CH_4	Yes	Level, Trend	
4.A.3	Enteric fermentation—sheep	CH_4	Yes	Level, Trend	
4.B	Manure management	CH_4	Yes	Level	
4.B	Manure management	N_2O	Yes	Trend	
4.D	Agricultural soils	N_2O	Yes	Level, Trend	
4.E	Prescribed burning of savannas	CH_4	Yes	Level, Trend	
4.E	Prescribed burning of savannas	N_2O	Yes	Level, Trend	

	Land use change and forestry				
5.B	Forest and grassland conversion	CO_2	Yes	Level, Trend	
5.B	Forest and grassland conversion	CH_4	Yes	Level, Trend	
	Waste				
6.A	Solid waste disposal on land	CH_4	Yes	Level, Trend	

5.4 Uncertainty Analysis

The IPCC *Good Practice* report encourages publication of uncertainty levels surrounding the emission estimates of the various components of the inventory, with the aim of informing directions for future methodological development of the inventory. Uncertainty is inherent within any kind of estimation—be it an estimate of the national greenhouse gas emissions, or the national gross domestic product. While it is in some cases possible to continuously monitor emissions, it is not always practical or economical to do so. This leads to estimations based on samples or studies being used which carry a degree of uncertainty attached to them. Uncertainty also arises from the limitations of the measuring instruments, and the variability of the source, particularly in emission factors for sources, which may vary over time and space within a specific source category.

Australia has conducted an uncertainty analysis across the sectors of *energy*, *industrial processes*, *agriculture*, *land use change* and *waste*, in line with the IPCC *Good Practice* guidelines. Monte Carlo and Latin Hypercube approaches were used to estimate emission uncertainty, which is equivalent to the UNFCCC Tier 2 methodology.

While some sectors have a relatively low uncertainty attached to them, as the relationship between the source and emissions is well documented and understood, other areas carry an inherently high uncertainty due to the very nature of the processes involved (e.g. any kind of biological process).

The estimates presented show that the uncertainty ranges reported for the various components of the Australian inventory are largely consistent with the typical uncertainty ranges expected for each sector, as identified in the IPCC *Good Practice Report*. Moreover, as the same method is used to estimate the emissions from each sector across years, the uncertainty about the trend in greenhouse gas emissions is lower than the uncertainty attached to each estimate within the trend.

Australia is currently reviewing the estimates of uncertainty presented within this chapter for accuracy, completeness, consistency and comparability. Following this review an uncertainty estimate for the inventory as a whole, as well as for the trends in emissions, will be able to be calculated.

5.4.1 Energy

5.4.1-1 Stationary energy

Uncertainty analyses were conducted for emissions from three sectors: 1.A.1.a. *Electricity*, 1.A.1.b. *Petroleum refining* and 1.A.1.c. *Manufacture of solid fuels and other energy industries* (Table 15). The overall uncertainty in estimated emissions from *electricity generation* was ±5%. The highest uncertainty was for N_2O emissions, with an associated uncertainty of up to ±16%. However, as emissions of N_2O (and CH_4) account for only a small fraction, 0.4%, of the subsector's total emissions, there is a negligible impact on overall uncertainty for this sector.

Table 15. Quantified uncertainty values for key stationary energy subcategories[(a)]

Greenhouse gas source and sink category	Uncertainty (%)				Share of inventory (UNFCCC) (%)
	CO_2	CH_4	N_2O	Total CO_2-e	
1. ENERGY					
A Fuel combustion activities					
1.A.1.a. Electricity	**±5**	**±4**	**±15**	**±5**	**33.7**
Black coal	±6	±6	±15	±6	
Brown coal	±4	±4	±15	±4	
Petroleum	±4	±4	±7	±4	
Natural gas	±4	±4	±16	±4	
Biomass	NA	±4	±4	±4	
Biogas	NA	±4	±16	±4	
1.A.1.b. Petroleum refining	**±4**	**±9**	**±12**	**±4**	**1.3**
Petroleum	±4	±9	±12	±4	
Gas	±4	±9	±12	±4	
1.A.1.c Manufacture of solid fuels and other energy industries	**±4**	**±9**	**±12**	**±4**	**2.1**
Coal	±4	±9	±12	±4	
Petroleum	±4	±9	±12	±4	
Gas	±4	±9	±12	±4	

(a) Uncertainty reported at 95% confidence limits estimated using Latin Hypercube (a type of Monte Carlo) analysis

Overall uncertainty associated with emissions estimates from both 1.A.1.b. *Petroleum refining* and 1.A.1.c. *Manufacture of solid fuels and other energy industries* sectors was ±4%. Again, the uncertainty associated with emissions of N_2O and CH_4 has negligible impact on overall uncertainty. An uncertainty analysis on minor, mobile source categories of the *stationary energy* sector gave uncertainty values ranging from ±16.4% to ±24.5% for CO_2, from ±25.4% to ±63.9% for CH_4, and ±44.7% to ±64.2% for N_2O (Table 16).

Table 16. Quantified uncertainty values for mobile source categories[(a)]

Greenhouse gas source and sink category	Uncertainty (%)			Share of inventory UNFCCC (%)
	CO_2	CH_4	N_2O	
1.A.4. Other sectors				
b. Residential				
Lawn mowers	±24.5	±45.2	±46.3	0.1
1.A.5. Other				
b. Mobile	**±16.4**	**±25.4**	**±44.7**	**0.3**
Military transport—land	±18.5	±32.9	±54.6	
Military transport—water	±24.4	±63.9	±62.7	
Military transport—aviation	±24.0	±47.2	±64.2	

(a) Uncertainty reported at 95% confidence limits estimated using Monte Carlo analysis.

5.4.1-2 Transport

Monte Carlo analyses were conducted for all subsectors and fuel types. The uncertainty distributions for emission factors and activity data were developed on the basis of expert judgement.

The total estimated uncertainties in the *transport* subsector were ±4% for CO_2, ±24% for CH_4, and ±42% for N_2O. Uncertainties in the emissions from individual source categories ranged from ±1% to ±24% for CO_2, ±23% to ±59% for CH_4, and ±32% to ±63% for N_2O. The largest source of uncertainty is in the emission factors.

Table 17. Emissions and quantified uncertainty values for key transport subcategories[(a)]

Greenhouse gas source and sink category	Uncertainty (%)			Share of inventory UNFCCC (%)
	CO_2	CH_4	N_2O	
1.A.3. Transport	**±4**	**±24**	**±42**	**14.7**
	±4	±23	±41	
a. Civil aviation	**±9**	**±52**	**±52**	**2.7**
b. Road transport	**±4**	**±25**	**±42**	**13.0**
i. Passenger cars	±6	±31	±44	
ii. Light trucks	±7	±38	±41	
iii. Medium trucks	±9	±41	±60	
iv. Heavy trucks	±10	±44	±61	
v. Buses	±8	±36	±53	
vi. Motorcycles	±10	±43	±61	
c. Railways	**±5**	**±39**	**±39**	**0.3**
d. Navigation	**±8**	**±59**	**±32**	**0.3**
e. Other transportation	**±24**	**±46**	**±63**	**0.01**
International bunkers				
Aviation	±10	±58	±59	
Marine	±4	±47	±52	

(a) Uncertainty reported at 95% confidence limits.

COMPARISON OF AUSTRALIAN METHODOLOGY WITH IPCC REFERENCE APPROACH

Total CO_2 emissions from *fuel combustion activities* (covering both *stationary energy* and *transport*) estimated using Australia's National approach methodology are 333.7 Mt. Total CO_2 emissions estimated using the Reference approach[9] are 325.2 Mt. This is an overall 2.6% difference between the two methods, which is largely due to uncertainty within the 2002 Reference approach figure for petroleum fuel. A detailed account of reasons underlying the difference is given in CRF Table 1.A(c).

[9] The IPCC Reference approach is a 'top–down' Tier 1 methodology for estimating CO_2 emissions from Fuel Combustion Activities (1.A). The National approach (described in sections 3.1.1 and 3.1.2) includes a mix of Tier 1 and Tier 2 methods.

5.4.1-3 Fugitives

An uncertainty analysis was conducted for *fugitive emissions* of CO_2, CH_4 and N_2O. The uncertainty distributions for emission factors and activity data for fugitive emissions from *solid fuels* are developed from confidence levels specified in the *Workbook for Fugitive Fuel Emissions 2.1* (NGGIC 1996). Confidence levels used for *oil and natural gas* were based on expert judgement.

The overall uncertainty for *fugitive* emissions was estimated to be ±11% (Table 18). The estimated uncertainty for *solid fuels* CH_4 was ±19%. Uncertainties in oil and natural gas emissions were estimated to be ±4% for CO_2, ±5% for CH_4 and ±4% for N_2O.

Table 18. Quantified uncertainty values for key fugitive emissions subcategories[(a)]

Greenhouse gas source and sink category		Uncertainty (%)				Share of inventory (UNFCCC) (%)
		CO_2	CH_4	N_2O	CO_2-e	
1. ENERGY						
B. Fugitive emissions		**±4**	**±14**	**±4**	**±11**	**5.6**
1.B.1. Solid fuels		**NE**	**±19**	**NE**	**±19**	**3.2**
1B1ai	Underground mines	NE	±21	NE	±21	
	Underground activities	NE	±21	NE	±21	
	Post mining	NE	±17	NE	±17	
1.B.1.a.i.i.	Surface mining	NE	±17	NE	±17	
1.B.2. Oil and natural gas		**±4**	**±5**	**±4**	**±4**	**2.4**
1.B.2.a. Oil		±8	±5	±8	±7	
1.B.2.b. Natural gas		±9	±9	NA	±9	
1.B.2.c. Venting and flaring		±4	±4	±4	±4	

(a) Uncertainty reported at 95% confidence limits estimated using Latin Hypercube analysis.

5.4.2 Industrial Processes

An analysis of uncertainty was conducted using the methods recommended in the *Revised 1996 IPCC Guidelines* and random sampling techniques described in the IPCC *Good Practice* report (Monte Carlo and Latin Hypercube simulations). Uncertainty estimates of the components of each emission estimate (activity levels and emission factors) are based on expert judgement.

Using the IPCC approach (and assuming the estimates are independent) gives an overall uncertainty for estimated CO_2 emissions from the *industrial processes* sector of ±6% (Table 19). The overall uncertainty for CO_2 emissions from *metal products* is estimated to be ±7%. Uncertainty in these estimates is the major determinant of uncertainty in aggregate emissions for *industrial processes*.

Table 19. Quantified uncertainties for industrial processes subsectors using the IPCC approach

Greenhouse gas source and sink categories	Uncertainty (%)				Share of inventory (UNFCCC) (%)
	CO_2	CH_4	N_2O	PFCs	
2 INDUSTRIAL PROCESSES	**±6**	**±9**	**±16**	**NA**	**4.9**
A Mineral products	**±5**	**NA**	**NA**	**NA**	**1.0**
1 Cement production	±7	NA	NA	NA	
2 Lime production	±13	NA	NA	NA	
3 Limestone and dolomite use	±9	NA	NA	NA	
4 Soda ash production and use	±22	NA	NA	NA	
B Chemical industry	**±7**	**NA**	**±16**	**NA**	**0.7**
1 Ammonia production	±7	NA	NA	NA	
2 Nitric acid production	NA	NA	±16	NA	
C Metal production	**±7**	**±11**	**±11**	**NA**	**2.7**
1 Iron and steel production	±10	±11	±11	NA	
3 Aluminium production	±7	NA	NA	NE	

As the IPCC approach is not suitable for assessing uncertainty where approximately normal distribution assumptions cannot be sustained, an analysis was undertaken using Monte Carlo and Latin Hypercube techniques. These techniques can take into account asymmetric probability distributions associated with emission factors. For example, as the average emission factor for PFCs tends to the minimum limit that is understood to be technically feasible, the probability of the emission factor being lower than estimated is less than the probability of it being higher than estimated.

The Monte Carlo analysis yielded an overall uncertainty of ±6% and the Latin Hypercube analysis gave an uncertainty of ±5% (Table 20). The uncertainty in the *industrial processes* subsectors ranged from ±7% to ±29%.

Table 20. Quantified uncertainty values for key industrial processes subsectors using different techniques[(a)]

Greenhouse gas source and sink categories	Uncertainty (%)	Derivation
2 INDUSTRIAL PROCESSES		
A.1. Cement production (CO_2)	±7	Based on IPCC approach
	±7	Monte Carlo
	±7	Latin Hypercube
A.2. Lime production (CO_2)	±14	Based on IPCC approach
	±14	Monte Carlo
	±15	Latin Hypercube
A.3. limestone use (CO_2)	±11	Based on IPCC approach
	±11	Monte Carlo
	±12	Latin Hypercube
A.3. dolomite use (CO_2)	±11	Based on IPCC approach
	±11	Monte Carlo
	±11	Latin Hypercube
B.2. Nitric acid (N_2O)	±16	Based on IPCC approach
	±15	Monte Carlo
	±16	Latin Hypercube
C.1. Iron and steel (CO_2)	±10	Based on IPCC approach
	±11	Monte Carlo
	±10	Latin Hypercube
C.1. Aluminium production (CO_2)	±7	Based on IPCC approach
	±7	Monte Carlo
	±7	Latin Hypercube
C.1. Aluminium production (CF_4 as CO_2-e)	NE	Based on IPCC approach
	±29	Monte Carlo
	±27	Latin Hypercube
C.1. Aluminium production (C_2F_6 as CO_2-e)	NE	Based on IPCC approach
	±27	Monte Carlo
	±28	Latin Hypercube
Total CO_2-e for these subsectors	NE	Based on IPCC approach
	±6	Monte Carlo
	±5	Latin Hypercube

(a) Uncertainty reported at 95% confidence limits assuming approximately normal distributions.

5.4.3 Agriculture

5.4.3-1 Livestock

An uncertainty analysis was undertaken for the *livestock* subsectors, addressing both CH_4 and N_2O emissions. Uncertainty distributions were developed for the inputs and the relationships used in the inventory. Where possible, uncertainties were based on quantitative analysis of probability distributions. Nevertheless, many of the distributions remain based on expert judgement. For many biological variables there are limits to the likely minimum and maximum values, and these constrain the distributions. For example, feed intakes have maximum values that are defined by the physiology of the livestock and the characteristics of the feed. Minimum values of feed intake relate to productivity and survival below which the industry wouldn't attempt to operate.

The estimated uncertainty in *enteric fermentation* emissions ranged from –5.1% to +5.9% (Table 21) while the uncertainty in the *manure management* emissions was in the order of 10%. For total CO_2-e emissions from *livestock* the uncertainty was estimated to be –5.3% to +6.1%. The uncertainty in the reported cattle numbers was the most significant contributor to the overall uncertainty.

Recent measurements of methane emissions from sheep on high-quality pastures and cattle on grain diets in Australia show that the inventory procedure produces accurate estimates of methane emission rates. However, further work is needed to reduce uncertainties relating to feed intakes, methane emissions from sheep on low-quality pasture, methane emissions from beef cattle, and emissions from manure under a range of conditions.

Table 21. Relative uncertainty in emission estimates for the livestock subsector[a]

Greenhouse gas source and sink categories	Uncertainty (%)		Share of inventory (UNFCCC) (%)
	CH_4	N_2O	
A. Enteric fermentation	–5.1 to +5.9		11.9
B. Manure management	–9.8 to +11.1	–10.1 to +10.6	0.6

(a) Uncertainty reported at 95% confidence limits estimated using Monte Carlo analysis.

5.4.3-2 Other Agriculture

Estimates of uncertainties in the emissions for the *other agriculture* subsectors were determined using a Latin Hypercube analysis (Table 22). Ideally, the probability distributions of the input variables would be determined by statistical analysis of real data. However, in the current analysis, suitable data sets were not available and the probability distributions were defined using expert judgement. The uncertainty in emission factors and associated parameters were determined from surveys of the published international literature, with emphasis on local Australian measurements. All variables are considered to be independent except fuel load and burning efficiency, which were positively correlated. The activity data with the greatest uncertainties are the areas of savanna fires. These are collated from a large and dispersed number of state government organisations with a wide range of data quality protocols.

There is large relative uncertainty in the emission estimates from all subcategories, including approximately –34 to +50% for methane in the *field burning of residues* subsector and –52% to +110% for nitrous oxide from *agricultural soils*. By way of comparison, estimates presented in the IPCC *Good Practice* guidelines indicate uncertainties of up to +55% and +500% for these sectors respectively as being likely to be typical. Significantly, in all subsectors, most of this uncertainty was derived from the uncertainties in emission factors and associated parameters. Uncertainty in the activity data was a minor contributor to overall uncertainty. This is a result of using three-year averages of annual activity data. The effect of averaging is to significantly reduce the sensitivity of the emissions estimates to uncertainty in the value for any individual year. In most cases, the uncertainty ranges are distributed asymmetrically around the estimates because, while emission factors usually have well constrained minima, their maxima are generally unconstrained.

Table 22. Relative uncertainty in emission estimates for other agriculture subsectors[(a)]

Greenhouse gas source and sink categories	Uncertainty (%)					Share of inventory (UNFCCC) (%)
	CH_4	N_2O	NO_x	CO	NMVOC	
4. AGRICULTURE						**19.6**
C. Rice cultivation						**0.1**
1. Irrigated	–19 to 22					
D. Agricultural soils		**–52 to 110**				**3.6**
1. Direct soil emissions		–51 to 102				
2. Animal production		–91 to 344				
4. Other		–76 to 189				
E. Prescribed burning of savannas	**–64 to 120**	**–67 to 131**	**–67 to 131**	**–63 to 116**	**–62 to 115**	**3.3**
F. Field Burning of agricultural residues	**–34 to 50**	**–36 to 51**	**–38 to 54**	**–36 to 57**	**–37 to 54**	**0.1**
1. Cereals	–37 to 54	–44 to 66	–45 to 69	–40 to 62	–40 to 60	
2. Pulse	NE	NE	NE	NE	NE	
3. Tuber and root	NE	NE	NE	NE	NE	
4. Sugar cane	–49 to 69	–51 to 72	–51 to 71	–49 to 66	–49 to 66	

(a) Uncertainty reported at 95% confidence limits estimated using Latin Hypercube.

5.4.4 Land Use Change and Forestry

Estimating emissions in the *land use change and forestry* sector is complex and difficult due to the inherent uncertainties associated with measuring anthropogenic or natural exchanges of greenhouse gases between the biosphere and the atmosphere. Generally a qualitative assessment of the uncertainties was made using professional judgement of those developing the methodologies and compiling the inventory rather than a rigorous statistical analysis (Table 23). Sensitivity and uncertainty analyses specific to the *forest and grassland conversion* subsector are documented in AGO (2002b).

Table 23. Estimation of uncertainties in components of the land use change and forestry subsectors (UNFCCC accounting)

Subsector	Uncertainty Level	Share of inventory (UNFCCC) (%)
5A Changes in forest and other woody biomass	Medium	-4.0
5B Forest and grassland conversion	Low	7.8
5D Minimum tillage and pasture improvement	High	-0.8
5E Prescribed burning and wildfire	Medium	0.4

Low: Uncertainty of less than 20%; Medium: Uncertainty of 20–60%; High: Uncertainty of greater than 60%.

5.4.5 Waste

The level of uncertainty associated with *landfill* methane recovery is lower than the level of uncertainty associated with methane generated (gross emissions) from *solid waste* and methane generated and recovered from *wastewater*. Landfill recovery data are obtained from organisations operating landfill gas recovery projects. The amounts of methane generated from *solid waste* and *wastewater* are derived from default values and population data. It is conjectured that the uncertainty in emissions estimates from the *waste* sector are substantial and could be as high as 50%. Comparisons against estimates from the IPCC default method reinforce the assessment of uncertainty, although it is known that the IPCC default method overestimates emissions. To some extent, the assessment of uncertainty is conditioned by the fact that it is difficult to make a judgement about the data due to a lack of information, and it is considered appropriate that this be reflected in the assignment of a higher level of uncertainty.

It is recognised that the uncertainty could be substantially lower than 50%. For example, assuming that per capita waste, methane potential and methane recovered are approximately normally distributed with 95% confidence intervals of ±20%, overall uncertainty derived from Latin Hypercube random sampling was ±23.6%. Using these assumptions and assessing uncertainty for all years from 1990 to 2000 simultaneously, uncertainty ranged from ±20.4% in 1990 to ±23.6% in 2000. These results suggest that the overall uncertainty for *solid waste disposal* is likely to be less than ±50%. The uncertainty analysis will be refined once an expert review of the sector is undertaken.

Table 24. Relative uncertainty in emission estimates for key waste subsectors

Greenhouse gas source and sink categories	Uncertainty (%)					Share of inventory (UNFCCC) (%)
	CH_4	N_2O	NO_x	CO	NMVOC	
6. Waste						
A. Solid waste disposal on land	± 50%	NA	NA	NA	NA	**2.9**

GLOSSARY

activity	a process that generates greenhouse gas emissions or uptake – In some sectors it refers to the level of production or manufacture for a given process or category.
automotive diesel oil (ADO)	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.
anaerobic	a process relying on bacteria that can live without oxygen
anthropogenic	resulting from human activities – In the inventory, *anthropogenic emissions* are distinguished from *natural emissions*.
bagasse	the fibrous residue of the sugar cane milling process which is used as a fuel in sugar mills
briquettes	a composition fuel manufactured from brown coal which is crushed, dried and moulded under high pressure without the addition of binders.
clinker	an intermediate product from which cement is made
coke	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 as an energy source and chemical agent. Semi-coke or coke obtained by carbonisation at low temperatures is included in this category.
dolomite	a naturally occurring mineral ($CaCO_3.MgCO_3$) which can be used to produce lime, iron and steel
emission factor	the quantity of greenhouse gases emitted per unit of some specified activity
emission intensity	the total emissions divided by the total energy content of the fuels or the total energy used in a sector – The overall emissions intensity of coal used in Australia, for example, is determined by the quantity and emission factors for each of the many types and grades of coal used.
enteric fermentation	the process in animals by which gases, including methane, are produced as a by-product of microbial fermentation associated with digestion of feed
feedlot	a confined yard area with watering and feeding facilities where livestock (mainly beef cattle) are completely handfed for the purpose

	of production – It does not include the feeding or penning of cattle for weaning, dipping or similar husbandry purposes or for drought or other emergency feeding, or at a slaughtering place or in recognised saleyards.
feedstocks	products derived from crude oil and destined for further processing in the refining industry, other than blending – Products include those imported for refinery intake and those returned from the petrochemical industry to the refining industry, such as naphtha.
flaring	the process of combusting unwanted or excess gases at a crude oil or gas production site, a gas processing plant or an oil refinery
forest	Parties are required to select single minimum values for land area, tree crown cover and tree height. The NCAS when assessing Australia's land use change emissions uses a criteria of 20% tree crown cover, 2 metre minimum tree height, and a minimum of 0.2 hectares in land area for inclusion. These minimum criteria are within the ranges outlined in the Marrakech Accords.
fuel oil	covers all residual (heavy) fuel oils including those obtained by blending
fugitive emissions	generally deliberate but not fully controlled emissions that typically result from leaks, including those from pump seals, pipe flanges and valve stems – Fugitive emissions also include methane emitted from coal mine seams. During petroleum storage tank filling, venting loss of vapour is a fugitive emission.
global warming potential (GWP)	represents the relative warming effect of a unit mass of a gas compared with the same mass of CO_2 over a specific period – Multiplying the actual amount of gas emitted by the GWP gives the CO_2-equivalent emissions.
greenhouse gases	gases that contribute to global warming, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) – In addition, the photochemically important gases—NMVOCs, 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.
hydrofluorocarbons (HFCs)	used as substitutes for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)
industrial diesel fuel (IDF)	a petroleum product primarily consumed in the rail and water transport sectors.
Intergovernmental Panel on Climate Change (IPCC)	the international body responsible for assessing the state of knowledge about climate change – The IPCC increases international awareness of climate change

	science and provides guidance to the international community on issues related to climate change response.
key source	The IPCC *Good Practice* report (IPCC 2000) introduces the concept of key source categories for prioritising the inventory development process. A key source category has a significant influence on a country's total inventory of direct greenhouse gases in terms of absolute level of emissions, the trend in emissions, or both. The Tier 1 key source analysis identifies sources that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms. Tier 2 analysis identified sources that contribute to 90% of total uncertainty in the inventory.
Kyoto Protocol	The Kyoto Protocol to the Convention on Climate Change was developed through the UNFCCC negotiating process. The protocol was negotiated in Kyoto, Japan, in 1997. It sets binding greenhouse gas emissions targets for UNFCCC developed country parties that ratify the agreement.
liquefied petroleum gas (LPG)	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 of the two. In Australia, LPG as marketed contains more propane than butane.
lubricants	hydrocarbons that are rich in paraffin and not used as fuels – They are obtained by vacuum distillation of oil residues.
military transport	includes all activity by military land vehicles, aircraft and ships
National Carbon Accounting System	an integrated suite of models that estimate emissions from biomass, litter and soil carbon in a geographic information system framework with the support of resource inventories, field studies and remote sensing to assess land cover change
natural gas	consists primarily of methane (around 9%, with traces of other gaseous hydrocarbons, as well as nitrogen and carbon dioxide) occurring naturally in underground deposits – As a transport fuel it is generally used in compressed or liquefied form.
navigation	all civilian (non-military) marine transport of passengers and freight – Domestic marine transport consists of coastal shipping (freight and cruises), interstate and urban ferry services, commercial fishing, and small pleasure craft movements. International shipping using marine bunker fuel purchased in Australia is reported but not included in the National Inventory emissions total.
NMVOC	non-methane volatile organic compounds such as alkanes, alkenes and alkynes, aromatic compounds and carbonyls that are gases at standard temperature and pressure (i.e. boiling points below 200°C) and normally 10 or less carbon atoms per molecule; excludes chlorofluorocarbons (CFCs)
PFC	perfluorocarbons, chemical compounds containing carbon and fluorine

	atoms only (e.g. CF_4 and C_2F_6)
prescribed burning	the intentional burning of forests to reduce the amount of combustible material present and thereby reduce the risk of wildfires – In Australia this is known as 'fuel reduction burning'.
process emission	the gas released as a result of chemical or physical transformation of materials from one form to another
Reference approach	a 'top–down' Tier 1 IPCC methodology for estimating CO_2 emissions from fuel combustion activities (1.A).
savanna	a grassland ecosystem with associated woody shrub and/or tree overstorey, the latter with projective foliage cover comprising less than 30% of the area – The IPCC category of 'savanna' is extended to include all non-agricultural grassland ecosystem types that experience burning in Australia.
sink	any process or activity which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere – It includes chemical transformations in the atmosphere and uptake of the gases from the atmosphere by the underlying land and ocean surfaces.
solid waste	waste from various activities; includes *municipal solid waste* (waste from domestic premises and council activities largely associated with servicing residential areas; such as street sweepings, street tree lopping, parks and gardens and litter bins), *commercial and industrial waste*, and *building and demolition waste*
solvent	an organic liquid used for cleaning or to dissolve materials
source	any process or activity that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere
Tier	The IPCC methods for estimating emissions and removals are divided into 'Tiers' encompassing different levels of activity and technology detail. Tier 1 methods are generally very simple (activity multiplied by default emissions factor) and require less data and expertise than the most complicated Tier 3 methods. Tier 2 and 3 methods generally require more detailed country-specific information on things such as technology type or livestock characteristics. The concept of Tiers is also used to describe different levels of key source analysis, uncertainty analysis, and quality assurance and quality control activities.
town gas	includes all manufactured gases that are typically reticulated to consumers, including synthetic natural gas, reformed natural gas, tempered LPG, and tempered natural gas
uncertainty	Uncertainty is a parameter associated with the result of measurement that characterises the dispersion of values that could be reasonably attributed to the measured quantity (e.g. the sample variance or coefficient of variation). In general inventory terms, uncertainty refers to the lack of certainty (in inventory components) resulting from any causal factor such as unidentified sources and sinks, lack of

	transparency etc.
United Nations Framework Convention on Climate Change (UNFCCC)	entered into force in 1994 – Parties to the convention have agreed to work towards achieving the its ultimate aim of stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.
venting	the process of releasing gas into the atmosphere without combustion – This may be done either at the production site or at the refinery or stripping plants. It is done to dispose of non-commercial gas or to relieve system pressure.

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