Australian Government

Department of the Environment

National Inventory Report 2012
Volume 3

The Australian Government Submission to the United Nations Framework Convention on Climate Change

Australian National Greenhouse Accounts

April 2014

© Commonwealth of Australia, 2014.

National Inventory Report 2012 Volume 3 is licensed by the Commonwealth of Australia for use under a Creative Commons By Attribution 3.0 Australia licence with the exception of the Coat of Arms of the Commonwealth of Australia, the logo of the agency responsible for publishing the report, content supplied by third parties, and any images depicting people. For licence conditions see: http://creativecommons.org/licenses/by/3.0/au/

This report should be attributed as '*National Inventory Report 2012 Volume 3*, Commonwealth of Australia 2014'.

The Commonwealth of Australia has made all reasonable efforts to identify content supplied by third parties using the following format '© Copyright, [name of third party] '.

Disclaimer
The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment.

Table of Contents

Volume 3

8. Waste 1

8.1 Overview 1

8.2 Overview of Source Category Description and Methodology – Waste 2

8.3 Source Category 6.A Solid Waste Disposal On Land 3

8.4 Source Category 6.B Wastewater Handling 23

8.5 Source Category 6.C Incineration 39

8.6 Source Category 6.D Biological Treatment of Solid Waste 40

8.7 Uncertainties and Time Series Consistency 42

8.8 Source Specific QA/QC 43

8.9 Recalculations Since the 2011 Inventory 47

8.10 Source Specific Planned Improvements 50

9. Other (UNFCCC Sector 7) 52

10. Recalculations and Improvements 53

10.1 Explanations and Justifications for Recalculations 53

10.2 Implications for Emission Levels 56

10.3 Implications for Emission Trends, Including Time Series Consistency 56

10.4 Recalculations, Including in Response to the Review Process, and Planned Improvements to the Inventory 57

11. Kyoto Protocol LULUCF 69

11.1 General Information 69

11.2 Land-Related Information 71

11.3 Activity-Specific Information 73

11.4 Article 3.3 76

11.5 Article 3.4 91

11.6 Other Information 91

12. Information on Accounting of Kyoto Units 94

12.1 Summary of information reported in the Standard Electronic Format Tables 94

12.2 Discrepancies and notifications 102

12.3 Publically Accessible Information 102

12.4 Calculation of the Commitment Period Reserve 102

12.5 KP-LULUCF Accounting 102

13. Changes to the National System 104

14. Changes to the National Registry 105

15. Minimization of Adverse Impacts in Accordance with Article 3.14 107

ANNEX 1: Key category Analysis 108
A1.1 Convention Accounting 108
A1.2 Kyoto Protocol LULUCF Activities 108

ANNEX 2: Methodology and Data for Estimating Carbon Dioxide Emissions from Fossil Fuel Combustion 128

ANNEX 3: Other Detailed Methodological Descriptions 129

ANNEX 4: Carbon Dioxide Reference Approach for the Energy Sector 130

ANNEX 5: Assessment of Completeness 131

ANNEX 6: Additional Information: Quality Controls including Australia's National Carbon Balance 132
A6.1 Additional information on the QA/QC Plan 132
A6.2 Australia's National Carbon Balance 136
A6.3 Summary of Responses to UNFCCC ERT Recommendations and Comments 145

ANNEX 7: Uncertainty Analysis 167

ANNEX 8: Description of Australia's National Registry 196

ANNEX 9: Glossary 203
9.1 Glossary 203
9.2 Abbreviations 207

ANNEX 10: References 214

List of figures

Figure 8.1:	Emissions from solid waste disposal on land, 1990–2012	2
Figure 8.2:	Australian landfill locations	4
Figure 8.3:	Solid waste to landfill by state	5
Figure 8.4:	Paper consumption, recycling and disposal to landfill - Australia: 1940-2012	7
Figure 8.5:	Estimated wood product wastes production, recycling, aerobic treatment processes and disposal to landfill - Australia: 1990-2012	8
Figure 8.6:	Carbon stock model flow chart	13
Figure 8.7:	Australian climate zones	15
Figure 8.8:	Pathways for Wastewater	24
Figure 8.9:	Sydney Water Wastewater Systems	27
Figure 8.10:	Methane capture from domestic and commercial wastewater treatment 1990 – 2012	33
Figure 8.11:	Quantities of material processed via composting 1990-2012	41
Figure 11.1:	Grassland converted to forestland implied emission factors for Annex I countries and Australia	76
Figure 11.2:	Location (in red) of land included in the deforestation account for 2012	78
Figure 11.3:	Location (in green) of land included in the afforestation/reforestation account for 2012	79
Figure 11.4:	Relative and cumulative frequency histograms of the time since clearing until detection of reforestation event by area	87
Figure 11.5:	Classification and attribution of forest cover gain and loss events in a sequence. This particular sequence, as of 2001, represents the category "forest cover loss and gains detected."	88
Figure 11.6:	Improved spatial analysis applied to the 2012 forest cover loss and gain event sequences to detect deforestation on afforestation/reforestation lands	89
Figure 11.7:	Shows output from spatial analysis of afforestation/reforestation lands in south west Western Australia (mapsheet SI50).	90
Figure A.6.1:	Balance flow chart showing carbon inputs and distribution of outputs for 2012	138
Figure A.6.2:	Fugitive gas balance flow chart for underground mines, 2012	139
Figure A.6.3:	Fugitive gas balance flow chart for open cut mines, 2012	140
Figure A.8.1:	ANREU Logical Network Topology (Production Environment)	197

List of Tables

Table 8.1:	Waste CO_2-e emissions, 2012	1
Table 8.2:	Summary of methods and emission factors used to estimate emissions from waste	2
Table 8.3:	Waste streams: municipal, commercial and industrial, construction and demolition: percentages by State: 2012	6
Table 8.4:	Paper consumption, waste generation and disposal: Australia	8
Table 8.5:	Wood product production, waste generation and disposal: Australia	9
Table 8.6:	Principal data sources and key assumptions made with respect to disposal of paper; waste from HWP production and wood	9
Table 8.7:	Additions and deductions from harvested wood products: 2012	11
Table 8.8:	Individual waste type mix: percentage share of individual waste streams disposed to landfill 2012	12
Table 8.9:	Total waste and individual waste types disposed to landfill (kt): Australia	12
Table 8.10:	Key model parameters: DOC values by individual waste type	14
Table 8.11:	Key model parameters: 'k' values by individual waste type and State	16
Table 8.12:	DOC_f values for individual waste types derived from laboratory experiments	17
Table 8.13:	Derivation of a weighted average DOC_f value for paper	19
Table 8.14:	Key model parameters: DOC_f values by individual waste types	20
Table 8.15:	Methane generation and emissions, Australia: 1990 to 2012	22
Table 8.16:	Wastewater treatment plants by level of treatment	25
Table 8.17:	Effluent discharged from wastewater treatment plants by type of aquatic environment for 2008 and 2009	26
Table 8.18:	Survey data for sludge reuse and disposal in 2008 and 2009	27
Table 8.19:	Sydney Water Corporation Wastewater Treatment Plants 2008	28
Table 8.20:	MCF values listed by wastewater treatment process	32
Table 8.21:	IPCC emission factors for disposal of effluent by type of aquatic environment	36
Table 8.22:	Country-specific COD generation rates for industrial wastewater, 2012	37
Table 8.23:	Methane Conversion factors for industrial wastewater emissions, 2012	38
Table 8.24:	Methane recovered as a percentage of industrial wastewater treatment 2012	38
Table 8.25:	Parameters used in estimation of waste incineration emissions	40
Table 8.26:	Composting emission factors (t CO_2-e/t material processed) used in the Australian inventory	41
Table 8.27:	Estimates of implied protein per capita: Australia: 1990-2012	43
Table 8.28:	Estimates of implied protein per capita for Sydney Water Corporation: 2008, 2009	46
Table 8.29	6.A: Solid Waste: recalculation of methane emissions (Gg CO_2-e)	47
Table 8.30	6.B: Domestic and commercial wastewater: recalculation of emissions (Gg CO_2-e)	48
Table 8.31	6.B: Industrial wastewater: recalculation of emissions (Gg CO_2-e)	48
Table 8.32	6.C: Incineration: recalculation of emissions (Gg CO_2-e)	49
Table 8.33	6.D: Biological Treatment of Solid Waste: recalculation of emissions (Gg CO_2-e)	49
Table 10.1:	Reasons for the recalculations for the 2012 inventory (compared with the 2011 inventory)	54
Table 10.2:	Estimated recalculations for this submission (compared with previous submission): 1990, 2005-2011	56
Table 10.3:	Estimated recalculations for this submission (compared with the previous submission); 1990-2011	57
Table 10.4:	Principal benefits of the NGERS data for the inventory, by IPCC sector	61
Table 10.5:	Summary of planned uses of NGERS data for Australia's national inventory, by IPCC sector	63
Table 10.6:	Summary of planned uses of Carbon Farming Initiative data for Australia's national inventory, by IPCC sector	65

Table 11.1:	Selection of parameters for defining '*Forest*' under the Kyoto Protocol.	69
Table 11.2:	Summary of pools and emissions reported under Article 3.3 and elected activities under Article 3.4	70
Table 11.3:	Land transition matrix for the current inventory year[(1), (2), (3)]	72
Table 11.4:	Summary of methodologies and emission factors – Article 3.3 Kyoto Protocol Land Use Change activities	74
Table 11.5:	Reconciliation of emissions between Kyoto Protocol Deforestation and UNFCCC forest land converted to cropland and forest land converted to grassland	78
Table 11.6:	Distribution of additional, cumulative A/R lands and net sequestration, 2012	80
Table 11.7:	Analysis of afforestation/reforestation lands	90
Table 11.8:	Cumulative area of confirmed deforestation on afforestation/reforestation lands	91
Table 11.9:	Annual area of Afforestation/Reforestation 1990-2012	92
Table 11.10:	Cumulative harvest area within the Afforestation/Reforestation estate 2008-2012	92
Table 11.11:	Summary overview for key categories for land use, land use change and forestry activities under the Kyoto Protocol.	93
Table 12.1:	SEF Table 1, Total quantities of Kyoto Protocol units by account type at beginning of reported year	95
Table 12.2:	SEF Table 2(a), Annual internal transactions	96
Table 12.3:	SEF Table 2(b), Annual external transactions	97
Table 12.4:	SEF Table 2(c), Total annual transactions	97
Table 12.5:	SEF Table 3, Expiry, cancellation and replacement	98
Table 12.6:	SEF Table 4, Total quantities of Kyoto Protocol units by account type at end of reported year	99
Table 12.7:	SEF Table 5(a), Summary information on additions and subtractions	100
Table 12.8:	SEF Table 5(c), Summary information on retirement	101
Table 12.9:	SEF Table 6(a), Memo item: Corrective transactions relating to additions and subtractions	101
Table 12.10:	SEF Table 6(b), Memo item: corrective transactions relating to replacement	101
Table 12.11:	SEF Table 6(c), Memo item: Corrective transactions relating to retirement	101
Table 12.12:	Accounting of Kyoto Protocol Units	102
Table 12.13:	Information table on accounting for activities under articles 3.3 and 3.4 of the Kyoto Protocol	103
Table 13.1:	Change to the national system	104
Table 14.1:	Change to the national registry	105
Table A.1.1:	Key categories for Australia's 2012 inventory-level assessment including LULUCF	109
Table A.1.2:	Key categories for Australia's 2012 inventory—trend assessment including LULUCF	111
Table A.1.3:	Key categories for Australia's 2012 inventory—summary including LULUCF	114
Table A.1.4:	Key categories for Australia's 2012 inventory-level assessment excluding LULUCF	116
Table A.1.5:	Key categories for Australia's 2012 inventory—trend assessment excluding LULUCF	118
Table A.1.6:	Key categories for Australia's 2012 inventory—summary excluding LULUCF	121
Table A.1.7:	Summary overview for key categories for Land use, Land-use Change and Forestry activities under the Kyoto Protocol – 2012	124
Table A.1.8:	Key categories for Australia's 1990 inventory-level assessment including LULUCF	124
Table A.1.9:	Key categories for Australia's 1990 inventory-level assessment excluding LULUCF	126
Table A.6.1:	Summary of principal mitigation strategies and quality control measures	133
Table A.6.2:	Australia's National Carbon Balance 2012	136
Table A.6.3:	Underground mining raw coal production, by coal field	141
Table A.6.4:	Stock of carbon in Australia's living forests, 2001-10	144
Table A.6.5(a):	Summary of responses to UNFCCC ERT recommendations: energy and cross cutting	146
Table A.6.5(b):	Summary of responses to UNFCCC ERT recommendations: Industrial processes	153

Table A.6.5(c):	Summary of responses to UNFCCC ERT recommendations: Agriculture	157
Table A.6.5(d):	Summary of responses to UNFCCC ERT recommendations: Waste	159
Table A.6.5(e):	Summary of responses to UNFCCC ERT recommendations: Land Use Land Use Change and Forestry	160
Table A.6.5(f):	Summary of responses to UNFCCC ERT recommendations: ARTICLE 3.3 ACTIVITIES	164
Table A.7.1:	General reporting table for uncertainty (IPCC Good Practice Guidance Reporting Table 6.1) including LULUCF	168
Table A.7.2:	General reporting table for uncertainty (IPCC Good Practice Guidance Reporting Table 6.1) excluding LULUCF	172
Table A.7.3:	Quantified uncertainty values for key stationary energy subcategories	176
Table A.7.4:	Quantified uncertainty values for mobile source categories	177
Table A.7.5:	Emissions and quantified uncertainty values for key transport subcategories	178
Table A.7.6:	Quantified uncertainty values for key fugitive emissions subcategories	178
Table A.7.7:	Quantified uncertainty values for key industrial processes subsectors using different techniques	180
Table A.7.8:	Relative uncertainty in emission estimates for the livestock subsector	181
Table A.7.9:	Relative uncertainty in emission estimates for other agriculture subsectors	182
Table A.7.10:	Probability density functions used in the uncertainty analysis for agriculture subsectors	183
Table A.7.11:	Estimation of uncertainties in components of the land use change and forestry subsectors	193
Table A.7.12:	Relative uncertainty in emission estimates for key waste subsectors	193
Table A.7.13:	Specific distributions, parameters and results: Solid Waste	194

8. Waste

8.1 Overview

Total estimated waste emissions for 2012 were 11.7 Mt CO_2-e, or 2.2% of total net national emissions (excluding LULUCF) (Table 8.1). The majority of these emissions were from *solid waste disposal on land*, contributing 9.0 Mt CO_2-e or 76.6% of waste emissions. *Wastewater handling* contributed a further 2.6 Mt CO_2-e (22.3%) of waste emissions while waste incineration and biological treatment of solid waste contributed 0.03 Mt CO_2-e (0.3%) and 0.1 Mt CO_2-e (0.8%) respectively. *Waste* emissions are predominantly methane-generated from anaerobic decomposition of organic matter. Small amounts of carbon dioxide are generated through the incineration of solvents and clinical waste and nitrous oxide through the decomposition of human wastes.

Table 8.1: Waste CO_2-e emissions, 2012

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)			
	CO_2	CH_4	N_2O	Total
6 WASTE	30	11,266	427	11,723
A. Solid waste disposal on land	NA	8,981	NA	8,981
B. Wastewater handling	NA	2,201	416	2,617
C. Waste incineration	30	NA	NE	30
D. Other waste	NA	84	11	95

Trends

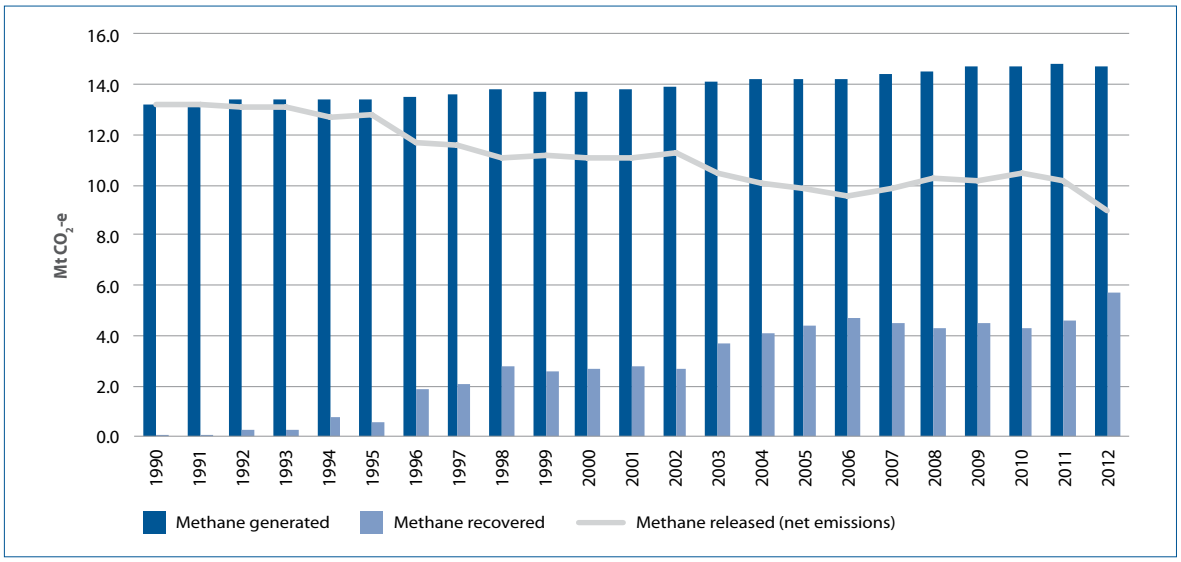
Waste emissions were 31.2% (5.3 Mt CO_2-e) lower in 2012 than they were in 1990 and 9.5% (1.2 Mt CO_2-e) lower than in 2011.

Emissions from municipal *solid waste disposal on land* decreased by 31.9% (4.2 Mt CO_2-e) over the period 1990 to 2012 (Figure 8.1) and were 11.5% (1.2 Mt CO_2-e) lower than in 2011. As waste degradation is a slow process, estimates of methane generation for 2012 reflect waste disposal over more than 50 years.

Rates of methane recovery from solid waste have improved substantially since 1990, increasing from a negligible amount to 5.7 Mt CO_2-e of methane in 2012.

Wastewater handling emissions decreased by 30.4% (1.1 Mt CO_2-e) over the period 1990 to 2012, with a decrease of 2.5% (0.1 Mt CO_2-e) since 2011. Changes in estimates for *wastewater handling* emissions are largely driven by changes in industry production, population loads on centralised treatment systems and the amount of methane recovered for combustion or flaring.

Figure 8.1: Emissions from solid waste disposal on land, 1990–2012



Emissions of CO_2 from the incineration of solvents and clinical waste decreased by 65.0% (0.1 Mt) between 1990 and 2012. Emissions from the biological treatment of solid waste have increased by 1.7% (0.002 Mt CO_2-e) since 2011.

8.2 Overview of Source Category Description and Methodology – Waste

Table 8.2: Summary of methods and emission factors used to estimate emissions from waste

Greenhouse Gas Source And Sink Categories	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
6. Waste	T2	CS	T2	CS,D	CS	D
A. Solid Waste Disposal on Land	NA	NA	T2/3	D	NA	NA
B. Wastewater Handling	NA	NA	T2/3	CS,D	CS	D
C. Waste Incineration	T2	CS	NE	NA	T2	CS
D. Other	NA	NA	T1	CS,D	T1	CS,D

T1= Tier 1, T2 = Tier 2, CS = country specific, M = model, D = default, NE = not estimated, NA = not applicable

8.3 Source Category 6.A Solid Waste Disposal On Land

8.3.1 Source Category Description

The anaerobic decomposition of organic matter in a landfill is a complex process that requires several groups of microorganisms to act in a synergistic manner under favourable conditions. Emissions emanate from waste deposited over a long period (in excess of 50 years in the Australian inventory). The final products of anaerobic decomposition are CH_4 and CO_2. Emissions of CO_2 generated from solid waste disposal are considered to be from biomass sources and therefore are not included in the waste sector of the inventory. CO_2 produced from the flaring of methane from waste is also considered as having been derived from biomass sources.

Solid waste treatment in Australia

Common with the practice in many other developed economies, solid waste is processed in Australia via four main mechanisms:

- landfill;
- biological treatment/composting ;
- incineration; and
- recycling/reuse.

DEWHA (2009) reported that there are at least 665 operating landfills in Australia receiving around 21 Mt of waste. This amount equates to approximately 48% of the estimated total waste generated (44 Mt). The balance of waste, 52% of waste material generated, is recycled or reprocessed (including biological treatment/composting) while a negligible amount is treated thermally (incinerated) (DEWHA 2009). Figure 8.2 shows the physical locations of the major landfills in Australia. The map shows that landfills are clustered around the large population centres around Australia's coastline.

A landfill industry survey conducted by the Waste Management Association of Australia (WMAA) in 2007 found that a relatively small number of sites are responsible for the bulk of the waste received in Australia. Of the landfills surveyed, 39 process more than 200 kt of waste per year, 24 process between 100 kt and 200 kt per year, 32 process between 50 kt and 100 kt per year, 38 process between 25 kt and 50 kt per year, 61 process between 10 kt and 25 kt per year and the remainder (around 55% of the total number of landfills) process less than 10 kt each per year.

Overall, these statistics show the concentrated nature of the landfill industry in Australia. The top 8% of landfills (i.e. the top 39) manage over 55% of total waste received while almost 90% of solid waste sent to landfill in Australia is received in 133 large landfills with capacity to process 25 kt or more of waste each year. In terms of waste management practices in place at Australian landfills, 11% of landfills have a landfill gas collection system in place. However, in the larger scale landfills, this practice is more common meaning that around 30% of the methane generated is collected for either flaring or energy generation.

Figure 8.2: Australian landfill locations

Source: Geoscience Australia

Common management practices amongst larger landfills include the use of leachate collection systems (38% of landfills). Landfill designs include 38% of landfills with clay cell liners in place, 9% use HDPE cell liners while 7% use GCL liners. In terms of capping practices, 59% of landfills use clay capping, whilst 12% of landfills use either HDPE, GCL or evapotranspiration caps.

8.3.2 Activity data

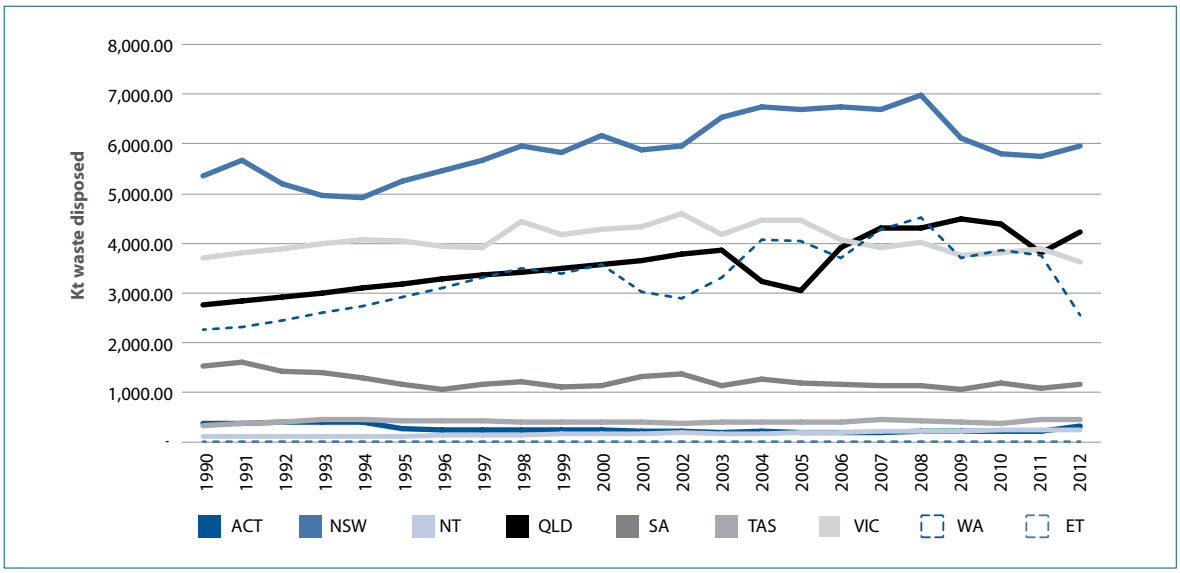
The Australian methodology for calculating greenhouse gas emissions from solid waste is consistent with the IPCC tier 2 First Order Decay (FOD) Model (IPCC 2006). The methodology deployed utilises a dynamic model driven by landfill data provided by the relevant State/Territory Government agencies responsible for waste management together with facility-level data obtained under the NGER (2009-2012) system. Although the structure of the methodology is constant across States, climate-specific parameters introduce variations in estimated emissions depending on location. The model tracks the stock of carbon estimated to be present in the landfill at any given time. Emissions are generated by the decay of that carbon stock, and reflect waste disposal activity over many decades. The methodology is fully integrated with the results of the Harvested Wood Products (HWP) model reported in Chapter 7.

8.3.2.1 Australian waste generation and disposal to landfill

Quantities of waste disposed to landfill are collected by State Government agencies (and in most cases also published). A mix of steady growth and some declines in waste tonnages disposed to landfill has been observed in Australia's States and Territories since 1990 reflecting, in part, differences in population growth and the impact of State government policies on waste management (Figure 8.3). In addition to total disposal in each State/Territory, disposal at individual landfills is obtained under the NGER (2009-2012) system for landfills meeting the reporting thresholds. Approximately 50% of total disposal is covered by NGER facility data. The residual

disposal not covered by the NGER (2009-2012) system is calculated as the total disposal reported for each state and territory minus the sum of NGER disposal in each State and Territory. It is important to note that activity data reported in this NIR and the accompanying CRF tables are for waste disposal to landfill as opposed to waste generated. State and Territory landfill levy schemes are applied specifically to waste disposed and the NGER (2009-2012) system reporting requirements have also been designed to be consistent with this principle.

Figure 8.3: Solid waste to landfill by state



Sources: NSW Department of Environment Climate Change and Water; Sustainability Victoria; QLD Department of Environment and Resource Management; SA Environment Protection Authority; WA Department of Environment and Conservation; Tasmanian Department of Primary Industries, Parks, Water and Environment; ACT Department of Territory and Municipal Services and NGER 2009-2012.

8.3.2.2 Waste streams

Total waste to landfill data is disaggregated into three major waste streams, defined according to relevant State and Territory Government legislation and broadly consistent with the following:

- municipal solid waste – waste generated by households and local government in their maintenance of civic infrastructure such as public parks and gardens;
- commercial and industrial waste – waste generated by business and industry, for example shopping centres and office blocks or manufacturing plants; and,
- construction and demolition waste – waste resulting from the demolition, erection, construction, alteration or refurbishment of buildings and infrastructure. Construction and demolition waste may also include hazardous materials such as contaminated soil or asbestos.

State/Territory and NGER (2009-2012) data have been used to determine the stream percentages. Where disaggregated historical data cease, the stream shares have been held constant back to 1940 (Table 8.3).

Table 8.3: Waste streams: municipal, commercial and industrial, construction and demolition: percentages by State: 2012

	NSW[a]	VIC[b]	QLD[c]	NT[d]	SA[e]	WA[f]	TAS[g]	ACT[h]
Municipal Solid Waste	30%	35%	31%	40%	36%	42%	37%	30%
Commercial and Industrial	43%	39%	38%	40%	39%	27%	56%	45%
Construction and Demolition	27%	26%	31%	20%	25%	32%	7%	25%

Sources: [a] NSW Department of Environment Climate Change and Water; [b] Sustainability Victoria; [c] QLD Department of Environment and Resource Management; [d] SA Environment Protection Authority; [e] WA Department of Environment and Conservation; [f] Tasmanian Department of Primary Industries; [g] Department of Territory and Municipal Services and NGER 2012

Note: External Territories waste stream breakdown is assumed to be the same as QLD.

Some States include clean fill (uncontaminated inert solid material) in their waste to landfill estimates provided and this has an influence on the waste stream proportions, however, as this type of waste is largely inert, there is little effect on the final emissions estimate.

8.3.2.3 Individual waste types

Each waste stream is further disaggregated into a mix of individual waste type categories that contain significant fractions of biodegradable carbon. The categories considered are as follows:

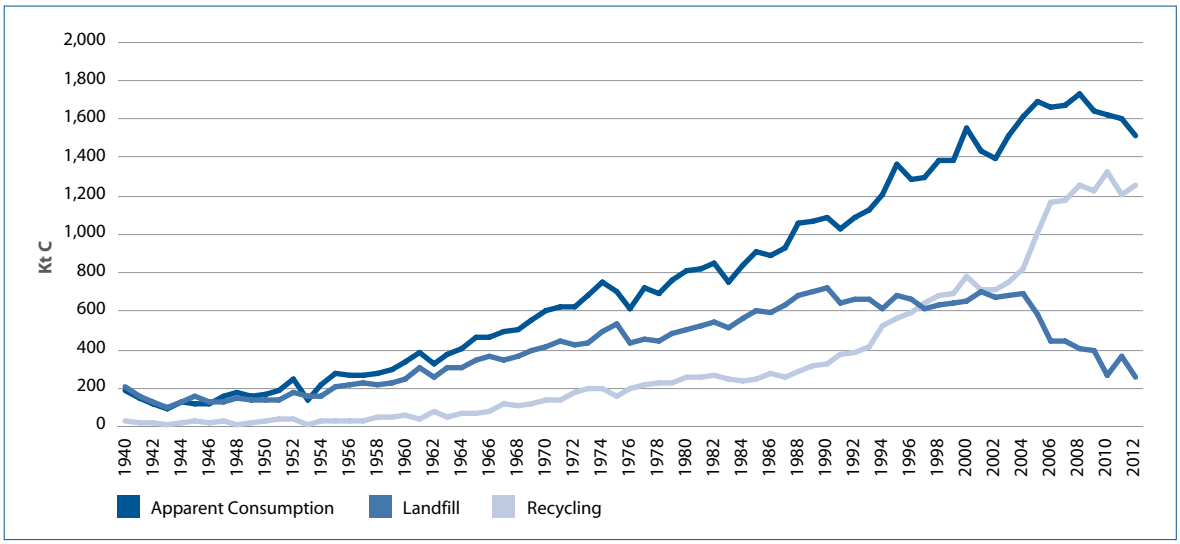
- Food;
- Paper;
- Garden and green;
- Wood;
- Wastes from the production of harvested wood products;
- Textiles;
- Sludge (including biosolids);
- Nappies;
- Rubber and leather; and,
- Inert (concrete, metal, plastics, glass, soil etc).

Harvested wood products - Paper, wood and wood waste generation and disposal

The solid waste disposal estimates and composition are integrated with the wood, wood waste and paper disposal estimates output from the harvested wood products model. These quantities of disposal are used to adjust the waste mix percentages for the non-NGER residual proportion of the waste load going to landfill. This adjustment is undertaken to ensure that the total wood, wood waste and paper disposed to all Australian landfills is consistent with the output of the harvested wood products model.

The amount of paper disposed to landfill reflects those factors that affect the amount of paper in stock reaching the end of its useful life and therefore available for disposal and the changes that have occurred in disposal behaviour - particularly the shift in disposal from landfill to recycling that has occurred since the late 1980s (Figure 8.4). Data on paper and wood reaching the end of their useful life is relatively robust given the long data series available for paper and wood product production, trade and consumption and the assumptions about lifetimes of products reported in Appendix 7.I. This function is a constrained form of the function specified in Section 12.2.2 in IPCC 2006.

Figure 8.4: Paper consumption, recycling and disposal to landfill - Australia: 1940-2012



Source: Refer to table 8.5

Over time the amount of paper waste generated for disposal will be consistent with the amount of paper consumption given the short life time assumed for this product. Overall paper consumption is estimated to have risen from 475 kt in 1940 to reach 3,815 kt in 2012 (ABARES 2013) reflecting both increasing population and increasing per capita consumption levels. In terms of carbon, these consumption estimates translate into an estimated 190 kt C in 1940 and 1,512 kt C in 2012 (Table 8.4). Per capita consumption of paper has increased from an estimated 26 kg C per person in the 1940s to 67 kg C per person in 2012. Reflecting the growth in paper consumption, waste paper generation is estimated to have increased from 245 kt C in 1940 to 1,552 kt C in 2012.

The proportion of paper waste generated that reaches landfill depends critically on the amount of paper diverted to other disposal paths. In Australia, an increasing trend to paper recycling has led to a decrease in the proportion of paper disposed to landfill. The amount of waste paper disposed to recycling as a share of product reaching the end of its useful life has increased from an estimated 30% in 1990 to 81% in 2012, with a sharp jump recorded in 2006 reflecting in part the effectiveness of a number of State Government waste management initiatives. The share of paper disposed to landfill has declined commensurately.

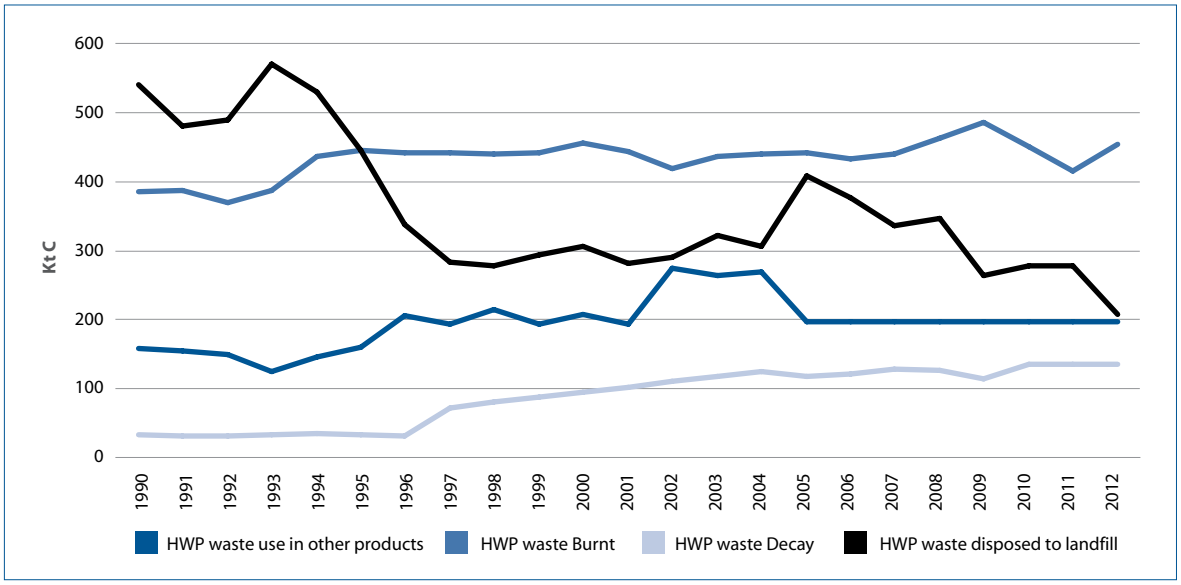
The generation of wastes from the production of harvested wood products, mainly sawmill residues and commercial offcuts, is also a significant source of waste generation and reflects two conflicting trends. The overall production of harvested wood products, particularly sawnwood from hardwoods, increased significantly between 1940 and 1960. Production has increased significantly again since the early 1990s, particularly sawnwood from softwood species and paper production, which has offset declines in the production of sawnwood from hardwood species. The ratio of waste generated to harvested wood product produced has fallen over time, however, reflecting both efficiencies in production and the changes in the mix of products produced and offsetting the effect of the overall increase in production to a large extent. In 1940, the ratio of waste generated to wood and paper product produced was 53%. By 2012, this ratio had fallen to 27%.

The amount of wastes generated from the production of harvested wood products that are disposed to landfill depends critically on how much of the wastes are estimated to have been diverted to other disposal paths or uses including the quantities combusted for energy[1], the quantities of fibre used in the production of other products

[1] Non-CO_2 emissions associated with the combustion of HWP wastes are accounted for in the *energy* sector. CO_2 emissions are reported as a memo item.

(paper) and the quantities disposed to aerobic treatment processes. Of these three possible alternative disposal options, there has been rapid growth in the disposal of wastes to aerobic treatment processes in recent years with a concomitant reduction in wood wastes going to landfill (Figure 8.5).

Figure 8.5: Estimated wood product wastes production, recycling, aerobic treatment processes and disposal to landfill - Australia: 1990-2012



Source: Refer to table 8.5

Table 8.4: Paper consumption, waste generation and disposal: Australia

	Apparent paper consumption	Per capita paper consumption	Closing stock of paper product	Total paper available for disposal/ waste generation	Paper recycling	Paper disposal to landfill	Recycling share of total disposal	Disposal to landfill as share of total disposal
	kt C	kg C/head	kt C	kt C	kt C	kt C		
1940	190	26	200	245	27	204	0.14	0.83
1990	1,086	64	601	1,076	325	719	0.30	0.67
2000	1,548	81	835	1,482	783	655	0.53	0.44
2001	1,434	74	812	1,457	715	699	0.49	0.48
2002	1,398	72	784	1,426	710	674	0.50	0.47
2003	1,514	77	824	1,474	751	679	0.51	0.46
2004	1,608	80	877	1,555	818	690	0.53	0.44
2005	1,691	84	925	1,643	1,007	587	0.61	0.36
2006	1,661	81	926	1,660	1,163	447	0.70	0.27
2007	1,673	79	928	1,671	1,175	446	0.70	0.27
2008	1,735	81	954	1,709	1,256	402	0.73	0.24
2009	1,646	75	928	1,673	1,226	397	0.73	0.24
2010	1,623	73	907	1,644	1,325	269	0.81	0.16
2011	1,605	72	895	1,617	1,202	366	0.74	0.23
2012	1,512	67	855	1,552	1,252	254	0.81	0.16

Source: DE estimates: derived from ABARES 2013, Department of National Development 1969, Jaakko Pöyry Consulting 2000, Recycled Organics Unit 2009. See Table 8.6.

Table 8.5: Wood product production, waste generation and disposal: Australia

	HWP production[(a)]	HWP waste generation	Ratio of HWP waste generation to HWP production	Shares of HWP waste generation combusted (for energy)	Share of HWP waste disposed to landfill	Share of HWP waste disposed to aerobic treatment	Share of HWP waste used in other products
	kt C	kt C					
1940	1,766	932	0.53	0.30	0.67	0.03	0.00
1990	3,307	1,118	0.34	0.34	0.48	0.03	0.14
2000	3,791	1,065	0.28	0.43	0.29	0.09	0.19
2001	3,682	1,021	0.28	0.43	0.28	0.10	0.19
2002	3,918	1,095	0.28	0.38	0.27	0.10	0.25
2003	4,084	1,141	0.28	0.38	0.28	0.10	0.23
2004	4,163	1,141	0.27	0.39	0.27	0.11	0.24
2005	4,249	1,164	0.27	0.38	0.35	0.10	0.17
2006	4,232	1,129	0.27	0.38	0.33	0.11	0.17
2007	4,137	1,103	0.27	0.40	0.31	0.12	0.18
2008	4,204	1,133	0.27	0.41	0.31	0.11	0.17
2009	3,942	1,060	0.27	0.46	0.25	0.11	0.19
2010	3,962	1,062	0.27	0.43	0.26	0.13	0.19
2011	3,825	1,028	0.27	0.38	0.30	0.05	0.27
2012	3,712	995	0.27	0.46	0.21	0.14	0.20

(a) Includes waste generation but excludes roundwood log and woodchip exports.

Source: DE: derived from ABARES 2013, Department of National Development 1969, Jaakko Pöyry 2000. See Table 8.6.

Table 8.6: Principal data sources and key assumptions made with respect to disposal of paper; waste from HWP production and wood

	Paper	Waste from HWP production	Wood
Waste generation inputs			
(1) Production and apparent consumption	ABARES 2013; Jaakko Pöyry 2000, Department of National Development 1969.	Not applicable.	ABARES 2013; Jaakko Pöyry 2000, Department of National Development 1969.
(2) End of useful product life	End of useful life function specified in Jaakko Pöyry 2000 (See Appendix 7.I).	Not applicable.	End of useful life function specified in Jaakko Pöyry 2000 (See Appendix 7.I).
(3) Waste generation	Derived from (1) and (2).	Jaakko Pöyry 2000 (See Appendix 7.I).	Derived from (1) and (2).
Method of disposal			
Landfill	Balance of paper waste generation (3) and paper disposed through recycling, combustion and aerobic decay.	Balance of HWP production waste generation (3) and wastes disposed through recycling, combustion and aerobic decay.	Determined exogenously based on GHD (2008) and Hyder Consulting (2008).

	Paper	Waste from HWP production	Wood
Recycling	Source: ABARES 2013, Jaakko Pöyry 2000.	Source: Jaakko Pöyry 2000, Australian Plantations Products and Paper Industry Council (2006).	Balance of waste generation from wood reaching end-of-useful life and wood disposed to landfill, combustion and aerobic decay.
Combusted for energy / waste incineration	0% assumed combusted for energy or incineration.	Derived as the balance of wood and wood waste combusted by manufacturing industry (Source: BREE 2013a and ABARES 2013) and assumptions on combustion of wood. No data is available on waste incineration.	Combusted for energy: 5% of product disposal (see Appendix 7.I). Source: Jaakko Pöyry 2000. Zero percent of product disposal assumed to be incinerated (i.e. not for energy).
Aerobic treatment processes	3% of product assumed to decay due to aerobic processes based on expert judgement. Source: Jaakko Pöyry 2000.	Source: Recycled Organics Unit (2009). Prior to 1995, 3% of product assumed to decay due to aerobic processes. Source: Jaakko Pöyry 2000.	Decay assumed to be 0% based on expert judgement. Source: Jaakko Pöyry 2000.

The key data sources and assumptions made in relation to the estimation of the data presented in Table 8.4 and Table 8.5 are reported in Table 8.6. The amount of paper disposed to landfill is estimated as the balance of the amount of paper waste generated from paper in stock reaching the end of its useful life and the amount of paper disposed to recycling, combustion and aerobic treatment processes. This estimator ensures completeness and consistency with the estimates of the stock of harvested wood products presented in Appendix 7.I and is considered to produce robust estimates because of the high quality of the available data on apparent paper consumption (ABARES 2013 and the Department of National Development 1969) and paper recycling (ABARES 2013). It also allows for the share of paper in total waste disposed to landfill to vary in response to observed rapid changes in disposal behaviour, in particular, the rapid increase in recycling of paper in Australia.

Similarly, data on the wastes from HWP production are considered robust because of the availability of high quality data on HWP production (ABARES 2013 and the Department of National Development 1969) and on the combustion of wood and wood waste (BREE 2013a). Data on the amount of wastes disposed to aerobic treatment processes is available from the Recycled Organics Unit of the University of New South Wales. The other important assumption set out in Table 8.6 concerns the percentage of wastes lost through incineration. No data is currently available on the amount of waste incinerated as opposed to combusted for energy. Obtaining more accurate data on this variable is difficult. Consequently, the assumption made has been the subject of sensitivity testing, which demonstrates that waste disposed to landfill is inversely related to the assumption on incineration, indicating that there is limited risk of the estimates of waste disposed to landfill used in the inventory being underestimates.

Table 8.7: Additions and deductions from harvested wood products: 2012

	kt C
Additions to the HWP carbon stock	
Apparent consumption of HWP	3,334
Generation of HWP wastes	995
Total additions	4,380
Deductions from the HWP carbon stock	
Disposal to landfill	841
Disposal through combustion for energy/ waste incineration	569
Disposal through aerobic decay	184
Recycling/use in other products	1,283
Total deductions	2,877
Net increment in HWP stock	**1,502**

Combustion of HWP for energy reduces the amount of the HWP stock and is effectively recorded as a reduction in stock (or, equivalently, a source of emissions). In 2012, the reduction in carbon stock from combustion for energy of HWP and wastes generated from HWP production is estimated at 569 ktC. This source of emissions is effectively recorded within the HWP category. Non-CO_2 emissions from the combustion of these products are recorded in Fuel Combustion 1.A. Similarly, the disposal of HWP to landfill reduces the stock of product and is also effectively recorded as a reduction in stock (or source of emissions) against the HWP category. In 2012, the reduction in carbon stock from disposal to landfill is estimated at 841 ktC. Half of this carbon will also eventually be converted to methane in the landfills (effectively, the carbon is counted twice).

Back casting of total waste disposed to landfill

The data available from State Government agencies on total waste disposed to landfill does not extend to the period prior to 1990. Nor are there any possibilities for filling in the gaps with future surveys. In these circumstances, IPCC 2006 notes that a range of splicing and extrapolation techniques are available. The technique chosen to determine the historical time series was a surrogate-data technique where the drivers used to determine total waste to landfill were the amount of waste generated from paper consumption and the estimated amount of waste generated from the production of harvested wood products. These data were chosen because published datasets of production and consumption of these variables, which are closely related to disposal, were available back to 1936. The surrogate technique applied was to assume that the total waste to landfill is perfectly correlated with the sum of paper and wood wastes disposed to landfill for years prior to 1990. This assumption ensures that the more general underlying influences affecting waste generation impact these estimates since a) rising per capita incomes and rising population are reflected in rising demand for paper consumption and consequent waste generation and b) changes in production functions over time (improvements in efficiency) are reflected in the amount of waste generated in HWP.

For disposal data reported under the NGER (2009-2012) system, information is available on the entire operational life of the landfills extending to the pre-1990 period. Where these disposal data available, they have been used. However, it must be noted that this represents only a small proportion of currently operating landfills.

Waste mixes disposed to landfill

Waste composition is determined in two ways. For landfills covered by the NGER (2009-2012) system, their reported waste composition is used directly. Where these data are not available, country-specific waste mix percentages are used. These waste mix percentages are obtained as outlined below.

The base waste mix percentages are derived as a simple average of waste mixes presented in studies conducted by GHD (2008) and Hyder Consulting (2008), except for data on paper and wastes from the production of harvested wood products disposed to landfill which are based on data and assumptions set out in Table 8.6. Actual waste mix percentages change over time as the amount of wood waste and paper entering landfills vary – percentages for 2012 are reported in Table 8.8.

Table 8.8: Individual waste type mix: percentage share of individual waste streams disposed to landfill 2012

	Municipal Solid Waste	Commercial & Industrial	Construction & Demolition
Food	38.5%	24.7%	0.0%
Paper [(a)]	4.3%	4.2%	1.1%
Garden and Green	18.1%	4.6%	2.0%
Wood [(a)]	1.1%	7.1%	6.0%
Waste from HWP production [(a)]		5.9%	
Textiles	2.2%	4.6%	0.0%
Sludge	0.0%	1.7%	0.0%
Nappies	4.4%	0.0%	0.0%
Rubber and Leather	0.5%	4.0%	0.0%
Inert (concrete, metal, plastics and glass, soil etc)	30.8%	43.1%	90.8%

Sources: Derived from GHD 2008 and Hyder Consulting 2008; (a) DE estimates based on data and assumptions in Table 8.6 and GHD 2008.

Table 8.9: Total waste and individual waste types disposed to landfill (kt): Australia

Year	Total waste to landfill [(a,b)]	Food [(b)]	Paper [(b)]	Garden [(b)]	Wood and wood waste [(b)]	Textiles, Sludge, Nappies, Rubber and Leather [(b)]	Other [(b)]
	kt	kt	Kt	kt	kt	kt	kt
1940	10,444	1,978	933	1,878	1,925	421	4,726
1990	16,425	3,039	1,817	1,317	1,913	741	7,599
2000	19,594	3,429	1,740	1,460	1,565	979	10,420
2001	19,021	3,419	1,815	1,473	1,459	959	9,896
2002	19,390	3,488	1,797	1,546	1,488	944	10,128
2003	19,818	3,279	1,840	1,470	1,581	931	10,717
2004	20,587	3,396	1,889	1,519	1,619	964	11,200
2005	20,225	3,419	1,743	1,512	1,742	974	10,833
2006	20,396	3,704	1,527	1,583	1,692	1,071	10,818
2007	21,215	3,794	1,546	1,634	1,692	1,092	11,457
2008	21,794	3,896	1,513	1,654	1,740	1,137	11,854
2009	19,999	3,642	1,531	1,540	1,523	1,081	10,682
2010	19,916	3,627	1,490	1,574	1,552	1,059	10,612
2011	19,207	3,417	1,625	1,479	1,454	1,051	10,179
2012	18,547	3,602	1,553	1,452	1,323	1,095	9,523

(a) State Government Agencies;

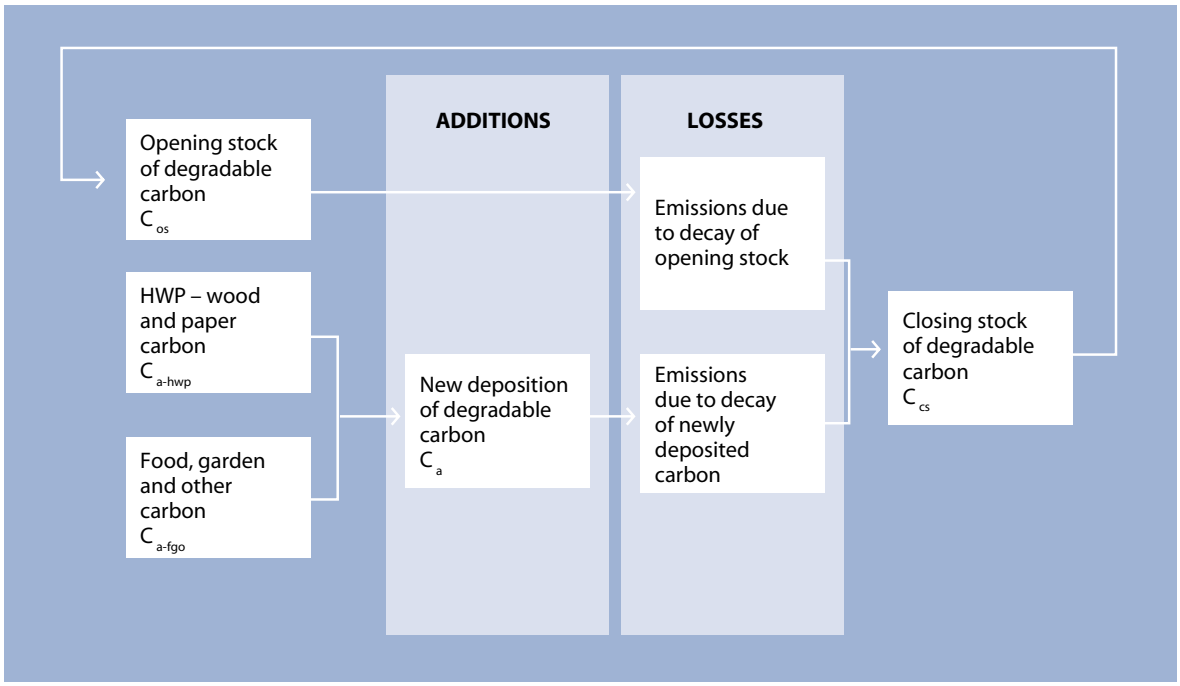
(b) DE estimates.

8.3.3 Methodology

The Australian methodology for the estimation of emissions from solid waste disposal utilises the IPCC tier 2 FOD model presented in the *Guidelines for National Greenhouse Gas Inventories* (IPCC 2006).

The key parameters determining the amount of methane emissions are the fraction of degradable organic carbon in each individual waste type (DOC); the rate of decay assumed for each individual waste type (decay function 'k'); the fraction of degradable organic carbon that dissimilates through the life of the waste type (DOC_f); the methane correction factor (MCF) and the amount of methane captured for combustion. The model is explained in detail in IPCC 2006. The model takes account of the stock of carbon in a landfill by keeping track of additions of carbon through waste disposal and losses due to anaerobic decay. The concept of the carbon stock model approach is illustrated in Figure 8.6.

Figure 8.6: Carbon stock model flow chart



Carbon enters the landfill system via new deposition of waste C_a. Deposition is based on wood and paper carbon transferred from the HWP carbon pool $C_{a\text{-}hwp}$ and carbon in food, garden and other waste derived from data provided by State and Territory waste authorities $C_{a\text{-}fgo}$. A portion of the newly deposited carbon decays in the first year ΔC_a and the remainder contributes to the closing stock of carbon C_{cs}. Additionally, the opening stock of carbon decays over the year ΔC_{os} with the remainder going to the year's closing stock. The closing stock then becomes the next year's opening stock C_{os}. The total change in carbon stock is estimated simultaneously with estimated emissions of methane.

$C_{cs} = C_{os} - \Delta C_{os}$ (emissions lost from opening stock) $+ C_a - \Delta C_a$ (emissions lost from new deposition)

In Australia recent field work estimating methane generated at particular landfills (Bateman 2009, Dever *et al.* 2009 and Golder Associates 2009) has demonstrated that there is potentially a wide variation in methane generation rates across Australian landfills. In Australia, this is interpreted as principally reflecting:

- differences in waste composition at landfills, reflecting both the differing values of degradable organic carbon (DOC) of individual waste types and differing degradable organic carbon that is dissimitable (DOC_f) values of individual waste types; and
- differences in the decay rate 'k' reflecting differences in waste composition, management regimes or local climatic conditions.

8.3.3.1 Degradable Organic Carbon

Values for the degradable organic carbon (DOC) content for each waste mix category used in the model are listed in Table 8.10. The source for these parameters is IPCC (2006).

Table 8.10: Key model parameters: DOC values by individual waste type

Waste Type (wet)	DOC
Food	0.15
Paper	0.40
Garden and Green	0.20
Wood and waste from HWP production	0.43
Textiles	0.24
Sludge	0.05
Nappies	0.24
Rubber and Leather	0.39
Other	-

Source: IPCC 2006.

8.3.3.2 Decay function values 'k'

The half-lives and associated 'k' values for each waste mix category applied in the FOD model are consistent with those provided in IPCC 2006.

Figure 8.7: Australian climate zones

Decay rate constants are applied to disposed waste in two ways. For landfills covered by the NGER (2009-2012) system, the geographical location of the landfill is used to determine which of the 4 IPCC climatic zones is applicable. The distribution of the climate zones across Australia is illustrated in Figure 8.7. The map below has been produced on the basis of average monthly grids of rainfall, pan-evaporation and average temperature from Bureau of Meteorology records between 1970 and 2010.

For the proportion of disposed waste which is not covered by the NGER (2009-2012) system, decay rate constants are assigned according to the on prevailing climatic conditions at the landfill sites of the principal cities in each State and Territory. In each State, average annual temperature and annual rainfall data for the principal landfill sites were taken from data published by the Australian Bureau of Meteorology. The assumptions of climatic conditions for each State/Territory and 'k' values for each waste mix category are outlined in Table 8.11.

Table 8.11: Key model parameters: 'k' values by individual waste type and State

State / Territory	Climate description	Waste mix category	k value
NSW	Wet Temperate	Food	0.185
		Paper and Textiles	0.06
		Garden and Green	0.10
		Wood	0.03
		Textiles	0.06
		Sludge	0.185
		Nappies	0.04
		Rubber and leather	0.06
VIC, WA, SA, TAS, ACT	Dry Temperate	Food	0.06
		Paper and Textiles	0.04
		Garden and Green	0.05
		Wood	0.02
		Textiles	0.04
		Sludge	0.06
		Nappies	0.04
		Rubber and leather	0.04
QLD, NT	Moist and Wet Tropical	Food	0.4
		Paper and Textiles	0.07
		Garden and Green	0.17
		Wood	0.035
		Textiles	0.07
		Sludge	0.4
		Nappies	0.07
		Rubber and leather	0.07

Source: IPCC 2006.

8.3.3.3 Fraction of degradable organic carbon dissimilated (DOC_f)

DOC_f is an estimate of the fraction of carbon in waste that is ultimately degraded anaerobically and released from solid waste disposal site (SWDS) and reflects the fact the some carbon in waste does not degrade or degrades very slowly under anaerobic conditions (IPCC 2006,Vol 5 p3.13). Most countries (but not all) utilise the IPCC default factor 0.5 which is an average DOC_f value that is used for all putrescible waste types and which appears to be based on the results of one study in the Netherlands. On the use of country-specific DOC_f values the IPCC *Good Practice Guidance* states the following:

> *National values for DOC_f or values from similar countries can be used for DOC_f, but they should be based on well documented research.*

There is a growing body of research into the fraction of degradable carbon that is available for anaerobic decay from both Australia and overseas. There is evidence that for certain types of waste such as wood the IPCC default DOC_f value of 0.5, which is an average value, may be an overestimate whilst for waste types such as food it may be an underestimate.

In the Australian context there has been an ongoing program of research into the decay of wood in landfill by researchers from the NSW Department of Primary Industries, the Cooperative Research Centre for Greenhouse Accounting, the Research and Development Division of State Forests NSW and the Chemistry Centre of Western Australia.

This research program was initiated in 2001 when excavated wood samples taken from two sites at Sydney landfills were examined for the extent of decomposition (Gardner *et al.* 2004). The extent of loss of initial carbon from softwood and hardwood materials retrieved from the two landfills that had been closed for 19 and 29 years was found to be insignificant (4.1%). The tests showed slightly greater decay in the samples taken from the site closed for 19 years than the 29 year samples which was explained by the waste management practices at the two sites (one site had leachate recirculation whilst the other had an active methane extraction system in place).

Ximenes *et al.* (2008b) supplemented this work with further field-based research, extracting wood samples from a second Sydney landfill that had been closed for 46 years. Carbon loss from softwood and hardwood material retrieved from the third landfill from the site closed for 46 years was found to be 18% and 17% respectively.

As these investigations are field-based, the results reflect the prevailing conditions and waste management practices in the particular landfills under examination. Nevertheless, the results suggest that wood products are much more resistant to decay under anaerobic conditions than would be implied by the use of the average DOC_f value of 0.5.

The Australian field-based results reflect decomposition over restricted time profiles. They reflect both the DOC_f applicable to the wastes types analysed, which represents the total decomposition of the waste under anaerobic conditions over very long term time horizons, but also the rate of decomposition, 'k', experienced for the period that the waste has been in place.

Estimates of DOC_f that are applicable to very long term time horizons (3-5 half lives) can be estimated from investigations into the carbon storage under anaerobic conditions of a range of waste types under laboratory conditions (Doorn and Barlaz 1995; Barlaz 1998, 2005 and 2008). This experimental work involves the testing of a range of waste types in reactors operated to obtain maximum methane yields. As the laboratory work optimises the conditions for anaerobic decay, the results can be considered as true estimates of the DOC_f value that would apply over very long time horizons. These estimates could also be considered to represent an upper limit of the decay processes found in landfills under anaerobic conditions over more restricted time horizons.

The results of the Barlaz work are presented in Table 8.12 which shows reported values for the initial carbon content and carbon remaining after decomposition and the derived DOC_f value.

Table 8.12: DOC_f values for individual waste types derived from laboratory experiments

Waste type	Initial total organic carbon (kg/dry kg) A	Organic carbon remaining after decomposition (kg/dry kg) B	DOC_f (A-B)/A
Newsprint	0.49	0.42	0.15
Office paper	0.4	0.05	0.88
Old corrugated containers	0.47	0.26	0.45
Coated paper	0.34	0.27	0.21
Branches	0.49	0.38	0.23
Grass	0.45	0.24	0.47
Leaves	0.42	0.3	0.28
Food	0.51	0.08	0.84

Source: Derived by Hyder Consulting 2009 in consultation with Morton Barlaz.

In research currently underway, Barlaz is continuing with the examination of further waste samples including softwood, hardwood, plywood and MDF as well as some Australian wood species. Preliminary results from these laboratory-based experiments broadly confirm the earlier result that the value for wood is significantly less than 0.5. The testing on the additional wood samples is not yet complete. However, the results are expected to be available in the near future. In addition to the examination of wood samples in the study currently underway, a range of Australian paper types have been examined. Preliminary results from this portion of the study are also broadly consistent with results obtained previously and again highlight the range of different DOC_f values observed for different paper types.

Overall, well documented research is available on DOC_f values for individual waste types both from laboratory conditions and from field tests conducted in Australia. The quality of the work conducted in Australia by Ximenes *et al.* 2008b has recently been recognised by the IPCC Emission Factor Database Editorial Board. This well documented research supports the use of DOC_f values for individual waste types for this inventory.

The *2006 IPCC Guidelines* offer further recommendations on the use of DOC_f values for individual waste mix types:

> *Higher-tier methodologies (tier 2 or 3) can also use separate DOC_f values defined for specific waste types... The introduction of waste-type specific values for DOC_f can introduce additional uncertainty into estimates where good waste composition data are not available. Therefore it is good practice to use waste type specific DOC_f values only when waste composition data are based on representative sampling and analysis.*

As outlined above, Australia's waste to landfill data is currently supplied by State and Territory agencies responsible for waste management. The data are collected under the various levy schemes in place in each jurisdiction and are disaggregated into MSW, C&I and C&D waste streams. For example, in NSW landfills are licensed under the *Protection of the Environment Operations Act* 1997 – as part of the licensing provisions, landfill operators are required to report on quantities of waste received at the landfill. Similar arrangements are in place in all jurisdictions. The waste mix percentages used to further disaggregate the waste streams are based upon a wide range of waste audits carried out across Australian landfills typically commissioned by local and State/Territory Governments.

To assess the quality of Australia's waste composition data and acceptability for use with individual waste type DOC_f values, a review was undertaken by an external expert (Guendehou 2010). Guendehou concluded that 'Australia should take advantage of the availability of good waste composition data to apply waste type specific DOC_f in order to improve the accuracy of the emissions estimate'.

Australia's waste type specific DOC_f values

Values of DOC_f for individual waste types that are appropriate for Australia have been selected based on well documented research on DOC_f values contained in Barlaz 1998, 2005 and 2008. These estimates provide an upper limit of an appropriate DOC_f value. The approach adopted, while conservative, is based on the recommendations of Guendehou (2010) after consultations with a range of experts in the industry GHD (2010), Hyder Consulting (2010) and Blue Environment (2010).

For wood products, Australia has selected a value of 0.23 to apply to all wood deposited in landfills in Australia based on the Barlaz estimate for 'branches'. This should be considered as an upper limit of the DOC_f values that are applicable to the anaerobic decay of Australian wood products as the research of Ximenes *et al.* 2008b and Gardner *et al.* 2004 indicates that a range of lower DOC_f values may be possible depending on the type of timber and type of wood product. Ximenes *et al.* 2008b, for example, note that the use of the Barlaz result for 'branches' for timber and wood products could be refined as it is likely that true DOC_f values for certain wood products may be lower depending on the type of timber and wood product. This view was confirmed by Barlaz in the preparation of the 2008 inventory (Hyder Consulting 2009) and supported by GHD 2010. Future research may provide a basis for a review of this factor at some later time and, in fact, preliminary data from Barlaz

(forthcoming) indicates that certain timber classes may be displaying much lower rates of degradation for a range of timber classes in ideal anaerobic conditions. However, until these results are available, the Barlaz 1998 result for branches represents the best possible estimate for the anaerobic decay of timber and wood products.

For food waste the DOC_f value of 0.84 reported in Table 8.13, based on the work of Barlaz 1998 has been used.

For paper, the Barlaz work translates into a range of DOC_f values, for four classes of paper types meaning that it is important to understand the types of paper waste entering the landfill waste system in order to assign the appropriate weights for each of the Barlaz results. Newsprint contains high levels of lignin, which inhibits decomposition in anaerobic conditions, while office paper contains almost no lignin and therefore experiences high levels of decomposition even under anaerobic conditions. In addition, the Barlaz paper classes are not exhaustive of all paper types. Allowance must be made for non-identified paper classes. In these cases, consideration must be given to the possible chemical composition of the paper and theoretical approaches to the estimation of methane potential.

Consequently, it was necessary to make use of available waste audit data to compile a weighted average DOC_f value for the "paper and cardboard" waste mix category. Based on paper waste composition data presented in GHD 2008 and Lamborn 2009, the proportions of paper types corresponding to the Barlaz DOC_f categories have been derived for Australian landfills (Table 8.13).

Given that the classes of paper analysed by Barlaz were not comprehensive, a DOC_f value is also required to be assumed for 'other' paper. One factor important to the analysis of decomposition under anaerobic conditions relates to the amount of cellulose and hemicellulose in the product (see for example, Lamborn 2009). In the case of the paper types analysed with DOC_f values, the reported cellulose and hemicellulose proportions in the product range from 51.7 for coated paper up to 91.3 for office paper (Barlaz 1998). For the classification of 'other' paper, the value of cellulose and hemicellulose reported by Lamborn 2009 is 72.0 – which is very much in the middle of the range reported for the waste paper types for which DOC_f values are available. Consequently, the assumption made is that the DOC_f for the 'other' paper is the weighted average of the paper types for which DOC_f values are available.

Table 8.13: Derivation of a weighted average DOC_f value for paper

Paper type	Composition (% of total paper in analysis) [(a)]	Cellulose and hemicellulose (%) [(b)]	DOC_f [(c)]
Newspaper	4%	54.6	15%
Office paper	11%	91.3	88%
Cardboard	58%	67.2	45%
Coated Paper	1%	51.7	21%
Other paper	25%	72.0	49%
Weighted average of above			49%

(a) Lamborn 2009,

(b) Barlaz 1998,

(c) Hyder consulting 2009, except for 'other paper'.

Micales and Skog (1996) published a range of methane potentials for a comprehensive list of paper types (based on data in Doorn and Barlaz 1995) which show that methane potentials range between 0.054 g CH_4/g refuse for newspaper and 0.131 g CH_4/g refuse for office paper. These results also suggest that the range of DOC_f values shown in Table 8.13 above derived from Barlaz data encompass the broad range of paper types that may be present in Australian landfills and the degradabilities observed in the experimental data.

For garden and park waste a DOC_f value of 0.47 based on the work of Barlaz 1998 has been used. This value assumes the upper estimate calculated by Barlaz for "leaves" and "grass". On this assumption, it represents a conservative upper limit on the likely true DOC_f value for this category.

For the remaining waste categories in the inventory the IPCC default value of 0.5 has been retained. This includes values for textiles, sludge, nappies, and rubber and leather which require additional research to be undertaken before waste type specific values are adopted.

The complete list of DOC_f values for each inventory waste mix type is presented in Table 8.14. As indicated in the QA/QC section, the weighted average DOC_f value for Australian landfills is estimated to be 59.9 for 2012.

Table 8.14: Key model parameters: DOC_f values by individual waste types

Waste type	DOC_f value
Food	0.84
Paper and paper board	0.49
Garden and park	0.47
Wood	0.23
Wood waste	0.23
Textiles	0.50
Sludge	0.50
Nappies	0.50
Rubber and Leather	0.50
Inert waste (including concrete, metal, plastic and glass)	0.00

8.3.3.4 Methane correction factor (MCF)

An important parameter for the emissions calculation is the methane correction factor (MCF) which is intended to represent the extent of anaerobic conditions in landfills. It is assumed that all *solid waste disposal on land* in Australia is disposed to well managed landfills, hence a methane correction factor of 1.0 has been applied to all years. Data from a Waste Management Association of Australia (WMAA 2007) survey on waste management practices undertaken in 2007 was reviewed for this inventory and considered to provide strong evidence that the landfills in Australia adopt management practices that are consistent with the IPCC characterisation of well-managed landfills. 71% of landfills, receiving an estimated 95% of waste, operate with some form of permanent cover. The balance of landfills are assumed to operate within the meaning of well-managed landfills, as defined by the IPCC. No comprehensive data are available to accurately characterise changes to management practices over time.

8.3.3.5 Delay time

The IPCC default delay time of six months (M =13) has been used to reflect the fact that methane generation does not begin immediately upon deposition of the waste. Under this assumption, and given that all waste is assumed to be delivered at the mid-point of the year, anaerobic decay is set to start, on average, on the first day of the year following deposition.

8.3.3.6 Fraction of decomposition that results in methane (F)

The IPCC default value of 0.5 is assumed for this inventory, reflecting the assumption that the decomposition of organic carbon under anaerobic conditions is equally split between the generation of methane and the generation of carbon dioxide.

8.3.3.7 Oxidation factor (OF)

The IPCC default value of 0.1 is assumed for this inventory, reflecting the proportion of methane generated by the decomposition of organic carbon under anaerobic conditions that is oxidised before the gas reaches the surface of the landfill.

8.3.3.8 Methane capture

Net emissions are derived after accounting for methane recovery undertaken at the landfill site. The quantity of methane recovered for flaring and power is based upon reported methane capture under the NGER (2009-2012) system for 2009 onwards and industry survey for the years 1990-2008.

Methane capture reported by landfill gas capture companies is measured according to the gaseous fuels measurement provisions set out in the *NGER (Measurement) Determination*. Under these provisions, a range of options are available to reporters including indirect measurement on the basis of invoices or electricity dispatched or direct measurement at the point of consumption using gas measuring equipment operated in accordance with set standards. Under these reporting provisions, landfill gas companies must also specify whether the collected gas is combusted for power generation, flared or sent offsite for other uses.

Methane recovered (R(t)) is subtracted from the amount generated before applying the oxidation factor, because only landfill gas that is not captured is subject to oxidation in the upper layer of the landfill.

Emissions from the combustion of landfill gas for power generation are reported in the energy sector (1.A.1.a – public electricity and head production)

8.3.4 Emission Estimates

8.3.4.1 Methane

Additions to and losses from the pool of organic carbon in landfills including both degradable and non-degradable organic carbon from all waste types are presented in Table 8.14. Half of the carbon losses are assumed to result in the generation of methane (assuming that F, the share of carbon decay resulting in methane, is the IPCC default value of 0.5). The other half is assumed to be carbon dioxide and is effectively estimated when this carbon is deducted from the pool of carbon in the harvested wood product pool.

Table 8.15: Methane generation and emissions, Australia: 1990 to 2012

Year	Carbon additions to landfill (kt C)	Carbon loss (through emissions) (kt C)	Methane generated (Gg CH_4) [a]	Methane capture (Gg CH_4)	Net methane (Gg CH_4)
1990	2,464	1,048	686	2	684
1991	2,422	1,050	700	2	698
1992	2,398	1,057	702	11	691
1993	2,446	1,057	706	11	695
1994	2,383	1,055	706	35	671
1995	2,397	1,056	705	28	677
1996	2,319	1,058	705	91	614
1997	2,282	1,064	707	98	609
1998	2,367	1,069	711	130	581
1999	2,351	1,067	714	121	593
2000	2,444	1,068	713	129	584
2001	2,440	1,074	713	131	582
2002	2,434	1,082	716	128	587
2003	2,432	1,091	721	176	545
2004	2,474	1,092	726	197	528
2005	2,476	1,092	725	207	518
2006	2,447	1,091	725	222	503
2007	2,441	1,103	723	216	508
2008	2,465	1,116	730	205	525
2009	2,272	1,129	738	215	524
2010	2,175	1,135	745	204	541
2011	2,204	1,134	749	221	528
2012	2,134	1,121	747	272	475

Source: DE estimates.

Note: (a) methane generated prior to oxidation.

8.3.4.2 Non-Methane Volatile Organic Compounds (NMVOC)

Small quantities of NMVOC are contained in landfill gas emitted from landfills in Australia. Some of these NMVOC are generated by the decomposition process and others are residuals from the particular types of waste dumped in the landfill.

The CSIRO Division of Coal and Energy Technology in Sydney (Duffy *et al.* 1995) investigated NMVOC emissions from four landfills in the Sydney region. They found significant concentrations, up to 10 parts per million by volume (ppmv), for approximately 60 different compounds. Researchers in the UK (Baldwin and Scott 1991) have found between 2,200 and 4,500 milligrams per cubic metre (mg/m^3) of NMVOC present in landfill gas.

In Australian landfills, liquid waste is rarely disposed of with solid waste whereas co-disposal is common practice in the UK. On this basis the lower range of 2,000 mg/m^3 found by the UK researchers is used for NMVOC emissions from Australian landfills unless other site-specific information is available.

It is assumed that NMVOC emissions from landfills comprise 0.2% of total landfill gas emissions; the average methane fraction of landfill gas as generated before release to the atmosphere is 0.5. This quantity is a weighted mean for all previous years of waste data used to calculate any inventory year's data and the proportion of methane emitted after oxidation is 0.9.

8.4 Source Category 6.B Wastewater Handling

8.4.1 Source Category Description

The anaerobic decomposition of organic matter in wastewater results in emissions of methane while chemical processes of nitrification and denitrification in wastewater treatment plants and discharge waters give rise to emissions of nitrous oxide.

Large quantities of CH_4 are not usually found in wastewater due to the fact that even small amounts of oxygen are toxic to the anaerobic bacteria that produce the CH_4. In wastewater treatment plants, however, there are a number of processes that foster the growth of these organisms by providing anaerobic conditions.

As methane is generated by the decomposition of organic matter, the principal factor which determines the methane generation potential of wastewater is the amount of organic material in the wastewater stream. This is typically expressed in terms of Chemical Oxygen Demand (COD). COD is a measure of the oxygen consumed during total chemical oxidation (both biodegradable and non-biodegradable) of all material in the wastewater (IPCC 2006).

Nitrous oxide, N_2O, is also generated from municipal wastewater treatment plants. Nitrogen, which is present in the form of urea in urine and also as ammonia in domestic wastewater, can be converted to another compound—nitrate (NO_3). Nitrate is less harmful to receiving waters since it does not take oxygen from the water. The conversion of nitrogen to nitrate is usually done by secondary and tertiary wastewater treatment plants using special bacteria in a process called nitrification. Following the nitrification step some facilities will also use a second biological process, known as denitrification. Denitrification further converts the nitrogen in the nitrates to nitrogen gas, which is then released into the atmosphere. Nitrification and denitrification processes also take place naturally in rivers and estuaries. N_2O is a by-product of both nitrification and denitrification.

Municipal wastewater treatment plants in Australia treat a major portion of the domestic sewage and commercial wastewater, and a significant part of industrial wastewater. Approximately 5% of the Australian population is not connected to the domestic sewer and instead utilise on-site treatment of wastewater such as septic tank systems (WSAA 2005). Some industrial wastewater is treated on-site and discharged either to an aquatic environment or to the domestic sewer system which then feeds into a municipal wastewater treatment plant. A schematic diagram of the pathways for the treatment of wastewater in Australia is shown in Figure 8.8.

Consistent with IPCC *good practice*, methane emissions from effluent discharge to receiving waters is not reported in the inventory. Similarly, N_2O emissions from any form of industrial wastewater discharge and from discharge of municipal wastewater to ocean and deep ocean waters or used in irrigation are considered negligible and are not reported in the inventory.

Sludge removed from wastewater treatment plants is either disposed to landfill or can be further treated to produce biosolids and then used in a land application such as agriculture, horticulture, composting or site rehabilitation. Emissions of methane from disposal of sludge in a landfill are included in the solid waste sector. Emissions of nitrous oxide from land application are not included in the agriculture sector but are included within the wastewater sector itself.

Methane generated at wastewater treatment facilities may be captured and combusted for energy purposes or flared. The amount of CH_4 captured or flared is subtracted from the total CH_4 generated. Quantities of sludge biogas combusted for the production of energy and the associated non-CO_2 emissions are reported in the *stationary energy* sector.

Carbon dioxide emissions are not reported in the *wastewater handling* sector except where they are derived from non-biomass sources of carbon.

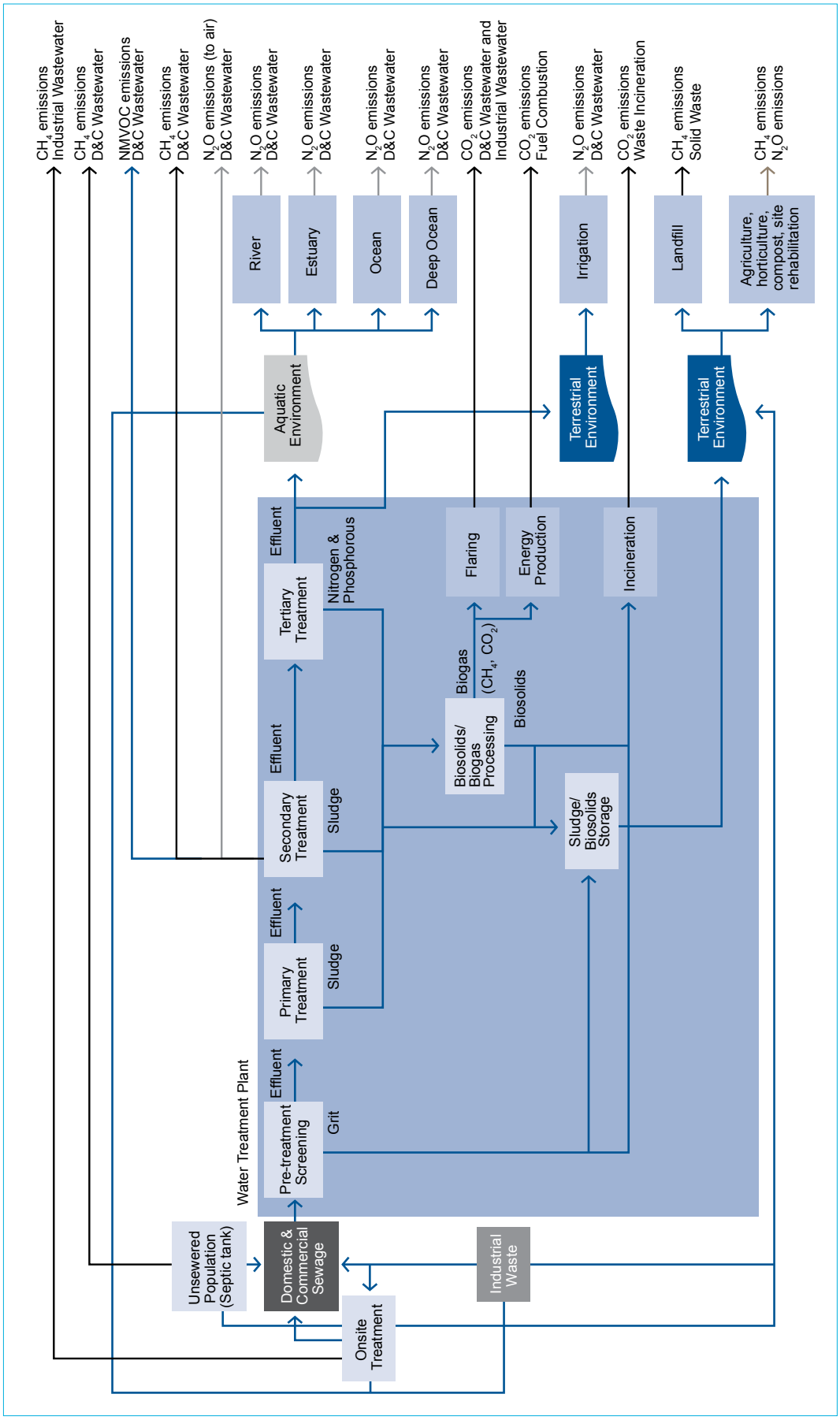


Figure 8.8: Pathways for Wastewater

Wastewater treatment in Australia

A survey of the Australian wastewater industry was conducted by Department of Climate Change in 2009 (DCC 2009) to gather information on the operational characteristics of the wastewater sector including the location of discharge points, treatment levels, effluent volumes and type of aquatic environment to which the effluent flowed. The utilities which participated in the survey were selected on the basis of two criteria: that they serviced more than 50,000 customers and that these customers were living in coastal areas. The 11 utilities in Australia which met these criteria were asked to take part in the survey and 10 of these provided a response. In total, the respondents represented wastewater utilities which operate more than 100 facilities and treat wastewater for over 60% of the Australian population, all of which were living in coastal cities or communities.

More than three quarters of Australia's total population live in coastal areas. According to data from the Australian Bureau of Statistics (ABS 2009e), in 2009 the total Australian population was approximately 22 million people and around 16 million of these were living in capital cities and major centres on the coast of Australia. The residual population not covered by the DCC survey was approximately eight million people and it is estimated that at least three million of these people were also living on the coast of Australia.

The survey found that wastewater treatment facilities in Australia predominantly process wastewater to a secondary or tertiary treatment level before discharging the wastewater into an aquatic environment. However, some large facilities process the wastewater to a primary level only. As the treatment level increases from primary to secondary to tertiary, the number of unit operations used to treat the wastewater and the amount of organic matter and nitrogen removed before discharge to an aquatic environment increases.

Proportions of Australia's population connected to each treatment level are presented in Table 8.16 together with data for the residual population not covered by the survey which has been extrapolated from the survey data where possible. Nitrogen entering and leaving each treatment level is also shown in Table 8.16. The data clearly show that more complex treatment systems remove a greater proportion of nitrogen and thus generate more N_2O.

Table 8.16: Wastewater treatment plants by level of treatment

Wastewater Treatment Level	Population serviced		Annual quantity of nitrogen entering the system (tonnes of N)		Annual quantity of nitrogen in effluent discharged (tonnes of N) [c]	
Primary	2,761,280	13%	15,931	14%	16,169 [d]	66%
Secondary	6,960,027	32%	27,333	25%	6,170	25%
Tertiary	3,231,570	15%	15,849	14%	2,001	8%
Residual - Coastal Area	3,131,923 [a]	14%	18,040 [b]	16%	N/A	N/A
Residual - Inland Area	5,880,487 [a]	27%	33,872 [b]	31%	N/A	N/A
Total	**21,965,287**		**111,024**		**24,341**	

(a) Estimated using data from Australian Bureau of Statistics 2008a.

(b) Estimated using the IPCC default method and protein intake of 0.036 tonnes per year and IPCC default, 0.16 tonnes of nitrogen per tonne of protein.

(c) Total nitrogen discharged does not include the nitrogen discharged for the residual.

(d) Nitrogen discharged from primary treatment is greater than nitrogen received due to the lower removal rate for primary systems and the transfer of wastewater between plants.

The survey also examined the discharge practices of Australian wastewater facilities. The effluent discharged by wastewater treatment plants enters one of four classes of aquatic environment which are defined as follows:

- River means all waters other than estuarine, ocean or deep ocean waters;
- Estuarine waters means all waters (other than ocean or deep ocean waters):
  - (a) that are ordinarily subject to tidal influence, and
  - (b) that have a mean tidal range greater than 800 mm (being the average difference between the mean high-water mark and the mean low-water mark, expressed in millimetres, over the course of a year);
- Ocean means all waters except for those waters enclosed by a straight line drawn between the low-water marks of consecutive headlands and deep ocean waters; and
- Deep ocean means all waters, except for river and estuarine waters, that are more than 50 metres below the ocean surface.

Survey results shown in Table 8.17 indicate that the majority of effluent is discharged to either ocean or deep ocean outfalls. Only a small proportion of effluent from coastal treatment plants is discharged to a river environment (9%). However, when the non-coastal population is taken into consideration, this proportion becomes 29%, with the additional assumption that all wastewater generated from the non-coastal population is also discharged to river. The residual population also includes the population that is unsewered; estimated at approximately 5% of the Australian population. As the type of discharge environment is critical to emissions of N_2O from discharge, this information is also included in Table 8.16 and shows a large proportion of nitrogen discharged goes to deep ocean outfalls, typically more than two kilometres from the coastline at a depth of 50 metres or more.

Table 8.17: Effluent discharged from wastewater treatment plants by type of aquatic environment for 2008 and 2009

Type of aquatic environment	Population serviced		Annual volume of effluent discharged (kilolitres)		Annual quantity of nitrogen entering the plant (t)		Annual quantity of nitrogen in effluent discharged (t)	
River	2,564,463	12%	117,734,320	9%	11,545	10%	1,334	5%
Estuary	2,920,629	13%	187,480,682	14%	16,862	15%	1,775	6%
Ocean	4,405,912	20%	385,746,932	29%	23,055	20%	6,376	22%
Deep Ocean	3,015,430	14%	360,797,519	27%	17,601	15%	16,562	57%
Residual - Coastal Area	3,178,366 [(a)]	14%	N/A	N/A	18,307 [(b)]	16%	N/A	N/A
Residual - Inland Area	5,880,487 [(a)]	27%	269,972,736	20%	28,384 [(b)]	25%	3,162 [(c)]	11%
Total	21,965,287		1,321,732,189 [(d)]		115,756		29,210 [(d)]	

(a) Estimated using data from Australian Bureau of Statistics 2008a.

(b) Estimated using the IPCC default method and protein intake of 0.036 tonnes per year and IPCC default, 0.16 tonnes of nitrogen per tonne of protein

(c) Data value estimated from extrapolation of survey data for river discharge

(d) Total effluent and nitrogen discharged does not include the nitrogen discharged for the residual coastal population.

Sludge treatment and disposal practices were also examined in the survey. Results show that approximately 87% of the nitrogen in sludge transferred out of treatment plants was reported as being used in a land application and 13% was reported as being sent to landfills. The sludge generated by the residual population not covered by the survey has been estimated by extrapolating the data from the survey using a per-capita sludge generation value. Emissions from sludge sent to landfills are included in the solid waste sector while emissions from biosolids (treated sludge) used in a land application are included in wastewater treatment.

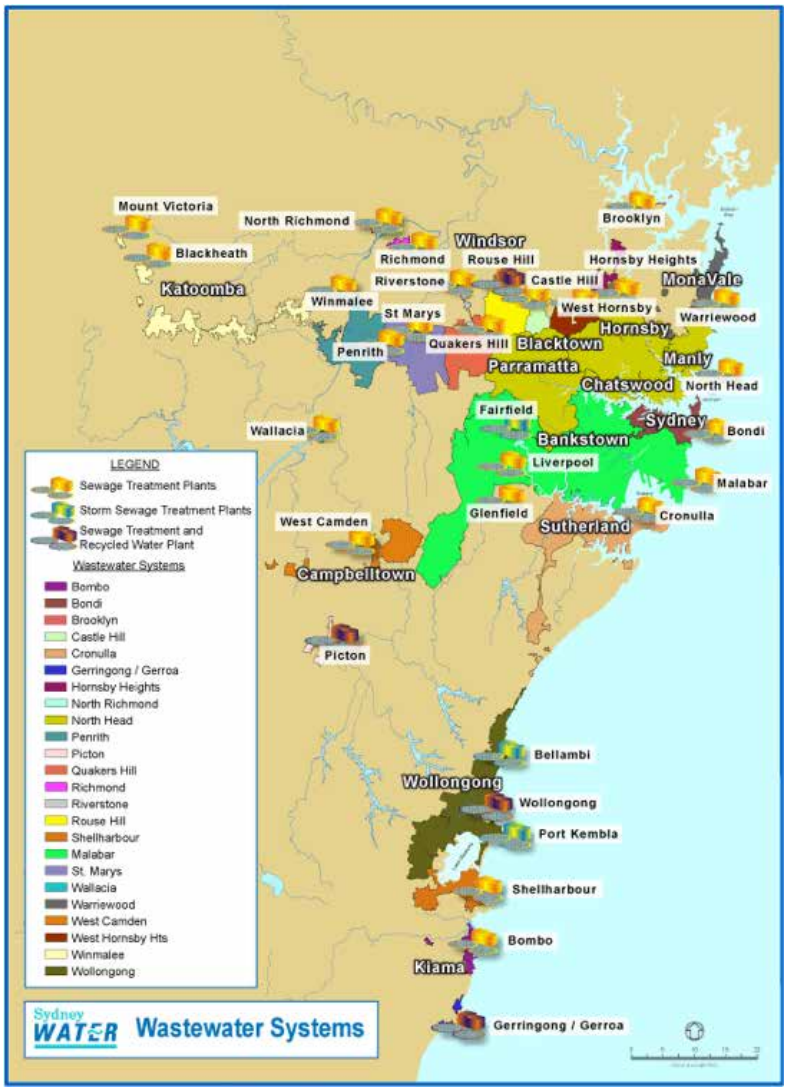
Table 8.18: Survey data for sludge reuse and disposal in 2008 and 2009

	Nitrogen (t)	% Contribution
Sludge to Landfill	1,435	13%
Sludge Reused in Land Application	5,494	49%
Residual Population - Sludge	4,336 [(a)]	38%
Total	**11,264**	

(a) Data value estimated from extrapolation of survey data for sludge

Sectoral snapshot: Sydney Water's effluent discharge Sydney Water Corporation is Australia's largest wastewater utility, with around 30 facilities servicing approximately 20% of Australia's population mainly living in the cities of Sydney and Wollongong. In addition to providing annual reports on each facility to the New South Wales state government, Sydney Water also publish information about their operations on their website at www.sydneywater.com.au. A map of Sydney Water's operations is shown in Figure 8.9 and information made available on their website has been summarised in Table 8.19 below. The data in Table 8.19 shows that 17 of Sydney Water's facilities discharge into a river, however, most of the effluent discharged by volume, approximately 87%, enters ocean and deep ocean waters.

Figure 8.9: Sydney Water Wastewater Systems



Source: Sydney water

Table 8.19 Sydney Water Corporation Wastewater Treatment Plants 2008

	Discharge Type	Discharge Point	Level of Treatment	Total volume of treated wastewater discharged to the waterway (million litres)	Estimated population Serviced	Total discharge load to waterway (kg)	
						BOD	Total nitrogen
Inland sewage treatment plants							
St Marys	River	South Creek (a tributary of South Creek)	Tertiary treatment	14,829	139,700	57,925	63,824
Quakers Hill	River	South Creek (Breakfast Creek, a tributary of Eastern Creek)	Tertiary treatment	13,816	144,400	36,693	64,606
Riverstone	River	South Creek (Eastern Creek, a tributary of South Creek)	Tertiary treatment	743	8400	1,532	5,796
Brooklyn	River	Hawkesbury River at Kangaroo Point	Tertiary treatment	14	500	36	127
West Hornsby	River	Waitara Creek, a tributary of Berowra Creek	Tertiary treatment	5,210	53,500	9,876	21,645
West Camden	River	Matahill Creek, a tributary of the Nepean River	Tertiary treatment	3,913	49,700	13,156	49,545
North Richmond	River	Redbank Creek, a tributary of the Hawkesbury River	Tertiary treatment	341	3,760	886	2,005
Richmond	River	Discharging mainly to irrigation schemes for a local university campus and golf course. Excess flows are discharged to an inland waterway (Rickabys Creek).	Tertiary treatment	391	7,800	675	1,671
Winmalee	River	Unnamed tributary of the Nepean River	Tertiary treatment	6,792	56,300	22,005	66,220
Hornsby Heights	River	Calna Creek, a tributary of Berowra Creek	Tertiary treatment	2,496	28,300	6,058	7,826
Rouse Hill	River	Second Ponds Creek, a tributary of Cattai Creek (partial discharge only)	Tertiary treatment plant and recycled water plant	4,355	63,100	6,168	31,662
Castle Hill	River	Cattai Creek	Tertiary treatment	3,134	24,900	13,157	46,805

	Discharge Type	Discharge Point	Level of Treatment	Total volume of treated wastewater discharged to the waterway (million litres)	Estimated population Serviced	Total discharge load to waterway (kg)	
						BOD	Total nitrogen
Penrith	River	Boundary Creek, a tributary of the Nepean River	Tertiary treatment	9,541	96,800	18,776	39,799
Wallacia	River	Warragamba River	Tertiary treatment	242	2,670	721	1,351
Picton	River	discharging mainly to an irrigation scheme for a local agricultural farm. There are occasional wet weather discharges to an inland waterway (Stonequarry Creek	Tertiary treatment	76	10,200	-	174
Blackheath	River	Hat Hill Creek, a tributary of the Grose River	Tertiary treatment	424		1,676	10,983
Mount Victoria	River	Fairy Dell Creek, a tributary of the Cox's River	Tertiary treatment	72		843	885
Gerringong Gerroa	Recycled or to wetland	Treated wastewater is mainly discharged to an irrigation scheme for a local dairy farm.	Tertiary treatment		11,000	326	201
Coastal sewage treatment plants							
Wollongong (incl. Bellambi and Port Kembla STPs)	Ocean	Reuse at Bluescope steelworks with remainder discharging to the ocean via an extended outfall one kilometre from the shoreline	Tertiary treatment	21,238	199,000	142,551	377,149
Shellharbour	Ocean	Ocean via a nearshore outfall (at Barrack Point).	Secondary treatment	6,681	60,000	29,557	121,904
Bombo	Ocean	Ocean via a shoreline outfall at the headland north of Bombo Beach	Secondary treatment	1,372	13,300	7,212	11,683

	Discharge Type	Discharge Point	Level of Treatment	Total volume of treated wastewater discharged to the waterway (million litres)	Estimated population Serviced	Total discharge load to waterway (kg)	
						BOD	Total nitrogen
North Head	Deep Ocean	Ocean Outfall - The outfall discharges 3.7 km from the shoreline at 65 m maximum water depth	Primary treatment	138,623	1,240,000	34,096,767	6,816,185
Malabar (incl. Liverpool, Glenfield and Fairfield STPs)	Deep Ocean	Ocean Outfall - outfall discharges 3.6 km from the shoreline at 82 m maximum water depth	Primary treatment	185,415	1,690,000	38,204,663	7,669,426
Bondi	Deep Ocean	Ocean outfall 2.2 km from the shoreline at 63 m maximum water depth	Primary treatment	45,256	480,000	9,441,442	2,218,050
Cronulla	Ocean	Ocean via a shoreline outfall at Potter Point	Tertiary treatment	26,930	200,000	84,719	551,882
Warriewood	Ocean	Ocean via a shoreline outfall at Turimetta Head	Secondary treatment	6,878	59,000	71,445	216,595
TOTAL (for all plants)				**498,782**	**4,647,335**	**82,268,865**	**18,397,999**

8.4.2 Domestic and Commercial Wastewater (6.B.2) Methodology

8.4.2.1 Methane Emissions from Wastewater Treatment at Municipal Wastewater Treatment Plants (MWTPs)

Methane emissions from the treatment of wastewater at municipal wastewater treatment plants are estimated according to the default method set out in The IPCC *Good Practice Guidance* which relates emissions to the total quantity of organic waste treated at the MWTP. The emission factors applied to this quantity of organic waste are derived from a consideration of the type of treatment process used at the MWTP and the degree to which the organic waste is treated anaerobically.

Activity data: Organic waste in wastewater

Quantities of organic waste in wastewater treated at individual MWTPs have been obtained under the NGER (2009-2012) system and used for the first time in this inventory. Around 60% of facilities reporting under the NGER (2009-2012) system (numbering 75 in total and servicing around 60% of Australia's population) measured the quantity of COD entering their facility directly. The weighted average per-capita COD entering these facilities is 0.06426 tonnes of COD per person per year.

For the remainder of the category's facilities, a country-specific value of 0.0585 tonnes of COD per person per year (NGGIC 1995) was used for the amount of organic waste in wastewater received at their sites.

Utilities reporting under the NGER (2009-2012) system are also required to report the quantities of COD leaving their facility in effluent and treated in the form of sludge. Sludge refers to the solids generated in the wastewater treatment process. All wastewater treatment plants produce sludge requiring disposal. Sludge generated in Australia is often treated in sludge lagoons, sludge drying beds or anaerobic digesters. Treatment of this sludge can produce methane if it is allowed to decompose anaerobically. The amount of methane generated is variable depending on the type of treatment applied to the sludge. Biosolids are the product of sludge treatment suitable for use in land applications. Emissions from application of biosolids to land are included in the agriculture sector. Sludge and biosolids may also be sent to landfill. Emissions arising from the decomposition of sludge disposed to landfill are included in the solid waste sector.

As with the COD entering the facilities, NGER facility-specific data on COD sludge leaving the facility has been used where this variable has been measured directly. Where this data was unavailable, a country-specific fraction of COD removed and treated as sludge of 0.54 has been applied (NGGIC 1995).

Methodology

Emissions generated from the treatment of COD in wastewater are estimated according to the following equation:

$$CH_{4(t)} = (COD_{in} - COD_{sl} - COD_{out}) * EF_t$$

Where: $CH_{4(t)}$ is the estimated CH_4 emissions from the treatment of sewage at wastewater plants

COD_{in} is the amount of COD input entering into wastewater treatment plants

COD_{sl} is the amount of COD treated separately as sludge

COD_{out} is the amount of COD effluent discharged from wastewater treatment plants into aquatic environments

EF_t is the emission factor for wastewater treated by wastewater plants

Emissions generated from the treatment of sludge are estimated according to the following equation:

$$CH_{4(t)} = (COD_{sl} - COD_{trl} - COD_{tro}) * EF_{sl}$$

Where: $CH_{4(t)}$ is the estimated CH_4 emissions from the treatment of sewage at wastewater plants

COD_{sl} is the amount of COD treated separately as sludge

COD_{trl} is the amount of COD as sludge removed and sent to landfill

COD_{tro} is the amount of COD as sludge removed and to a site other than landfill

EF_{sl} is the emission factor for sludge treated by wastewater plants

Under the NGER (2009-2012) system reporting provisions, wastewater facilities must characterise the type of treatment process used in terms of the fraction of COD (as both sludge and wastewater) treated anaerobically. This parameter is defined as the methane conversion factor (MCF). The 2006 IPCC default MCF values and the definition of the corresponding treatment processes associated with these defaults in Australia are shown in Table 8.20. Facilities reporting under the NGER (2009-2012) system select the most appropriate MCF value for their operational circumstances.

Table 8.20: MCF values listed by wastewater treatment process

Classes of wastewater treatment in *2006 IPCC Guidelines*	MCF Values	Applicable Wastewater Treatment Processes
Managed Aerobic Treatment	0.0	• Preliminary treatment (i.e. screens and grit removal) • Primary sedimentation tanks (PST) • Activated sludge processes, inc. anaerobic fermentation zones and anoxic zones for biological nutrient removal (BNR) • Secondary sedimentation tanks or clarifiers • Intermittently decanted extended aeration (IDEA), intermittently decanted aerated lagoons (IDAL) and sequencing batch reactors (SBR) • Oxidation ditches and carrousels • Membrane bioreactors (MBR) • Mechanically aerated lagoons • Trickling filters • Dissolved air flotation • Aerobic digesters • Tertiary filtration • Disinfection processes (e.g. chlorination inc. contact tanks, ultraviolet, ozonation) • Mechanical dewatering (e.g. centrifuges, belt filter presses)
Unmanaged Aerobic Treatment	0.3	• Gravity thickeners • Imhoff tanks
Anaerobic Digester / Reactor	0.8	• Anaerobic digesters • High-rate anaerobic reactors (e.g. UASB)
Anaerobic Shallow Lagoon (< 2 m deep)	0.2	• Facultative lagoons • Maturation / polishing lagoons • Sludge drying pans
Anaerobic Deep Lagoon (> 2 m deep)	0.8	• Sludge lagoons • Covered anaerobic lagoons

Source: WSAA 2011

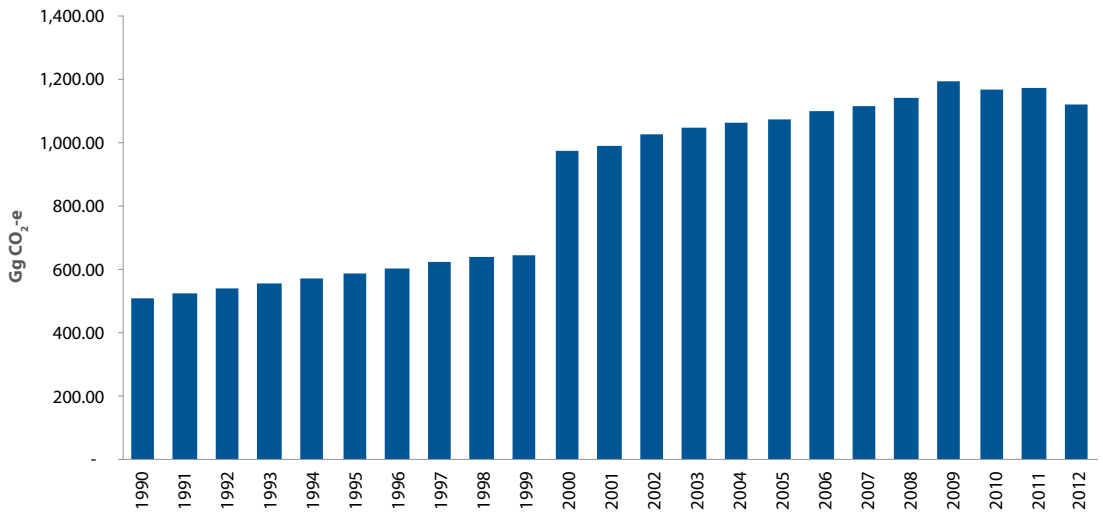
Emission factors for each facility for wastewater and sludge are derived using equation 6.2 in the IPCC *Good Practice Guidance*. The IPCC default maximum methane producing capacity (B_o) of 0.25 kg CH_4/kg COD is used for all facilities.

Methane Capture

Methane recovered for combustion for energy or flared is deducted from the estimated methane generated and is based on directly measured quantities of methane captured for combustion and flaring reported under the NGER (2009-2012) system for the years 2009 onwards. For 1990-2008, recovery is based upon a consideration of historical changes in methane capture capacity at individual wastewater treatment plants. A capture time-series for each wastewater utility has been established based on capture rates for 1990 reported in NGGIC 1995 and on subsequent reported commissioning of cogeneration plants, odour control system upgrades, and general plant capacity upgrades.

Figure 8.10 shows the time-series for methane capture from domestic and commercial wastewater treatment. The significant increase in capture from the year 2000 corresponds to an improvement in capture capacity due to the commissioning of cogeneration facilities at a number of key wastewater treatment facilities serving particularly large populations. The small decline in capture in 2010 reflects a combination of changes to treatment processes (i.e. a shift to aerobic treatment) and reported declines in flaring and combustion of sludge biogas for energy production.

Figure 8.10: Methane capture from domestic and commercial wastewater treatment 1990 – 2012



No data is available on the precise split of methane recovery between wastewater and sludge treatment. For the purposes of reporting in table 6.B.s1 of the CRF table, methane recovery is allocated between wastewater and sludge such that emissions generated from the treatment of sludge are captured and the balance of reported capture is then allocated to wastewater treatment.

Choice of emission factor

There is a proportion of the wastewater treatment sector where no facility-specific data is available under NGER. The choice of parameters applicable to the residual portion of the sector was made in accordance with the decision tree described in Section 1.4.1.

As treatment processes employed at individual facilities are highly technology specific, it was not considered reasonable to extrapolate the factors obtained from NGER data to the facilities in the residual portion of the sector. Consequently, the per-capita COD and region-specific MCF values from NGGIC 1995 were used for 2009 for the residual of the category where no facility-specific data under NGER was available.

Time-series consistency

The use of NGER data has required careful consideration of time-series consistency issues. Facility-level activity data and emission factors are available for 2009–2012 only. In order to preserve time-series consistency, facility-level activity data obtained under NGER has been back-cast as a fixed proportion of total population serviced in each state. Constant facility level MCF values and the proportion of methane generated that was captured in 2009 have been used with the back-cast activity data. This approach to maintaining time series consistency was based on the consideration that the larger-scale facilities covered by NGER utilise well established infrastructure and treatment processes that have not undergone significant changes since 1990.

The residual portion of the sector, for which no NGER facility-specific data is available, has been handled as described above for the entire time-series.

8.4.2.2 Methane Emissions from On-Site Domestic and Commercial Wastewater Treatment

The IPCC *good practice* default method for estimating methane emissions is used to estimate emissions from on-site domestic and commercial wastewater treatment. The total unsewered population on a State by State basis is calculated according to the Australian Bureau of Statistics (ABS 2009e) and WSAA data (WSAA 2005). It is assumed that each person in unsewered areas in Australia produces 0.0585 tonnes of COD per person per year (NGGIC 1995). The amount of COD that settles out as solids and undergoes anaerobic decomposition (MCF) is assumed to be 15%, which is the IPCC default fraction for total urban wastewater (IPCC Vol. 3 1997). The IPCC good practice default emission factor of 0.25 kg CH_4/kg COD is used.

Sludge is also generated by on-site domestic and commercial wastewater treatment. Septic tank systems must be emptied occasionally of the sludge that accumulates inside the system. This sludge is typically transferred to a municipal wastewater treatment facility for further treatment.

8.4.2.3 Nitrous Oxide Emissions from Domestic and Commercial Wastewater Treatment

The methodology used to estimate N_2O emissions from domestic and commercial wastewater treatment utilises a detailed IPCC good practice methodology and comprises estimates for emissions from sewage treatment at a wastewater plant; emissions from discharge of effluent into aquatic environments; and emissions from disposal of treated sludge to land.

$$\text{Total } N_2O\text{-}N = N_2O_{(t)}\text{-}N + N_2O_{(d)}\text{-}N + N_2O_{(l)}\text{-}N$$

Where: N_2O-N is the estimated N_2O emissions from domestic and commercial wastewater treatment

$N_2O_{(t)}$-N is the estimated N_2O emissions from sewage treatment at a wastewater plant

$N_2O_{(d)}$-N is the estimated N_2O emissions from discharge of effluent

$N_2O_{(l)}$-N is the estimated N_2O emissions from application of treated sludge to land

N_2O emissions from sewage treatment at wastewater treatment plants

The emissions of N2O from sewage treatment at wastewater treatment plants are estimated using the following equation:

$$N_2O_{(t)}\text{-}N = (N_{in} - N_{out} - N_{trl} - N_{tro}) * EF_6$$

Where: $N_2O_{(t)}$-N is the estimated emissions from the treatment of sewage at wastewater plants

N_{in} is the amount of nitrogen input entering into wastewater treatment plants

N_{out} is the amount of nitrogen effluent discharged from wastewater treatment plants into aquatic environments

N_{trl} is the amount of nitrogen removed from wastewater treatment plants as sludge and disposed to landfill

N_{tro} is the amount of nitrogen removed from wastewater treatment plants as sludge and disposed at a site other than landfill (reused in land applications) and

EF_6 is the emission factor for sewage treated by wastewater plants

The total nitrogen input entering wastewater treatment plants for Australia in 2009 is obtained from facility specific measurements under NGER and, in addition, DCC 2009 yielded nitrogen treatment and discharge data for a group of utilities not captured under NGER. In total, facility level data obtained under NGER and DCC 2009 covered 108 facilities.

Estimates of the remainder of the nitrogen entering the national system is based on the residual population not covered by the facilities reporting under NGER or DCC 2009 and the average nitrogen input received by the wastewater plants per person serviced by the plants derived from the NGER (2009-2012) system and DCC 2009 facility data. Together with the IPCC good practice assumption for the fraction of nitrogen in protein, 0.16 kg N/kg protein, the facility level data translates into a per capita protein consumption level of 31.9 kg per person per year in 2010 and 31.1kg per person per year in 2011.

Estimates of nitrogen leaving the system as effluent or as sludge disposed to landfill or to a land application, N_{out}, N_{trl} and N_{tro} have also been obtained by facility under the NGER (2009-2012) system and DCC (2009).

The emission factor for the estimation of N_2O emissions from wastewater treatment, EF_6, is the IPCC *good practice* default, 0.01 kg N_2O-N/kg N.

N_2O emissions from discharge of effluent

The effluent discharged into an aquatic environment may enter directly into a river, estuary, ocean surface waters or deep ocean environment depending on the location of the wastewater outfall of each treatment plant. As extensive facility-level information has been collected from verifiable sources on the quantities of nitrogen discharged by location of outfall, Australia is able to use a more detailed country-specific method rather than the IPCC tier 1 method while using IPCC (1997) default factors available for each aquatic receiving environment.

The emissions of N_2O from the discharge of effluent are estimated using the following equation:

$$N_2O_{(d)}\text{-}N = N_{outr} * (EF_{5\text{-}r} + EF_{5\text{-}e}) + N_{oute} * (EF_{5\text{-}e})$$

Where: $N_2O_{(d)}$-N is the emissions from discharge of effluent

N_{outr} is the amount of nitrogen discharged into rivers which then flows into an estuary

N_{oute} is the amount of nitrogen discharged into estuaries

$EF_{5\text{-}r}$ is the emission factor for rivers

$EF_{5\text{-}e}$ is the emission factor for estuaries

The amount of nitrogen discharged by aquatic environment for 2012 is obtained by facility under the NGER (2009-2012) system and DCC 2009.

The IPCC good practice default initial emission factors are 0.0075 kg N_2O-N/kg N for wastewater discharged into rivers ($EF_{5\text{-}r}$) and 0.0025 kg N_2O-N/kg N for wastewater discharged into estuaries ($EF_{5\text{-}e}$) (IPCC good practice 4.73). For wastewater discharged into rivers, the final emission factor is cumulative, ($EF_{5\text{-}r} + EF_{5\text{-}e}$), as it is assumed that the wastewater passes from the river system, through the estuaries and then into the sea. For wastewater discharged directly into an estuary, only ($EF_{5\text{-}e}$) is applied.

While the IPCC *Guidelines* state that nitrous oxide emissions resulting from sewage nitrogen are estimated from 'input of sewage nitrogen to rivers and estuaries' (IPCC 1997 page 4.109) it also states that no methodology is provided for 'N_2O from nitrogen exported to the continental shelf region' (IPCC 1997 page 4.108). Consequently, it is considered that there is no IPCC default method available for the estimation of emissions from effluent discharged directly to ocean waters. Nor is there any empirical literature available on emissions from disposal to ocean waters in Australia - such a study would be prohibitively expensive at this time. The results of the limited number of studies conducted that relate to ocean bodies outside of Australia are not considered appropriate to Australian marine conditions. They are, nonetheless, reviewed in the QA-QC section of this Chapter.

Ocean waters are defined to include only those bodies of water that are beyond the straight line drawn between the low-water marks of consecutive headlands so that waters within headlands, such as bays and basins, are included as part of the estuarine waters. Consequently, the delineation of ocean waters is considered conservative.

Table 8.21: IPCC emission factors for disposal of effluent by type of aquatic environment

Type of Aquatic Environment	Emission factor for initial disposal
River (EF_{5-r}).	0.0075 kg N_2O-N/kg N
Estuary (EF_{5-e}).	0.0025 kg N_2O-N/kg N

Source: IPCC (1997) page 4.110.

N_2O emissions from the application of treated sludge to land

The emissions of N_2O from the application of treated sludge to land is estimated using the following equation:

$$N_2O_{(l)}\text{-}N = N_{tro} * EF_7$$

Where: $N_2O_{(l)}$-N is the emissions from treated sludge applied to the land

N_{tro} is the amount of nitrogen removed as treated sludge and applied to the land

EF_7 is the emission factor for treated sludge applied to land

The amount of nitrogen applied to land is obtained by facility under the NGER (2009-2012) system and DCCEE (2009b). The emission factor for the application of treated sewage to land is 0.009 kg N_2O-N/kg N applied (see Table 6.23 of Volume 1) and is consistent with the N_2O emission factors for manure applied to crops and pastures (Bouwman *et al.* 2002). Emissions from the application of sludge to agricultural land are reported under agricultural soils (4.D) consistent with good practice guidance.

Non-Methane Volatile Organic Compounds (NMVOC)

There has been little research into the release of NMVOC from wastewater treatment plants. BOD values obtained and used for calculations of methane emissions are used for the calculation of NMVOC from domestic and commercial wastewater and for industrial wastewater. A default value of 0.3 kg NMVOC/ tonne BOD for municipal wastewater treatment plants is used.

8.4.3 Industrial Wastewater (6.B.1) Methodology

Technologies for dealing with industrial wastewater in Australia are varied. Some industrial wastewater is treated entirely on-site, while a large amount is treated entirely off-site at municipal wastewater treatment plants. Increasingly industrial wastewater is partially treated on-site before being recycled or discharged to the sewer and treated at municipal wastewater treatment plants. This is due to trade waste discharge licence compliance requirements for a certain quality of wastewater to be achieved prior to sewer discharge.

Most of the industrially produced COD in wastewater comes from the manufacturing industry. According to the IPCC, sectors like food and beverage manufacturing produce significant amounts of COD, some of which is anaerobically treated. Some concentrated industrial wastewater is removed from factories in tankers operated by specialised waste disposal services. This wastewater is usually transported to a special treatment facility.

The methodology to determine the amount of CH_4 generated from industrial wastewater is based on IPCC 2000 and focuses on the 9 industrial sectors which are considered to generate the most significant quantities of wastewater in Australia:

- Dairy production;
- Pulp and paper production;
- Meat and poultry processing;
- Organic chemicals production;

- Sugar production;
- Beer production;
- Wine production;
- Fruit processing; and
- Vegetable processing.

Organic waste in wastewater

Quantities of organic waste in wastewater treated at industrial facilities have been obtained under the NGER (2009-2012) system for 2009 onwards. Where available, the quantity of COD treated at each facility has been taken from direct measurements reported under the NGER (2009-2012) system. Where facility-specific data under the NGER (2009-2012) system are unavailable, estimates are based on country-specific wastewater and COD generation rates shown in Table 8.22.

NGER data are used where industry coverage is considered sufficient to provide a representative picture of wastewater treatment practices in a given industry. In the 2014 inventory submission, NGER data covering the pulp and paper, beer and sugar, dairy, meat and poultry, wine, fruit and vegetables industries are used.

Table 8.22: Country-specific COD generation rates for industrial wastewater, 2012

Commodity	Wastewater generation rate (m^3 wastewater/ t commodity produced)	COD generation rate (kg COD/ m^3 wastewater generated)
Dairy	5.7	1.11
Pulp and Paper	26.7[(b)]	1.00
Meat and Poultry	13.7	0.98
Organic Chemicals	67.0 [(a)]	1.00
Sugar	0.4	1.00
Beer [(c)]	C	C
Wine	23.0 [(a)]	0.54
Fruit	20.0	1.27
Vegetables	20.0	0.18

Source: O'Brien 2006a and NGER 2012 unless otherwise stated.

(a) NGGIC 1995,

(b) Australian Plantation Products and Paper Industry Council 2006,

(c) facility-level parameters obtained for beer production under the NGER (2009-2012) system are confidential.

Choice of methane correction factor

Emission factors for each facility for wastewater and sludge are derived using equation 6.2 in the IPCC *Good Practice Guidance*. The IPCC default maximum methane producing capacity (B_o) of 0.25 kg CH_4/kg COD is used for all facilities.

Under the NGER (2009-2012) system reporting provisions, industrial wastewater facilities must characterise the type of treatment process used in terms of the fraction of COD (as both sludge and wastewater) treated anaerobically. This parameter is defined as the methane conversion factor (MCF). As with COD, data on facility-specific MCF values at industrial wastewater facilities are available for the sugar, pulp and paper and beer industries. Country-specific values outlined in Table 8.23 have been used for other industries based on data in O'Brien (2006a) or NGGIC (1995).

Table 8.23: Methane conversion factors for industrial wastewater emissions, 2012

Commodity	MCF wastewater	MCF Sludge
Dairy	0.5	0.3
Pulp and Paper	0.7	0.7
Meat and Poultry	0.4	0.2
Organic Chemicals	0.1 [(a)]	0.2
Sugar	0.3	0.2
Beer [(b)]	C	C
Wine	0.3	0.4
Fruit	1	0.2
Vegetables	1	0.2

Source: NGER 2012 unless otherwise stated.

(a) NGGIC 1995,

(b) facility-level parameters obtained for beer production under the NGER (2009-2012) system are confidential.

Methane Emissions from Disposal of Sludge Generated by Industrial Wastewater Treatment

A proportion of the COD generated in the industrial wastewater is ultimately treated as sludge. Quantities of COD treated as sludge have been obtained for the dairy, paper, meat and poultry, sugar, beer, wine, fruit and vegetable processing industries from the NGER (2009-2012) system. For the organic chemicals, a constant fraction of COD of 0.15 is assumed to be treated separately as sludge (NGGIC 1995).

Methane Capture

Estimates of the quantities of methane captured have been obtained from the NGER (2009-2012) system for dairy, paper, meat and poultry, sugar, beer, wine, fruit and vegetable processing facilities for 2009 onwards and derived from facility-level data in O'Brien (2006a) and NGGIC (1995) for the years 1990-2008. For organic chemicals for which NGER data has not been used, the sources are O'Brien (2006a) and NGGIC (1995).

As with domestic and commercial wastewater treatment, no data is available on the precise split of methane recovery between wastewater and sludge treatment. For the purposes of reporting in Table 6.B.s1 of the CRF table, methane recovery is allocated between wastewater and sludge on the basis of emissions generated from sludge treatment as a proportion of total capture with the balance being allocated to wastewater.

Table 8.24: Methane recovered as a percentage of industrial wastewater treatment 2012

Commodity	Fraction of methane recovered/flared (%)
Dairy [(b)]	27%
Pulp and Paper [(c)]	67%
Meat and Poultry [(b)]	9%
Organic Chemicals [(b)]	6%
Sugar [(c)]	0%
Beer [(a),(c)]	23%
Wine [(b)]	26%
Fruit [(b)]	7%
Vegetables [(b)]	17%

Source: (a) O'Brien 2006a

(b) NGGIC 1995

(c) NGER 2012.

Time-series consistency

Time-series consistency has been maintained through the interpolation of MCF values and proportions of methane captured for pulp and paper , sugar, dairy, meat and poultry, wine and fruit and vegetables for 1990-2008. For the beer industry, facility-specific MCF values and quantities of methane captured were available for the years 2003 to 2005. For the years 1990-2002 in the beer time series, the 2003 values for MCF and proportion of methane generated that was captured have been used. For the years 2006 – 2008, the 2009 NGER MCF and proportion of methane captured have been applied. This introduces a step change in the methane capture estimates for beer in 2006 where the amount of methane captured doubles, reflecting a doubling in treatment plant capacity in the beer industry during 2006.

For the organic chemicals where NGER data have not been used, time-series consistency is ensured through the use of a consistent methodology and associated parameters.

Nitrous oxide emissions from industrial wastewater

Nitrogen generated and discharged to the sewer system is ultimately treated at centralised municipal wastewater treatment plants. As N_2O emissions estimates at these plants are estimated based on the measurement of nitrogen entering the plant, this value is also inclusive of any nitrogen originating from industrial sources. Therefore emissions of N_2O from *industrial wastewater* are included in the estimate of N_2O emissions from *domestic and commercial wastewater*.

8.5 Source Category 6.C Incineration

Emissions are estimated from the incineration of solvents and municipal and clinical waste. Incineration estimates include a quantity of solvent generated through various metal product coating and finishing processes. In this instance, incineration is used as a method to minimize emissions of solvents and VOCs to the atmosphere and leads to emissions of CO_2. Data on the incineration of solvents prior to 2004 is based on company data after which emissions from this source have been based on data estimated by the DE.

Carbon dioxide emissions from incineration of solvents are estimated by converting the volume of solvent incinerated (Litres) to the weight of solvent (using specific volume factor of 1229 L/t), deriving the energy content of the mass of solvent (using the energy content of 44 GJ/t), and using a carbon dioxide emission factor per petajoule of solvent (69.6 Gg/PJ).

Between 1990 and 1996, there were three incinerators receiving municipal solid waste. These were located in New South Wales and Queensland. All three incinerators ceased operations in the mid-1990's.

In addition to the incineration of municipal solid waste, a quantity of clinical waste is incinerated in four major facilities located in Queensland, New South Wales, South Australia and Western Australia. Data on the quantities of municipal solid waste incinerated are based upon published processing capacities of the three incineration plants prior to decommissioning. Data on the quantities of clinical waste incinerated have been obtained from a per-capita waste generation rate derived from data reported under the NGER (2009-2012) system, by O'Brien (2006b) and an estimate of State population reported by the Australian Bureau of Statistics.

The quantity of CO_2 emitted as a result of the incineration of municipal and clinical waste is based upon the quantity of waste incinerated, the carbon content of the waste and the proportion of that carbon which is of fossil origin and the efficiency of the combustion process (oxidation factor). The country-specific fossil carbon content of municipal waste of 7% is based upon empirical data presented in NGGIC (1995) for incineration activities occurring in 1990. Of this 7% of fossil carbon in municipal waste, it is estimated that 80% of this carbon is combustible (NGGIC 1995). Emissions of N_2O from the incineration of municipal solid waste are also estimated based on a country-specific emission factor of 0.00015 Gg of N_2O/G of waste taken from NGGIC (1995). The carbon content factors used in the emissions estimation are shown in Table 8.25.

Table 8.25: Parameters used in estimation of waste incineration emissions

	Municipal Solid Waste [(a)]	Clinical Waste [(b)]
Proportion of waste that contains fossil carbon	0.07	
Proportion of waste that is carbon		0.6
Proportion of fossil carbon containing products that is carbon	0.80	
Fossil carbon content as a proportion of total carbon		0.4
Oxidation factor	1	0.95

Sources: (a) NGGIC 1995,
(b) IPCC 2000.

8.6 Source Category 6.D Biological Treatment of Solid Waste

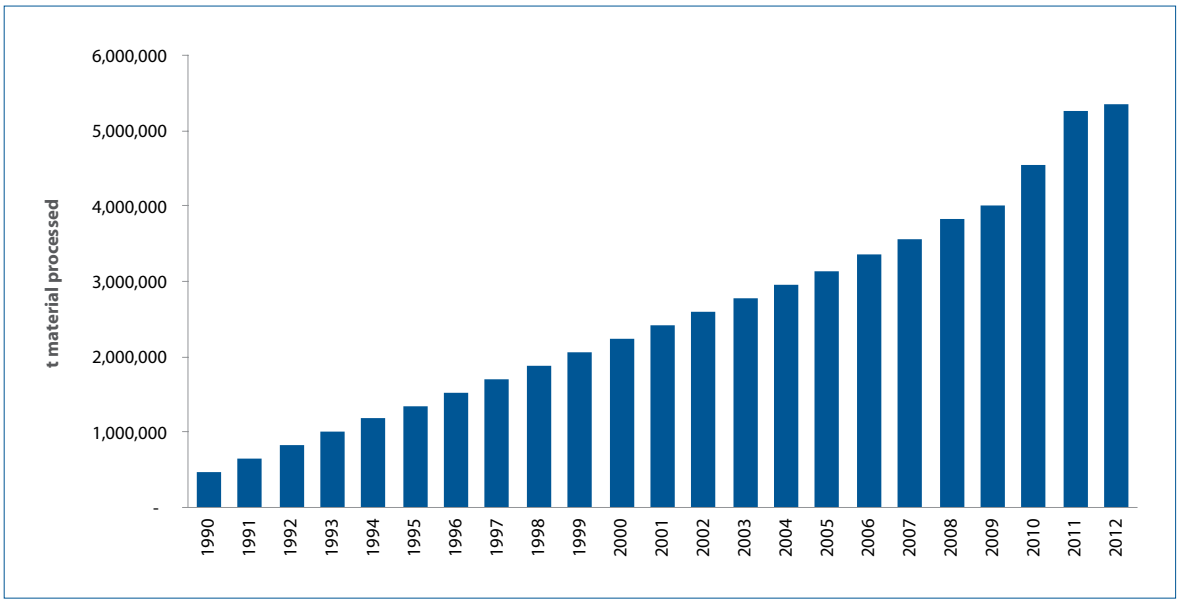
Estimates of emissions from the biological treatment of solid waste (for example, composting and anaerobic digestion) have been included for the first time in this submission. Emissions from the biological treatment of solid waste were 95 Gg CO_2-e in 2012.

Biological treatment of solid waste through processes such as windrow composting and enclosed anaerobic digestion is considered an emerging treatment pathway in Australia and one where a small amount of activity data has become available under the NGER (2009-2012) system and through an annual industry survey. For this inventory, there is no anaerobic digestion being undertaken in Australia, however, it is expected that the use of these kinds of waste treatment processes will be taken up and reported on in coming years. This is based on more recent NGER facility level data now available.

Methodology

Australia has applied the tier 1 method from the *2006 IPCC Guidelines* to derive estimates of emissions based upon the total amount of material processed through composting and anaerobic digestion. Activity data are obtained from an annual industry survey undertaken by the Recycled Organics Unit at the University of New South Wales. Survey data cover the years 2004 to 2010 with extrapolation used to derive activity data for the years 1990 to 2003 (ROU various years). The time-series of quantities of waste material processed via composting is shown in Figure 8.11.

Figure 8.11: Quantities of material processed via composting 1990-2012



Choice of Emission Factors

Australia has adopted country-specific emission factors for CH_4 and N_2O emissions from composting based on research conducted by Amlinger (2008) covering the composting of bio-waste, loppings and home composting material. The emission factors are shown in Table 8.26.

Table 8.26: Composting emission factors (t CO_2-e/t material processed) used in the Australian inventory

	CH_4 emission factor (t CO_2-e/t material processed)	N_2O emission factor (t CO_2-e/t material processed)
Composting	0.016	0.030

The country-specific emission factors have been drawn from the document *Update of emission factors for N_2O and CH_4 for composting, anaerobic digestion and waste incineration* (DHV 2010) which itself cites Amlinger 2008 as the source of its recommended emission factors. DHV 2010 presents a synthesis of all available research data covering emissions from the biological treatment of solid.

These emission factors are considered suitable for use in Australia's inventory due to the following:

1. Emission factors fall within the IPCC default ranges.

While the CH_4 and N_2O emission factors chosen are towards the lower end of the default range, it has been concluded by Alminger (2008) that values in excess of 0.065 t CO_2-e / t material processed probably indicate some kind of system mis-management such as insufficient aeration or mechanical turning. The mid-range IPCC default factors according to this conclusion would suggest a level of system mismanagement not thought to occur in Australia.

2. Waste types considered by Amlinger (2008) are representative of waste types commonly processed via biological treatment in Australia (namely bio-waste and greenwaste).

GHD 2010 cites typical materials treated by the various biological processes in Australia:

- Source separated garden organics;
- Source separated garden organic organics with biosolids;
- Source separated garden organics with food waste;
- Source separated garden organics with food waste and biosolids;
- Source separated food waste; and
- Mixed residual waste containing food waste and paper.

3. The technologies examined (windrow composting processes) are reflective of those commonly used in Australia. The Recycled Organics Unit identifies aerobic windrow composting as the dominant form of biological treatment of solid waste currently employed in Australia.

8.7 Uncertainties and Time Series Consistency

8.7.1 Waste sector

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and gas. Time-series consistency is ensured by use of consistent models, model parameters and datasets for the calculations of emissions estimates. Where changes to emission factors or methodologies occur, a full time-series recalculation is undertaken.

8.7.2 Wastewater handling

Facility level data on nitrogen entering the domestic and commercial wastewater system is used for the years 2008 onwards, as reported in DCC 2009 and under the NGER (2009-2012) system. Time-series consistency has been maintained for the estimates of Australia's protein per capita intake through the following assumptions. The protein per capita consumption value for the years 1990 to 1993 of 99.4 g/day (36.28 kg/year) is sourced from the Australian Institute of Health and Welfare (AIHW) (de Looper and Bhatia 1998). The values for 1994 to 1998 are based upon data presented in AIHW 2002. Linear interpolation was used to derive values for 1999 to 2007, which is the period for which no data are available. The following table shows the time series for values used for protein per capita consumption.

Table 8.27: Estimates of implied protein per capita: Australia: 1990-2012

Year	Protein per capita g/capita/day
1990	99.4
1991	99.4
1992	99.4
1993	99.4
1994	97.9
1995	96.6
1996	97.4
1997	100.5
1998	101.0
1999	100.5
2000	100.0
2001	99.5
2002	99.0
2003	98.6
2004	98.1
2005	97.6
2006	97.1
2007	96.6
2008	96.1
2009	98.3
2010	87.3
2011	85.2
2012	90.6

Sources: de Looper and Bhatia 1998 (1990-1993), AIHW 2002 (1994 – 1998), DCC 2009 (2008), NGER 2009- 2012.
Note: interpolation used for years 1999 to 2007 inclusive.

8.8 Source Specific QA/QC

8.8.1 Solid waste disposal on land

Emissions from solid waste disposal reflect a large amount of activity data and assumptions in relation to parameters in the IPCC first order decay model. Consequently, an intensive and systematic quality control system is required to ensure that emission estimates meet the required quality characteristics of accuracy, completeness, comparability, time series consistency and transparency.

The quality control system has established measures to test the key data inputs and emissions estimates against each of these criteria.

The solid waste sector category is covered by the general QC measures undertaken for inventory identified in Section 1.6. In particular, emissions are estimated subject to the application of carbon balance constraints that ensures completeness; that carbon is tracked from harvest to disposal and that consistency between the harvested wood product and landfill pools is maintained. Estimates of carbon stored in wood products and in landfills are provided in Annex 6.

Quality assurance in relation to key parameters and the overall method for the sector was provided through review by an international external expert not involved in the inventory process (Guendehou 2009). Independent external review provides assurance that the approach adopted by Australia is consistent with the approaches adopted by other parties.

Additionally, as part of a systematic quality control process the emission estimates obtained for the Australian inventory are compared with those reported by other parties. Methane generation at landfills in Australia was assessed against the reported estimates of methane generated at landfills across all Annex I parties. It was concluded that the implied emission factor for Australian landfills was not significantly different to the mean implied emission factor for all Annex I parties.

Key parameters such as waste type fractions have been the subject of consultations with industry and industry experts. In particular, external experts have been utilised or review of available waste audit data, MCF, DOC_f and oxidation rates.

Analysis of available waste audit data utilised in this inventory was undertaken independently by two external expert consultancies (Hyder consulting 2008, GHD 2008).

The methane correction factor (MCF), which is intended to represent the extent of anaerobic conditions in landfills, was reviewed for this inventory by GHD 2010. The assessment of GHD confirmed that an MCF factor of 1.0 is appropriate for Australian landfills.

Country specific values for DOC_f for individual waste types were selected after consultation with independent consultants (GHD 2010, Hyder consulting 2010, Blue Environment 2010) and reviewed by an international expert reviewer not involved in the preparation of the inventory (Guendehou 2010). Guendehou concluded that the approach adopted lead to a significant improvement in the emission estimates.

Oxidation rates were reviewed (GHD 2010). Following the review, it was decided to retain the IPCC default assumption of 10% until further research can be undertaken.

When NGER data were used for methane capture for the first time in the inventory in 2010, it was important to ensure time-series consistency was maintained. In order to ensure this was the case, the DCCEE engaged the external consultant who was previously used to collect methane capture information from landfill gas capture companies to undertake a QC analysis of the NGER capture data. Data were assessed for completeness and consistency with previously reported values. Capture estimates were compared with data available from the renewable energy certificate register as well as the NSW Greenhouse Gas Reduction Scheme register. The analysis confirmed that methane capture for energy generation was complete and consistent with previously reported data. For methane flaring, the analysis highlighted a completeness issue with respect to flaring occurring at local council landfills (in general, councils are not required to report under the NGER (2009-2012) system). Therefore, this portion of flaring activity data had to be estimated for 2009 based on previously reported data.

Through this QC project, the DE was able to ensure continuity of expertise and knowledge used in the compilation of previous inventory submissions.

CRF table checks

The CRF tables are populated automatically using a piece of software developed in Australia called the CRF wizard. The CRF wizard is the interface between our Australian Greenhouse Emissions Information System (AGEIS) and the CRF reporter tool. The wizard undertakes the process of merging AGEIS data into CRF reporter XML output files.

In order to check CRF data are merged correctly by the wizard, there are general checks that are undertaken:

Emissions

1. Check overall aggregate emissions exactly match those output by our AGEIS software – if there is a mismatch then go to 2.

2. Check sectoral totals match AGEIS output – if there is a mismatch then go to 3

3. Check sub-sectoral emissions by gas match AGEIS output by gas

These steps are taken iteratively until Aggregate CO_2-e exactly match the AGEIS output.

Activity Data

Activity data issues are identified using 3 main approaches:

1. Check implied emission factor time-series fluctuations. Where implied emission factors change beyond the expected levels, then AD are assessed and corrected manually where necessary.

2. Check time-series AD using CRF reporter chart functionality

3. Sectoral experts perform manual checks of AD

CRF additional information

CRF additional information is more difficult to check than emissions or AD. Additional information is not generated by AGEIS in many cases. Most additional information is calculated within the calculation spread-sheets that are used as a QC check for AGEIS output.

CRF additional information QC these checks rely on manual crosschecking between the CRF reporter information and the spread-sheets used to derive additional information.

8.8.2 Wastewater handling

The quality of the data utilised in this report has been assessed against facility data available through the State government EPA licensing system. The Australian wastewater industry is heavily regulated by State governments, which administer relevant state legislation such as the *Environmental Protection Act 1994* in Queensland and the *Protection of the Environment Operations Act 1997* in New South Wales. Under this legislation the State governments issue environment protection licences to each premises treating wastewater. The licences require compliance with strict conditions including limits on odours, noise and organic matter and nutrients (nitrogen and phosphorus) discharged to water catchments. Annual reports must be submitted by wastewater facility operators to their state government to demonstrate their compliance and some of this information is publicly available through public registers, the National Pollutant Inventory and, in some cases, the operator's own website.

The protein per capita intake applied in this inventory was compared with an estimate calculated using the nitrogen entering treatment plants reported by Sydney Water in DCC 2009 and the population for Sydney Water's service area in 2007 according to the Australian Bureau of Statistics (Sydney Water services the cities of Sydney and Wollongong excluding Gosford and Wyong). A comparison of the calculated values for protein per capita is presented in Table 8.27 below.

Table 8.28: Estimates of implied protein per capita for Sydney Water Corporation: 2008, 2009

	Population	Protein per capita g/capita/day 2009
Sydney Water Estimated Population Serviced (DCC 2009)	4,262,840	98.3
ABS Population for Sydney and Wollongong (excluding Gosford and Wyong) in 2007	4,307,057	97.3
Inventory values used for residual population connected to the sewer	6,734,007	98.3

The estimated population serviced as reported by Sydney Water in DCC (2009) is less than the 2007 population reported by the Australian Bureau of Statistics (ABS 2007). Sydney Water's estimate of population serviced excludes four of the smaller facilities and the unsewered population and is derived from forecast dwellings in the NSW Government's Metropolitan Development Program (MDP) for 2007/08. The protein per capita values calculated using the Sydney Water estimated population therefore provide a more appropriate estimate of the protein per capita value than those derived from the ABS population figures. Per capita protein consumption based on Sydney Water population serviced and DCC 2009 has been estimated as 98.3 g/day for 2009.

The protein per capita consumption for the 2012 inventory, derived from NGER facility data, has decreased to 90.6 g/day. Facility data received under the NGER (2009-2012) system for the first three years of reporting indicates a degree of volatility associated with this factor. Those facilities reporting the underlying data, however, do undertake frequent sampling and analysis and must also adhere to legislated requirements to ensure the data is representative and free from bias. Nitrous oxide emissions are concentrated in rivers and estuaries where the processes for N_2O production can take place in both the water column and the sediments. N_2O emissions also arise from ocean waters in the continental shelf region; however, while these emissions may occur from human activity, they also occur naturally and are very difficult to isolate empirically.

A good understanding of how N_2O emissions occur in the continental shelf region and the influences of human activity on them is still being formed. Nitrous oxide formation is very dependent on regional conditions and chemistry and location of outfalls. Some studies have been undertaken which attempt to measure or characterise the N_2O in the continental shelf regions of Europe (Bange 2006, Barnes and Owens 1998), Canada (Punshon and Moore 2004) and North China (Zhang *et al.* 2008). A literature survey of four such studies determined an average emission rate for continental shelf/oceanic coastal waters of 0.0018 kg N_2O-N/kg N discharged. The regions studied, however, are influenced by very different marine conditions to those in Australian waters and also do not consider the effects of treated wastewater discharges (Foley and Lant, 2007). The regional marine conditions are a major influence on the production of N_2O (Zhang *et al.* 2008). An appropriate method and emission factor for estimating N_2O emissions from wastewater discharged to coastal and continental shelf waters would require further research.

A reconciliation of the quantity of sludge transferred from wastewater treatment to landfills and the sludge entering the landfills has been undertaken. To estimate the sludge transferred from industrial wastewater treatment it is assumed that 40% of the sludge removed from the wastewater is sent to landfill. The conversion of COD to wet sludge is calculated by assuming the volatile solids proportion of dry solids is in the range of 60 – 90% and the dry content matter of wet sludge is 15%. For domestic and commercial wastewater, the tonnes of nitrogen sent to landfill are converted to wet sludge using a nitrogen content range of 40,000 to 80,000 mgN per kg dry solids and a dry content matter of wet sludge of 15%.

Using these assumptions an estimate of the minimum and maximum possible quantities of wet sludge sent to landfill has been calculated for 1990 to 2012. The range of estimates for each year was found to be very large. In 2012, the minimum quantity of wet sludge sent to landfill from wastewater treatment was 613 kt while the

maximum quantity was estimated to be 1,229 kt. These values are significantly higher than the estimate of wet sludge disposed to landfills estimated under the solid waste sector (less than 100 kt). This comparison highlights the challenges in converting quantities of nitrogen and COD to a quantity of wet sludge disposed to landfill. The assumptions and parameters such as nitrogen content of dry solids require further investigation to determine their suitability and exact magnitude.

The wastewater sector source categories are also covered by the general QA/QC of the greenhouse gas inventory in Section 1.6.

8.9 Recalculations Since the 2011 Inventory

8.9.1 Solid waste disposal on land

Recalculations have been performed for solid waste as a result of the incorporation of additional NGER facility data into the estimates for this submission. These NGER data include quantities and composition of waste disposed in landfill, methane capture and decay rate constants based on the geospatial coordinates of each landfill. Where new facilities begin to report under the NGER (2009-2012) system, their entire historical waste disposal profile since landfill opening needs to be taken into account in the estimates. As a result, recalculations have occurred in all inventory years as set out in Table 8.29.

Table 8.29 6.A: Solid Waste: recalculation of methane emissions (Gg CO_2-e)

	2013 Submission	2014 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.A Solid Waste Disposal on Land				
1990	13,555	13,188	-367	-2.7%
2000	11,216	11,041	-175	-1.6%
2001	11,254	11,084	-170	-1.5%
2002	11,402	11,238	-164	-1.4%
2003	10,616	10,449	-168	-1.6%
2004	10,214	10,051	-164	-1.6%
2005	10,004	9,865	-139	-1.4%
2006	9,715	9,581	-135	-1.4%
2007	9,980	9,855	-125	-1.3%
2008	10,334	10,220	-114	-1.1%
2009	10,296	10,195	-101	-1.0%
2010	10,554	10,466	-88	-0.8%
2011	9,997	10,143	147	1.5%

8.9.2 Wastewater handling

Minor revisions have been made to sewered populations serviced by various utilities between 2008–2011. This has resulted in a minor revision to emissions estimates over this period.

Table 8.30 6.B: Domestic and commercial wastewater: recalculation of emissions (Gg CO_2-e)

	2013 Submission	2014 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.B.2 Domestic and Commercial Wastewater				
1990	1,765	1,765	-	0.0%
2000	1,533	1,533	-	0.0%
2001	1,548	1,548	-	0.0%
2002	1,548	1,548	-	0.0%
2003	1,555	1,555	-	0.0%
2004	1,573	1,573	-	0.0%
2005	1,590	1,590	-	0.0%
2006	1,619	1,619	-	0.0%
2007	1,647	1,647	-	0.0%
2008	1,692	1,692	0.5	0.0%
2009	1,684	1,684	0.6	0.0%
2010	1,726	1,726	0.2	0.0%
2011	1,628	1,628	0.3	0.0%

Table 8.31 6.B: Industrial wastewater: recalculation of emissions (Gg CO_2-e)

	2013 Submission	2014 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.B.1 Industrial Wastewater				
1990	1,997	1,997	-	0.0%
2000	1,230	1,230	-	0.0%
2001	1,355	1,355	-	0.0%
2002	1,298	1,298	-	0.0%
2003	1,177	1,177	-	0.0%
2004	1,193	1,193	-	0.0%
2005	1,196	1,196	-	0.0%
2006	1,193	1,193	-	0.0%
2007	1,208	1,208	-	0.0%
2008	1,205	1,205	-	0.0%
2009	1,197	1,197	-	0.0%
2010	1,099	1,099	-	0.0%
2011	1,055	1,055	-	0.0%

8.2.7.3 Waste incineration

There have been no recalculations in incineration in the 2012 Inventory.

Table 8.32 6.C: Incineration: recalculation of emissions (Gg CO_2-e)

	2013 Submission	2014 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.C Waste Incineration				
1990	85	85	-	0.0%
2000	28	28	-	0.0%
2001	28	28	-	0.0%
2002	28	28	-	0.0%
2003	28	28	-	0.0%
2004	28	28	-	0.0%
2005	28	28	-	0.0%
2006	29	29	-	0.0%
2007	29	29	-	0.0%
2008	29	29	-	0.0%
2009	30	30	-	0.0%
2010	30	30	-	0.0%
2011	30	30	-	0.0%

8.2.7.4 Biological treatment of solid waste

A composting industry survey has been completed and compiled for the 2011 inventory year. These revised activity data have been incorporated into the emissions estimates for this submission. The impact of the recalculation is set out in table 8.33 below.

Table 8.33 6.D: Biological Treatment of Solid Waste: recalculation of emissions (Gg CO_2-e)

	2013 Submission	2014 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.D Biological Treatment of Solid Waste				
1990	8	8	-	0.0%
2000	40	40	-	0.0%
2001	43	43	-	0.0%
2002	46	46	-	0.0%
2003	49	49	-	0.0%
2004	52	52	-	0.0%
2005	55	55	-	0.0%
2006	60	60	-	0.0%
2007	63	63	-	0.0%
2008	68	68	-	0.0%
2009	71	71	-	0.0%
2010	81	81	-	0.0%
2011	82	94	12	14.6%

8.10 Source Specific Planned Improvements

8.10.1 Solid waste disposal on land

Australia has initiated a move to the use of tier 3 methods for the estimation of emissions from solid waste disposal in this submission. The availability of facility-level data collected under the NGER (2009-2012) system has enabled a facility-specific and spatially explicit approach to be adopted for the largest landfills which has supplemented the previous State-based approach which continues to be used for the non-NGER proportion of the landfill sector.

Facility-level data used in this submission are limited to waste disposal quantities and composition and methane capture for all landfill facilities triggering NGER (2009-2012) system reporting thresholds. Decay rate constants have been assigned to each landfill based on their individual geospatial coordinates and BOM climate data. It is anticipated that with further refinements to the reporting provisions introduced in the 2012/13 NGER (2009-2012) system reporting period, facility-specific decay rate constants based on measurements of gas flow at the landfill will become available for use in the inventory.

Under the NGER (2009-2012) system, operators of landfills are encouraged to undertake audits of waste data received and to collect data on methane generation rates to enable the operator to determine a facility-specific 'k' value so that 'k' will reflect both localised climate and management conditions. Over time, this data will be used to ensure that the decay functions applied at individual landfills reflect both local climatic conditions and facility management practices. The latter is particularly important as practices can vary considerably – for example, two in every five landfills practice leachate control which would significantly increase the value of 'k' at a landfill facility.

Initial testing of the methods at landfills has demonstrated the value of ensuring that local climate and management practices are explicitly taken into account. The methods to be used to determine 'k' are provided in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008*.

For the residual disposal not covered by the NGER (2009-2012) system reporting, Australia will explore the possibility of estimating emissions at a more spatially disaggregated level to enable climatic variation to be accounted for in the residual estimates.

Research is continuing into the DOC_f and decay values applicable to Australian waste types in Australia under both laboratory conditions and *in situ* across various regions of Australia. When finalised, the new empirical results will be reviewed for their appropriateness to Australian conditions and to the Australian national inventory.

Australia plans to improve the internal consistency of the estimation by refining the estimate of wet sludge transferred to landfill from wastewater treatment and then to use this data to calibrate the data used for the estimation of emissions from solid waste. The amount of wet sludge transferred to landfill from wastewater and the wet sludge entering landfills under the solid waste sector have been compared. This comparison indicates that the wet sludge entering landfill in the solid waste model is low. Clarification of the assumptions used to estimate the wet sludge from wastewater treatment is required, however, prior to recalculation of the estimates of emissions from solid waste disposal.

As part of the in-country review of Australia's 2008 national inventory, the Expert Review Team encouraged Australia to develop country-specific DOC values. This will be explored over coming years to determine the best empirical approach to support the development of such values.

Similarly the ERT encouraged Australia to further investigate methane correction factors for the period prior to 1990. Australia plans to undertake this verification process subject to the availability of suitable historical data on waste management practice.

8.10.2 Wastewater handling

Australia has expanded the use of NGER facility level industrial wastewater data in this inventory. Australia will keep industrial wastewater model parameters and methods under review based on facility level data reported under the NGER (2009-2012) system.

8.10.3 Waste incineration

As with *wastewater handling*, only a limited subset of NGER data has been used for incineration in this submission. The DE will review NGER (2009-2012) system reports for the 2012-13 reporting period with a view to the potential inclusion of additional facility data for future inventory submissions.

8.10.4 Biological treatment of solid waste

Methods and emission factors will be kept under review.

9. Other (UNFCCC Sector 7)

Australia does not report any emissions under the UNFCCC category 7, 'Other'.

10. Recalculations and Improvements

National greenhouse gas inventories have been produced for a comparatively short time, especially when compared with other major national statistics, such as gross domestic product. Emissions processes are pervasive and complex and, consequently, emissions estimation techniques and data sources for the Australian inventory are still evolving, particularly in some sectors. Internationally, this is also the case for the inventories of other countries. In addition, the *IPCC Guidelines* on national inventory preparation themselves have been revised over time.

The development of improved estimation techniques is a resource intensive exercise and the IPCC encourages the allocation of development resources into priority areas. A number of recalculations have been undertaken for the 2012 inventory and these have been summarised in Section 10.1-10.3 below. More generally, the development effort behind recalculations is undertaken in line with the *Inventory Improvement Plan* for the Australian inventory. This plan is aimed at reducing existing emission estimate uncertainties as much as possible, with development focused on key source categories, sources with high uncertainties and where implementation of new methods is feasible (for example, as a result of new data becoming available). The Australian improvement plan also seeks to respond to international expert reviews and revisions to international guidelines on inventory preparation. Some of the principal elements of the improvement programme are set out in Section 10.4.

10.1 Explanations and Justifications for Recalculations

Within the 1990–2011 time series there have been a number of sectors where recalculations have been undertaken. Details of these recalculations are given in the sectoral Chapters and are summarised in Table 10.1. Principal reasons include revisions of activity data, the inclusion of additional sources of data or from refinements in the estimation methodology including in response to recommendations of previous UNFCCC expert reviews. To ensure the accuracy of the estimates, and to maintain consistency of the series through time, recalculations of past emission estimates are undertaken for all previous years.

A key reason for recalculations within the Energy sector arises from changes to the *Australian Energy Statistics* (BREE 2013a). This is due to BREE revisions to estimates in response to improved activity data available under the NGER (2009-2012) system. This has resulted in revisions to fuel consumption and the reallocation of fuel use between source categories, particularly for 2003-2011.

Table 10.1: Reasons for the recalculations for the 2012 inventory (compared with the 2011 inventory)

Sector		Category	Reason for Recalculation
1.A	Energy		The primary driver for recalculations in the fuel combustion sector is updates to fuel consumption reported in Australia's Energy Statistics (BREE). Improved activity data available under the NGER (2009-2012) system from its implementation in 2009 has informed recalculations in some sectors from 2003-2011.
	Stationary Combustion	1.A.1	Electricity Generation: Updates to AES (BREE 2013a) data and the inclusion of new survey data has led to recalculations in emissions estimates for natural gas, liquid fuels and biomass for the period 2003 to 2011. Petroleum Refining: Coal by-products have been reallocated to 1.A.2.c chemicals in response to questions during the previous ERT review. Oil and Gas Extraction: Natural gas consumption has been revised for the period 2004-2011 in response to revisions made in the AES (BREE 2013a).
		1.A.2	Iron and Steel: In response to a previous ERT recommendation there has been a reallocation of black coal used as a reductant to 2.C.1 metal production. Non-Ferrous Metals: An improvement in the time series consistency of the solid fuel CO_2 IEF has resulted in recalculations for 2003-2011. Chemicals: A reallocation has been undertaken for particular fuels between subsectors in response to ERT comments in an effort to improve time series consistency of various CO_2 IEFs.
	Transport	1.A.3.a	There have been revisions made to the Tier 2 models for aviation fuels along with updates to the aviation fuel consumption and LTO data time series which together have resulted in emissions adjustments for the time series.
		1.A.3.b	Recalculation of ADO, petrol and LPG consumed in the road transport sector throughout the time series due to revisions in the AES (BREE 2013a).
		1.A.5	Recalculations in emissions from military transport across the time series due to the revised fuel consumption data reported in the *Australian Energy Statistics* (BREE 2013a).
1.B	Fugitive Emissions	1.B.1	NGER data for open cut coal mines have been incorporated into the emission estimates resulting in recalculations throughout the time series. A method adjustment to include NGER mine emission data for estimating decommissioned mine emissions has resulted in recalculations for the time series.
		1.B.2	Improved crude oil production and well drilling data throughout the oil time series has resulted in emissions recalculations.
2	Industrial Processes	2.C	The re-allocation of emissions from pulverised coal has resulted in a recalculation from 2003-2011. NGER data for coke consumption has been included for the first time for 2009-2011 replacing previously used AES data. CH_4 and N_2O associated with carbon reductant consumption have been included in the Inventory for the first time.

Sector		Category	Reason for Recalculation
		2.F	Revisions to bulk gas allocation, the calculation of emissions from initial charging of new equipment for 1994-2011 and annual leakage rates for commercial equipment. Revision to stock of SF_6 in operating equipment in 2011.
4	Agriculture	4. A-F	End of time-series recalculations due to 3 year averaging of reported emissions.
		4.A,B, D	Animal input and activity data has been revised as described in section 6.3.5.
		4.D	The time series was recalculated due to the inclusion revised fertiliser application rates for sugar cane. Revisions to the biomass burnt for savannas and crop residues also resulted in changes to atmospheric deposition estimates .
		4E	Updates made to the area of temperate grassland burnt in the years 2010 and 2011.
		4F	Correction made to fraction of sugar cane burnt in 2010.
5	LULUCF	5.A.1	Within the *forest land remaining forest land* sub-category the Other Native Forests classification has been updated so that estimates of emissions associated with changes in canopy cover are consistent with observed changes in forest cover. This has resulted in recalculations to the time series.
		5.A.2	The annual update of remote sensing data of forest cover change has resulted in a recalculation of the *grassland converted to forest land* sub-category.
		5.B.1	Time-series was recalculated due to implementation of a crop/pasture growth module in *FullCAM* and the implementation of a new method for estimating emissions from perennial woody crops.
		5.B.2	The method to initialise soil carbon stocks for land observed as clear of forest in 1972 was updated to be consistent with the method used in 5.B.1.
		5.C.1	The time-series of the soil carbon estimate has been recalculated due to the implementation of a crop/pasture growth module in FullCAM.
		5.C.2	The method to initialise soil carbon stocks for land observed as clear of forest in 1972 was updated to be consistent with the method used in 5.C.1.
6	Waste	6.A	Recalculations have been performed for all years for solid waste as a result of the incorporation of additional NGER data into the estimates for the first time in this submission.
		6.B	Minor revisions have been made to sewered populations serviced by various utilities between 2008–2011. This has resulted in a minor revision to emissions estimates over this period.
		6.D	A composting industry survey has been completed, compiled and incorporated into the emissions estimates which have resulted in a recalculation in 2011.

10.2 Implications for Emission Levels

The net impact of the recalculations on emission levels was relatively small for the sectors excluding LULUCF leading to a decrease in the estimate of total emissions excluding LULUCF of 2.8 Mt or -0.7% in 1990 and a decrease in emissions of 10.7 Mt or 1.9% in 2011 compared with estimates presented in the *National Inventory Report 2011* (see Table 10.2). The recalculations are greater after including the LULUCF sector with an increase in the estimate of total emissions of 21.4 Mt or 4.1% in 1990 and a decrease of 31.0 Mt or 6.1% in 2011.

Table 10.2: Estimated recalculations for this submission (compared with previous submission): 1990, 2005-2011

Sector	1990	2005	2006	2007	2008	2009	2010	2011
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt
1.A Fuel Combustion	-1.9	-6.0	-5.4	-5.2	-6.0	-7.8	-8.7	-9.7
1.A.1, 2, 4, 5 Stationary Energy	-0.1	-4.9	-4.6	-4.8	-5.7	-7.7	-8.9	-10.6
1.A.3 Transport	-1.8	-1.1	-0.8	-0.4	-0.3	-0.1	0.2	0.9
1.B Fugitives	-0.5	-0.3	0.0	-1.3	-1.3	-1.2	-1.5	-2.4
2 Industrial Processes	0.0	1.5	1.8	2.1	1.8	1.2	1.8	0.8
4 Agriculture	0.0	-1.0	-0.5	-0.1	-0.1	-0.1	-0.1	0.4
6 Waste	-0.4	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.2
Total recalculation (excluding LULUCF)	-2.8	-5.8	-4.3	-4.6	-5.8	-7.9	-8.5	-10.7
5 Land use, land use change and forestry	-24.2	-1.9	-10.4	24.3	22.7	-23.5	-10.5	-20.3
Total recalculation (including LULUCF)	-27.0	-7.8	-14.8	19.7	16.9	-31.4	-19.0	-31.0

10.3 Implications for Emission Trends, Including Time Series Consistency

The net effect of the recalculations on aggregate emission trends for the sectors excluding LULUCF is relatively small as the recalculations have been applied throughout the time series 1990 to 2011. The full time series of estimated recalculations is set out in Table 10.3. The recalculations for LULUCF have also been applied consistently throughout the time series although the net effect on emissions is much more variable in terms of the magnitude and direction of the changes given the nature of the data.

Table 10.3: Estimated recalculations for this submission (compared with the previous submission); 1990-2011

Year	Net Emissions Excluding LULUCF				Net Emissions Including LULUCF			
	Previous Estimate	Current Estimate	Difference		Previous Estimate	Current Estimate	Difference	
	Mt CO_2-e	Mt CO_2-e	Mt	%	Mt CO_2-e	Mt CO_2-e	Mt	%
1990	417.7	415.0	-2.8	-0.7%	524.0	545.5	21.4	4.1%
1991	419.4	416.5	-2.9	-0.7%	572.7	575.3	2.5	0.4%
1992	423.9	420.8	-3.1	-0.7%	510.2	508.5	-1.7	-0.3%
1993	425.6	422.8	-2.8	-0.7%	443.1	442.1	-1.0	-0.2%
1994	426.1	423.2	-2.9	-0.7%	441.4	474.3	33.0	7.5%
1995	439.1	436.9	-2.3	-0.5%	462.8	455.2	-7.6	-1.6%
1996	446.3	443.2	-3.1	-0.7%	476.6	475.4	-1.2	-0.3%
1997	458.8	455.7	-3.1	-0.7%	478.5	468.4	-10.2	-2.1%
1998	473.1	470.6	-2.6	-0.5%	526.9	507.4	-19.5	-3.7%
1999	482.4	479.6	-2.8	-0.6%	489.1	472.6	-16.5	-3.4%
2000	493.3	489.8	-3.5	-0.7%	556.4	513.0	-43.3	-7.8%
2001	504.0	502.3	-1.7	-0.3%	501.3	552.2	50.8	10.1%
2002	505.4	503.6	-1.9	-0.4%	602.0	593.6	-8.4	-1.4%
2003	509.6	506.2	-3.4	-0.7%	745.6	724.4	-21.2	-2.8%
2004	525.3	519.0	-6.2	-1.2%	476.3	516.5	40.2	8.4%
2005	529.3	523.5	-5.8	-1.1%	552.3	548.4	-3.9	-0.7%
2006	534.2	529.9	-4.3	-0.8%	526.0	532.1	6.1	1.2%
2007	542.5	537.9	-4.6	-0.8%	650.6	621.6	-28.9	-4.4%
2008	550.3	544.6	-5.8	-1.0%	520.6	537.5	16.9	3.3%
2009	549.1	541.2	-7.9	-1.4%	589.4	558.0	-31.4	-5.3%
2010	548.7	540.2	-8.5	-1.6%	587.8	568.8	-19.0	-3.2%
2011	552.3	541.5	-10.7	-1.9%	511.9	480.9	-31.0	-6.1%

Source: Previous estimate - DCCEE 2013.

10.4 Recalculations, Including in Response to the Review Process, and Planned Improvements to the Inventory

10.4.1 Planned Improvements – National Inventory Systems

Priorities for the inventory development process have been set out in the *National Inventory Systems Inventory Improvement Plan* and have been informed by analysis of key sources and key trends. The overall aim of inventory improvement is to improve the accuracy and reduce uncertainties associated with the national inventory estimates.

The Department has implemented systematic review processes into the national inventory system to drive continuous improvements in inventory quality. The *Quality Assurance-Quality Control Plan* is an integral part of this process.

In terms of emission estimation methodologies, these annual processes are principally implemented by the following.

Review of selection of methods

Decisions are made each year as to whether IPCC tier 1, 2 or 3 methods should be applied for a category, implementing QC Measure 3.A.1 (i) as set out in the *National Inventory Systems Quality Assurance-Quality Control Plan*. Method selection is reviewed in light of enhanced national data collection at facility or project level data available from private sources; public empirical literature; and in relation to updates in international guidelines and international practice.

Review of model parameters and emission factors – model validation and calibration:

This review implements QC Measures 3.A.1 (ii)-(iv) set out in the *National Inventory Systems Quality Assurance-Quality Control Plan*. The measures provide for review of model parameters in light of new data collected from private measurements or from public empirical research and provide either evidence to validate existing parameters or a basis for improving the parameters or method specification based on newly available information.

External factors also play a role in driving inventory improvements. The key external catalysts for inventory improvement are considered to include the following.

Progressive implementation of the UNFCCC revised inventory reporting guidelines

The revised UNFCCC inventory reporting guidelines, agreed by parties at COP-17 in December 2011, provide for the application of the *2006 IPCC Guidelines for the preparation of national inventories* on a trial basis for 2013 and on a full application basis by April 2015. The IPCC is also periodically requested by the parties to the UNFCCC or the Kyoto Protocol to undertake additional methodological development tasks which must also be taken into account.

All estimation methodologies will be reviewed and assessed against the new international guidelines and, as appropriate, refinement of Australia's methodologies will be progressively implemented. Refinements will be concentrated in the land based sectors as, for the most part, the *2006 IPCC Guidelines* have already been implemented in other sectors.

Changing international practice

The Department actively monitors the implementation of inventory guidelines by other parties to the UNFCCC / Kyoto Protocol to ensure comparability of national inventories. More specifically, the Department also monitors the implementation of other major domestic reporting systems. The European Union, for example, has established facility-level methods for the estimation of emissions for its emission trading system while the United States Environment Protection Agency has established similar methods for its mandatory reporting system. These major systems may set new benchmarks of international practice that the Department monitors and evaluates for their potential implications for Australia.

Enhancements to Australian National Greenhouse Accounts Framework

Australia's national inventory system incorporates an integrated national greenhouse accounts framework. This builds common approaches and estimation methods from national to State to company, facility and project levels across the national greenhouse accounts.

Implementation of domestic reporting systems may lead to enhanced availability of data that may be used to underpin the development of tier 3 methods which allow for spatial and facility-level differences in emissions to be incorporated into inventory. In addition to the application of facility data for some energy and industrial process categories, these information sources will also be developed for the waste and land sectors where appropriate.

Investment will also be undertaken in a set of regional greenhouse accounts, including in support of the national income accounts framework, and a carbon stock account, including for Australia's forest lands which will provide complementary information for the national inventory.

Responses to Quality Control Outcomes and Quality Assurance reviews

Responses to quality assurance reviews are an integral part of the inventory improvement process – in particular, the review by the Australian National Audit Office, the UNFCCC ERT reviews and public consultations on NGER methods. As part of the national inventory development process all issues raised by the UNFCCC ERT review teams are assessed for their implications for the national inventory. A full set of UNFCCC ERT recommendations, and Australia's responses to these recommendations, are included in Annex 6 (at the time of preparation of this inventory report, the Department had not received the final ERT report of the centralised review of Australia's 2013 Inventory). Areas for inventory improvement are identified each year in the *Evaluation of Outcomes* document.

10.4.2 Investment in National Inventory Systems

Ultimately, the quality of emission estimates depends on the quality of measurement, data management and quality control systems.

Investment in the National Measurement System

The national inventory system relies on a large number of measurements undertaken by private organisations. For this inventory, data collected for the *energy, industrial process* and *waste* sectors is largely obtained through the National Greenhouse and Energy Reporting (NGER) System. Estimation methods used for NGER are governed by the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* and are designed to be consistent with the national inventory estimation methods.

Improvements in accuracy of measurement will flow into improvements in the quality of the national inventory.

In support of the Carbon Farming Initiative, new standards are being developed to support improved measurements across the land sector. The Department has supported the development of sampling and testing protocols for the direct measurement of Soil Organic Carbon at paddock scale. New measurement protocols are also being developed for the measurement of vegetation both as environmental plantings (conversion to forests) and for rangelands vegetation. The new standards are designed to support confidence in data collected under private measurement systems and should be considered in conjunction with the Carbon Farming Initiative's compliance and enforcement regime.

Investment in Research and Development

The national inventory system utilises public funding for research into greenhouse gas measurement in Australia. In recent years there has been a focus on the land based sectors given the land sectors contribute significant key categories, the extent of the sectors, the relatively high cost of private measurement and the relatively high variability of spatial and temporal emission processes.

National Inventory quality control systems

The Department will continue to invest in the quality control framework that provides a systematic approach to the assessment of new information on emissions as it emerges over time.

As indicated in 10.4.1, in relation to NGER, a systematic assessment of all new facility-specific information received will be undertaken to test the quality of existing tier 2 country-specific parameters. New information will

be assessed against predetermined criteria for applicability. As a test of the quality of the existing parameters, the new information will either verify values currently used in the inventory or be used to update the parameters.

It is planned for these systems to be extended to other sectors over time. For example, new activities are being scheduled in order to carry out additional verification activities, such as a comparison of the land sector models' outputs with existing and new field data, the collection of additional field data and a discussion of the differences in the results with other programs carried out by individual states. The Cooperative Research Centre for Spatial Information (CRC SI) has been commissioned to undertake verification of forest extent and change data.

The Department will also continue to invest in the integration of new quality control tools within the AGEIS system. These tools include completion of the systematic carbon balance assessments; automated comparability tests with the inventories of other parties and development of tier 2 proxy methods where tier 3 methods have been implemented (e.g. coal mining). Similarly, the Department will invest in enhanced quality control and output reporting systems for the *LULUCF* sector.

Australia has a small network of atmospheric monitoring stations that provide data on atmospheric greenhouse gas concentrations which, when combined with air dispersion models, provide a complementary verification system to the estimates presented in this national inventory. In this submission, estimates are presented for PFCs, HFCs and SF_6. Work on other gases, particularly methane and nitrous oxide, is ongoing.

Investment in IT systems

Investment in IT software systems including the Australian Greenhouse Emissions Information System (AGEIS) and FullCAM for *LULUCF* is a critical part of the improvement plan. Investment will be focussed on the integration of the AGEIS and FullCAM systems, increasing the flexibility of the FullCAM with regard to the possibility of producing specific parameters and intermediate outputs to support enhanced quality control systems as well as regional accounts; and the development of project level tools to support the Carbon Farming Initiative.

10.4.3 Improvements to Activity Data

The Department is investing in an ongoing program to review and to update the quality of activity data used in the national inventory. A major focus includes data obtained under NGER and data for the land sector.

10.4.3.1 National Greenhouse and Energy Reporting (NGER) System

The National Greenhouse and Energy Reporting System commenced operation in July 2008 and marks a substantial advance in the national inventory system. The first reports were submitted by companies in October 2009 and this data is being used to progressively update the data sources used in the *energy, industrial process* and *waste* sectors. From a systems point of view, the principal benefits of the NGER for the national inventory include:

a) establishment of a systematic, mandatory data collection system at facility level for all facilities that exceed a certain threshold;

b) streamlined data collection processes – existing multiple collection processes undertaken by various agencies of the Australian Government have been streamlined into a single collection process;

c) facility level data are now available to the Department for the purposes of preparing the inventory by February each year – this allows a significant enhancement of the timeliness of previous collection processes;

d) improved data quality from reporters reflecting compliance and public disclosure provisions of the NGER Act; and

e) improved sectoral estimates for those sectors where existing data collection processes may have experienced limited coverage in the past – consequently, some small reallocation of emissions between sectors has been observed in this year's inventory.

For each IPCC sector, the principal benefits of NGER will differ depending on the current data collection processes. A summary of the expected relative benefits of NGER for various IPCC sectors is provided in Table 10.4.

Table 10.4: Principal benefits of the NGER data for the inventory, by IPCC sector

Category		Systematic data collection	Streamlined data collection	Improved timeliness	Improved data quality	Improved sectoral estimates
1	**Energy**					
1.A	**Fuel Combustion**					
1.A.1a	Electricity		Yes	Yes	Yes	
1.A.1b	Petroleum refining		Yes	Yes	Yes	Yes
1.A.1c	Coke production		Yes	Yes	Yes	Yes
1.A.2	Manufacturing		Yes	Yes	Yes	Yes
1.A.3	Transport					
1.A.4	Other sectors		Yes	Yes	Yes	Yes
1.A.5	Other		Yes	Yes	Yes	Yes
1.B	**Fugitive emissions**					
1.B.1	Coal Mining	Yes		Yes	Yes	
1.B.2	Oil & Gas	Yes		Yes	Yes	
2	**Industrial Processes**					
2.A	Mineral products		Yes	Yes	Yes	Yes
2.B	Chemical products		Yes	Yes	Yes	
2.C	Metal products		Yes	Yes	Yes	
2.D	Other		Yes	Yes	Yes	
2.E	HFC production					
2.F	HFC consumption					
3	**Solvents**					
4	**Agriculture**					
5	**LULUCF**					
6	**Waste**					
6.A	Solid waste		Yes	Yes	Yes	
6.B	Wastewater	Yes		Yes	Yes	
6.C	Waste incineration	Yes		Yes	Yes	
6.D	Biological treatment of solid waste	Yes		Yes	Yes	

10.4.3.2 Other sectors – improvements in inventory activity data

Outside the sectors covered by NGER and the Carbon Farming Initiative, the Department has been seeking to update the following activity data sources to improve their reliability, completeness, time series consistency or accuracy. Much of the improvements will occur for spatial data layers for the land sectors, as efforts are made to better provide for the progressive implementation of the *2006 IPCC Guidelines*.

Improved mapping of forest areas and forest management activities

Investment in the use of remote sensing techniques to support estimates of forest management activities is ongoing, utilising available spatial information for calibration. Time-series mapping of the transfer of harvested native forests to conservation reserves and improved accuracy of mapping of harvested native forest areas, public and private and including mapping of areas that are not available for harvesting due to, inter alia, codes of practice. The Department is collaborating with CSIRO to investigate use of Landsat data cube, developed by Geoscience Australia, which contains calibrated surface reflectance products from Landsat 5, 7 and 8 satellites to derive additional information on forest management.

Mapping of the effects of fire for the forest lands remaining forest lands category

Forest age and forest condition including historic wildfire effects are important aspects of modelling carbon stocks in harvested native forests. Information on forest age/forest condition enables improved estimation of carbon dynamics by better reflecting forest growth stages and dead organic matter dynamics. Similarly, mapping of fire in the harvested native forests is important to incorporate carbon stock changes due to both wildfire and controlled burning. Mapping of fire areas that incorporate fire severity may provide improved modelling of fire emissions and post fire recovery.

Mapping of sparse woody vegetation cover for the Grasslands remaining grasslands category

Mapping of time series sparse woody vegetation across Australia through remote sensing is being undertaken by CSIRO to improve the consistency of this data and, in combination with research into fire dynamics, will be used to improve estimates of emissions from grasslands remaining grasslands and savanna burning.

Agricultural practices

Significant changes to the types of crops and pastures produced in Australian agricultural systems, the various management practices imposed during their production, and where they are located have occurred since 1980. Work has commenced to develop a spatially explicit time-series of crop and pasture types/rotations and the tillage and stubble management practices applied. This data will be compiled from ABS and other dataset where available.

Development of extended time series of forest conversions

Current land use change categories utilise spatial data on land use conversions from 1972. Land remaining land categories also rely on assumptions about non-spatial rates of forest conversions prior to 1972 in particular, in order to allow a run-in for the soil carbon models from assumed pre-forest clearing initial soil carbon levels. Refined data sets are required for the period prior to 1972 and will be implemented following a literature survey of all available information.

10.4.4 Updates to Method and Method Selection

The selection of methods for emissions estimation for the inventory is in part undertaken to balance the costs of measurement with the expected benefits for the national inventory as a whole. For any particular sector, the lower the cost of accurate measurement, the more measurement activity might be expected to be undertaken. The expected benefits from additional measurement activity will depend on the existing uncertainties attached to existing methods and the size of the source.

Estimates of a source's uncertainty are not usually enough to identify the expected payoffs from additional measurement activity since, for example, biological sources are inherently more uncertain than uncertainties attached, for example, to fuel combustion sources. The expected benefit from additional measurement activity relate to the way that the new information can correct for a particular source of error within the category.

10.4.4.1 Using National Greenhouse and Energy Reporting System and other private sources of data for model validation and calibration

NGER establishes a framework to encourage the private measurement of key emissions data. Sources covered by NGER include *energy* (*fuel combustion*), *energy* (*fugitive emissions*), *industrial processes* and *waste*.

Data made available under NGER from private measurements of facility-specific emission factors and other parameters is used to systematically review or validate existing tier 2 model parameters in relevant sectors. If a tier 2 model parameter is not validated by new NGER data, then the inventory parameter may be recalibrated or the equation may be re-specified in accordance with the provisions of the Inventory Improvement plan.

Each year, as new data or information is collected under NGER, the method selected to estimate emissions for a source will be reviewed. At this stage there is a presumption that the inventory will transition to tier 3 methods over time as more data based on private measurements of emission parameters becomes available, assuming that data preconditions for a more disaggregated tier 3 structure to be implemented have been met.

Table 10.5: Summary of planned uses of NGER data for Australia's national inventory, by IPCC sector

Category		Facility – level activity data	Tier 2/3	Verification test for tier 2 parameters	Completeness/ sectoral improvement	Improved uncertainty estimates
1	**Energy**					
1.A.1a	Electricity (coal)	Implemented	Implemented	Yes	No	Yes
1.A.1a	Electricity (gas)	Implemented	Implemented	Yes	No	Yes
1.A.1a	Electricity (liquid)	Implemented	Potentially	Potentially	No	Potentially
1.A.1b	Petroleum refining	Implemented	Potentially	Potentially	Yes	Potentially
1.A.1c	Coke production	Potentially	Potentially	Potentially	No	Potentially
1.A.2	Manufacturing	Potentially	Potentially	Potentially	No	Potentially
1.A.3	Transport	Potentially	No	No	No	No
1.A.4	Other sectors	No	No	Potentially	No	No
1.A.5	Other	No	No	Potentially	No	No
1.B.1	Coal Mining	Implemented	Implemented	Potentially	Yes	Potentially
1.B.2	Oil & Gas	Partially Implemented	Potentially	Potentially	No	Potentially

Category		Facility – level activity data	Tier 2/3	Verification test for tier 2 parameters	Completeness/ sectoral improvement	Improved uncertainty estimates
2	**Industrial Processes**					
I2.A.1	Cement	Implemented	Potentially	Potentially	Yes	Potentially
2.A.2	Lime	Implemented	Implemented	Potentially	Yes	Yes
2.A.3	Limestone and Dolomite use	Implemented	Potentially	Potentially	No	Yes
2.A.4	Soda ash production and use	Implemented	Implemented	NA	Yes	Potentially
2.B.1	Ammonia	Implemented	Potentially	Potentially	Yes	Potentially
2.B.2	Nitric acid	Implemented	Implemented	NA	Yes	Potentially
2.B.5	Synthetic rutile and titanium dioxide	Implemented	Potentially	Potentially	Yes	Potentially
2.C.1	Iron and steel	Implemented	Potentially	Potentially	Yes	Potentially
2.C.2	Ferro-alloy metals	Implemented	Potentially	Potentially	Yes	Potentially
2.C.3	Aluminium	Implemented	Potentially	Potentially	Yes	Potentially
2.C.4	Other metals	Implemented	Potentially	Potentially	No	Potentially
2.E	HFC production	No	No	No	No	No
2.F	HFC consumption	No	No	No	No	No
2.F	SF_6 consumption	Implemented	Implemented	Potentially	Yes	No
3	**Solvents**	No	No	No	No	No
4	**Agriculture**	No	No	No	No	No
5	**LULUCF**	No	No	No	No	No
6	**Waste**					
6.A	Solid waste	Implemented	Implemented	No	No	Potentially
6.B.1	Domestic and Commercial Wastewater	Implemented	Implemented	No	No	Potentially
6.B.2	Industrial Wastewater	Partially implemented	Potentially	No	No	Potentially
6.C	Waste incineration	Partially implemented	Potentially	Yes	No	Potentially
6.D	Biological treatment of solid waste	No	No	No	No	No

Note: For activity data, 'implemented' means that data have been included in the national inventory calculations but unless the completeness column is also 'yes' the data do not change the total national activity data which is taken from alternative sources. This step is necessary, however, to be able to implement facility-specific emission factors at a later time. For emission factors, 'potentially' means that new NGER data is assessed each year in accordance with prescribed pre-conditions to test whether the method selection should be raised from tier 2 to tier 3 or the mixed tier 2/3. For the verification column, 'potentially' means that new NGER data is assessed each year in accordance with prescribed preconditions to test whether the parameters for the tier 2 component of the method are verified by the new data or whether the parameters should be revised or calibrated with the new data.

Similar approaches to the review of newly available data will be adopted for other potential sources of information, such as the Carbon Farming Initiative.

Table 10.6: Summary of planned uses of Carbon Farming Initiative data for Australia's national inventory, by IPCC sector

Category		Facility/ Project – level activity data	Tier 2/3	Verification test for tier 2 parameters	Completeness/ sectoral improvement	Improved uncertainty estimates
4.A	**Enteric Fermentation Dairy**	Yes (feeds)	Potentially	No	Partially	Yes
4.A.	**Enteric Fermentation Feedlot beef** [(a)]	Yes (feeds)	Potentially	No	Partially	Yes
4.B	**Manure Management**	Yes	No	No	Yes	Yes
4.E	**Savanna Burning**	Yes	No[(b)]	No	No	No
5.A	**Grasslands conversion to forests**	Yes	Yes	Yes	No	Yes

(a) There are currently no approved methodologies for feedlot cattle

(b) The inventory and CFI methodologies are the same. Only differ in resolution of remote sensing imagery used to identify fire areas

10.4.4.2 Using data from public research for method development and model validation and calibration

New information generated by publicly funded research programs or other sources also provide opportunities to test the validity of existing parameters, to consider changes to model structures, or to develop new methods.

Major areas of inventory where research data are being used for these purposes include the following.

Enteric fermentation from cattle herds

Research on enteric fermentation emissions from livestock, co-ordinated through the Reducing Emissions from Livestock Research Program, has now produced an important dataset on methane emissions from tropical and temperate beef cattle and dairy cattle Australia. The Department has initiated a process to have the data analysed with a view to developing a new country specific method/methods for beef and dairy cattle.

Nitrous oxide emissions from agricultural soils

The Nitrous Oxide Research Program (NORP) has been funded by the Australian Government to provide world-class data on N_2O emissions from agriculture and provide information to help farmers develop management strategies for reducing emissions.

The program builds on a large volume of data collected since 2003 using continuous chambers across a range of crops and crop practices. The program expands the work to include a greater comparison of management practices and nitrous oxide emissions and the use of products such as nitrification inhibitors to reduce overall emission during the cropping cycle. The collection of data using continuous chambers over the complete 12 month cycle has been shown to provide high quality data sets for inventory purposes. Some of this data has

already been submitted for inclusion into the IPCC Emission Factor Database. As data from the NORP are published the results are used to check the quality of the EFs selected in the inventory. Where new studies give values that are significantly different from the current EFs these factors are identified for review.

The initial biomass surface for forests - forests remaining forests and forest conversion to grasslands and croplands

The Department has initiated a process to review the relationships and data underpinning the assumed initial biomass surface during 2011. A major aim of this process is to engage stakeholders with interest, expertise, or data that is relevant to Australia's national inventory approach to modelling forest biomass. To facilitate this aim, the Department held a stakeholder workshop in 2011 in Canberra. The workshop enabled stakeholders to:

- share recent research in relation to estimating and modelling forest biomass;
- express interest to contribute to the scientific work of reviewing the biomass model;
- contribute and help identify new data that have become available since the initial data collection in 2003 (Raison *et al.* 2003); and
- help specify the data requirements and data quality standards required for accurate estimation, suitable for satisfying inventory reporting requirements.

The workshop was the first step in the process to review the forest productivity index to aboveground forest biomass relationship which is planned for2014.

Soil carbon modelling

The enhanced availability of soil carbon stock and composition from the Soil Carbon Research Program (SCaRP) and other sources over the last 10 years allows for the development of new spatial approaches. CSIRO has been using this data to construct new national spatial layers of soil carbon stocks and composition with corresponding estimates of certainty. The Department and CSIRO are investigating the development of spatial maps of soil carbon stocks and composition for 1970 and 1990 from the 2010 soil organic carbon stock map created by CSIRO. The 1970 surface could them be applied as a new spatial layer for use by *FullCAM*, alleviating the need to perform soil run-in calculations from 1800 or earlier. This data is also being reviewed to determine if it could be used to provide a range of verification targets for model testing and validation and/or data to recalibrate the soil carbon module (Roth-C) of *FullCAM*.

Fire

Two aspects of emissions from fire are being investigated: first, consumption rates - currently there is a need to improve the available information on the level of dead organic matter and biomass consumed during fire and in relation to fire intensity/severity; and second, changes in carbons stocks at a landscape scale as burning practices are changes from intense late season fires to more frequent less intense fires earlier in the dry season.

Solid waste disposal parameters

The DOC_f and decay values applicable to Australian waste types in Australia under both laboratory conditions and *in situ* across various regions of Australia will continue to be monitored by the department for possible elaboration and future update given the emerging character of this field of research.

10.4.4.3 Elaboration of national inventory methods

In general, Australia is planning to implement tier 3 models and approaches wherever appropriate in order to enhance accuracy of emission estimates, particularly of the land sector.

Within the land sectors, development activity will build on existing inventory models contained in FullCAM and will need to take into account:

- existing and future guidance under the UNFCCC inventory reporting guidelines;
- emerging empirical data from publicly-funded research programs into the effects on emissions and removals of changes in land management actions;
- the integration of project level data generated, for example, through the Carbon Farming Initiative;
- the importance of modelling long term responses to land management actions while abstracting from short term, temporal effects that are ephemeral in nature to ensure policy relevance;
- costs of data management and associated complexities; and
- the need for transparency and other related factors identified in the IPCC Workshop, '*Use of Models and Facility-Level Data in Greenhouse Gas Inventories, Report of the IPCC Expert Meeting on Use of Models and Measurements in GHG Inventories, 9-11 August 2010, Sydney, Australia*'
    - (i.e. reporting requirements include basis and type of model, application and adaptation of the model, main equations/processes, key assumptions, domain of application, how the model parameters were estimated, description of key inputs and outputs, details of calibration and model evaluation, uncertainty and sensitivity analysis, QA/QC procedures adopted and references to peer-reviewed literature).

Model development will be progressed across all land sectors. In particular, it is intended that the FullCAM will be extended to provide an improved modelling framework for the consideration of new data as it becomes available:

- methods for forest lands remaining forests will be elaborated over time to provide for a tier 3 spatially explicit method with additional estimation of forest carbon stocks as well as fluxes;
- methods for spatial modelling of sparse woody vegetation across Australia's grasslands;
- fire mapping will be incorporated to support improved estimates of emissions and carbon stocks across both forests and grasslands;
- soil modelling will be developed to integrate carbon and nitrogen cycles; and
- grassland modelling will be developed to ensure the reconciliation of vegetation and livestock models.

PART 2:

SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1 OF THE KYOTO PROTOCOL

11. Kyoto Protocol LULUCF

The supplementary information in this Chapter is provided in accordance with Decisions 15/CMP.1 (FCCC/KP/CMP/2005/8/Add.2) and 15/CP.10 (FCCC/CP/2004/10/Add.2). Australia will use annual accounting for activities under Article 3.3.

11.1 General Information

11.1.1 Definition of forest and other criteria

Australia has chosen the following definition of a forest:

- tree height of at least 2 metres;
- tree crown cover of 20% or more; and,
- a minimum area of 0.2 hectares.

Table 11.1: Selection of parameters for defining '*Forest*' under the Kyoto Protocol.

Parameter	Range	Selected value
Minimum land area	0.05 - 1 ha	0.2
Minimum crown cover	10 - 30%	20
Minimum height	2 - 5 m	2

11.1.2 Elected activities under Article 3.4

Australia has not elected any activities under Article 3.4.

11.1.3 Description of how the definitions of each activity under Article 3.3 and 3.4 have been implemented and applied consistently over time

The area of forest that meets the forest definition, specified in Section 11.1.1, is mapped using Landsat remote sensing data in a spatially and temporally consistent manner from 1972 to present. With the addition of each new Landsat coverage the entire time-series is re-analysed, ensuring that the stream of activity data is consistent both spatially and temporally. This time-series consistent wall-to-wall monitoring also ensures that there is clear separation in reporting of *afforestation, reforestation* and *deforestation* lands. The methods of mapping forest extent and change in extent are outlined in Chapter 7 (Appendix 7.A) of the NIR.

Table 11.2: Summary of pools and emissions reported under Article 3.3 and elected activities under Article 3.4

Activity		Change in carbon pool reported(1)					Greenhouse gas sources reported(2)						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood (5)	Soil	Fertilization(3)	Drainage of soils under forest management	Disturbance associated with land-use conversion to croplands	Liming	Biomass burning(4)		
							N_2O	N_2O	N_2O	CO_2	CO_2	CH_4	N_2O
Article 3.3 activities	Afforestation and Reforestation	R	R	R	R	R	IE	IE		R	IE	R	R
	Deforestation	R	R	R	R	R			R	R	IE	R, IE	R,IE
Article 3.4 activities	Forest Management	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA
	Cropland Management	NA	NA	NA	NA	NA				NA	NA	NA	NA
	Grazing Land Management	NA	NA	NA	NA	NA					NA	NA	NA
	Revegetation	NA	NA	NA	NA	NA					NA	NA	NA

(1) Indicates whether carbon pool is R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3 or elected activity under Article 3.4. NA (not applicable) indicates activities that have not been elected under Article 3.4.

(2) Indicates whether greenhouse gas source is R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring). NA (not applicable) indicates activities that have not been elected under Article 3.4.

(3) N_2O emissions from fertilization are reported in the *agriculture* sector.

(4) CO_2 emissions from biomass burning are included under changes in carbon stocks.

11.1.4 Precedence conditions and hierarchy among Article 3.4 activities

Not applicable as Australia has not elected any Article 3.4 activities.

11.2 Land-Related Information

11.2.1 Spatial assessment unit used for determining the area of Article 3.3 lands

Australia uses the individual pixel (nominally 25 m x 25 m or approximately 0.0625 ha), as its analytic unit for the determination of forest (20% crown cover). Australia uses a spatially and temporally consistent forest cover assessment from Australia's Landsat archive to map areas of forest and forest cover change through time. A full description of the forest cover assessment is provided in Appendix 7.A.

11.2.2 Methodology used to develop the land transition matrix

The land transition matrix is developed using the forest extent data derived from Australia's Landsat archive. The data used is the same as that used for the UNFCCC reporting categories (Table 7.4 in Section 7.4) but only includes areas subject to afforestation/reforestation or deforestation since 1 January, 1990.

Table 11.3: Land transition matrix for the current inventory year[(1), (2), (3)]

From previous inventory year \ To current inventory		Article 3.3 activities		Article 3.4 activities				Other [(4)]	Total area at the beginning of the current inventory year[(5)]
		Afforestation and Reforestation	Deforestation	Forest Management (if elected)	Cropland Management (if elected)	Grazing Land Management (if elected)	Revegetation (if elected)		
		(kha)							
Article 3.3 activities	Afforestation and Reforestation	1,121.82	0.00						1,121.82
	Deforestation		6,636.46						6,636.46
	Forest Management (if elected)		NA	NA					NA
Article 3.4 activities	Cropland Management (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation (if elected)	NA			NA	NA	NA		NA
Other [(4)]		14.46	56.31	NA	NA	NA	NA	761,170.95	761,241.72
Total area at the end of the current inventory year		1,136.28	6,692.77	NA	NA	NA	NA	761,170.95	769,000.00

(1) This table reports land area and changes in land area subject to the various activities in the inventory year. For each activity it reports area change between the previous year and the current inventory year.

(2) Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

(3) In accordance with Section 4.2.3.2 of the IPCC *Good Practice Guidance* for LULUCF, the value of the reported area subject to the various activities under Article 3.3 and 3.4 for the inventory year are that on 31 December of that year.

(4) "Other" includes the total area of the country that has not been reported under an Article 3.3 or an elected Article 3.4 activity.

(5) The value in the cell of row "Total area at the end of the current inventory year" corresponds to the total land area of a country and is constant for all years.

11.2.3 Identification of geographical locations

The exact geographic location of each unit of land entering the *afforestation/reforestation* and *deforestation* accounts is mapped at 25 m resolution using continental coverages of Landsat data.

Australia's ability to track consistently through time individual units of land down to 0.2 ha results in millions of reportable units of deforestation and afforestation/reforestation. For the purpose of reporting under Article 3.3 the areas of reforestation and deforestation are summed into larger reporting units. This is achieved by co-locating the areas of change on maps that represent logical identification codes. The initial divisions are the Australian states and territories. For *afforestation/reforestation* the areas are then reported by 3 broad types of forest: softwood, hardwood and native. These labels are obtained from more detailed analysis of the Landsat data (see Appendix 7.A). Each of these is then further divided into areas subject to harvest during the first commitment period to allow future reporting of the harvest sub-rule. For *deforestation* the units of land are identified by the Major Vegetation Groups (MVG) (see Appendix 7.H). The MVG classifications provide a description of the type of forest being cleared.

11.3 Activity-Specific Information

11.3.1 Methods for carbon stock changes and GHG emissions and removal estimates

11.3.1.1 Description of the methodologies and underlying assumptions

Australia applies a full tier 3, Approach 3 system to estimate emissions and removals under Article 3.3. These are the same methods as used to report under the UNFCCC inventory, but use additional data and policy rule settings to meet the particular requirements of the Kyoto Protocol and Chapter 4 of the 2003 IPCC *Good Practice Guidance for Land Use, Land Use Change and Forestry* (IPCC, 2003). These additional features are detailed in the following sections.

Table 11.4: Summary of methodologies and emission factors – Article 3.3 Kyoto Protocol Land Use Change activities

Greenhouse Gas Source And Sink	CO_2		CH_4		N_2O	
	Method applied	EF	Method applied	EF	Method applied	EF
Article 3.3 activities						
Afforestation/Reforestation						
C stock changes	T3	M				
Biomass burning[(a)]	IE	IE	CS	CS	CS	CS
Liming	T1	CS				
Deforestation						
C stock changes	T3	M				
Biomass burning[(a)]	IE	IE	CS	CS	CS	CS
Liming	T1	CS				

(a) CO_2 emissions and removals associated with biomass burning are included in the C stock changes.
EF = emission factor, CS = country specific, M = Model, NO = not occurring, IE=included elsewhere, T1 = Tier 1 and T3 = Tier 3.

Deforestation

For *deforestation*, Australia applies the same tier 3, Approach 3 system as that used to report under the UNFCCC inventory (see Appendices 7.B and 7.F) but with additional data to meet the requirements of the Kyoto Protocol. CO_2 emissions associated with burning of harvest residues are calculated using the tier 3 model and are included in the change in litter carbon stocks. Non-CO_2 emissions are estimated using the amount of C mass emitted and country specific emissions factors. The C mass emitted due to biomass burning is estimated using the tier 3 model.

Liming

Emissions from liming ($CaCO_3$) activities in Australia are only estimated for hardwood plantations. A survey conducted for the Department by GHD Australia found that liming activity in the softwood plantation sector does not occur (GHD, 2009b). The survey provided both qualitative (based on industry practice with findings on the scale of the activity, i.e. limited, rare and widespread) and quantitative (gross amounts purchased by plantation companies and application rates) information. GHD Australia discussed liming management practices with forest plantation companies throughout Australia in a two-stage process; the first stage identifying the usage of lime and the second stage assessing the quantities of lime used in post-1990 plantations, generally related to first rotation stands.

Based on the information collected from the forest plantation companies the rate of lime application to post-1990 hardwood plantations is assumed to be 1.5 t ha^{-1}. The lime is applied at establishment and in 2010 the areas of new hardwood plantations was 12,316 ha as determined through the remote sensing program.

11.3.1.2 Justification for omitting pools or GHG emissions and removals

Australia has not omitted any carbon pools.

11.3.1.3 Factoring out of indirect and natural GHG emissions and removals

Australia does not factor out indirect, natural and pre-1990 effects on GHG emissions and removals. Australia explicitly accounts for natural variability in emissions and removals through the application of a process-based tier 3, Approach 3 modelling approach. Indirect emissions due to increased N deposition are considered insignificant in Australia given the large land mass and very small areas of highly concentrated population, intensive agriculture and industry.

11.3.1.4 Changes in data and methods since previous submission

Australia's archive of Landsat data has been updated to include the most recent satellite data to include coverage of 2011.This is consistent with the annual update process for Australia's remote sensing program and results in minor recalculations throughout the time-series. This process is detailed in Appendix 7.A.

The methods applied for afforestation and reforestation have been updated in this submission. The changes include:

- Implementing updated growth calibrations of mixed species, environmental plantings and the inclusion of mallee eucalypt species based on CSIRO research; and
- Updating the initialisation of the soil carbon pool to be consistent with the method used for initially clear land in the deforestation and other land use classifications.

Further details are available in section 7.6.4.

The method to initialise soil carbon stocks for land observed as clear of forest in 1972 was updated to be consistent with the method used for UNFCCC categories 5.B.1 and 5.C.1.

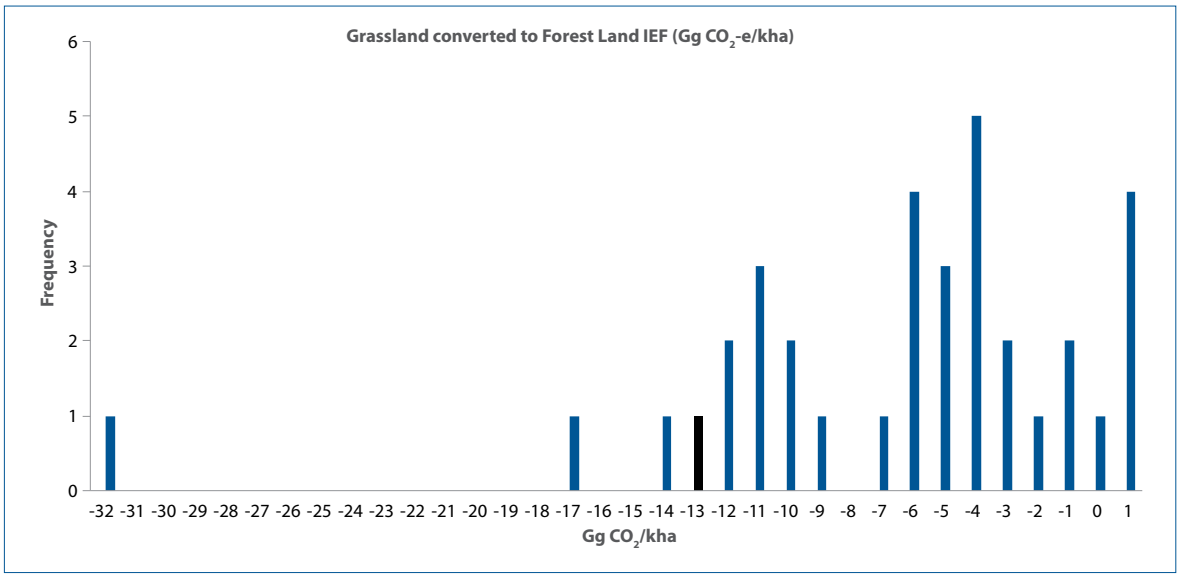
11.3.1.5 Uncertainty estimates and quality control

As the same methods and data are used to estimate emissions and removals due to *afforestation/reforestation* and *deforestation* as are used for the associated UNFCCC categories (*land converted to forest land* and *forest land converted to grassland* and *cropland* respectively), the uncertainty estimates of +/- 10% for CO_2 and +/- 20% for non-CO_2 also apply to the reporting of the Kyoto Protocol activities. The only exception is the uncertainty for non-CO_2 emissions due to wildfire (not prescribed burning) reported under *afforestation/reforestation* which are estimated at -46 to +77% for CH_4 and -47 to +88% for N_2O. This reflects the use of average debris loads used for wildfire (Section 7.12) to estimate C mass emitted due to fire. However, as the amount of emissions due to wildfires under *afforestation/reforestation* is extremely small (< 0.1% of total removals) this uncertainty does not affect the overall uncertainty for *afforestation/reforestation*. Non-CO_2 emissions due to slash burning following harvest are based on estimates of the C mass of dead organic matter derived directly from the tier 3 model and the uncertainty is estimated at +/- 20%.

The tier 3 model used to develop these estimates, FullCAM, is a full mass-balance carbon cycle model that accounts for the flow of carbon from the atmosphere to the plant which then flows through to the soil and debris (see Appendix 7.B). Carbon can only be sequestered from the atmosphere via photosynthesis, held in a pool, transferred to another pool or emitted back to the atmosphere. Hence the estimate of emissions and removals for each pool is reliant on the flow of carbon from the previous pool and the rate of loss from the existing pool. This mass balance approach means that the +/- 10% uncertainty is therefore applicable to all the pools reported (above and belowground biomass, litter, deadwood and soil). This differs from other methods commonly used to estimate emissions and removals in the LULUCF sector (in particular tier 1 and tier 2 methods) which use separate models for each pool and therefore require individual estimates of uncertainty.

Comparisons of implied emission factors and activity data with international data sources are conducted systematically for the Australian inventory. The implied emission factor per hectare is reported with the distribution of the implied emission factors of other Annex-1 parties.

Figure 11.1: Grassland converted to forestland implied emission factors for Annex I countries and Australia



11.3.1.6 Information on other methodological issues

Australia has no other methodological issues.

11.3.1.7 The year of the onset of an activity, if after 2008.

The onset of monitoring *afforestation/reforestation* and *deforestation* activities commenced in 1990. Each activity is tracked in a detailed spatially explicit way and reported annually. Monitoring of *afforestation/reforestation* and *deforestation* activities is being conducted annually using the fully spatial Approach 3 methods as outlined in Appendix 7.A. The use of the spatially and temporally consistent land cover change data, combined with detailed attribution ensures that all activities meet the definition of direct human induced and allows for the separation of these activities to prevent double counting of lands. Furthermore, the density of the time series (annual acquisition since 2004) allows activities to be assigned to a specific year with a high degree of confidence.

11.4 Article 3.3

11.4.1 Information that demonstrates that Article 3.3 activities began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Using a time series of Landsat imagery, Article 3.3 activities are monitored through time, to the present day. This enables Australia to demonstrate the date at which the Article 3.3 activities began.

Consistent with the methods outlined under Section 4.2.6.2 (page 4.57) of the 2003 IPCC *Good Practice Guidance for LULUCF,* the Kyoto Protocol *deforestation* account includes areas of clearing that:

1) meet or exceed the size of the country's minimum forest area (i.e. 0.05 to 1 ha);
2) have met the definition of forest on 31 December, 1989; and,
3) have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced deforestation.

Australia's approach to the identification of deforestation activity includes two components. One component identifies deforestation activity on land that was forest land on 31 December 1989. The second component is complementary to the first and is used to identify deforestation activity on land that was not forest on 31 December 1989 but which has been converted to forest land through afforestation or reforestation activity since 1 January 1990.

For land that was forest on 31 December 1989, the 1990 forest extent layer (created from satellite data available at the end of 1989) derived from Australia's remote sensing program is used as a base map to mask areas of non-forest in 1990. All deforestation activities on these lands are therefore determined with reference to this base map as described in Chapter 4 of the 2003 IPCC *Good Practice Guidance for LULUCF*, (Section 4.1.1, page 4.11 and Section 4.2.6.2, page 4.57).

For land that was clear of forest on 31 December 1989 and has been converted to forest land through afforestation or reforestation activity since 1 January 1990, the 1990 forest extent layer is not used for the identification of subsequent deforestation activity. These lands first enter the accounting framework through afforestation of reforestation activity which is identified by studying each area of change on land that was clear of forest on 31 December 1989 for factors including the planting geometry, consistency of cover and temporal pattern of change. These lands are then monitored each year to determine if forest cover loss and subsequent land use change (*deforestation*) activity has occurred (see Sections 11.4.2 and 11.4.3). The location of land included in the *deforestation* account for 2012 is shown in Figre 11.2.

The 1990 criteria applied for the purposes of reporting *deforestation* under Article 3.3 of the Kyoto Protocol leads to some differences between the Kyoto *deforestation* account and the UNFCCC *forest land converted to cropland* and *grassland* estimates. Table 11.5 provides reconciliation between emissions reported under Kyoto *deforestation* account (Table 11.5, Component A) and the UNFCCC *forest land converted to cropland* and *forest land converted to grassland* classifications. Differences between these two classifications arise because the *deforestation* account does not include:

- areas of land where there was no forest cover in 1990 on which natural forest regrowth has subsequently occurred followed by a clearing event (this land was not classified as Afforestation or Reforestation land) (Table 11.5, Component B);
- Land that was clear of forest on 31 December 1989 that has naturally regrown and had not been cleared (this land is not classified as Afforestation or Reforestation land) (Component C); and
- the ongoing emissions and removals from land cleared prior to 1990 that has remained cleared (Table 11.5, Component D);
- Land cleared prior to 1990 that was forest in 1990 and has not been cleared since (Table 11.5, Component E).

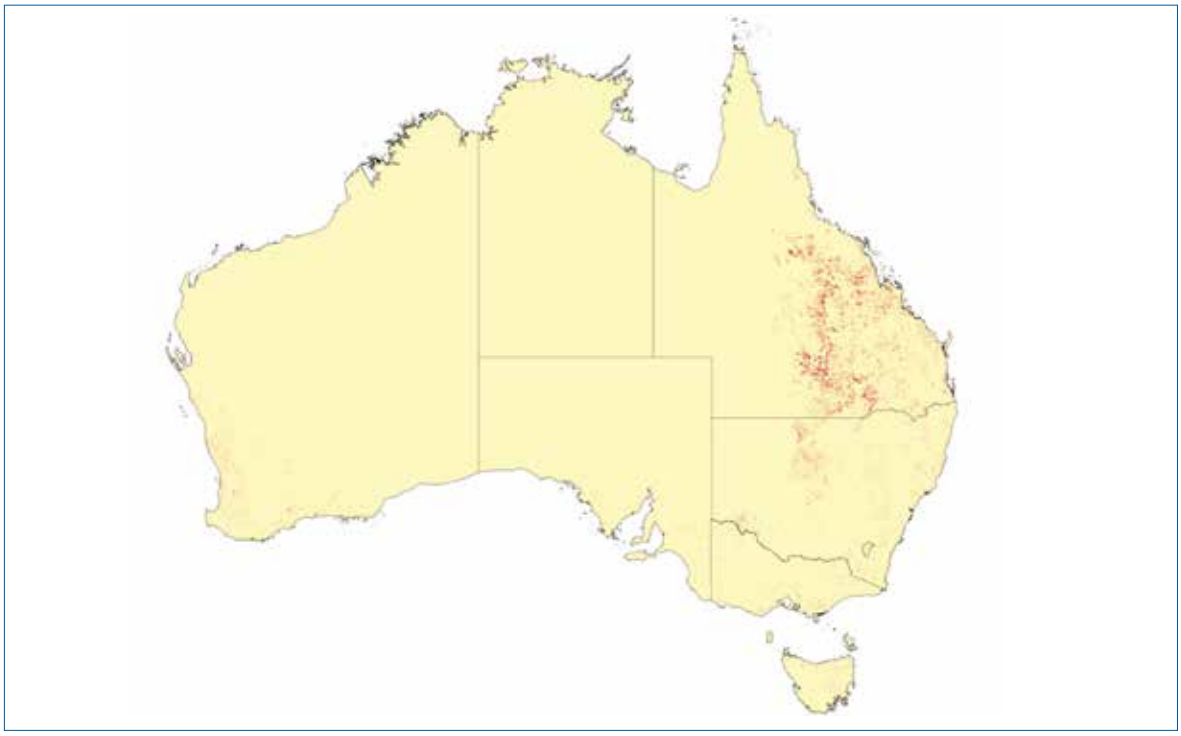
Table 11.5: Reconciliation of emissions between Kyoto Protocol Deforestation and UNFCCC *forest land converted to cropland* and *forest land converted to grassland*

	Deforestation (including Deforestation of Afforestation and Reforestation land) (Gg CO_2-e)	Clear 1990 Regrown and cleared post 1990 (Not classified as A/R) (Gg CO_2-e)	Clear 1990 Regrown and not cleared, Forest 2012 (Not classified as A/R) (Gg CO_2-e)	Clear 1990 Remains clear 2012 (Gg CO_2-e)	Clear 1972 Regrown to forest 1990 Remains forest 2012 (Gg CO_2-e)	Total UNFCCC Forest land converted to other land uses (Gg CO_2-e)
Component	**A**	**B**	**C**	**D**	**E**	**A+B+C+D+E**
2008	56,463	2,728	-1,058	7,691	-710	65,113
2009	48,526	2,621	-1,086	7,013	-599	56,475
2010	47,214	2,434	-1,814	11,728	-796	58,766
2011	38,225	2,818	-2,005	7,393	-674	45,758
2012	32,495	2,583	-1,723	10,949	-504	43,800

Note: This table only includes CO_2 emissions due to carbon stock change and non-CO_2 emissions due to biomass burning. Emissions due to lime application and non-CO_2 emissions associated with soil disturbance are not included in this table.

Changes in carbon stock associated with biomass burning (primarily slash burning following clearing) are determined using the tier 3 model and are included under the net change in litter carbon stocks and are not reported separately. Non-CO_2 emissions associated with biomass burning are estimated using the amount of C mass emitted and country specific emissions factors. The C mass emitted due to biomass burning is estimated using the tier 3 model.

Figure 11.2: Location (in red) of land included in the deforestation account for 2012

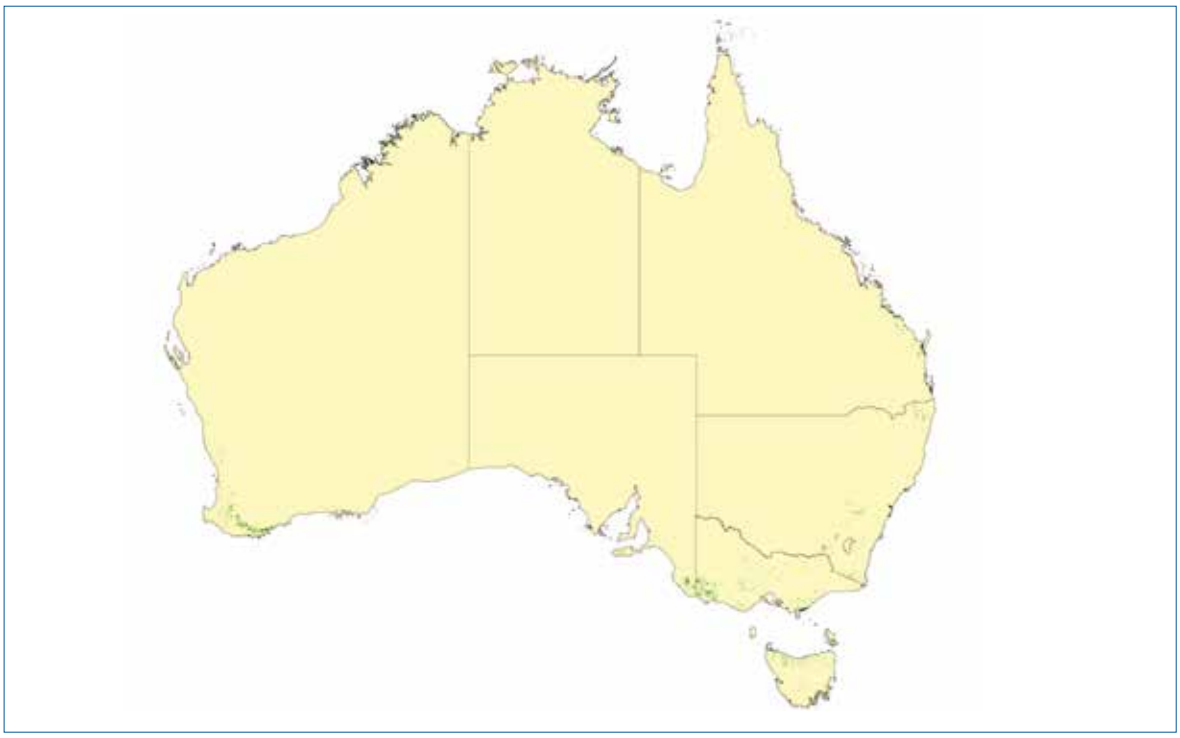


Afforestation & Reforestation

For *afforestation/reforestation*, Australia applied the same tier 3, Approach 3 system as that used to report emissions and removals from *land converted to forest land* under the UNFCCC inventory (see Appendix 7.A and 7.G). The use of the tier 3, Approach 3 system means that the combined reporting of *afforestation* and *reforestation* does not affect the area of land reported or estimates of the emissions and removals.

To ensure that only lands that were non-forest at 31 December 1989 are included in the *afforestation/reforestation* account, the 1990 base map derived from Australia's remote sensing program is used to mask out areas of existing forest. All *afforestation/reforestation* activities are therefore determined with reference to this base map. Only areas afforested/reforested on or after 1990 in addition to the lands identified in the base map are included in the emissions estimates. The location of land included in the *reforestation* account for 2012 is shown in Figure 11.3.

Figure 11.3: Location (in green) of land included in the afforestation/reforestation account for 2012



To ensure that only direct human-induced change is reported for Article 3.3 activities a process of attribution is carried out (see Section 7.A.2.4, Appendix 7.A) to assign a cause to the change mapped using remote sensing. To prevent the inclusion of false change in the accounts land areas affected by fire are masked out during the attribution process, except where a direct human induced land use change occurs after fire. This manual process of attribution involves expert assessment (visually and analytically) of the remotely sensed areas of change. Change is attributed as either natural (e.g. natural regrowth and dieback) or human induced. This is determined by studying each area of change for factors including the planting geometry, consistency of cover and temporal pattern of change.

To implement the harvested forest sub-rule all areas of *afforestation/reforestation* are categorised as either harvested or not harvested (2003 IPCC GPG; 4.55). Harvested areas are those areas which have been harvested since 1 January 2008. All other afforested/reforested (since 1990) lands are considered as not harvested. Australia has taken harvesting to be a direct human activity which removes stem wood from the forest. This includes both thinning (removal of a proportion of trees) and complete harvest (clearfell) but does not include silvicultural activities such as branch pruning. The area subject to harvesting is estimated from regional and species specific management information.

Direct human induced A/R

The 2012 ERT report argued that Australia did not identify lands that had naturally regenerated into forest land since 1990 as A/R lands. In similar circumstances, natural regeneration of forest land occurring within legislative frameworks have been classified as direct human induced conversion of grassland to forest land and as A/R lands by other parties and this approach has been accepted by ERTs. The ERT identified that Australia had not included the removals from these lands and, where subsequent clearing activity had occurred on a portion of these lands, the resultant emissions had not been included under the Deforestation account.

In this report, Australia has implemented A/R so that only vegetation that has been either planted or sown is included within the A/R lands.

Nonetheless, Australia recognises that the identification of A/R lands could be expanded to also include land which is allowed to naturally regenerate into forest land following direct human inducement. In particular, it is estimated that there was approximately 2.18 million hectares of land which was not forest on 31 December 1989 (and was not forested at any time between 1972 and 1989), which was subsequently converted to forest land through natural regeneration and remained forest in 2012. The distribution of these lands across Australia's States and Territories is provided in Table 11.6.

Table 11.6: Distribution of additional, cumulative A/R lands and net sequestration, 2012

Jurisdiction	Area in 2012 (M ha)	Mt CO_2-e
New South Wales	0.05	-0.07
Northern Territory	0.19	-0.25
Queensland	0.35	-0.47
South Australia	0.20	-0.27
Tasmania	0.05	-0.07
Victoria	0.24	-0.32
Western Australia	1.10	-1.47
Total	2.18	-2.92

Australia has in force a framework of federal, state and territory legislation and guidelines regulating clearing of native vegetation and forests (see below). These laws establish a framework whereby land that has naturally regenerated to meet the forest definition has been allowed to do so as a result of a deliberate management decision not to clear those lands.

As part of its inventory improvement program Australia is working to evaluate its treatment of direct human induced A/R and to enhance these analytical approaches to facilitate consideration of the inclusion of land which is allowed to naturally regenerate to forest. As part of this work programme during 2013, Australia has further investigated lands that on which forest has naturally regrown that is also subject to land clearing restrictions. To date all lands in South Australia, Tasmania, Victoria and Western Australia have been identified as subject to land clearing restrictions (Table 11.5). In Queensland lands mapped as high value regrowth under the *Vegetation Management Act 1999* and land that is included Collaborative Australian Protected Area Database (CAPAD) (see below) is considered as protected (Table 11.5). In the remaining jurisdictions (Australian Capital Territory, New South Wales and the Northern Territory) further analysis of land clearing regulations is required to include all protected lands as only CAPAD lands are included n Table 11.5. In NSW, in particular, the area identified as protected is likely to be a significant under estimate (Table 11.5). The focus of current analysis is to improve the estimated area of protected land in New South Wales.

The direct intent of national policy is to target the native vegetation extent and to promote revegetation for that purpose. All native vegetation in Australia is managed within the National Vegetation Framework, and its predecessor intergovernmental agreements, which place clear value on the extent of native vegetation cover and the activity of revegetation in particular. The framework is comprehensive – it covers all native vegetation - and is relevant for all levels of government as evidenced by the large range of supporting federal and State government programs.

Consequences for land managers flow from the promotion of revegetation such that they have a legal need for activities to prevent an undesired regrowth of an area to forest and that the regrowth of an area as forest should take place only where desired by land managers based on land managers' decisions. In Australia, the legal consequences of promoting revegetation take two forms.

1) Revegetation activity may be directly supported by federal or state government financial assistance or regulatory incentives which make the management decision to promote revegetation more attractive. There are many government programs that directly or indirectly support revegetation activity where demonstration of revegetation activity is legally required in return for financial assistance. Moreover, it is common in many states, including Queensland and New South Wales, for explicit offset policies to operate whereby revegetation activity may be undertaken by the land manager as part of a legal agreement to offset the environmental impact of approval for clearing of other vegetation under certain conditions.
2) There are the regulatory or legal consequences of converting land to forest. Once a management decision is taken to promote revegetation, the vegetated land enters the State regulatory systems. Revegetated land falls under the scope of the National Vegetation Framework and, as such, is assessed by regulators for forest system values such as its representativeness of threatened regional ecosystems, provision of habitats for wildlife, biodiversity, land and water quality values such as prevention of erosion and salinity and greenhouse gas net emissions. As a result, the development of forested land has significant forest management consequences for land managers.

Australia's native vegetation legislative framework

The *National Vegetation Framework* is an intergovernmental agreement among all levels of Australian government under the Council of Australian Governments (COAG). It provides for national objectives in relation to native vegetation cover, deforestation and 'revegetation'. In particular:

- the extent of native vegetation cover is an explicit policy objective;
- 'revegetation ' is identified as a critical activity that contributes towards this national goal; and
- there is flexibility for individual States and Territories to implement the framework in accordance with their own individual circumstances.

This agreement is critical context for understanding State and Territory government regulatory objectives and mechanisms.

Australia's Native Vegetation Framework has been developed by the Australian Government and State and Territory governments to maintain or build healthier and more connected native vegetation. The Council of Australian Governments Standing Council on Environment and Water will formally oversee implementation of the framework and coordinate regular reviews and updates.

The new vegetation framework was agreed on 19 December 2012 and provides for an explicit national target for native vegetation cover – see http://www.environment.gov.au/land/vegetation/nvf/pubs/native-vegetation-framework-summary.pdf . Some states already have native vegetation cover targets of their own. Victoria, for example, has in place the Native Vegetation Management – a framework for action adopted in 2002 and which provides for 'a reversal, across the entire landscape, of the long term decline in the extent and quality of native vegetation, leading to a net gain'. Under the new national framework all Australian state and territory governments will have developed targets for the extent of native vegetation in their jurisdictions by 2014.

The National Vegetation Framework has been designed to be complementary and consistent with Australia's Strategy for the National Reserve System 2009-2030. Under the Australia's Strategy for the National Reserve System 2009-2030 all the state and territory Governments and the Australian Government have agreed to adopt international standards for the definition of a protected area and management categories used by the IUCN.

Every two years, the Australian Government collects information on protected areas from state and territory Governments and other protected area managers. This information is published in the Collaborative Australian Protected Area Database (CAPAD).

CAPAD is used to provide a national perspective of the conservation of biodiversity in protected areas. It also allows Australia to regularly report on the status of protected areas to meet international obligations such as those in the Convention on Biological Diversity (CBD). Australian protected area information is also included in the World Database on Protected Areas (WDPA). The new framework provides continuity with the objectives, principles and targets of earlier COAG agreements and intergovernmental initiatives stretching back to 1990 and before - the National Vegetation Framework (2001) and the landmark National Strategy for Ecologically Sustainable Development (1992), which still provides the framework and context for major legislative initiatives http://www.environment.gov.au/epbc/review/publications/pubs/02-objectives.pdf, and the National Conservation Strategy negotiated in 1983.

The objectives of the 2001 National Vegetation Framework in relation to vegetation cover and the activity of revegetation were explicit.

The native vegetation outcomes being sought in this Framework include a reversal in the long-term decline in the extent and quality of Australia's native vegetation cover by:

- conserving native vegetation, and substantially reducing land clearing;
- conserving Australia's biodiversity; and
- restoring, by means of substantially increased revegetation, the environmental values and productive capacity of Australia's degraded land and water.

http://www.environment.gov.au/land/publications/nvf/framework3.html

For the first commitment period of the Kyoto Protocol, there was no presumption in these agreements that all deforestation activity would cease, but that it could be offset by revegetation activities in the pursuit of the national native vegetation cover objective.

Underpinning these objectives has been a basic set of principles designed to encourage actions to achieve sustainable native vegetation management including principles drawing heavily from the National Strategy on Ecologically Sustainable Development (1992). The ESD strategy provided agreement on national vegetation cover objectives and management principles while recognising existing programs such as the One Billion Trees program, announced 20 July 1989.

Objective 11.1 to foster a conservation ethic, while ensuring effective measures are in place for the conservation and management of native vegetation

Governments will:

- continue actions to promote whole-farm and catchment planning and group approaches to resource management in agriculture, such as those established under the National Soil Conservation Program, Save the Bush, the National Weeds Strategy, the One Billion Trees Program and the Decade of Landcare Plans (announced in the 20 July 1989 'Our Country Our Future' package)

- assess the current rate of native vegetation clearing on a national basis, including undertaking the development of national inventories of native vegetation
- support initiatives at the State and Territory level to protect native vegetation on private land, and enhance initiatives aimed at developing integrated catchment management policy structures
- work through appropriate agencies to develop a native vegetation conservation education program which is targeted at land managers, focuses on the value of retaining native vegetation in situ, while integrating this with major land uses
- review relevant legislation relating to clearing, and ensure criteria for assessing land clearance applications integrate enhancement of productivity of all lands with biodiversity conservation, land protection, water management and landscape values
- encourage voluntary management of native vegetation remnants, and review the effectiveness of mechanisms for the long term voluntary protection of native vegetation and wildlife, in order to provide a basis for deciding on the most appropriate mix
- undertake cooperative development of a range of measures, including financial incentives, cost reimbursements, and rate rebates to encourage land managers to better protect native vegetation

http://www.environment.gov.au/about/esd/publications/strategy/natveg.html

The succession of agreements under COAG has steadily advanced national vegetation protection principles and targets over an extended period of time providing clarity about the value placed on the conservation of native vegetation cover nationally, and on the national policy objective of enhancing revegetation, while providing a cohesive national framework to underpin State and Territory based management actions.

The actions of State and Territory governments are integrated by their commitments to the National Vegetation Framework principles and targets. The framework is not prescriptive, however, when it comes to implementation of individual measures. Individual jurisdictions implement the national native vegetation framework commitments in accordance with their own individual circumstances and land management practices and legislative frameworks.

While dedicated vegetation management legislation emerged in some states in the 1990s, land management activities have been, and continue to also be, regulated by more general land planning legislation introduced prior to, or around, 1990. A more complete listing of relevant State and Territory legislation governing land clearing is provided below.

State and territory native vegetation clearance statutes

New South Wales

- *Native Vegetation Act 2003*
- *Threatened Species Conservation Act 1995*
- *Environmental Planning and Assessment Act 1979 (Local Environmental Plan)*

Victoria

- *Victorian Planning Provision (Clause 52.17)*
- *Planning and Environment Act 1987*
- *Flora & Fauna Guarantee Act 1988*
- *Catchment and Land Protection Act 1994*

Queensland

- *Vegetation Management Act 1999 (prior to this, the Land Act 1994 and the Environmental Protection Act 1994)*
- *Integrated Planning Act 1997*
- *Nature Conservation Act 1992*

Western Australia

- *WA Environmental Protection Act 1986*

South Australia

- *SA Native Vegetation Act 1991*

Tasmania

- *Tasmania Forest Practices Act 1985*

Australian Capital Territory

- *ACT Planning and Development Act 2007*
- *Nature Conservation Act 1980*

Northern Territory

- *NT Planning Act 2002*
- *NT Planning Scheme*
- *Pastoral Land Act 1994*

A primary aim of the emergence of specific – purpose legislation, such as Queensland's *Vegetation Management Act 1999*, was to unify and make more consistent existing regulatory measures and, in particular, ensure consistency between regulations that applied to leasehold and freehold land (government and private lands).

While the legislative instruments in place have clearly evolved, the list shows that relevant regulations to govern the management of native vegetation have been in place over a long period of time in all States and Territories.

The assessment process of forest values differs from state to state. In Australia's system, individual States and Territories have the freedom to implement policies, regulations and administrative mechanisms of their choice to meet the objectives of the COAG intergovernmental agreement.

Examples of administrative processes include compliance with regional ecosystem plans established under legislation, individually negotiated property management plans or additional approval processes / permit processes for clearing.

Permits for conversion of all forests to grasslands for agriculture are required in the Northern Territory, Western Australia, Victoria, South Australia and Tasmania, with minor exceptions. The relevant acts and regulations specify exemptions from the current approval process for the routine maintenance of agricultural land but only for lands with regrowth of an age that is less than a specified number of years (usually between five and ten years) and only where a permit to clear has been previously issued. Effectively a legal consequence through an approval process is associated with all revegetation actions.

In Queensland the administrative processes are more complex. Legal consequences derive from a combination of regional ecosystem plans issued under regulation, individual property agreements and land clearing permits.

For regulated regrowth in Queensland, which relates only to land with regrowth forest not cleared since 31 December 1989, forest areas of high conservation value identified by the relevant Minister in maps published

under regulation are protected by permit approval processes. The technical nature of the assessment processes, and risks to land managers given uncertainty about outcomes following a series of well publicised prosecutions for non-compliance, has meant that there has also been considerable use of agreements known as property map of assessable vegetation plans. This represents an additional layer of approval process. These plans are individual legal agreements between the land manager and the State Government relating to specific properties and which identify both highly protected forests and forests where pre-approval for clearing is granted. In 2008-09 around half of all clearing of regrowth forests was undertaken in areas regulated by these types of legal agreements and around half was undertaken under the regional ecosystem plans issued under regulation (where further approval or permits in addition to the rulings set out in the ecosystem plans are not required).

A similar mix of instruments is applied in New South Wales. Protected regrowth is native vegetation that has grown since 1 January 1990 (or 1983 in the Western District), but is protected because it has grown on vulnerable land or has been identified as protected regrowth in a Property Vegetation Plan (PVP), an environmental planning instrument, a natural resources management plan or an interim protection order under the NV Act. It also includes native vegetation that is regrowth that has been grown or preserved with the assistance of public funds granted for biodiversity conservation purposes.

The regulations provide for clearing of other regrowth areas for agriculture without additional approval only if the land had been lawfully cleared previously or for the continuation of existing cultivation, grazing or rotational farming practices. This latter provision is akin to the provisions of regulations in other states but without the specification of a specific number of years of regrowth. As with other states, this provision implies that the land manager may control for vegetation regrowth without further approval only for the purpose of maintaining existing pastures.

The national regulatory framework, together with the raft of legislative instruments and other policies and measures in place at national and State and Territory level, demonstrate that land managers have a legal need for activities to prevent an undesired regrowth of an area to forest and that the regrowth of an area as forest should take place only where desired by land managers based on land managers' decisions. Deforestation of these lands is possible only under certain circumstances and several administrative steps must be taken before it is legally allowed.

At the national level, there are many relevant federal government programs which also aim to promote vegetation cover either directly or indirectly, such as through carbon or biodiversity objectives.

These measures continue past actions by the Federal government to promote vegetation outcomes across the country over a long period of time. For example, in the 'Our Country Our Future' package announced 20 July 1989, the measures included the National Soil Conservation Program, Save the Bush, the National Weeds Strategy, the One Billion Trees Program and the Decade of Landcare Plans. There have been many measures in the period between these two packages.

These federal government programs operate in addition to land management legislation operated by State and Territory governments identified above.

As the method used to identify areas of A/R land in Australia's national inventory is based on remote sensing techniques Australia has not allocated identified A/R or the additional, cumulative A/R lands to the many individual government programs. The remote sensing techniques employed for Australia's national inventory report have been designed to detect planting events only whereas the identified programs encourage revegetation through a mix of planting and regeneration of seed source approaches.

It could therefore be argued that additional lands could be identified as afforestation/reforestation lands, as the lands that were not a forest on 31 December 1989, and which have naturally regenerated through direct human induced means, have not been included in Australia's afforestation/reforestation account. Consequently,

it follows that lands that were not covered in forest on 31 December 1989, which have naturally regenerated under State vegetation regulatory frameworks, and which were then cleared, have also not been identified in Australia's national inventory submission as 'deforestation'. If Australia were to apply this broadened approach to the definition of A/R, the removals from the inclusion of the naturally regenerating forests in A/R would exceed emissions from the observed re-clearing of these forests.

It is recognised that while additional work must be undertaken under Australia's National Inventory System to consider the treatment of these lands, for the purpose of estimating emissions under Article 3.3 of the Kyoto Protocol the current approach is conservative and does not result in an under estimate of emissions from Article 3.3 activities.

Australia recognises the need for development in this aspect of its inventory and the development of this capability is a high priority for Australia.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

The key factors that lead to temporary change in forest cover in Australia are climate, fire and forest harvesting. Australia has a full time-series of land cover change mapping dating back to 1972 and therefore can readily identify forest areas that have undergone natural disturbance and regrowth as opposed to direct human-induced deforestation.

Natural disturbance

The length of the time series and frequency of national forest mapping allows Australia to detect with a high degree of certainty the permanency and cause of change in forest cover. This certainty is further enhanced through the use of time-series statistical methods (the Conditional Probability Network, CPN), land tenure mapping, manual attribution and mapping of fire affected areas. These methods are fully described in Appendix 7.A.

To distinguish between forest cover loss due to fire and *deforestation*, maps of areas affected by fire (fire scar mapping) are overlayed on forest change to ensure that only areas subject to direct human induced deforestation are accounted for. Other types of disturbance which affect forest cover, such as prolonged drought, are also excluded during the attribution process.

Deforestation of Afforestation or Reforestation land

Private forestry Managed Investment Scheme (MIS) companies have been responsible for the majority of new plantation establishment in Australia since 1990 on cleared lands. As a result approximately 80% of Australia's afforestation/reforestation (A/R) land is industrial plantations. Hardwood plantation development for short rotation (approx. 10-12 years) has been particularly prevalent from the late 1990's with significant areas of these plantations reaching commercially harvestable age from 2009. Softwood plantations operate over much longer rotations of 30+ years and environmental plantings are not for harvest management systems.

From early 2008 the major Forestry MIS companies responsible for the majority of hardwood plantation establishment and management entered administration and most were subsequently liquidated. Following the collapse of these companies many of these short rotation plantation resources have been harvested approximately as per schedule.

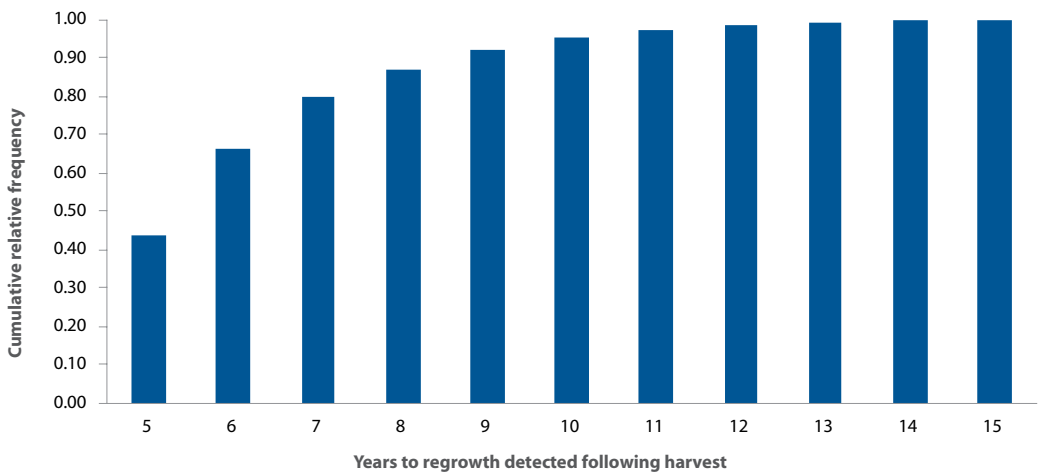
Following harvest, the majority of the afforestation/reforestation hardwood plantation lands have entered a period of uncertainty where new management arrangements have not been put in place. Anecdotal evidence suggests that an undefined but significant area of afforestation/reforestation lands have not been converted to another land

use and are awaiting certainty of tenure or capital prior to re-establishment of forest or conversion to agriculture. Thus such lands have often not transitioned from plantation management to another land use.

Australia has undertaken analysis of forests that are subject to afforestation/reforestation activity to identify the range of time periods between a clearing event and the re-establishment of a forest for a second rotation.

The purpose of this project was to identify an appropriate "time since harvest" (X number of years) which is applicable to industrial plantations in Australia's afforestation/reforestation estate in order to distinguish temporary forest cover loss from deforestation activity. The analysis was remote sensing based and used data available to the end of 2011 and so provided a 20 year record of forest cover gain and loss. This analysis showed that detection of reforestation is most common 5 years after a harvest event has been detected, with a decreasing occurrence of observations until 15 years following harvest (Figure 11.4).

Figure 11.4: Relative and cumulative frequency histograms of the time since clearing until detection of reforestation event by area

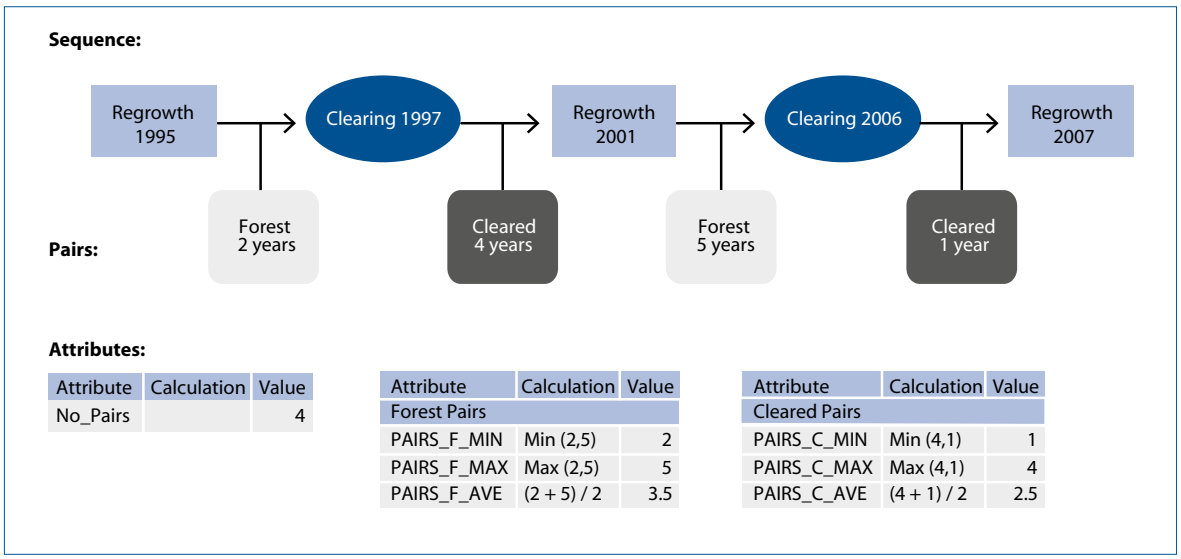


- As shown in Figure 11.4, 87% of the harvested areas are detected as regrowth within eight years of harvest while 92% of the harvested areas are detected as regrowth within nine years of harvest.
- Australia determined that it is appropriate to define the period to monitor harvested A/R lands in terms of 90% confidence.
- Nine years was not chosen as it was determined that 8 years was a conservative practical approximation of 90% confidence.
- Australia has specified an interval of 8 years following the year in which harvest was detected to monitor afforestation and reforestation lands that have been cleared to determine if they have been deforested: that is if a harvest event has been detected and forest cover is not detected within the eighth year after harvest then the land is confirmed as deforested.

The indicative estimate of deforestation on A/R lands reported in the NIR 2011, has been further refined based on a robust, spatially explicit classification of forest cover gain and loss temporal sequences over A/R lands. For example, each forest cover gain and loss events create an event sequence. This sequence can be analysed in pairs of two consecutive events. Event pairs can be classified as forest or cleared depending on the status of the pixel between the events. A series of statistics were derived to describe these event pairs, namely, minimum, maximum and average number of years a pixel was forest or cleared, as shown in Figure 11.5. Individual event pairs in the sequence were assessed against the 8 year rule. Clearing event pairs not meeting the required 8 year threshold,

that is, re planting within the 8 years subsequent to harvest, do not meet the criteria used to identify deforestation on A/R lands. However, the remainder of the sequence, if valid, is classified as deforestation within A/R lands if any clearing event pair exceeds the 8-year rule. If the last event in the sequence is clearing, and this clearing is less than 8 years from the current epoch, the land is monitored until it can be fully assessed against the 8-year rule. As result of this improved classification logic, additional deforested lands were detected and are reported in this NIR.

Figure 11.5: Classification and attribution of forest cover gain and loss events in a sequence. This particular sequence, as of 2001, represents the category "forest cover loss and gains detected."



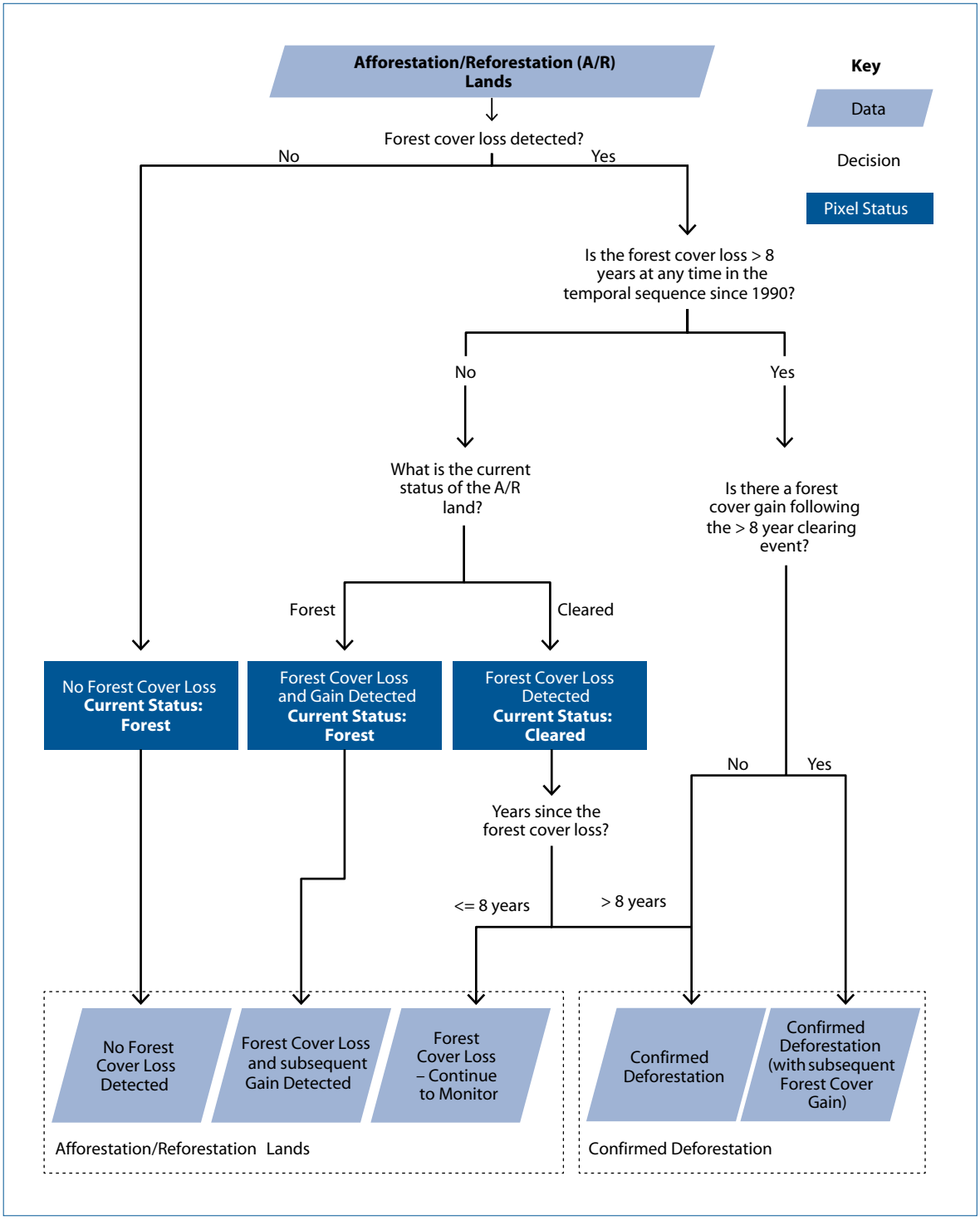
Attribute	Calculation	Value
No_Pairs		4

Attribute	Calculation	Value
Forest Pairs		
PAIRS_F_MIN	Min (2,5)	2
PAIRS_F_MAX	Max (2,5)	5
PAIRS_F_AVE	(2 + 5) / 2	3.5

Attribute	Calculation	Value
Cleared Pairs		
PAIRS_C_MIN	Min (4,1)	1
PAIRS_C_MAX	Max (4,1)	4
PAIRS_C_AVE	(4 + 1) / 2	2.5

The improved process to categorise A/R lands across the country based on the forest cover gain and loss event statistics is presented in Figure 11.6. The main advantage of this approach is that it can keep track of deforested A/R lands spatially and can detect subsequent regrowth, if any, on these deforested lands. Knowledge of the location and spatial extent of deforested lands allows more accurate estimation of emissions and removals by using appropriate site conditions in the FullCAM.

Figure 11.6: Improved spatial analysis applied to the 2012 forest cover loss and gain event sequences to detect deforestation on afforestation/reforestation lands



Where an epoch covered more than a single year the transitions during the period were divided by the number of years and assigned to each year. For example if an epoch contained three years and indicated 300 hectares of deforestation, 100 hectares was assigned to each year.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Areas of deforestation and afforestation/reforestation are only added to the accounts once it is shown with confidence that the land has been deforested or afforested/reforested as a result of human-induced activities. As new data are added to the time-series the certainty that deforestation and afforestation/reforestation occurred increases. This results in a small recalculation of these accounts (< 4%) each year and this is monitored through the continuing annual acquisition of remotely sensed data.

The results of the analysis indicate that a cumulative area of 277,929 hectares had been harvested by 2012 (Table 11.7). The area of afforestation/reforestation land identified as being harvested and where re-establishment has not been confirmed is approximately 174,048 hectares. Further work is in progress to improve the method including further assessment of the impact of fire on confirmed deforested lands.

Table 11.7: Analysis of afforestation/reforestation lands

Description	Area (ha)
Afforested/Reforested lands	1,172,218
• Harvested areas: 1990-2012	277,929
• Re-establishment confirmed (remains afforestation/ reforestation)	70,940
• Deforested — confirmed (1990–2004)	32,941
• Monitored to determine if re-establishment or land use change occurs (remains afforestation/reforestation)	174, 048

Figure 11.7: Shows output from spatial analysis of afforestation/reforestation lands in south west Western Australia (mapsheet SI50).

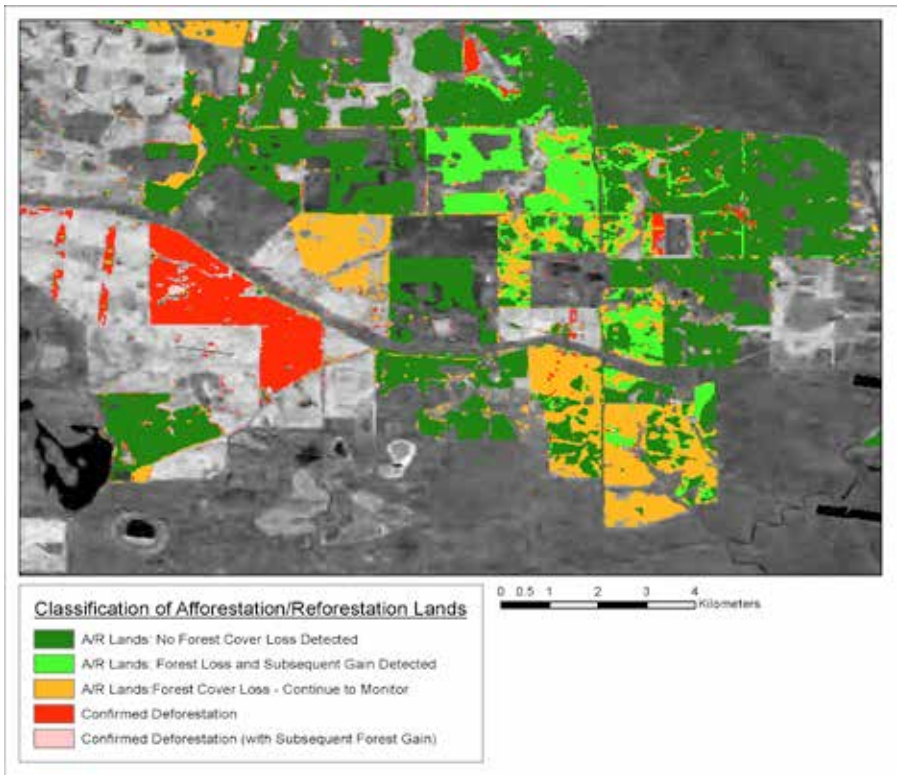


Table 11.8: Cumulative area of confirmed deforestation on afforestation/reforestation lands

Year of Harvest	Cumulative deforestation - confirmed (ha)
2000	15,670
2001	18,530
2002	22,685
2003	26,840
2004	32,941

The general rate of regeneration of plantation estates in Australia has been reported in the *Australia's State of the Forests Report 2008* (Montreal Process Implementation Group for Australia 2008). This reported data for the period 2000-2006 shows regeneration rates for plantations at around 93% for Tasmania and 98-100% for South Australia. These regeneration rates apply to all plantations in the state, including lands that do not meet the requirements to be included as afforestation/reforestation. High regeneration rates have normally been expected in Australia's plantation estates.

As indicated above, re-establishment rates of plantations are subject to more uncertainty in Australia given the current economic conditions and the rate of re-establishment is likely to fall over the next few years. The use of an eight year observation period as defined in this paper is expected to allow an appropriate time period for not only the detection of plantation re-establishment but also to allow for an economic decision to be made by land owners regarding whether to re-plant a forest or convert the land to a non-forest land use.

11.5 Article 3.4

Not applicable as Australia has not elected Article 3.4 activities.

11.6 Other Information

11.6.1 Annual area of Afforestation/Reforestation

The annual area of Afforestation/Reforestation is presented in Table 11.9.

Table 11.9: Annual area of Afforestation/Reforestation 1990-2012

Year	Area of Afforestation/Reforestation (ha)
1990	46,088
1991	42,701
1992	45,318
1993	48,409
1994	46,046
1995	31,194
1996	33,084
1997	30,337
1998	38,040
1999	40,908
2000	65,997
2001	75,437
2002	71,542
2003	76,045
2004	71,326
2005	53,841
2006	47,672
2007	62,347
2008	65,426
2009	59,104
2010	39,236
2011	31,728
2012	14,457

Australia's Afforestation/Reforestation estate has increased in area over the period 1990-2012, especially in the five years from 2000. However, in 2012 the rate of Afforestation/Reforestation activity was the lowest since 1990 (Table 11.9). This may have been caused by the economic conditions for forest products, including the historically high value of the Australian currency in 2010 and 2011, making it more challenging to export plantation products overseas. Furthermore, several major players exited the market resulting in the reduction of plantation establishment.

11.6.2 Area and harvest type within the Afforestation/Reforestation estate

The area and type of harvest implemented in the Afforestation/Reforestation FullCAM simulation is reported in Table 11.10.

Table 11.10: Cumulative harvest area within the Afforestation/Reforestation estate 2008-2012

Harvest type	2008	2009	2010	2011	2012
Clear Fell (ha)	17,807	35,639	58,890	83,701	117,381
Thin (ha)	28,807	57,176	85,329	110,429	139,089
Total (ha)	46,615	92,815	144,218	194,130	256,470

The area of harvest within the Afforestation/Reforestation estate has been rising in the period 2008-2012 (Table 11.10) as an increasing area of forest established in the period since 1990 (on clear land) reaches harvest age. The total area of clear fell harvesting has increased over this period; however the majority of harvesting is attributable to thinning activity (Table 11.10). Harvest events within the FullCAM simulation are supply driven based on regional and species specific management practices (see Volume 2, section 7.6.1). This area of modelled supply driven harvest activity is consistent with observations of harvest activity within the Afforestation/Reforestation estate (Table11.7).

11.6.3 Key category analysis

The key category analysis for Article 3.3 activities are reported in Annex 1 and in Table 11.11.

Table 11.11: Summary overview for key categories for land use, land use change and forestry activities under the Kyoto Protocol.

Key Categories of Emissions and Removals	Gas	Criteria used for Key Category Identification			Comments
		Associated category in UNFCCC inventory is key	Category contribution is greater than the smallest category considered key in the UNFCCC inventory (including LULUCF)	Other	
Afforestation/ Reforestation	CO_2	Land converted to forest	YES	NA	UNFCCC category is key, category is greater than smallest UNFCCC key category
Deforestation	CO_2	Land converted to cropland Land converted grassland	YES	NA	UNFCCC category is key, category is greater than smallest UNFCCC key category
Deforestation	CH_4	Land converted to cropland	NO	NA	UNFCCC category is key

12. Information on Accounting of Kyoto Units

12.1 Summary of information reported in the Standard Electronic Format Tables

Annex I Parties are required to report from its national registry holdings and transactions of Kyoto units in the previous calendar year. In accordance with Decision 15/CMP.1 annex I.E paragraph 11 this information has been submitted in the standard electronic format (SEF) tables (Tables 12.1 to 12.6).

Table 12.1: SEF Table 1, Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	2863764055	NO	46294933	30002	NO	NO
Article 3.3/3.4 net source cancellation accounts	93815088	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	20500	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	2957579143	NO	46294933	50502	NO	NO

Table 12.2: SEF Table 2(a), Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			23834852				NO	NO	NO	NO		
3.3 Deforestation			NO				9593542	NO	46294933	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							2300861	150000	NO	108326	NO	NO
Sub-total		NO	23834852				11894403	150000	46294933	108326	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO

Table 12.3: SEF Table 2(b), Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Transfers and acquisitions												
CH	NO	NO	NO	20001	NO	NO	NO	NO	NO	1	NO	NO
EU	NO	NO	NO	397544	NO	NO	NO	NO	NO	347544	NO	NO
GB	NO	NO	NO	101	NO	NO	NO	NO	NO	5001	NO	NO
NL	NO	NO	NO	500	NO	NO	NO	NO	NO	NO	NO	NO
NZ	NO	150000	NO	112826	NO	NO	NO	NO	NO	50000	NO	NO
SE	NO	NO	NO	NO	NO	NO	NO	NO	NO	5000	NO	NO
Sub-total	NO	150000	NO	530972	NO	NO	NO	NO	NO	407546	NO	NO

Additional information	
Independently verified ERUs	NO

Table 12.4: SEF Table 2(c), Total annual transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of tables 2a and 2b)	NO	150000	23834852	530972	NO	NO	11894403	150000	46294933	515872	NO	NO

Table 12.5: SEF Table 3, Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs (tCERS)								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
Long-term CERs (lCERs)								
Expired in retirement and replacement accounts		NO						
Replacement of expired lCERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of lCERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
Total			NO	NO	NO	NO	NO	NO

Table 12.6: SEF Table 4, Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	2851869652	NO	23834852	NO	NO	NO
Entity holding accounts	NO	NO	NO	45102	NO	NO
Article 3.3/3.4 net source cancellation accounts	103408630	NO	46294933	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	2300861	150000	NO	128826	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	2957579143	150000	70129785	173928	NO	NO

Table 12.7: SEF Table 5(a), Summary information on additions and subtractions

Starting values	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Issuance pursuant to Article 3.7 and 3.8	2957579143											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	2957579143	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)	NO	NO	NO	1	NO	NO	NO	NO	NO	1	NO	NO
Year 4 (2011)	NO	NO	23032901	126851	NO	NO	49650531	NO	NO	75851	NO	NO
Year 5 (2012)	NO	NO	23262032	102714	NO	NO	44164557	NO	NO	123712	NO	NO
Year 6 (2013)	NO	150000	23834852	530972	NO	NO	11894403	150000	46294933	515872	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	NO	150000	70129785	760538	NO	NO	105709491	150000	46294933	715436	NO	NO
Total	2957579143	150000	70129785	760538	NO	NO	105709491	150000	46294933	715436	NO	NO

Table 12.8: SEF Table 5(c), Summary information on retirement

Year	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	NO	NO	NO	NO	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO	NO
Year 4 (2011)	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO

Table 12.9: SEF Table 6(a), Memo item: Corrective transactions relating to additions and subtractions

Additions						Subtractions					
Unit type						Unit type					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 12.10: SEF Table 6(b), Memo item: corrective transactions relating to replacement

Requirement for replacement		Replacement					
Unit type		Unit type					
tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 12.11: SEF Table 6(c), Memo item: Corrective transactions relating to retirement

Retirement					
Unit type					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.2 Discrepancies and notifications

Decision 15/CMP.1 annex I.E paragraphs 12-17 require Annex I Parties to report on various possible discrepancies and notifications. Australia's discrepancies and notifications are summarised in Table 12.7.

Table 12.12: Accounting of Kyoto Protocol Units

Annual Submission Item	Report
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	See section 12.1. The SEF tables have been submitted to the UNFCCC.
15/CMP.1 annex I.E paragraph 12: List of discrepant transaction	Australia had no discrepant transaction for the reporting period.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	Australia did not receive any CDM notifications.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	Australia had no non-replacements.
15/CMP.1 annex I.E paragraph 16: List of invalid units	Australia had no invalid units.
15/CMP.1 annex I.E paragraph 17: Actions and changes to address discrepancies	None required.
15/CMP.1 annex I.E paragraph 18: Commitment period reserve calculation	See section 12.4

12.3 Publically Accessible Information

Public information is available https://nationalregistry.cleanenergyregulator.gov.au/report/listPublicReports under the Public Reports facility. Please note that Personal information of Account Representatives, including their identification numbers, names, addresses, email and phone and fax numbers, is confidential and is not published, in accordance with Decision 13/CMP.1 Paragraph 44 of the Conference of the Parties to the Kyoto Protocol and Regulation 50 of the *Australian National Registry of Emissions Units Regulations 2011*.A full description of the information that is available is in Annex 8.

12.4 Calculation of the Commitment Period Reserve

The Annex to Decision 11/CMP.1 (paragraph 6) specifies that: 'each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol, or 100 per cent of five times its most recently reviewed inventory, whichever is lowest'.

Australia's commitment period reserve is 2,661,821,229 tonnes CO_2 equivalent calculated as 90% of Australia's assigned amount.

12.5 KP-LULUCF Accounting

Australia has elected to account for the Kyoto Protocol Article 3.3 LULUCF activities on an annual basis. Table 12.13 shows the accounting quantity for 2008, 2009, 2010, 2011 and 2012.

Table 12.13: Information table on accounting for activities under articles 3.3 and 3.4 of the Kyoto Protocol

Greenhouse gas source and sink activities	By[4]	Net emissions/removals						Accounting Parameters[6]	Accounting Quantity [7]
		2008	2009	2010	2011	2012	Total[5]		
		(Gg CO_2 equivalent)							
A. Article 3.3 activities									
A.1. Afforestation and Reforestation[1]		-18,593	-19,133	-22,893	-26,439	-21,885	-108,942		-108,942
A.2. Deforestation		56,747	48,784	47,706	38,525	32,805	224,567		224,567
B. Article 3.4 activities									
B.1. Forest Management (if elected)		NA	NA	NA		NA	NA		NA
3.3 offset[2]								92,000.93	NA
FM cap[3]								0.00	NA
B.2. Cropland Management (if elected)	0.00	NA	NA	NA		NA	NA	0.00	0.00
B.3. Grazing Land Management (if elected)	0.00	NA	NA	NA		NA	NA	0.00	0.00
B.4. Revegetation (if elected)	0.00	NA	NA	NA		NA	NA	0.00	0.00

(1) In accordance with paragraph 4 of the annex to decision 16/CMP.1, debits resulting from harvesting during the first commitment period following Afforestation and Reforestation since 1990 shall not be greater than credits accounted for on that unit of land

(2) In accordance with paragraph 10 of the annex to decision 16/CMP.1, for the first commitment period, a Party included in Annex I that incurs a net source of emissions under the provisions of Article 3.3 may account for anthropogenic greenhouse gas emissions by sources and removals by sinks in areas under Forest Management under Article 3.4, up to a level that is equal to the net source of emissions under the provisions of Article 3.3, but not greater than 9.0 megatonnes of carbon times five, if the total anthropogenic greenhouse gas emissions by sources and removals by sinks in the managed forest since 1990 is equal to, or larger than, the net source of emissions incurred under Article 3.3. Australia has not elected Forest Management.

(3) In accordance with paragraph 11 of the annex to decision 16/CMP.1, for the first commitment period only, additions to and subtractions from the assigned amount of a Party resulting from Forest Management under Article 3.4, after the application of paragraph 10 of the annex to decision 16/CMP.1 and resulting from Forest Management project activities undertaken under Article 6, shall not exceed the value inscribed in the appendix of the annex to decision 16/CMP.1, times five. Australia has not elected Forest Management.

(4) Net emissions and removals in the Party's base year, as established by decision 9/CP.2

(5) Cumulative net emissions and removals for all years of the commitment period reported in the current submission

(6) The values in the cells "3.3 offset" and "FM cap" are absolute values.

(7) The accounting quantity is the total quantity of units to be added to or subtracted from a Party's assigned amount for a particular activity in accordance with the provisions of Article 7.4 of the Kyoto Protocol.

13. Changes to the National System

Decision 15/CMP.1 annex I.F paragraph 21 requires Parties to include in the National Inventory Report information on any changes that have occurred in its national system compared with its last submission.

Since the 2013 inventory submission there have been some changes to the arrangements for approving the inventory, the process for inventory compilation and the QA/QC activities undertaken (see Table 13.1 for more details).

Table 13.1: Change to the national system

Reporting Item	Annual Report
15/CMP.1 annex II.E paragraph 30 (a) Change of name or contact information	Since the last submission the name of the single national entity has changed from the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to the Department of the Environment.
15/CMP.1 annex II.E paragraph 30 (b) Change of roles and responsibilities as well as change of the institutional, legal and procedural arrangements	On 18 September 2013, the Australian Government announced changes to the makeup of Australian Government Department's including the incorporation of climate change sections of the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE) into the Department of the Environment. The DIICCSRTE functions responsible for the compilation of the National Inventory have moved in their entirety and remain unchanged.
15/CMP.1 annex II.E paragraph 30 (c) Changes in the process of inventory compilation	Continuing on from the improvements in the 2011-2013 submissions the process of inventory compilation continues to incorporate more facility specific data obtained under the National Greenhouse and Energy Reporting (NGER) System. Recalculations flowing from the change have been identified in the relevant chapters of the NIR.
15/CMP.1 annex II.E paragraph 30 (d) Change of process for key category identification and archiving	No change in this submission
15/CMP.1 annex II.E paragraph 30 (e) Change of process for recalculations	No change in this submission
15/CMP.1 annex II.E paragraph 30 (f) Changes with regard to QA/QC plan, QA/QC activities and procedures	Since the 2013 inventory submission additional QA/QC activities and procedures have been implemented as identified in the relevant chapters of the NIR.
15/CMP.1 annex II.E paragraph 30 (g) Change of procedures for the official consideration and approval of the inventory	No change in this submission.

14. Changes to the National Registry

Under the Kyoto Protocol, Parties are required to put in place a national registry to report annually on acquisition, holding, transfer, cancellation, withdrawal and carryover of assigned amount units, removal units, emission reduction units and certified emission reductions during the previous year. A full description of Australia's national registry system is presented in Annex 8. Australia's national registry is referred to as the Australian National Registry of Emissions Units (ANREU).

Decision 15/CMP.1 annex I.G paragraph 22 requires Parties to include in the National Inventory Report information on any changes that have occurred in its national registry compared with its last submission.

Table 14.1: Change to the national registry

Reporting Item	Annual Report
15/CMP.1 annex II.E paragraph 32 (a) Change of name or contact	No change in this submission
15/CMP.1 annex II.E paragraph 32 (b) Change of cooperation arrangement	No change in this submission
15/CMP.1 annex II.E paragraph 32 (c) Change to database or the capacity of National Registry	Version 1.9.1 of the ANREU was released into production in October 2013. Apart from the added functionality provided for in this release there are no changes to the database and capacity of the ANREU. Functionality to support the DES requirements remains unchanged.
15/CMP.1 annex II.E paragraph 32 (d) Change of conformance to technical standards	No change in this submission. The ANREU web application is based on the RIDGE platform which retains, at a minimum, the same level of conformance to technical standards as the previous version of the ANREU. In addition, the ANREU fully supports the revised transaction message flows specified by the current version of the Data Exchange Standards (DES) for Registry Systems under the Kyoto Protocol. In addition, the ANREU is equipped to handle transactions and reconciliation events involving "large" numbers of unit blocks as verified during the coordinated large unit block testing with the ITL.
15/CMP.1 annex II.E paragraph 32 (e) Change of discrepancies procedures	No change in this submission
15/CMP.1 annex II.E paragraph 32 (f) Change of Security	No change in this submission.
15/CMP.1 annex II.E paragraph 32 (g) Change of list of publicly available information	No change in this submission. Personal information of Account Representatives, including their identification numbers, names, addresses, email and phone and fax numbers, is confidential and is not published, in accordance with Decision 13/CMP.1 Paragraph 44 of the Conference of the Parties to the Kyoto Protocol and Regulation 50 of the *Australian National Registry of Emissions Units Regulations 2011*. The non-confidential public information can now be found at https://nationalregistry.cleanenergyregulator.gov.au/report/listPublicReports under the Public Reports facility.

Reporting Item	Annual Report
15/CMP.1 annex II.E paragraph 32 (h) Change of Internet address	No change in this submission. Australia's national registry can be found at https://nationalregistry.cleanenergyregulator.gov.au/.
15/CMP.1 annex II.E paragraph 32 (i) Change of data integrity measure	No change in this submission.
15/CMP.1 annex II.E paragraph 32 (j) Change of test results	As part of the readiness for an infrastructure migration (anticipated to occur in 1st quarter 2014) Australia has undertaken revised "Annex H" testing (December 2013). Functionality to support the DES requirements however remains unchanged.
Response to previous Annual Review recommendations	No issues were identified through the 2013 Standard Independent Annual Review (SIAR) process.

15. Minimization of Adverse Impacts in Accordance with Article 3.14

Australia is pleased to provide an update to its last submission and supplementary information on how Australia is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement its greenhouse gas emission limitation and reduction commitments mentioned in Article 3, paragraph 1, of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the United Nations Framework Convention on Climate Change.

Australia is committed to taking cost-effective and practical steps to reduce emissions consistent with our target to reduce Australia's emissions by five per cent on 2000 levels by 2020. Australia's Emissions Reduction Fund will provide incentives for lowest cost emissions reduction activities within the Australian economy. Australia also supports international initiatives to advance practical climate action consistent with continued economic growth.

It is accepted that the cost of global climate action is lower than the cost of inaction. It follows that curbing emissions and reducing the impact of climate change will have substantial economic, social and environmental benefits, particularly for developing countries that are most vulnerable to climate impacts.

Australia cooperates with our neighbours in the Asia-Pacific region and other developing countries to build economic resilience. Australia is also undergoing efforts to develop and deploy low emissions technologies, including in developing countries. This includes efforts through technology partnerships such as the International Partnership for Geothermal Technology, Carbon Sequestration Leadership Forum, Global Methane Initiative and Australia-China Joint Coordination Group on Clean Coal Technology; as well as through participation in the broad-ranging work programme of the International Renewable Energy Agency which promotes the widespread adoption and sustainable use of all forms of renewable energy.

ANNEX 1: Key category Analysis

A1.1 Convention Accounting

A *key 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 for LULUCF* (IPCC 2003). This approach identifies sources that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms.

When the LULUCF sector is included in the analysis, Australia has identified *public electricity (solid fuel)*, *road transportation (liquid fuels)* and *land converted to grassland* as the most significant of the key categories (i.e. contributing more than 10% of the level or trend) in 2012. The full results for the 2012 key source analysis are reported in Tables A.1.1 to A1.3.

When the LULUCF sector is excluded from the analysis the most significant key categories in 2012 are *public electricity (solid fuel), road transportation (liquid fuels)* and *enteric fermentation (sheep).* The results of this latter analysis are presented in Tables A.1.4 to A.1.6. Table A.1.7 summarises the results of the key category analysis for LULUCF categories under KP accounting.

In response to recommendations from the ERT Australia has included a level by source analysis for 1990 in Tables A.1.8 and A.1.9.

The Australian analysis has been undertaken using a relatively high degree of disaggregation of sources, which permits a greater degree of understanding of Australia's key categories. Past analyses by the UNFCCC secretariat of Australian data, using higher levels of aggregation common in the analyses undertaken by other countries, have not produced any important distinctions.

A1.2 Kyoto Protocol LULUCF Activities

The concept of key categories is also used for choosing the good practice estimation methods for emissions and removals due to activities under Articles 3.3 and 3.4 of the Kyoto Protocol. The KP-LULUCF key categories have been identified as outlined in the *IPCC Good Practice for LULUCF* (IPCC 2003).

For the Article 3.3 activities Australia has identified both deforestation and afforestation/reforestation as key categories. The results in the format of Table NIR 3 are presented in Table A.1.7

Table A.1.1: Key categories for Australia's 2012 inventory-level assessment including LULUCF

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	168,912	0.26	0.26
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	74,850	0.12	0.38
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	45,423	0.07	0.45
5.C.2	Land converted to Grassland	CO_2	105,661	30,573	0.05	0.50
5.A.1	Forest Land remaining Forest Land	CO_2	45,447	23,067	0.04	0.53
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	21,074	0.03	0.57
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,565	0.02	0.59
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	14,675	0.02	0.61
5.B.2	Land converted to Cropland	CO_2	29,883	12,126	0.02	0.63
5.A.2	Land converted to Forest Land	CO_2	91	11,528	0.02	0.65
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	10,529	0.02	0.67
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	8,981	0.01	0.68
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	2,815	8,567	0.01	0.70
4.E	Prescribed Burning of Savannas	CH_4	4,909	8,454	0.01	0.71
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	7,863	0.01	0.72
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	7,714	0.01	0.73
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	7,368	0.01	0.74
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	958	7,011	0.01	0.75
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	6,577	0.01	0.77
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,372	6,140	0.01	0.77
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	5,888	0.01	0.78
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,220	0.01	0.80
5.G	Other (Harvested Wood Products)	CO_2	5,048	4,169	0.01	0.80
1.A.2.b	Non-Ferrous Metals \ Solid Fuels	CO_2	4,049	4,088	0.01	0.81
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	0	4,037	0.01	0.81
1.A.2.c	Chemicals \ Liquid Fuels	CO_2	3,263	3,904	0.01	0.82
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,730	0.01	0.82
4.D.3.1	Atmospheric Deposition	N_2O	3,150	3,642	0.01	0.83
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,620	0.01	0.83
2.A.1	Cement Production	CO_2	3,463	3,518	0.01	0.84
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,319	0.01	0.84
5.A.1	Forest Land remaining Forest Land	CH_4	1,348	3,284	0.01	0.85
4.E	Prescribed Burning of Savannas	N_2O	1,450	3,261	0.01	0.85

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
2.C.3	Aluminium Production	CO_2	2,021	3,194	0.00	0.86
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	0	3,041	0.00	0.86
5(V)	Forest Land remaining Forest Land \ Biomass Burning \ Wildfires	CH_4	813	2,961	0.00	0.87
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	2,844	0.00	0.87
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,950	2,819	0.00	0.88
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	2,776	0.00	0.88
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	1,811	2,691	0.00	0.89
5.B.1	Cropland remaining Cropland	CO_2	2,864	2,539	0.00	0.89
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,489	2,534	0.00	0.89
2.B	Chemical Industry	N_2O	1,035	2,504	0.00	0.90
1.B.2.c.2.2	Gas	CO_2	3,601	2,376	0.00	0.90
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,822	2,324	0.00	0.91
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,168	2,192	0.00	0.91
2.B	Chemical Industry	CO_2	603	2,148	0.00	0.91
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,056	0.00	0.92
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	1,233	1,847	0.00	0.92
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,765	0.00	0.92
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	1,676	0.00	0.92
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	1,513	0.00	0.93
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	1,441	1,480	0.00	0.93
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	690	1,476	0.00	0.93
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,246	1,468	0.00	0.93
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	1,383	1,437	0.00	0.93
5.G	Agricultural Liming	CO_2	170	1,419	0.00	0.94
5.C.1	Grassland remaining Grassland	CO_2	35,779	1,405	0.00	0.94
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CO_2	1,122	1,253	0.00	0.94
4.D.1.4	Crop Residue	N_2O	534	1,123	0.00	0.94
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,087	0.00	0.94
1.A.3.d	Navigation \ Liquid Fuels \ Gas/ Diesel Oil	CO_2	174	1,085	0.00	0.95
1.A.3.d	Navigation \ Liquid Fuels \ Gasoline	CO_2	901	1,047	0.00	0.95
4.B.8	Manure Management \ Swine	CH_4	1,050	1,036	0.00	0.95

Table A.1.2: Key categories for Australia's 2012 inventory—trend assessment including LULUCF

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
5.C.2	Land converted to Grassland	CO_2	105,661	30,573	0.13	0.20	0.20
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	168,912	0.08	0.12	0.32
5.C.1	Grassland remaining Grassland	CO_2	35,779	1,405	0.06	0.09	0.42
5.A.1	Forest Land remaining Forest Land	CO_2	45,447	23,067	0.04	0.06	0.48
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	74,850	0.04	0.06	0.53
5.B.2	Land converted to Cropland	CO_2	29,883	12,126	0.03	0.05	0.58
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	10,529	0.03	0.04	0.62
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	21,074	0.02	0.03	0.65
5.A.2	Land converted to Forest Land	CO_2	91	11,528	0.02	0.03	0.68
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	14,675	0.02	0.03	0.71
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	958	7,011	0.01	0.02	0.72
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	2,815	8,567	0.01	0.01	0.74
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	45,423	0.01	0.01	0.75
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	7,368	0.01	0.01	0.76
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	8,981	0.01	0.01	0.78
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	5,888	0.01	0.01	0.80
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	0	4,037	0.01	0.01	0.80
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	7,863	0.01	0.01	0.81
4.E	Prescribed Burning of Savannas	CH_4	4,909	8,454	0.01	0.01	0.82

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
2.C.3	Aluminium Production	CH_4	3,337	220	0.01	0.01	0.82
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	0	3,041	0.01	0.01	0.83
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	7,714	0.01	0.01	0.84
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	6,577	0.00	0.01	0.85
1.A.4.c	Agriculture/Forestry/ Fisheries \ Liquid Fuels	CO_2	3,372	6,140	0.00	0.01	0.85
5.C.2	Land converted to Grassland	CH_4	2,588	484	0.00	0.01	0.86
5(V)	Forest Land remaining Forest Land \ Biomass Burning \ Wildfires	CH_4	813	2,961	0.00	0.01	0.86
5.A.1	Forest Land remaining Forest Land	CH_4	1,348	3,284	0.00	0.00	0.87
4.E	Prescribed Burning of Savannas	N_2O	1,450	3,261	0.00	0.00	0.87
2.B	Chemical Industry	CO_2	603	2,148	0.00	0.00	0.88
2.B	Chemical Industry	N_2O	1,035	2,504	0.00	0.00	0.88
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	1,513	0.00	0.00	0.89
1.B.2.c.2.2	Gas	CO_2	3,601	2,376	0.00	0.00	0.89
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,319	0.00	0.00	0.89
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,730	0.00	0.00	0.90
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	2,844	0.00	0.00	0.90
5.G	Agricultural Liming	CO_2	170	1,419	0.00	0.00	0.90
1.A.4.b	Residential \ Biomass	CH_4	2,018	843	0.00	0.00	0.90
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,565	0.00	0.00	0.91
2.E.1.1	Production of HCFC-22	HFC-23	1,126	0	0.00	0.00	0.91
2.C.3	Aluminium Production	CO_2	2,021	3,194	0.00	0.00	0.91
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	1,369	359	0.00	0.00	0.92
5.G	Other (Harvested Wood Products)	CO_2	5,048	4,169	0.00	0.00	0.92
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	2,776	0.00	0.00	0.92

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
6.B.1	Industrial Wastewater \ Wastewater	CH_4	1,926	974	0.00	0.00	0.92
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,056	0.00	0.00	0.93
1.A.3.d	Navigation \ Liquid Fuels \ Gas/Diesel Oil	CO_2	174	1,085	0.00	0.00	0.93
1.B.2.c.2.2	Gas	CH_4	944	88	0.00	0.00	0.93
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,220	0.00	0.00	0.93
1.A.4.a	Commercial/ Institutional \ Gaseous Fuels	CO_2	1,811	2,691	0.00	0.00	0.94
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	690	1,476	0.00	0.00	0.94
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	1,676	0.00	0.00	0.94
4.B.13	Manure Management \ Solid storage and dry lot	N_2O	202	933	0.00	0.00	0.94
1.B.2.b.1	Exploration	CH_4	105	808	0.00	0.00	0.94
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,087	0.00	0.00	0.95
1.B.2.c.2.1	Oil	CO_2	0	635	0.00	0.00	0.95
1.A.2.c	Chemicals \ Solid Fuels	CO_2	861	266	0.00	0.00	0.95
2.C.3	Aluminium Production	C_2F_6	613	34	0.00	0.00	0.95

Table A.1.3: Key categories for Australia's 2012 inventory—summary including LULUCF

A		B	C	D
IPCC Source Categories		Direct Greenhouse Gas	Key Source Category Flag	If Column C is Yes, Criteria for Identification
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, Trend
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	YES	Level, Trend
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 \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	YES	Level, Trend
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	YES	Level
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 \ Liquid Fuels	CO_2	YES	Level
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	YES	Level
1.A.2.c	Chemicals \ Solid Fuels	CO_2	YES	Trend
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	YES	Level
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	YES	Level
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	YES	Level
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	YES	Level, Trend
1.A.3.c	Railways \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.d	Navigation \ Liquid Fuels \ Gas/Diesel Oil	CO_2	YES	Level, Trend
1.A.3.d	Navigation \ Liquid Fuels \ Gasoline	CO_2	YES	Level
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	YES	Trend
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	YES	Level, Trend
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	YES	Level
1.A.4.b	Residential \ Gaseous Fuels	CO_2	YES	Level, Trend
1.A.4.b	Residential \ Biomass	CH_4	YES	Trend
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	YES	Level, Trend
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	YES	Level, Trend
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	YES	Level, Trend
1.B.2.b.1	Exploration	CH_4	YES	Trend

A		B	C	D
IPCC Source Categories		Direct Greenhouse Gas	Key Source Category Flag	If Column C is Yes, Criteria for Identification
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	YES	Level
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	YES	Level, Trend
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	YES	Level, Trend
1.B.2.c.2.1	Oil	CO_2	YES	Trend
1.B.2.c.2.2	Gas	CO_2	YES	Level, Trend
1.B.2.c.2.2	Gas	CH_4	YES	Trend
2.A.1	Cement Production	CO_2	YES	Level
2.A.3	Limestone and Dolomite Use	CO_2	YES	Level
2.B	Chemical Industry	CO_2	YES	Level, Trend
2.B	Chemical Industry	N_2O	YES	Level, Trend
2.C.1.4	Iron and Steel\Coke	CO_2	YES	Level, Trend
2.C.3	Aluminium Production	CO_2	YES	Level, Trend
2.C.3	Aluminium Production	CH_4	YES	Trend
2.C.3	Aluminium Production	C_2F_6	YES	Trend
2.E.1.1	Production of HCFC-22	HFC-23	YES	Trend
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	YES	Level, Trend
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	YES	Level, Trend
4.A.1	Enteric Fermentation \ Cattle	CH_4	YES	Level, Trend
4.A.3	Enteric Fermentation \ Sheep	CH_4	YES	Level, Trend
4.B.13	Manure Management \ Solid storage and dry lot	N_2O	YES	Trend
4.B.8	Manure Management \ Swine	CH_4	YES	Level
4.D.1.1	Synthetic Fertilizers	N_2O	YES	Level, Trend
4.D.1.4	Crop Residue	N_2O	YES	Level
4.D.2	Pasture, Range and Paddock Manure	N_2O	YES	Level, Trend
4.D.3.1	Atmospheric Deposition	N_2O	YES	Level
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	YES	Level
4.E	Prescribed Burning of Savannas	CH_4	YES	Level, Trend
4.E	Prescribed Burning of Savannas	N_2O	YES	Level, Trend
5.A.1	Forest Land remaining Forest Land	CO_2	YES	Level, Trend
5.A.1	Forest Land remaining Forest Land	CH_4	YES	Level, Trend
5.A.2	Land converted to Forest Land	CO_2	YES	Level, Trend
5.B.1	Cropland remaining Cropland	CO_2	YES	Level
5.B.2	Land converted to Cropland	CO_2	YES	Level, Trend
5.C.1	Grassland remaining Grassland	CO_2	YES	Level, Trend
5.C.2	Land converted to Grassland	CO_2	YES	Level, Trend
5.C.2	Land converted to Grassland	CH_4	YES	Trend
5.G	Other (Harvested Wood Products)	CO_2	YES	Level, Trend
5.G	Agricultural Liming	CO_2	YES	Level, Trend
5(V)	Forest Land remaining Forest Land \ Biomass Burning \ Wildfires	CH_4	YES	Level, Trend
6.A.1	Managed Waste Disposal on Land	CH_4	YES	Level, Trend
6.B.1	Industrial Wastewater \ Wastewater	CH_4	YES	Trend

Table A.1.4: Key categories for Australia's 2012 inventory-level assessment excluding LULUCF

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	168,912	0.31	0.31
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	74,850	0.14	0.45
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	45,423	0.08	0.53
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	21,074	0.04	0.57
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,565	0.03	0.60
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	14,675	0.03	0.63
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	10,529	0.02	0.65
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	8,981	0.02	0.66
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	2,815	8,567	0.02	0.68
4.E	Prescribed Burning of Savannas	CH_4	4,909	8,454	0.02	0.69
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	7,863	0.01	0.71
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	7,714	0.01	0.72
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	7,368	0.01	0.74
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	958	7,011	0.01	0.75
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	6,577	0.01	0.76
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,372	6,140	0.01	0.77
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	5,888	0.01	0.78
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,220	0.01	0.80
1.A.2.b	Non-Ferrous Metals \ Solid Fuels	CO_2	4,049	4,088	0.01	0.81
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	0	4,037	0.01	0.81
1.A.2.c	Chemicals \ Liquid Fuels	CO_2	3,263	3,904	0.01	0.81
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,730	0.01	0.82
4.D.3.1	Atmospheric Deposition	N_2O	3,150	3,642	0.01	0.83
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,620	0.01	0.83
2.A.1	Cement Production	CO_2	3,463	3,518	0.01	0.84
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,319	0.01	0.85
4.E	Prescribed Burning of Savannas	N_2O	1,450	3,261	0.01	0.85
2.C.3	Aluminium Production	CO_2	2,021	3,194	0.01	0.86
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	0	3,041	0.01	0.86
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	2,844	0.01	0.87
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,950	2,819	0.01	0.87
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	2,776	0.01	0.88

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	1,811	2,691	0.00	0.88
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,489	2,534	0.00	0.89
2.B	Chemical Industry	N_2O	1,035	2,504	0.00	0.89
1.B.2.c.2.2	Gas	CO_2	3,601	2,376	0.00	0.90
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,822	2,324	0.00	0.90
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,168	2,192	0.00	0.91
2.B	Chemical Industry	CO_2	603	2,148	0.00	0.91
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,056	0.00	0.91
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	1,233	1,847	0.00	0.92
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,765	0.00	0.92
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	1,676	0.00	0.92
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	1,513	0.00	0.93
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	1,441	1,480	0.00	0.93
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	690	1,476	0.00	0.93
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,246	1,468	0.00	0.93
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	1,383	1,437	0.00	0.94
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CO_2	1,122	1,253	0.00	0.94
4.D.1.4	Crop Residue	N_2O	534	1,123	0.00	0.94
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,087	0.00	0.94
1.A.3.d	Navigation \ Liquid Fuels \ Gas/ Diesel Oil	CO_2	174	1,085	0.00	0.95
1.A.3.d	Navigation \ Liquid Fuels \ Gasoline	CO_2	901	1,047	0.00	0.95
4.B.8	Manure Management \ Swine	CH_4	1,050	1,036	0.00	0.95

Table A.1.5: Key categories for Australia's 2012 inventory—trend assessment excluding LULUCF

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	10,529	0.03	0.12	0.12
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	168,912	0.02	0.08	0.20
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	21,074	0.01	0.06	0.26
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	14,675	0.01	0.05	0.31
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	8,981	0.01	0.05	0.35
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	74,850	0.01	0.04	0.39
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	958	7,011	0.01	0.03	0.43
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	45,423	0.01	0.03	0.46
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	6,577	0.01	0.03	0.49
1.B.1.a.2.1	Fugitives\Coal Mining\ Surface mines	CH_4	2,815	8,567	0.01	0.03	0.51
2.C.3	Aluminium Production	CF_4	3,337	220	0.01	0.02	0.56
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	0	4,037	0.01	0.02	0.56
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	7,368	0.01	0.02	0.58
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	5,888	0.01	0.02	0.60
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	0	3,041	0.00	0.02	0.62
1.B.1.a.1.1	Fugitives/Coal Mining/ Underground	CH_4	13,948	15,565	0.00	0.02	0.64
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,730	0.00	0.01	0.65
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	7,863	0.00	0.01	0.67
1.B.2.c.2.2	Gas	CO_2	3,601	2,376	0.00	0.01	0.68
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,220	0.00	0.01	0.69

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	1,513	0.00	0.01	0.70
4.E	Prescribed Burning of Savannas	CH_4	4,909	8,454	0.00	0.01	0.71
1.A.4.b	Residential \ Biomass	CH_4	2,018	843	0.00	0.01	0.72
1.B.2.b.4	Fugitives\Natural Gas\ Distribution	CH_4	4,093	3,620	0.00	0.01	0.73
1.A.4.c	Agriculture/Forestry/ Fisheries \ Liquid Fuels	CO_2	3,372	6,140	0.00	0.01	0.74
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,056	0.00	0.01	0.75
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	7,714	0.00	0.01	0.76
6.B.1	Industrial Wastewater \ Wastewater	CH_4	1,926	974	0.00	0.01	0.77
2.E.1.1	Production of HCFC-22	HFC-23	1,126	0	0.00	0.01	0.78
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	1,369	359	0.00	0.01	0.79
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	1,676	0.00	0.01	0.80
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,822	2,324	0.00	0.01	0.80
4.E	Prescribed Burning of Savannas	N_2O	1,450	3,261	0.00	0.01	0.81
2.B	Chemical Industry	CO_2	603	2,148	0.00	0.01	0.82
1.A.2.b	Non-Ferrous Metals \ Solid Fuels	CO_2	4,049	4,088	0.00	0.01	0.83
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,087	0.00	0.01	0.83
1.B.2.c.2.2	Gas	CH_4	944	88	0.00	0.01	0.84
2.B	Chemical Industry	N_2O	1,035	2,504	0.00	0.01	0.84
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,950	2,819	0.00	0.01	0.85
2.A.1	Cement Production	CO_2	3,463	3,518	0.00	0.01	0.86
1.A.2.a	Iron and Steel \ Solid Fuels	CO_2	1,196	699	0.00	0.00	0.86
1.A.2.c	Chemicals \ Solid Fuels	CO_2	861	266	0.00	0.00	0.87
1.A.3.d	Navigation \ Liquid Fuels \ Gas/Diesel Oil	CO_2	174	1,085	0.00	0.00	0.87
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	2,844	0.00	0.00	0.88

A		B	C	D	E	F	G
IPCC Source Categories		Gas	Base Year Estimate	Current Year Estimate	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.2.f	Other (please specify) \ Other non-specified \ Gaseous Fuels	CO_2	1,046	552	0.00	0.00	0.88
1.A.2.f	Other (please specify) \ Mining \ Solid Fuels	CO_2	658	85	0.00	0.00	0.88
2.C.3	Aluminium Production	C_2F_6	613	34	0.00	0.00	0.89
1.A.4.b	Residential \ Liquid Fuels	CO_2	1,306	967	0.00	0.00	0.89
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,319	0.00	0.00	0.90
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,489	2,534	0.00	0.00	0.90
1.B.2.b.1	Exploration	CH_4	105	808	0.00	0.00	0.91
4.B.13	Manure Management \ Solid storage and dry lot	N_2O	202	933	0.00	0.00	0.91
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,168	2,192	0.00	0.00	0.91
1.A.4.a	Commercial/ Institutional \ Solid Fuels	CO_2	512	36	0.00	0.00	0.92
1.B.2.c.2.1	Oil	CO_2	0	635	0.00	0.00	0.92
1.A.2.e	Food Processing, Beverages and Tobacco \ Solid Fuels	CO_2	1,190	945	0.00	0.00	0.92
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	690	1,476	0.00	0.00	0.93
2.C.3	Aluminium Production	CO_2	2,021	3,194	0.00	0.00	0.93
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	2,776	0.00	0.00	0.93
4.D.3.1	Atmospheric Deposition	N_2O	3,150	3,642	0.00	0.00	0.93
2.B	Chemical Industry	CO_2	407	994	0.00	0.00	0.94
4.D.1.4	Crop Residue	N_2O	534	1,123	0.00	0.00	0.94
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-143a	0	415	0.00	0.00	0.94
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	1,441	1,480	0.00	0.00	0.94
6.B.2.1	Domestic and Commercial (w/o human sewage) \ Sludge	CH_4	871	749	0.00	0.00	0.95
1.A.3.b	Road Transportation \ Liquid Fuels	CH_4	467	222	0.00	0.00	0.95

Table A.1.6: Key categories for Australia's 2012 inventory—summary excluding LULUCF

A		B	C	D
IPCC Source Categories		Gas	Key Source Category Flag	If Colum C is Yes, Criteria for Identification
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, Trend
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	YES	Level, Trend
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 \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	YES	Level, Trend
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	YES	Level
1.A.2.a	Iron and Steel \ 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, Trend
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.2.c	Chemicals \ Liquid Fuels	CO_2	YES	Level
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	YES	Level, Trend
1.A.2.c	Chemicals \ Solid Fuels	CO_2	YES	Trend
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	YES	Level
1.A.2.e	Food Processing, Beverages and Tobacco \ Solid Fuels	CO_2	YES	Trend
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify) \ Other non-specified \ Gaseous Fuels	CO_2	YES	Trend
1.A.2.f	Other (please specify) \ Mining \ Solid Fuels	CO_2	YES	Trend
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.b	Road Transportation \ Liquid Fuels	CH_4	YES	Trend
1.A.3.b	Road Transportation \ Liquid Fuels	N_2O	YES	Level, Trend
1.A.3.c	Railways \ Liquid Fuels	CO_2	YES	Level, Trend
1.A.3.d	Navigation \ Liquid Fuels \ Gas/Diesel Oil	CO_2	YES	Level, Trend

A		B	C	D
IPCC Source Categories		Gas	Key Source Category Flag	If Colum C is Yes, Criteria for Identification
1.A.3.d	Navigation \ Liquid Fuels \ Gasoline	CO_2	YES	Level
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	YES	Trend
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	YES	Level
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	YES	Level
1.A.4.a	Commercial/Institutional \ Solid Fuels	CO_2	YES	Trend
1.A.4.b	Residential \ Gaseous Fuels	CO_2	YES	Level, Trend
1.A.4.b	Residential \ Biomass	CH_4	YES	Trend
1.A.4.b	Residential \ Liquid Fuels	CO_2	YES	Trend
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	YES	Level, Trend
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	YES	Level, Trend
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CO_2	YES	Level
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	YES	Level, Trend
1.B.2.b.1	Exploration	CH_4	YES	Trend
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	YES	Level, Trend
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	YES	Level, Trend
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	YES	Level, Trend
1.B.2.c.2.1	Oil	CO_2	YES	Trend
1.B.2.c.2.2	Gas	CO_2	YES	Level, Trend
1.B.2.c.2.2	Gas	CH_4	YES	Level, Trend
2.A.1	Cement Production	CO_2	YES	Level, Trend
2.A.3	Limestone and Dolomite Use	CO_2	YES	Level
2.B	Chemical Industry	CO_2	YES	Level, Trend
2.B	Chemical Industry	N_2O	YES	Level, Trend
2.B	Chemical Industry	CO_2	YES	Trend
2.C.1.4	Iron and Steel\Coke	CO_2	YES	Level, Trend
2.C.3	Aluminium Production	CO_2	YES	Level, Trend
2.C.3	Aluminium Production	CF_4	YES	Trend
2.C.3	Aluminium Production	C_2F_6	YES	Trend
2.E.1.1	Production of HCFC-22	HFC-23	YES	Trend
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	YES	Level, Trend
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	YES	Level, Trend
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-143a	YES	Trend
4.A.1	Enteric Fermentation \ Cattle	CH_4	YES	Level, Trend
4.A.3	Enteric Fermentation \ Sheep	CH_4	YES	Level, Trend
4.B.13	Manure Management \ Solid storage and dry lot	N_2O	YES	Trend
4.B.8	Manure Management \ Swine	CH_4	YES	Level, Trend
4.D.1.1	Synthetic Fertilizers	N_2O	YES	Level, Trend

A		B	C	D
IPCC Source Categories		Gas	Key Source Category Flag	If Colum C is Yes, Criteria for Identification
4.D.1.4	Crop Residue	N_2O	YES	Level, Trend
4.D.2	Pasture, Range and Paddock Manure	N_2O	YES	Level, Trend
4.D.3.1	Atmospheric Deposition	N_2O	YES	Level, Trend
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	YES	Level, Trend
4.E	Prescribed Burning of Savannas	CH_4	YES	Level, Trend
4.E	Prescribed Burning of Savannas	CH_4	YES	Level, Trend
6.A.1	Managed Waste Disposal on Land	N_2O	YES	Level, Trend
6.B.1	Industrial Wastewater \ Wastewater	CH_4	YES	Trend
6.B.2.1	Domestic and Commercial (w/o human sewage) \ Sludge	CH_4	YES	Trend

Table A.1.7: Summary overview for key categories for Land use, Land-use Change and Forestry activities under the Kyoto Protocol – 2012

Criteria used for Key Category Identification					
Key Categories of Emissions and Removals	**Gas**	**Associated category in UNFCCC inventory is key**	**Category contribution is greater than the smallest category considered key in the UNFCCC inventory (including LULUCF)**	**Other**	**Comments**
Afforestation/ Reforestation	CO_2	Land converted to forest	YES	NA	UNFCCC category is key, category is greater than smallest UNFCCC key category.
Deforestation	CO_2	Land converted to cropland Land converted grassland	YES	NA	UNFCCC category is key, category is greater than smallest UNFCCC key category.
Deforestation	CH_4	Land converted to cropland	NO	NA	UNFCCC category is key.

Table A.1.8: Key categories for Australia's 1990 inventory-level assessment including LULUCF

A		B	C	D	E
IPCC Source Category		**Gas**	**Base Year Estimate**	**Level Assessment**	**Cumulative Total**
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	117,909	0.18
5.C.2	Land converted to Grassland	CO_2	111,027	111,027	0.35
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	51,840	0.43
5.A.1	Forest Land remaining Forest Land	CO_2	45,447	45,447	0.50
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	39,017	0.56
5.C.1	Grassland remaining Grassland	CO_2	35,779	35,779	0.61
5.B.2	Land converted to Cropland	CO_2	32,735	32,735	0.66
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	24,595	0.70
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	13,948	0.72
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	13,188	0.74
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	9,018	0.76
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	8,239	0.77
5.G	Other (Harvested Wood Products)	CO_2	5,048	5,048	0.78
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,931	0.78
4.E	Prescribed Burning of Savannas	CH_4	4,909	4,909	0.79
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	4,881	0.80
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	4,613	0.81
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	4,593	0.81
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	4,140	0.82
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	4,093	0.83
1.A.2.b	Non-Ferrous Metals \ Solid Fuels	CO_2	4,049	4,049	0.83
1.B.2.c.2.2	Gas	CO_2	3,601	3,601	0.84

A		B	C	D	E
IPCC Source Category		Gas	Base Year Estimate	Level Assessment	Cumulative Total
2.A.1	Cement Production	CO_2	3,463	3,463	0.84
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,372	3,372	0.85
2.C.3	Aluminium Production	CF_4	3,337	3,337	0.85
1.A.2.c	Chemicals \ Liquid Fuels	CO_2	3,263	3,263	0.86
4.D.3.1	Atmospheric Deposition	N_2O	3,150	3,150	0.86
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,950	2,950	0.87
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,878	0.87
5.B.1	Cropland remaining Cropland	CO_2	2,864	2,864	0.88
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,822	2,822	0.88
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	2,815	2,815	0.88
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	2,809	0.89
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	2,588	0.89
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,489	2,489	0.90
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	2,353	0.90
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,168	2,168	0.90
2.C.3	Aluminium Production	CO_2	2,021	2,021	0.91
1.A.4.b	Residential \ Biomass	CH_4	2,018	2,018	0.91
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	1,966	0.91
6.B.1	Industrial Wastewater \ Wastewater	CH_4	1,926	1,926	0.92
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	1,811	1,811	0.92
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	1,741	0.92
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,734	0.92
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	1,717	0.93
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	1,529	0.93
4.E	Prescribed Burning of Savannas	N_2O	1,450	1,450	0.93
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	1,441	1,441	0.93
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	1,383	1,383	0.94
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	1,369	1,369	0.94
5.A.1	Forest Land remaining Forest Land	CH_4	1,348	1,348	0.94
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,345	0.94
1.A.4.b	Residential \ Liquid Fuels	CO_2	1,306	1,306	0.94
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,246	1,246	0.95
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	1,233	1,233	0.95
1.A.2.a	Iron and Steel \ Solid Fuels	CO_2	1,196	1,196	0.95

Table A.1.9: Key categories for Australia's 1990 inventory-level assessment excluding LULUCF

A		B	C	D	E
IPCC Source Category		Gas	Base Year Estimate	Level Assessment	Cumulative Total
1.A.1.a	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	117,909	0.28
1.A.3.b	Road Transportation \ Liquid Fuels	CO_2	51,840	51,840	0.41
4.A.1	Enteric Fermentation \ Cattle	CH_4	39,017	39,017	0.50
4.A.3	Enteric Fermentation \ Sheep	CH_4	24,595	24,595	0.56
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	13,948	0.60
6.A.1	Managed Waste Disposal on Land	CH_4	13,188	13,188	0.63
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	9,018	0.65
1.A.1.a	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,239	8,239	0.67
1.A.1.b	Petroleum Refining \ Liquid Fuels	CO_2	4,931	4,931	0.68
4.E	Prescribed Burning of Savannas	CH_4	4,909	4,909	0.69
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	4,881	0.70
1.A.4.b	Residential \ Gaseous Fuels	CO_2	4,613	4,613	0.72
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,593	4,593	0.73
1.A.2.b	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,140	4,140	0.74
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	4,093	0.75
1.A.2.b	Non-Ferrous Metals \ Solid Fuels	CO_2	4,049	4,049	0.76
1.B.2.c.2.2	Gas	CO_2	3,601	3,601	0.77
2.A.1	Cement Production	CO_2	3,463	3,463	0.77
1.A.4.c	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,372	3,372	0.78
2.C.3	Aluminium Production	CF_4	3,337	3,337	0.79
1.A.2.c	Chemicals \ Liquid Fuels	CO_2	3,263	3,263	0.80
4.D.3.1	Atmospheric Deposition	N_2O	3,150	3,150	0.81
1.A.2.f	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,950	2,950	0.81
1.A.1.a	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,878	2,878	0.82
1.A.2.b	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,822	2,822	0.83
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	2,815	2,815	0.83
1.A.2.f	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,809	2,809	0.84
1.A.3.a	Civil Aviation \ Liquid Fuels	CO_2	2,588	2,588	0.85
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,489	2,489	0.85
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,353	2,353	0.86
1.A.2.f	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,168	2,168	0.86
2.C.3	Aluminium Production	CO_2	2,021	2,021	0.87
1.A.4.b	Residential \ Biomass	CH_4	2,018	2,018	0.87

A		B	C	D	E
IPCC Source Category		Gas	Base Year Estimate	Level Assessment	Cumulative Total
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	1,966	0.88
6.B.1	Industrial Wastewater \ Wastewater	CH_4	1,926	1,926	0.88
1.A.4.a	Commercial/Institutional \ Gaseous Fuels	CO_2	1,811	1,811	0.89
1.A.2.f	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,741	1,741	0.89
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	1,734	0.89
1.A.3.c	Railways \ Liquid Fuels	CO_2	1,717	1,717	0.90
4.D.1.1	Synthetic Fertilizers	N_2O	1,529	1,529	0.90
4.E	Prescribed Burning of Savannas	N_2O	1,450	1,450	0.91
1.A.2.c	Chemicals \ Gaseous Fuels	CO_2	1,441	1,441	0.91
1.A.2.a	Iron and Steel \ Gaseous Fuels	CO_2	1,383	1,383	0.91
1.A.3.d	Navigation \ Liquid Fuels \ Residual Oil	CO_2	1,369	1,369	0.92
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,345	0.92
1.A.4.b	Residential \ Liquid Fuels	CO_2	1,306	1,306	0.92
1.A.2.e	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,246	1,246	0.93
1.A.4.a	Commercial/Institutional \ Liquid Fuels	CO_2	1,233	1,233	0.93
1.A.2.a	Iron and Steel \ Solid Fuels	CO_2	1,196	1,196	0.93
1.A.2.e	Food Processing, Beverages and Tobacco \ Solid Fuels	CO_2	1,190	1,190	0.93
2.E.1.1	Production of HCFC-22	HFC-23	1,126	1,126	0.94
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CO_2	1,122	1,122	0.94
4.B.8	Manure Management \ Swine	CH_4	1,050	1,050	0.94
1.A.2.f	Other (please specify) \ Other non-specified \ Gaseous Fuels	CO_2	1,046	1,046	0.94
2.B	Chemical Industry	N_2O	1,035	1,035	0.95
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	958	958	0.95

ANNEX 2: Methodology and Data for Estimating Carbon Dioxide Emissions from Fossil Fuel Combustion

The Australian methodology and data descriptions for the estimation of this inventory have been documented in Chapter 3.

ANNEX 3: Other Detailed Methodological Descriptions

The Australian methodology for the estimation of this inventory is documented in the relevant chapters.

ANNEX 4: Carbon Dioxide Reference Approach for the Energy Sector

Estimation of CO_2 Using the IPCC Reference Approach

The reference approach estimates CO_2 emissions from *fuel combustion activities* (covering both *stationary energy* and *transport*). It is calculated using a top-down approach based on national energy statistics for production, imports, exports and stock change. Data are obtained from BREE Australian national resource and energy statistics, supplemented by specific sectoral data where available. The Australian Petroleum Statistics are used as a basis for the liquid fossil fuel data.

Comparison of Australian Methodology with IPCC Reference Approach

Total CO_2 emissions estimated using Australia's National approach methodology are 369.2 Mt. Total CO_2 emissions estimated using the reference approach are 368.3 Mt - this is a 0.27% difference between the two methods.

ANNEX 5: Assessment of Completeness

The UNFCCC guidelines require inventory compilers to assess inventories for the level of completeness of national inventories. The sources of greenhouse gas emissions are many and diverse and, in general, are not directly observable without considerable cost. Many emission sources are minor and resource intensive to estimate. Consequently, all national inventories have minor omissions which, for transparency, need to be identified. This section addresses the completeness of key activity datasets, such as the consumption of fossil fuels, and the completeness of the coverage of emissions and removals sources for the Australian inventory.

Completeness of Activity Data

The emission estimates were reviewed for internal consistency and completeness through the application of mass balance approaches to ensure the reconciliation of carbon supplies and carbon uses within the economy for fossil fuels, carbonates and biomass entering the economy. Details have been provided in the respective sectoral chapters. An overview of the mitigation strategies and control measures adopted, monitoring mechanisms employed and quality objectives or targets results specified is provided in Annex 6.

Omitted Emission Sources

The UNFCCC reporting guidelines provide standard reporting templates that are designed to accommodate the circumstances of as many countries as possible. The reporting templates are not always closely aligned with Australia's circumstances. Consequently, in Australia's reporting tables there are a number of categories where the term "not occurring" has been reported for certain cells because of an absence of a certain economic activity. An example is *adipic acid* production, which does not occur in Australia.

Nonetheless, there are a small number of emission sources which are believed to be minor and which are reported as 'not estimated' either because of a lack of data or because the emission processes are not well enough understood to permit the development of reliable methodologies. In these instances, default methodologies are not specified by the IPCC due to limited understanding internationally of these processes. One example is CO_2 from Burning of Coal Deposits and Waste Piles (1B1). The spontaneous combustion of waste piles is a known source of CO_2 emissions. Research undertaken on the measurement of this emission source has not yet been able to develop any reliable approach to the estimation of this emission source. Similarly, neither the *1996 IPCC Guidelines* nor the *2006 IPCC Guidelines* include a default methodology that could be applied in the absence of information on this source.

ANNEX 6: Additional Information: Quality Controls including Australia's National Carbon Balance

A6.1 Additional information on the QA/QC Plan

The management of the QA/QC activities relating to the inventory are undertaken by the National Inventory Team within DE and detailed in the *National Greenhouse Accounts: Quality Assurance-Quality Control Plan.* An overview of the quality control system is provided in Chapter 1 while sector-specific information on quality control activities has been included in the QA/QC sections of each chapter. This Annex provides additional information and, in particular, provides information in relation to three aspects of the quality control system: i) a detailed description of the quality control measures in place; ii) results of the carbon balance for the economy; and iii) a description of Australia's responses to the recommendations contained in the previous UNFCCC ERT report.

The objectives of the national inventory quality system are to support the provision of emission estimates that meet the UNFCCC criteria of accuracy; time series consistency; transparency, completeness and comparability of estimates with those of other parties.

Key risks to the attainment of the defined quality objectives are identified at each level of inventory preparation including the measurement of data at the facility level; the collation of activity and other input data by DE and other agencies; and the process of emissions estimation.

Specified mitigation strategies, measures and routine actions are deployed to control the identified risks.

These strategies range from utilisation of data measurements governed by existing national measurement systems such as the National Measurement Act or various taxation acts to the use of automated quality control tools embedded in the Australian Greenhouse Emissions Information System (AGEIS). Principal mitigation strategies and control measures are set out in Table A6.1.

Monitoring of the quality measures and evaluation of the results are critical to the goal of maintaining the system's effectiveness. In particular, control measures include the use of mass balance checks for all years to assess completeness and accuracy. All carbon entering the market economy is accounted for—either as emissions or stored in products or stored in wastes. Carbon balances for fuels, biomass, carbonates and synthetic gases consumption have been constructed and the results presented as Australia's National Carbon Balance in Table A6.2.

In response to a recommendation by the previous UNFCCC ERT reports, models have been developed to demonstrate the flows of fugitive methane and carbon dioxide associated with underground and surface coal mines. The underground coal mine model shown in Figure 6.A.2 also demonstrates the effectiveness of methane capture for electricity generation or flaring in reducing the net fugitive emissions – capturing 25% of the gross methane generated from underground coal mining.

External review of the inventory is a critical part of the process of ensuring the quality of the estimates. In principle, the Australian inventory is subject to audit by the Australian National Audit Office (ANAO), and a performance audit was conducted by the ANAO in 2009-10. In addition, each year the inventory is reviewed by international experts organised as part of the UNFCCC expert review team process. In Tables 6.A.3a to 6.A.3e, the recommendations of previous UNFCCC ERT reports have been included for increased transparency and a summary of Australia's responses included. These tables provide a tool for tracking the management of the ERT recommendations and suggestions. At the time of publication of this report, the UNFCCC report on the centralised review of Australia's 2011 inventory submission had not yet been finalised.

Table A.6.1: Summary of principal mitigation strategies and quality control measures

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006 IPCC Guidelines Vol 1 cross reference
Measurement					
1.A.1	Accuracy, completeness and time series consistency	National emissions reporting system subject to national measurement system and Australian regulations and international standards as specified in the NGER Measurement Determination 2008	Compliance	DE	6.7.2.2, page 6.16
1.A.2	Accuracy	Data submitted under NGER subject to Clean Energy Regulator validation unit activities	Compliance	DE	6.7.2.2, page 6.16
1.B.1	Comparability	Integration of national and facility estimation methods within National Greenhouse Accounts Framework	Compliance	DE	6.7.1.2 page 6.12
1.D.1	Transparency	Company level data published by the Clean Energy Regulator under the NGER Act 2007	Compliance	DE	6.5, page 6.8
Collated data used for national emissions estimation					
2.A.1	Accuracy	Comparison of energy data with independent sources of activity data	<2%	AGEIS Automated Report	6.7.2.1, page 6.15
2.A.2	Accuracy	External consultants operate QC protocol	Compliance	National Inventory Team	6.4, page 6.16
2.A.3	Accuracy	Quality control systems for external data providers	Compliance	Agency governance boards	6.4, page 6.16
2.B.1	Completeness	Application of standardised rules for use of facility level data in national inventory	Compliance	National Inventory Team	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
2.B.2 (i)	Completeness	Reconciliation of estimates of carbon in fuel supplies to the Australian economy and carbon contained in emissions; or stored in products; or non-oxidised; or in permanent storage	<1%	National Inventory Team	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
2.B.2 (ii)	Completeness	Reconciliation of estimates of carbon in carbonate supplies to the Australian economy and carbon contained in emissions; or stored in products; or waste residues or in permanent storage	<0.1%	AGEIS Automated Report	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
2.B.2 (iii)	Completeness	Reconciliation of estimates of carbon in biomass supplies to the Australian economy and carbon contained in emissions or stored in products or waste residues or in permanent storage	<1%	AGEIS Automated Report	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006 IPCC Guidelines Vol 1 cross reference
2.B.2 (iv)	Completeness	Reconciliation of estimates of carbon in wastewater to the Australian economy and carbon contained in emissions or stored in products or waste residues or in permanent storage	<1%	AGEIS Automated Report	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
2.B.2 (v)	Completeness	Reconciliation of estimates of nitrogen in wastewater to the Australian economy and nitrogen contained in emissions or stored in products or other by-products	<1%	AGEIS Automated Report *	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
2.B.2 (vi)	Completeness	Reconciliation of estimates of carbon in synthetic gases supplied to the Australian economy and synthetic gases contained in emissions or stored in products or destroyed	<1%	National Inventory Team	Table 6.1, page 6.11; Section 6.7.2.1, page 6.15
National Emissions Estimation					
3.A.1	Accuracy	Emission estimation methodologies should be consistent with IPCC Good Practice and comparable with international practice	Compliance	NGGI Committee	IPCC Good Practice Guidance
3.A.2 (i)	Accuracy	AGEIS development in accordance with COBIT	Compliance	AGEIS Strategic Plan	AGEIS implementation report
3.A.2 (ii)	Accuracy	AGEIS operation in accordance with COBIT	Compliance	AGEIS Strategic Plan	AGEIS implementation report
3.A.2 (iii)	Accuracy	Allocation of separate staff roles and responsibilities	Compliance	AGEIS Strategic Plan	6.4, page 6.7
3.A.3	Accuracy	Validation of selected AGEIS estimates by sectoral experts	<0.01%	National Inventory Team	6.7.3, page 6.16
3.A.4	Accuracy	The estimated uncertainty of the overall inventory should decline over time	Compliance	National Inventory Team	6.9, page 6.18
3.B.1 (i)	Completeness	Reconciliation of fuel data submitted into the AGEIS and carbon contained in emissions or stored in products or non-oxidised or permanent storage	<0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3 page 6.16
3.B.1 (ii)	Completeness	Reconciliation of carbonate data submitted into the AGEIS and carbon contained in emissions or stored in products or waste residues or in permanent storage	<0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3 page 6.16
3.B.1 (iii)	Completeness	Reconciliation of biomass data submitted into the AGEIS and carbon contained in emissions or stored in products or waste residues or in permanent storage	<0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3 page 6.16

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006 IPCC Guidelines Vol 1 cross reference
3.B.1 (iv)	Completeness	Reconciliation of carbon in synthetic gases in data submitted into the AGEIS and carbon contained in emissions or stored in products or destroyed	<0.001%	AGEIS Automated Report *	Table 6.1, page 6.10; 6.7.3 page 6.16
3.B.2 (i)	Completeness	Reconciliation of National Inventory with aggregate of State and Territory inventories	<0.1%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3 page 6.16
3.B.2 (ii)	Completeness	Reconciliation of the National Greenhouse Gas Inventory with the National Inventory by Economic Sector	<0.1%	AGEIS Automated Report	6.7.2.1, page 6.14
3.B.2 (iii)	Completeness	Reconciliation of the National Greenhouse Gas Inventory against OLAP output from the AGEIS database	<0.1%	AGEIS Automated Report	Table 6.1, page 6.10
3.B.3	Completeness	Number of emission sources 'not estimated', for which IPCC methods exist, comparable with international practice	Compliance	DE assessment of UNFCCC ERT report	6.7.2.1, page 6.14
3.B.4	Completeness	Number of significant completeness issues should reduce over time	Compliance	DE assessment of UNFCCC ERT report	6.8, page 6.18
3.C.1	Comparability	Implied emission factors for key variables should not be significantly different to those of other UNFCCC reporting parties	Compliance	AGEIS Automated Report	6.8, page 6.18
3.C.3	Comparability	Recalculation percentages for the national inventory Annex A sectors should not be significantly different to those of other UNFCCC reporting parties over time	Compliance	AGEIS automated report	6.8, page 6.18
3.C.4	Comparability	Implied emission factors for key variables should not be significantly different to those of available plant-specific data	Compliance	AGEIS Automated Report	6.7.1.2, page 6.13
3.D.1	Time series	Analysis by category for time series consistency	Compliance	AGEIS automated report	Table 6.1, page 6.11
3.D.2	Time series	The number of significant time-series consistency issues raised by the UNFCCC ERT, and agreed by the DE, should reduce over time	Compliance	DE assessment of UNFCCC ERT report	Table 6.1, page 6.11
3.E.1	Transparency	Publication of assumptions, methodologies, data sources and emission estimates in the National Inventory Report and related products	Compliance	National Inventory Team	6.5, page 6.8
3.E.2	Transparency	Publication of the AGEIS emissions database on the DE website	Compliance	National Inventory Team	6.5, page 6.

* Planned for AGEIS implementation 2012-13.

A6.2 Australia's National Carbon Balance

Table A.6.2: Australia's National Carbon Balance 2012

Supply	Kt C	Uses	Kt C
Fossil fuel consumption (a)	110,235	Emissions	
Carbonate consumption (a)	2,196	1.A Combustion emissions (fossil fuels)	100,704
Hydrofluorocarbon consumption (d)	3,018	1.B Fugitive emissions	196
		2.A Industrial process fossil fuel emissions	3,641
		Memo: International bunker fuels	3,331
		2.A Mineral product carbonate emissions	2,177
Biomass consumption		2.F Hydrofluorocarbon emissions (d)	2,167
Wood and paper products (a)	3,199	Memo: Combustion emissions (wood products and waste)	605
Bagasse, ethanol, biogas (b)	2,577	Memo: Combustion emissions (bagasse, ethanol, biogas)	2,526
Firewood (b)	1,220	Memo: Combustion emissions (all wood)	1,801
		6.A Landfill emissions (methane and carbon dioxide)	882
Waste disposal (food, garden, textiles, rubber – landfill)(c)	1,221	Aerobic treatment processes (paper, wood and wood waste)	176
		Increment to product stocks	
		Petrochemical and steel products	89
		Carbonate products	3
		Hydrofluorocarbon products (d)	747
		Biomass finished products	1,137
		Biomass fibre recycled	1,481
		Increment to waste stocks and residues	
		Carbon dioxide captured for permanent storage	0
		Non-oxidised carbon	1,741
		Carbonate wastes	37
		Landfill	39
		Miscellaneous	
		Hydrofluorocarbons destroyed	103
		Residual	-17
Total supply	123,565	**Total uses**	123,565

Notes: (a) entering market;
(b) final consumption;
(c) entering waste stream;
(d) based on carbon dioxide equivalents.

Australia's National Carbon Balance records the supply of carbon entering the market economy through the most important channels and tracks the uses or fates of that carbon allocated amongst greenhouse emissions, increments to the stock of carbon in products and increments to the stock of carbon in waste residues. Of the 123,565 kt C of carbon entering the market economy, 118,205 kt C is estimated to result in greenhouse gas emissions; 3,457 kt C is estimated to result in increments of the carbon stock in products and 1,817 kt C is estimated to result in increments to carbon stored in waste product and residues.

Assessments of the total amount of carbon in stock are more difficult to assess and depend critically on starting assumptions. Bearing this in mind, it is estimated that there is approximately 105 Mt of carbon stored in harvested wood products in Australia and about the same amount again stored in landfills. The latter estimate relies on the relatively strong assumption that all landfills have been maintained in order to fulfil anaerobic conditions. If the alternative assumption was adopted, such that it was assumed that all landfills were eventually exposed to aerobic conditions, then the amount of carbon stored in landfills would tend to zero over very long time periods.

The National Carbon Balance is also used as a quality control tool. The Australian inventory utilises a very large number of disaggregated data inputs for energy-related emission calculations (~ 15 000 per year). Consequently, a carbon balance is undertaken to compare carbon input to carbon output for all years. The carbon input represents the carbon embodied within the total quantity of energy and non-energy fuels which have been consumed in a year, and are entered into the AGEIS for calculation. The carbon output represents the distribution of the carbon utilised throughout the economy, as determined by the output of the calculations within the AGEIS. The carbon output is distributed as either emissions from fuel combustion, emissions from the use of fossil fuels as reductants, non-energy uses (e.g. feedstocks, bitumen, coal oils and tar), use of biomass sources of energy and international bunkers. While the predominant outcome of carbon entering the economy is emissions, a small portion of the carbon is stored in carbon-containing products or non-oxidised as ash. A flow chart detailing the results of the carbon balance for 2012 is at Figure A.6.1.

Results from the carbon balance have shown that all carbon is effectively accounted for. For 2012, all carbon has been accounted for down to 0.006%. This discrepancy relates to carbon contained in carbon dioxide from biofuels, within the memo items. Further work will continue on resolving this discrepancy.

Figure A.6.1: Balance flow chart showing carbon inputs and distribution of outputs for 2012

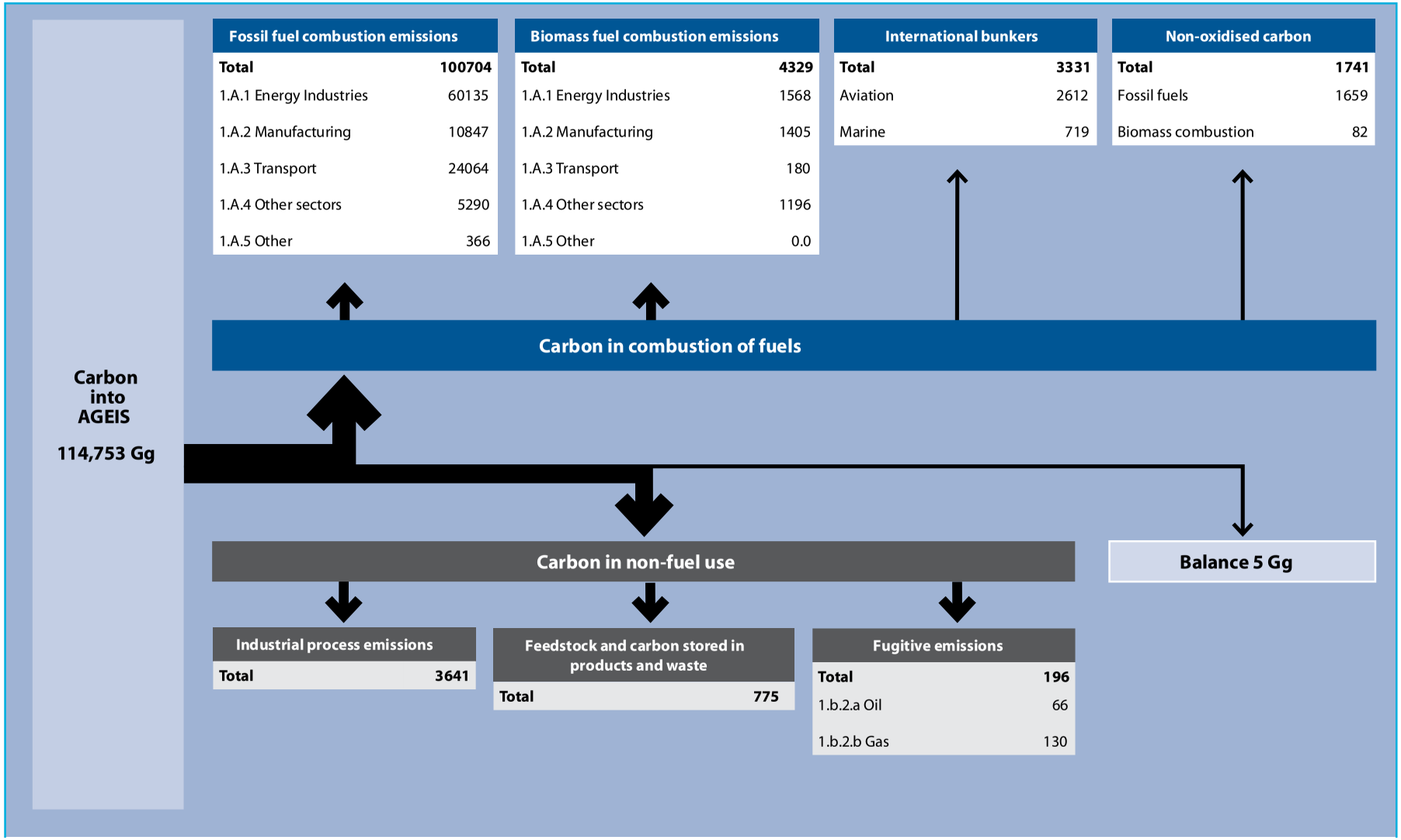


Figure A.6.2 Fugitive gas balance flow chart for underground mines, 2012

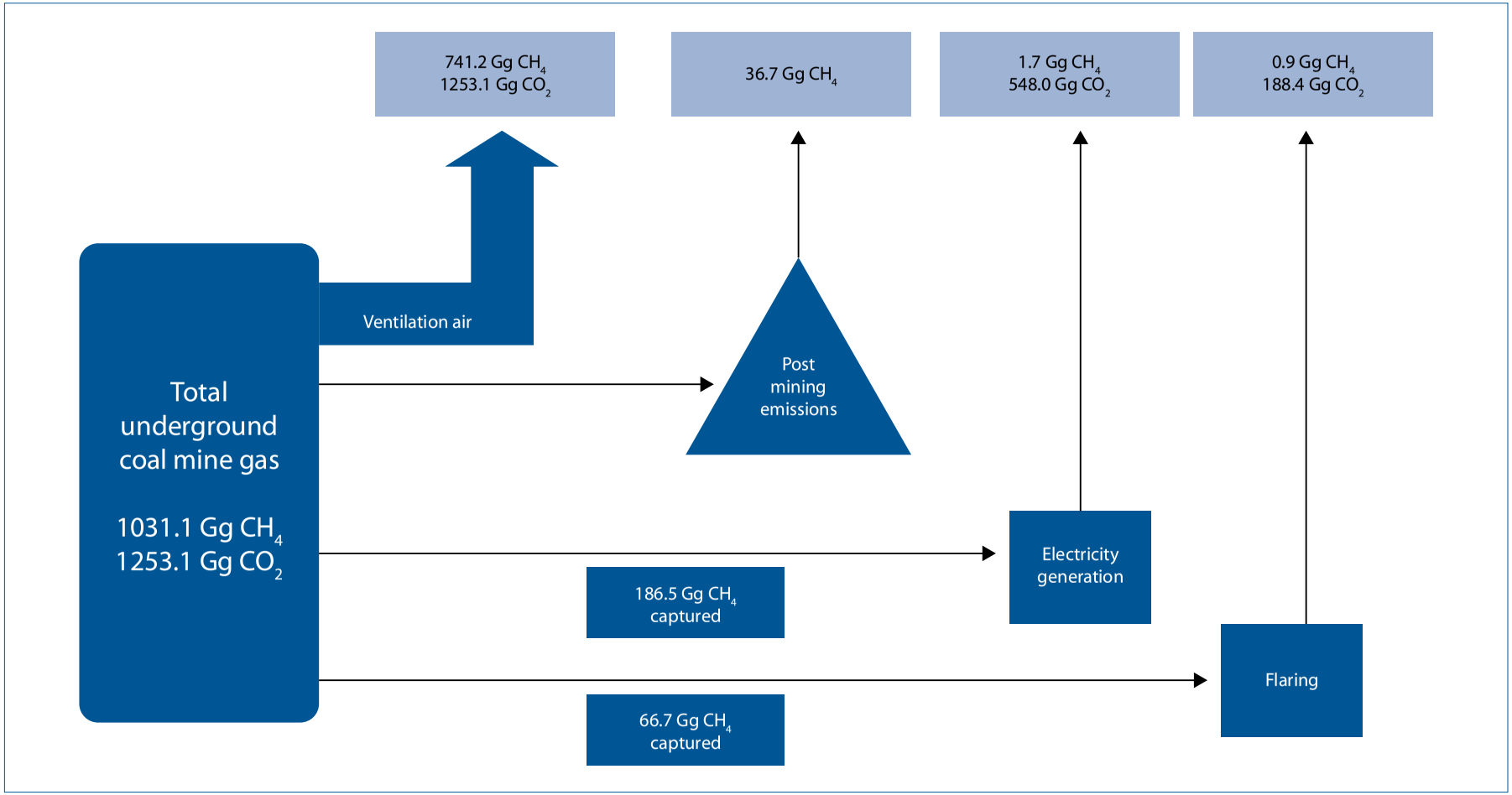


Figure A.6.3: Fugitive gas balance flow chart for open cut mines, 2012

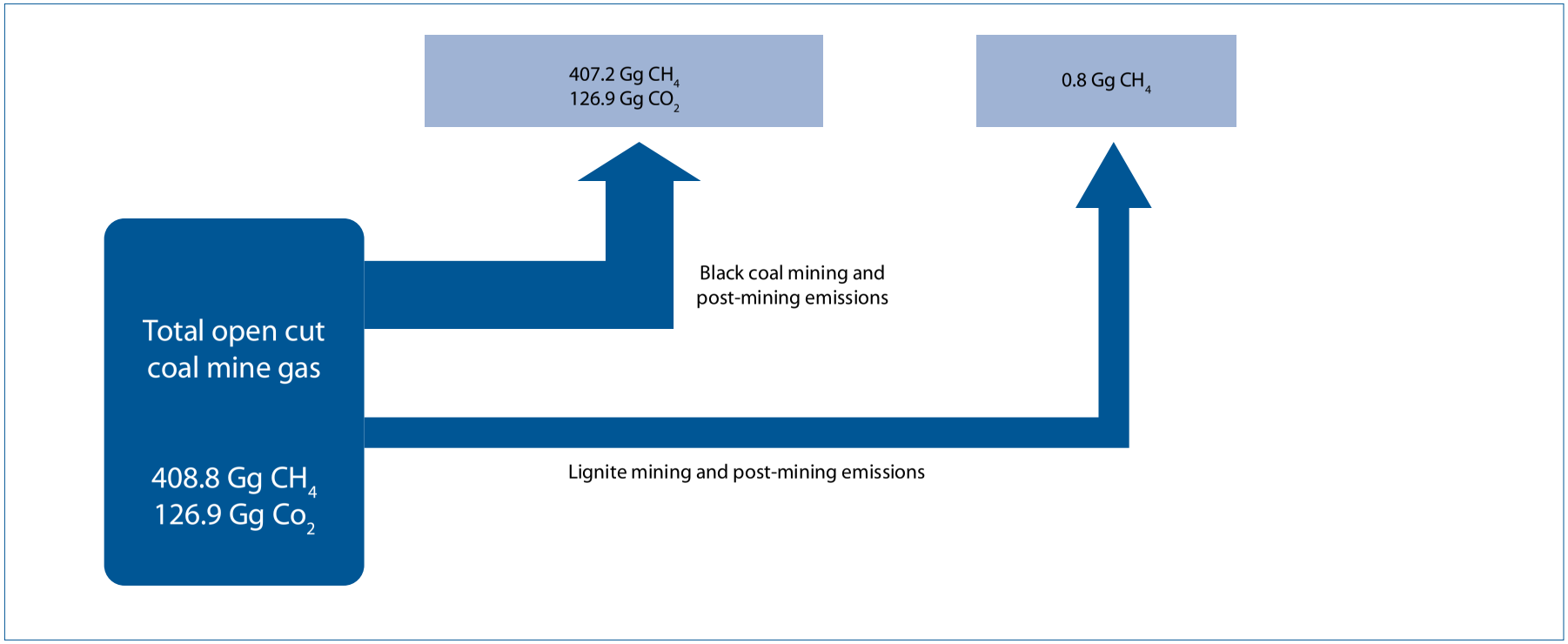


Table A.6.3: Underground mining raw coal production, by coal field

Year	Coal Production by Basin (tonnes of production)							
	HUNTER	NEWCASTLE	WESTERN	SOUTHERN	BOWEN CENTRAL	BOWEN NORTHERN	BOWEN SOUTHERN	QLD SOUTHERN
1990	4,344,800	18,971,900	8,685,300	17,771,200	5,173,984	684,542	591,808	523,410
1991	4,848,129	18,435,910	9,433,269	18,134,150	6,549,461	659,348	635,513	779,744
1992	5,197,075	18,423,863	7,806,943	18,071,525	8,175,110	508,221	548,438	595,156
1993	4,622,113	17,705,992	9,947,807	17,566,298	8,782,642	589,456	632,108	692,298
1994	3,371,283	16,824,755	10,377,687	16,217,123	10,711,371	1,159,564	629,277	618,883
1995	6,364,090	16,061,104	11,613,380	14,663,729	13,172,078	2,564,908	0	687,236
1996	9,192,400	16,804,600	13,002,300	15,314,900	10,992,009	1,612,780	0	597,411
1997	10,813,245	15,346,470	12,697,898	15,784,757	13,756,322	3,846,835	0	558,769
1998	14,144,563	16,783,447	12,010,638	15,360,353	19,158,765	4,543,003	0	0
1999	13,680,481	13,664,985	10,860,591	13,112,341	20,290,940	7,398,073	0	0
2000	15,252,463	15,257,326	10,447,917	11,805,638	25,006,028	13,169,231	0	0
2001	14,589,035	13,751,733	12,775,399	12,602,477	27,105,717	11,214,891	0	0
2002	13,081,548	13,831,303	12,984,571	12,693,281	26,580,624	12,196,246	0	0
2003	12,257,057	10,842,531	12,683,711	11,174,159	23,111,145	11,661,140	0	0
2004	16,582,600	11,412,069	10,924,964	10,434,890	22,058,438	9,618,348	0	0
2005	15,207,383	10,901,574	13,655,101	12,142,786	22,731,234	11,953,481	0	0
2006	15,674,644	10,540,319	12,676,749	13,340,369	22,534,011	11,754,358	0	0
2007	16,875,285	14,023,563	12,929,478	13,412,166	21,268,729	14,351,067	0	0
2008	17,311,462	13,917,235	12,741,554	11,507,490	25,972,448	16,842,856	0	0
2009	19,245,169	14,552,747	16,562,805	12,707,969	24,262,219	16,778,503	0	0
2010	19,580,571	15,211,443	15,026,978	12,985,314	30,182,038	21,775,029	0	0
2011	16,028,421	16,016,035	15,827,685	14,261,975	28,099,846	17,056,976	0	0
2012	11,579,449	16,741,428	15,581,607	16,559,350	24,734,441	10,634,861	0	0

Source: Queensland Department of Energy and Water, Coal Services Pty Ltd

Carbon stock account for Australia's forests 2001–2010

Introduction

This summary of the carbon stock account for Australia's forests is adapted from material to be presented in *Australia's State of the Forests Report*.

Development of the carbon stock account for Australia's forests

The carbon stock accounts for Australia's forest have been derived under national inventory system. These estimates provide information for policy makers and act as a quality control tool which will be used to assess quality of inventory estimates.

Causes of carbon stock changes in forest systems

Major events that cause reductions in national carbon stocks that are monitored and estimated include:

- Harvest from production forests;
- Natural disturbance events such as fires; and
- Forest clearing.

Major events that cause increases in carbon pools include planting events. Major increases in carbon stocks also occur in forest lands that have been subject to past disturbance events such as harvest or fire; regrowth from harvest events may take 100 years for the regrowth trees to approach maturity.

Results of the carbon stocks analysis 2001–05 and 2006–10

The stock of carbon in Australia's forests in 2010 is estimated to be 12,841 Mt C (Table A6.3). It is estimated that the stock of carbon in forests decreased by 81 Mt C (0.6 per cent) between 2001 and 2010. While these figures are indicative, time frames longer than one decade are needed to properly assess trends in carbon stocks in Australia's forests.

The key feature of this decade is the shift from a net loss of carbon in the period 2001–05 (91 Mt C) to a small net gain in the period 2006–10 (10 Mt C; Table A6.3).

Key drivers of the decline in the period 2001–05 were wildfire (a loss of 93 Mt C) and reclassification to non-forest of land that lost its forest cover through clearing together with a change in land use (a loss of 97 Mt C) (Table A6.3). In the period 2001–2005 the millennium drought had taken hold. With fuel loads that had built up over decades and the hot dry conditions due to the drought, wildfire caused a high loss of carbon from Australia's forests; especially in 2003.

Over the period 2006–10, the recovery of forest carbon stocks was driven by a combination of reduced reclassification of forest land to non-forest land, less wildfire losses, and growth in stock associated with recovery of forests following wildfires in the period 2001–05.

Carbon stock gains - Growth in stock

Over the period 2001–10, gross[2] increases in carbon stocks in Australia's forests (due to tree growth and increases in the debris and soil pools) were estimated to be 416 Mt C (Table A6.3). The majority of the gross carbon stock gains (357 Mt, 88 per cent) occurred in Australia's native forests (Table A6.3). Gains in both plantations and native forests were slightly higher in the period 2006–10 compared to 2001–05 (Table A6.3). The increased

[2] Gross increases do not include losses to atmosphere (e.g. fire), transfers out of forest land (e.g. to harvested products), or land reclassification: which are detailed separately in Table A6.3.

growth in carbon stock in native forests was likely due to forests regrowing after fire early in the decade, and the increased growth in carbon stock in plantations was likely due to the growth of young plantations following the peak planting period between 2000 and 2005.

Carbon stock gains - Reclassification to forest

The reclassification of land from grassland to forest appears as a gain in stock in the carbon accounts (Table A6.3); however it does not represent a gain in carbon from the atmosphere. This item represents carbon stocks on the land transferred in to the forest land base. Thus, when a plantation is established on ex-agricultural land or when native forests regenerate naturally, all of the soil and debris carbon on that land is transferred into the forest land classification.

Carbon stock losses - Transfer to product pools

Transfer of carbon to product pools occurred at a relatively stable rate between 2001–05 and 2006–10 (Table A6.3). There was a slight increase (from 34 per cent to 38 per cent) in the proportion of carbon transferred to the product pool that originated from plantations (Table A6.3).

In the period 2001–10, an estimated 50 Mt of firewood was burned for heating, equivalent to the consumption of around 24.5 Mt of carbon.

Carbon stock losses - Managed losses

Managed losses are losses of carbon directly from forests to the atmosphere that are associated with the management of forests, for example prescribed burning or post-harvest burning. Post-harvest burning as part of native forest harvesting operations and for the purpose of fire suppression was estimated to cause the loss of approximately 15 Mt C in 2001–05 and 16 Mt C 2006–10. However, the largest source of carbon stock loss in this category occurs when forests are cleared for agriculture or other development. As part of this process, forest debris is generally burnt, resulting in a direct loss of greenhouse gases to the atmosphere.

No emissions from this source are recorded for plantation forests as part of this analysis. The carbon stock changes associated with post-harvest burning in plantations are included in the modelling of carbon stocks in these forests, and embedded in the overall carbon stock gain data from this source.

Carbon stock losses - Catastrophic losses

Losses of carbon stocks due to wildfire were 93 Mt C in 2001–05, and declined by 40 per cent to 55 Mt C in the period 2006–10. The higher losses of carbon stocks due to wildfire in the period 2001–05 were a key contributor to the net loss of carbon from Australia's forests recorded for that period. The lower carbon stock losses from this source in the period 2006–2010, and the carbon stock increase resulting from regrowth from fires in 2001–05, were key drivers of net increase in carbon stocks in Australia's forests in the period 2006–10.

Relative to the carbon stock losses due to wildfire in native forests, the loss of carbon stocks due to wildfires in plantations is minor (0.01 per cent and 0.03 per cent of total catastrophic losses in 2001–06 and 2006–11, respectively). The low losses from this source are due to the small area of plantations relative to native forest, and may also be due to management of some plantations to limit exposure to the effects of wildfire.

Carbon stock losses - Re-classification to non-forest

Reclassification of forest to non-forest occurs when forest cover is lost (excepting temporary losses in forests which are managed on a harvesting and regrowth cycle, or in forests which degrade and regenerate in response to physiological drivers of growth). This re-classification occurs because forests are cleared for agriculture, urban development or mining.

Over the period 2001–10, re-classification of forest land to non-forest land resulted in a reported decrease of carbon stocks in forest lands of approximately 169 Mt C (Table A6.3).

The decline in human-induced forest clearing in 2001–05 and 2006–10 (Table A6.3) was one of the main reasons why Australia's forest changed from a net source to a net sink of carbon between 2001–05 and 2006–10.

The conversion of plantations to non-forest became an increasing issue towards the end of the decade. It is expected that data will be available on the effect of this activity on carbon stocks in Australia's plantation forests in the near future.

Net exchange with atmosphere and net effect of transfers and re-classification

The net change in Australia's forest carbon stocks was -91 Mt C in 2001–05, and +10 Mt C in 2006–10 (Table A6.3). This net change can be separated into the net exchange with the atmosphere (e.g. through tree growth and fire) and the net transfers in and out of the forest (e.g. through harvesting wood products) (Table A6.3). In the decade to 2010, net exchange with the atmosphere increased from a gain of 51 Mt C during 2001–05 to a gain of 127 Mt C during 2006–10 (Table A6.3). This was primarily due to a reduction in losses associated with fire and an increase in carbon stock gains associated with recovery from fire during 2006–10. Over this same period, there was a decrease in losses associated with carbon stock transfers and the re-classification of land, from 142 Mt C in 2001–05 to 117 Mt C in 2006–11. The key cause of this reduced rate of loss was a decline in losses from re-classification of land to non-forest (forest clearing).

Table A.6.4: Stock of carbon in Australia's living forests, 2001-10

	2001-05 Mt C	2006-10 Mt C	2001-10 Mt C
Opening stock	**12,922**	**12,831**	**12,922**
Gains in stock			
Growth in stock			
Native forests	175	182	357
Plantations	27	32	59
Total	202	214	416
Reclassification to forest [1]			
Native forests	-	-	-
Plantations	8	5	12
Total	8	5	12
Total additions to stock	**209**	**219**	**428**
Losses from stock			
Transfer to product pools [2]			
Native forests	35	31	66
Plantations	18	19	37
Total	53	50	103
Managed losses [3]			
Native forests	58	32	90
Plantations	-	-	-
Total	58	32	90

	2001-05 Mt C	2006-10 Mt C	2001-10 Mt C
Opening stock	**12,922**	**12,831**	**12,922**
Catastrophic losses			
Native forests	93	55	148
Plantations	0	0	0
Total	93	55	148
Reclassification to non-forest 4			
Native forests	97	72	169
Plantations	-	-	-
Total	97	72	169
Total reductions in stock	**300**	**209**	**509**
Closing stock	**12,831**	**12,841**	**12,841**
Net change	-91	10	-81
Net exchange with atmosphere [5]	51	127	178
Net change from re-classification of land to and from forest and transfers to products [6]	-142	-117	-259

1 Gain by sector of carbon in debris and soil associated with transfer of land into sector

2 Transfers to wood and wood products in service

3 Emissions from prescribed burns, post-harvest burns, and burning as part of forest clearing

4 Loss from sector of carbon in debris and soil associated with transfer out of sector of cleared forest land or land where forest cover has been lost through dieback or degradation

5 Sum of growth in stock, managed losses and catastrophic losses

6 Sum of reclassification to forest, transfer to product pools and reclassification to non-forest

A6.3 Summary of Responses to UNFCCC ERT Recommendations and Comments

Note: At the time of preparation of this report for publication, the ERT report for Australia's 2013 Inventory submission has not yet been finalised. However draft issues raised during the review of the 2013 submission have been included in the table.

Table A.6.5(a): Summary of responses to UNFCCC ERT recommendations: energy and cross cutting

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
CC	ARR 2012 10 &16	Populate CRF table 7 for 1990.	Accept	CRF table 7 for 1990 has been completed in this submission.
CC	ARR 2013 draft	Australia is recommended to ensure consistency between information in the NIR and CRF Summary table 3.	Accept	Implemented in the 2013 submission.
CC	ARR 2013 draft	Australia is recommended to complete CRF table 8(b).	Accept	Implemented in the 2013 submission.
1A	ARR 2011 48	The ERT noted that the AD for public electricity and heat production over certain thresholds is collected through NGERS, and that the energy use of small power stations is estimated as the difference between the total of reported values under NGERS and the ABARE energy statistics. The ERT reiterates the recommendation in the previous review report that Australia collect these data on a regular basis. Such data collection should be incorporated into the implementation plan for future annual submissions.	Accept	Australia's Bureau of Resources and Energy Economics (BREE) have conducted a regional and remote electricity generator survey for 2011-12. The results from this have been incorporated for the first time in the 2012 Inventory. Refer to section 3.3.2 for more information.
Energy	ARR 2012 31	Review opportunities to incorporate NGERS data into the annual submission and ensure time-series consistency where NGERS data are used	Updated natural gas combustion emissions under Oil and Gas Extraction to incorporate NGER facility data for LNG production. Updated the time series to maintain consistency. Updated fugitive emissions from open cut coal mining to incorporate measured emissions from mines reporting under NGER using facility-specific gas measurement approach. New NGER data on upstream natural gas consumption has been reported for the first time and incorporated into a new quality control procedure that verifies the amount of natural gas reported in the inventory.	Recalculation for Oil and Gas Extraction provided in section 3.3.5 Recalculation for open cut coal mine fugitive emissions provided in section 3.8.5 New NGER data has been incorporated into the natural gas quality control procedure in section 3.2.6.

Annexes

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
1.A.1.a	ARR 2012 37	Collect and incorporate activity data from a survey of small power stations	Accept	Australia's Bureau of Resources and Energy Economics (BREE) have conducted a regional and remote electricity generator survey for 2011-12. The results from this have been incorporated for the first time in the 2012 Inventory. Refer to section 3.3.2 for more information.
1.A	ARR 2013 draft	Revise the reference approach tables for the years prior 2011 in the next inventory submission	Accept. Due to the significant work required to update the reference approach for all years back to 1990, Australia intends to implement this recommendation in steps over the 2014 and 2015 submissions.	The reference approach has been updated for years 2008 to 2011 in this submission. Years 1990 to 2002 will be updated in the April 2015 submission.
1.A.3.a	ARR 2013 draft	International comparisons –1.A.3.a - domestic aviation CRF tables for domestic aviation are systematically lower than in IEA data by around 10% for most years, with larger differences (up to 16%) for 1999 to 2004.	The domestic and international splits for fuel consumption are sourced from the *Australian Energy Statistics* (BREE 2013a).	Further details explaining comparisons with IEA data are provided in section 3.2.6 of the NIR
1.A.3.d	ARR 2013 draft	International comparisons –1.A.3.d - domestic navigation The inter-annual change for fuel consumption between 2006 and 2007 (35.4%) has been identified as an outlier.	The domestic and international splits for fuel consumption are sourced from the *Australian Energy Statistics* (BREE 2013a).	Further details explaining comparisons with IEA data are provided in section 3.2.6 of the NIR.
1.B.1	ARR 2013 draft	International comparisons – 1.B.1 –solid fuels The data on coal production in the CRF table are higher than those reported to the IEA by 13-23% for 1990-2011 Include the explanation provided by Australia to the ERT during the review in the section on international comparisons in the next inventory submission.	Accept.	An explanation of the differences between CRF coal production and the IEA data is provided in section 3.2.6

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
	ARR 2013 draft	International bunker fuels, jet kerosene For jet kerosene in international aviation, data are consistent within 2% for all years except 2001 (CRF data 5% lower), and 2002 (CRF data 4% higher).	The domestic and international splits for fuel consumption are sourced from the *Australian Energy Statistics (*BREE 2013a).	Further details explaining comparisons with IEA data are provided in section 3.2.6 of the NIR.
	ARR 2013 draft	International bunker fuels, marine bunkers For 1990 to 1999, residual fuel oil figures for international marine bunkers are 5-22% lower in the CRF tables than in the IEA data; for 2002 an opposite (-11%) discrepancy is observed.	The domestic and international splits for fuel consumption are sourced from the *Australian Energy Statistics (*BREE 2013a).	Further details explaining comparisons with IEA data are provided in section 3.2.6 of the NIR.
1.A.1.a	ARR 2013 draft	1.A.1.a - Public Electricity and Heat Production – liquid fuels The ERT has identified the inter-annual changes in the CO_2 IEF between 1997 (74.94 t/TJ) and 1998 (72.87 t/TJ) as well as between 2008 (72.93 t/TJ) and 2009 (72.00 t/TJ) as outliers. The 1998 value is 2.8% lower than the 1997 value. The 2009 value is 1.3% lower than the 2008 value. Include the information provided to the ERT in response to this issue in its next annual submission to improve transparency.	Accept	An explanation of IEF variation is provided in section 3.3.3 of the NIR.
1.A.1.b	ARR 2013 draft	1.A.1.b - Petroleum Refining – liquid fuels – CO_2 The inter-annual changes in the CO_2 IEF between 2008 (68.29 t/TJ) and 2009 (66.87 t/TJ) as well as between 2009 (66.9 t/TJ) and 2010 (68.3 t/TJ) outliers. The 2009 value is 2.1% lower higher than the 2008 value and the 2010 value is 2.2% higher than the 2009 value. Include the information provided to the ERT in response to this issue in its next annual submission to improve transparency.	Accept	An explanation of CO_2 IEF variation is provided in section 3.3.3 of the NIR.

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
1.A.1.b	ARR 2013 draft	1.A.1.b – Petroleum Refining – solid fuels The time series for the Petroleum refining/ solid fuels (1.AA.1.B) in CRF table 1A(a) of the 2013 submission shows the values for CO_2, CH_4 and N_2O data for AD and emissions for the years 2007 and 2008 with application of the country-specific emission factors and tier 2 methodology for these two years. However, for all other years within the time series 1990-2011 emissions in this category are stated as "NA" and the activity data as "NO". The NIR text does not have supporting explanations for the anomaly of the 2007 and 2008 records for this category. Include the explanation provided to the ERT during the review in the next inventory submission to improve transparency. Also, include the relevant note to the 2007 and 2008 years of the time series in the CRF tables.	Accept	Solid fuels in 1A.1.b Petroleum refining have been reallocated to 1.A.2.c Chemicals to improved time series consistency. See section 3.3.5 of the NIR for more detail.
1.A.2.a	ARR 2013 draft	1.A.2.a - Iron and Steel – liquid fuels The ERT has identified the inter-annual changes in the CO_2 IEF between 2000 (64.29 t/TJ) and 2001 (70.96 t/TJ) as an outlier. The 2001 value is 10.4% higher than the 2000 value. Include the explanation provided to the ERT during the review in the next inventory submission to improve transparency.	Accept	An explanation is provided in section 3.4.3.

Annexes

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
1.A.2.b	ARR 2013 draft	1.A.2.b - Non-Ferrous Metals – all fuels CO_2 emissions peaked in 2008. Thereafter, the trend is decreasing. CO_2 emissions in 2011 (11,392 t CO_2) are similar to those in 1991-1992 Include the explanation provided to the ERT during the review in the next inventory submission to improve transparency.	Accept. Revisions of the AES (BREE 2013a) undertaken by BREE involving the reallocation of fuels between stationary energy categories have now significantly improved the time series consistency of Non Ferrous metals in this submission.	Explanations are provided in sections and 3.4.3 and 3.4.5 of the NIR.
1.A.2.b	ARR 2013 draft	1.A.2.b - Non-Ferrous Metals – solid fuels The time series reported in the 2013 inventory submission shows a notable stepwise drop in the implied emission factors between 2002 and 2003. The drop between the averages of 1990-2002 and 2003-2011 IEFs (1.75) is over 10 times greater than standard deviations in the IEF datapoints (approx. 0.15 and 0.07 for each time sub-series respectively) Incorporate the revised time series with a consolidated explanation in the future inventory submission.	Accept	A reallocation of solid fuels has been implemented to the Chemicals subsector to improve the time series consistency of solid fuel CO_2 IEFs in both subsectors Explanation provided in section 3.4.5 of the NIR.
1.A.2.c	ARR 2013 draft	1.A.2.c - Chemicals – solid fuels The ERT has identified the inter-annual change in the CO_2 IEF between 2002 (84.70 t/TJ) and 2003 (94.09 t/TJ) as an outlier. The 2003 value is 11.1% higher than the 2002 value. Incorporate the revised time series with a consolidated explanation in the future inventory submission.	Accept	A reallocation of solid fuels has been implemented to the Non-ferrous metals subsector to improve the time series consistency of solid fuel CO_2 IEFs in both subsectors Explanation provided in section 3.4.5 of the NIR.
1.A.3.a	ARR 2013 draft	Include the 2011 LTO data in the next inventory submission.	Accepted.	2011 LTO data is now available and has been included in the 2012 NIR – see section 3.5.2.

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
1.A.3.b	ARR 2013 draft	For gasoline, the inter-annual change in the CO_2 IEF between 2009 (69.83 t/TJ) and 2010 (68.00 t/TJ) was identified as an outlier. The 2010 value is 2.6% below the 2009 value. Include the corrected values for the activity data in the next inventory submission.	Accept.	See section 3.5.2 of the NIR.
1.A.3.b	ARR 2013 draft	For LPG, the constant CO_2 IEF (59.60 t/TJ) is one of the lowest between reporting Parties.	Australia acknowledges it is at the lower end of international comparisons, a function of Australia's country specific emissions factor for LPG. In response to a recommendation from a previous review report, a study was commissioned by in 2011 to investigate the appropriateness of the fuel characteristics, including the CO_2 EF, for liquid fuels types used in the Inventory. The report compared the energy contents, density, carbon content and EF of the fuel types used to produce the inventory compared to publically available Australian data and other public European and US sources. The report also compared inventory fuel characteristics to an unpublished Australian database accumulated from fuel testing. The report concluded that the CO_2 EFs for petrol, aviation turbine fuel, diesel, fuel oil and LPG are almost the same as the Australian published data .	See section 3.5.2 of the NIR.
1.A.3.c	ARR 2013 draft	The inter-annual change for fuel consumption between 2007 and 2008 (19.3%) has been identified as an outlier.	Accepted.	See section 3.5.2 of the NIR for further details.

Sector	Report and paragraph reference	ERT Recommendation	Response	Implementation
1.B.2.b	ARR 2013 draft	1.B.2.b - Natural Gas, Exploration CH_4 emissions decreased by 95.6% between 2009 and 2010, and increased by 1755.1% between 2010 and 2011. Meanwhile, CO_2 emissions in the same subcategory increased by 1023.6% between 2009 and 2010, and decreased by 75.8% between 2010 and 2011. Recalculation of the CH_4 emissions for 2010 (underestimated value) is included in request for re-submission as a part of the Saturday paper. ERT also recommends recalculation overestimated CO_2 emissions for the same year for the next inventory submission.	Accept. This was caused by an allocation error in the population of the CRF reporter tool. For natural gas exploration in 2010 only, a component of CH_4 emissions was misallocated to CO_2 emissions for this sub-sector. This misallocation affected the gas breakdown, with the overall CO_2-e emissions trend for natural gas exploration remaining unchanged.	Australia resubmitted the CRF tables in response to a Saturday Paper that included this issue. Australia also enhanced its QA/QC processes in this sector to reduce the likelihood of this error recurring in the future.
1.A.2.a	ARR 2013 draft	1.A.2.a - Iron and Steel – solid fuels The ERT has identified the inter-annual changes in the CO_2 IEF between 2002 (49.11 t/TJ) and 2003 (66.20 t/TJ) as an outlier. The 2003 value is 34.8% higher than the 2002 value. Include the explanation provided by Australia to the ERT during the review in the section on international comparisons in the next inventory submission	Resolved by allocating PCI coal used as a reductant to sector 2.C metal production in the Industrial Processes sector	Explanation of the reallocation to IP sector is provided in sections 3.4.5 and 4.5.8 of the NIR.

Table A.6.5(b): Summary of responses to UNFCCC ERT recommendations: Industrial processes

Sector	Report ref	ERT Recommendation	Response	Implementation
2B	ARR 2011 63	Although Australia has taken some steps to increase the transparency of its estimates of emissions from this category, aggregation of emissions continues to impede transparency. In the NIR, Australia notes that it plans to explore ways of disaggregating ammonia data while still protecting other confidential chemical industry data aggregated with ammonia. In response to a question raised by the ERT, Australia further noted that it had commissioned an independent review by CSIRO of the handling of confidential data in the inventory. The ERT strongly recommends that Australia continue to increase the transparency of the chemical industry inventory by disaggregating data further.	Australia will continue to explore options for increasing the transparency of IP emissions estimates while remaining sensitive to the confidentiality requirements of NGER data.	Ongoing
2C	ARR 2011 64	The use of coke and natural gas as reducing agents is reported in the industrial processes sector, while the use of pulverized coal as a reducing agent is allocated to the energy sector. The ERT reiterates the recommendation of previous review reports that Australia reallocate the coal used as a reducing agent to the industrial processes sector. The ERT encourages Australia to determine whether new data collected via NGERS could facilitate this reallocation, as it did for ferroalloys.	Australia accepts this recommendation and has reallocated emissions from the use of pulverised coal in iron and steel production from 1.A.2 manufacturing to 2.C.1 metal production.	See section 4.5 of the NIR.
2F	ARR 2011 66	In the planned improvements section of its NIR, Australia notes that it expects that NGERS will provide country-specific information on annual leakage rates from commercial and industrial refrigeration and air-conditioning applications. The ERT encourages Australia to make use of this information, as well as any available information on commercial and industrial refrigeration equipment stocks, to develop more accurate and precise estimates of emissions across the air-conditioning and refrigeration end use.	Accept. Australia has made use of new annual leakage rate information for commercial equipment in this submission.	See section 4.8.6 of the NIR.

Sector	Report ref	ERT Recommendation	Response	Implementation
2F	ARR 2011 73	One area where Australia could further improve the transparency of its inventory is regarding the treatment of sealed-pressure electrical equipment in its NGERS programme and inventory. Because sealed-pressure equipment is rarely serviced during its lifetime, the mass balance methods used by utilities reporting under Australia's NGERS programme will not capture emissions from this source. Instead, the 2006 IPCC Guidelines recommend that appropriate EFs be applied to the data for the total nameplate capacity of sealed-pressure equipment reported in the country. The ERT, therefore, encourages Australia to more clearly discuss the fraction of reported nameplate capacity that consists of sealed-pressure equipment and the methods that Australia uses to estimate emissions from this equipment. The ERT notes that reporting by equipment importers, which Australia indicated could occur under proposed legislation, could be quite helpful in developing or checking estimates of the nameplate capacity of sealed-pressure equipment.	Australia will review this area of the inventory and provide further information in future submissions pending the availability of suitable data.	To be implemented in future submissions subject to data availability.
2	ARR 2012 50	Where NGERS data are used, transparently describe how the multiple data sets reflect the national GHG emissions for each subcategory, how it is ensured that all emission categories are covered by these data sets and how verification of the data is carried out, as well as how the data result in a consistent time series	The use of NGER data is discussed in general in chapter 1 of the NIR. The use of activity data and emission factors based on NGER data in the industrial processes sector is described throughout chapter 4.	See chapters 1 and 4 of the NIR

Sector	Report ref	ERT Recommendation	Response	Implementation
2.B	ARR 2012 51	Provide the disaggregated data, or information on the improvement plan, to improve transparency in relation to the chemical industry	Confidentiality continues to be an issue in the chemicals sector where there are only a small number of companies in operation. The confidentiality provisions of the NGER Act under which chemical industry data are obtained are explicit and restrict publication of such confidential data. In recent years, Australia has invested effort in providing as much information as it can within the restrictions of the NGER Act, including provision of implied emission factor information and discussions of comparisons with other Annex 1 parties. Australia remains committed to enhancing the transparency of the chemicals sector estimates and will continue to explore additional options within the confidentiality restrictions of the NGER Act.	
2.C	ARR 2012 52	Reallocate the pulverized coal used as a reducing agent, along with the corresponding emissions, to the industrial processes sector	Accept. Emissions from the use of pulverised coal in the production of iron and steel has been reallocated from 1.A.2 manufacturing to 2.C.1 metal production.	See section 4.5 of the NIR.
2.F	ARR 2012 53	Provide the recalculated data for HFC emission estimates	The recommendation to provide further information in relation to HFC and non HFC use in equipment stocks has been actioned. There have been no recalculations as a result of this recommendation.	See section 4.8 of the NIR.
2.A	ARR 2012 54	Include additional information on the derivation of the EFs for lime production, including references to the data sources	Accept. Australia has provided further information in relation to the derivation of lime emission factors in its 2013 submission.	See section 4.3 of the NIR.

Sector	Report ref	ERT Recommendation	Response	Implementation
2.F	ARR 2012 55	Disaggregate the emissions from electrical equipment and report them separately under each function (operation and disposal)	Australia does not currently have access to data that would make this disaggregation possible. As set out in the NIR, the emission factors obtained under NGERS have been derived from gas mass balances and integrate operational and disposal phases of the equipment life-cycle. Any effort to disaggregate emissions estimates currently would be based on an assumption and would likely result in inaccurate allocation between the operation and disposal.	
2.F	ARR 2013 Draft	The ERT recommends that Australia disaggregate the emissions and report the estimates separately under each function (operation and disposal) in its next annual submission.	See item above.	
2.C	ARR 2013 Draft	The ERT recommends that Australia reallocate the use of pulverized coal used as a reducing agent, along with the corresponding emissions, to the industrial processes sector in its next annual submission	Accept. Emissions from the use of pulverised coal in the production of iron and steel has been reallocated from 1.A.2 manufacturing to 2.C.1 metal production.	See section 4.5 of the NIR.
2.C	ARR 2013 Draft	The ERT recommends Australia to provide revised CO_2 estimates for this category using the recommended method for natural gas consumption (without an oxidation factor) including information on the methods, parameters and assumptions used as recommended by the GPG.	Accept. Emissions from ammonia production have been revised incorporating an oxidation rate of 100%.	See section 4.4 of the NIR.
	ARR 2013 Draft	The ERT recommends Australia that for the next submission make correction of PLF values in the CRF and properly fill table 2(II).Fs1	Accept	See CRF table 2(II).Fs1.
2.F	ARR 2013 Draft	The ERT recommends Australia that for the next submission reports disaggregated emissions by gas in table 2(II).Fs1.	Accept	See CRF table 2(II).Fs1.

Sector	Report ref	ERT Recommendation	Response	Implementation
2.F	ARR 2013 Draft	The ERT recommends that Australia provide revised SF_6 estimates for this category that include the SF_6 emissions from the use of AWACS aircraft, indicating the methods, parameters and assumptions used to estimate these emissions as recommended by the GPG. The ERT notes that, if survey data on SF_6 consumption for AWACS are not available, these emissions could be estimated using methods that other similar countries apply. For example, for SF_6 emissions from AWACS, Germany reports an SF_6 EF defined as average SF_6 consumption per AWACS airplane per year of 740 kg, which is based on Schwarz (2005).	Australia has obtained information from manufacturers and operators that confirm that no SF6 is used in this application.	See section 4.8 of the NIR.

Table A.6.5(c): Summary of responses to UNFCCC ERT recommendations: Agriculture

Sector	Report ref	ERT Recommendation	Response	Implementation
4	ARR 2011 77 ARR 2012 58	Provide a transparent description of the tier 2 uncertainty analysis in annex 7 to the NIR, including information on the sources of the applied values and distributions used.	Accept. Specific parameters and distributions used in the tier 2 uncertainty analysis included in the 2013 submission.	See uncertainty sections in Chapter 6 of the NIR.
4	ARR 2012 60	Include the references for sources of AD (e.g. amount of synthetic fertilizer used, the allocation of animal waste management systems, and the area of cultivated histosols).	Accept. Additional information in the 2013 submission.	See section 6.2.1 Data Sources.
4A	ARR 2009 91, 94, 95 ARR 2011 79	The ERT noted that many of the studies are relatively old (over 10 years). The ERT strongly recommends that Australia explain in its next annual submission how it plans to update such studies. Regarding research on Tropical EF: The ERT commends the efforts made by Australia and recommends that the Party provide an update of the results in the next annual submission Australia provided its improvement plan indicating that the in-country peer review of tier 2 parameters for enteric fermentation is in progress. The ERT encourages Australia to finalize these studies and to apply the results for the preparation of the inventory as soon as the study has been finalized	New research on tropical cattle produced significantly different results to previous study. Based on advice from the FullCAM and Agriculture Inventory Expert Advisory Panel no changes to the methods will be made until further analysis of tropical cattle studies can be undertaken. Review of other methods pending release of publications from the Reducing Emissions from Livestock Research Program	See section 6.4.6 - source specific planned improvements.

Annexes

Sector	Report ref	ERT Recommendation	Response	Implementation
4A	ARR 2011 80 ARR 2012 62	The ERT recommends that, in its next annual submission, Australia also include information in the NIR to explain that feedlot cattle are reported under other (enteric fermentation) in the CRF tables	Accept. Implemented in the 2013 submission.	Footnote included on NIR Table 6.2.
4A	ARR 2012 59	Report the appropriate notation keys in CRF table 4.A instead of the value 0.00.	Accept.	Implemented in 2013 submission.
4A&B	ARR 2013 Draft	Recommend including the explanation for weight loss in cattle in some States and season in the NIR	Accept.	See section 6.2.1 Data Sources.
4B	ARR 2008 45 ARR 2009 69,71 ARR 2010 100 ARR 2011 82 ARR 2012 64 ARR 2013 Draft	Australia calculated N_2O emissions from dairy cattle, with protein intake from dairy calves not included due to the early removal of calves from the herd. In response to a question raised by the ERT during the course of the review, Australia indicated that it intends to review the age at which calves are removed from the herd for its next annual inventory submission. The 2009-2013 ERTs reiterated the recommendation made during the previous reviews that Australia implement changes or report on progress made.	Accept. Current method assumes that calves are on pasture from birth. Most dairy calves are removed from cows within days and placed on milk replacement and supplements until weaned. If this approach is implemented it will result in a small increase in N_2O emissions but will also result in a reduction in enteric fermentation. Review documented under QA/QC Section.	See section 6.4.6 - Source Specific Planned Improvements Implementation of new method has been delayed due to resource constraints. The new method represents a significant change to the structure of the AGEIS (Australian Greenhouse Emissions Information System). Specifications for changes are being prepared and will be implemented in the 2015 submission
4B	ARR 2012 65	Include in CRF table 4.B (b) the nitrogen excretion rate for ostriches for 2010.	Accept	Implemented in 2013 submission.
4D	ARR 2012 66 ARR 2013 draft	Provide information to demonstrate the representativeness for the value of the fraction of nitrogen that volatilises as ammonia and nitrogen oxides from animal manure (FracGASM) from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.	Accept. Additional explanation provided in NIR and specific table reference given for 2006 IPCC Guidelines factors.	See section 6.6.2.8 of the NIR.
4D	ARR 2013 Draft	Recommend that Australia provide a transparent description of the AD, EF(s) used and emissions of N_2O from fertilizer application to forests in the NIR.	Accept.	See section 6.6.2.1 of the NIR.
4E	ARR 2012 67	Document the results of the planned QA/QC processes for the new emission estimation method.	Accept.	See section 6.7.4 of the NIR.

Table A.6.5(d): Summary of responses to UNFCCC ERT recommendations: Waste

Sector	Report ref	ERT Recommendation	Response	Implementation
6A	ARR 2011 107	In the previous annual review report, Australia was encouraged to develop country-specific DOC and k values. As indicated in paragraph 107 above in its 2011 annual submission Australia still uses default values for DOC and k. The ERT reiterates the encouragement of the previous review report to adopt country-specific values for these parameters, but notes that this matter will be addressed in Australia's plan to use facility-specific parameter values from the NGER (2009-2012) system in future annual submissions.	To date, no facility-level decay rate constant information has been available under the NGER (2009-2012) system. Australia will continue to monitor NGER landfill data and make use of it as appropriate.	See section 8.10.1 of the NIR.
6C	ARR 2011 120	However, the CRF tables incorrectly report N2O and CH4 emissions from the incineration of waste (clinical waste and solvents) as "NA". Since these emissions are likely occurring, the ERT recommends that Australia quantify the emissions of N2O from this category. If no data on EFs are available, the ERT recommends that Australia report those emissions as "NE", rather than "NA".	No EFs are provided for N_2O from the incineration of clinical waste or solvents in GPG. 2006 Guidelines do include emission factors for sludge and industrial waste. Australia will review these factors to determine whether they are appropriate for application in clinical waste and solvent incineration.	An update will be provided in future inventory submissions.
6	ARR 2012 91	Fully implement the QC procedures so as to eliminate mistakes when filling in data in the CRF tables.	Accept	
6.A	ARR 2012 93	Provide information to explain why the Party does not take into account the fraction of municipal solid waste incinerated in the additional information to CRF table 6.A.	Accept	See section 8.3.2.2 of the NIR and CRF table 6.A.
6.A	ARR 2012 94	Correct the delay time in the additional information to CRF table 6.A.	Accept – this was implemented in the 2013 submission.	See CRF table 6.A
6.B	ARR 2012 97	Include the conversion ratio between chemical oxygen demand and biochemical oxygen demand used in the estimation of domestic and commercial wastewater handling.	Accept	See CRF table 6.Bs1
6.B	ARR 2012 98	Improve the QC procedures for the reporting of COD in industrial wastewater.	Accept	
6.B	ARR 2012 100	Reallocate emissions from sludge application on agricultural land to the agriculture sector of the inventory.	Accept. Emissions from sludge application to land were reallocated to the agriculture sector in the 2013 submission.	Refer to 2013 submission.

Sector	Report ref	ERT Recommendation	Response	Implementation
6.C	ARR 2012 102	Provide detailed information on the properties of the country-specific EFs and the national circumstances in relation to aerobic windrow composting, referencing the appropriate literature.	Accept.	Refer to 2013 submission.
6	ARR 2013 Draft	The ERT recommends to include the information on QA/QC procedures for waste in next NIR.	Accept	See section 8.8.1.
6.B	ARR 2013 Draft	The ERT recommends to include in the CRF documentation box clarifying the use of COD in CRF table 6.Bs1 in its next submission.	Accept	See CRF table 6.Bs1.

Table A.6.5(e): Summary of responses to UNFCCC ERT recommendations: Land Use Land Use Change and Forestry

Sector	Report ref	ERT Recommendation	Response	Implementation
LULUCF	ARR 2011 92	Australia chose 50 years as the transition period for land-use conversion but this was not fully applied in its disaggregation of land uses into the land-use remaining and land-use conversion subcategories, which is inconsistent with the IPCC good practice guidance for LULUCF. The ERT recommends that Australia implement this planned improvement in its next annual submission, as it is needed so that the report is consistent with the IPCC good practice guidance for LULUCF.	Accept	Australia is currently reviewing the most appropriate length of conversion period for its national circumstances. Once this review is finalised the transition period policy will be implemented within the FullCAM Outputs Analysis System (OASys). FullCAM OASys is a system for the storage and analysis of FullCAM outputs. The project has reached the detailed design phase.
LULUCF	ARR 2011 93	Australia has elected to move lands from the conversion subcategory to the remaining category after 50 years but also use subcategories to separate recent land conversions from older land conversions. As Australia's current reporting is not consistent with the IPCC good practice guidance for LULUCF, which requires that any change in area of forest land should correspond to a change in land use, the ERT reiterates the recommendation of the previous review report that Australia apply this method consistently in its next annual submission.	Accept	Australia is developing a FullCAM Outputs Analysis System (OASys) to store, and support the analysis of, FullCAM outputs. This will allow Australia to improve the disaggregation of land use categories. The project has reached the detailed design phase.

Sector	Report ref	ERT Recommendation	Response	Implementation
LULUCF	ARR 2011 94	As indicated in the previous review report, Australia explained that changes in forest area under the subdivision "other native forests" do not always correspond to real changes in land use. In its 2011 annual submission, Australia reports that it plans to implement a research project to improve the reporting on these changes in land use and that the project will take the recommendation from the previous review report into consideration. The ERT welcomes this action, reiterates the recommendation from the previous review report and looks forward to the results being reported in Australia's next annual submission.	Accept	Forest land area changes (and associated carbon stock changes) due to natural changes in forest cover are currently reported under Forest land, other native forests. The observed natural gains and losses in forest cover are most likely driven by climatic fluctuations. In the absence of land use change (and climatic change) these lands are expected to change back to their originally observed status (e.g. lands that have naturally lost cover will naturally re-gain forest cover). That is, in most cases, it is likely that woody vegetation that could potentially reach the threshold values used to define Forest land remains *in situ*. A key aspect of this research project will be using a new data set that has become available in Australia to identify woody vegetation that does not meet forest thresholds.
LULUCF	Para 95	Australia assumes that there is no change in the soil carbon stock in the category forest land remaining forest land, which is estimated following the tier 1 approach of the IPCC good practice guidance for LULUCF. Australia reports that research is ongoing to implement higher tier modelling of soil carbon in all forest land remaining forest land subcategories. The ERT welcomes these activities and looks forward to the results of higher-tier modelling being implemented and reported in its next annual submission.	Implement	Australia's progress to move to higher tier modelling of Forest land remaining Forest land has been slower than planned. Australia plans to implement spatial modelling of Forest land remaining Forest land for future inventory submissions.
LULUCF	ARR 2011 99	The ERT reiterates the recommendation of the previous review report that Australia improve the consistency of reporting and provide estimates for the full chosen period (50 years) in its next annual submission.	Review	Australia is currently reviewing the most appropriate length of conversion period for its national circumstances. Once this review is finalised the transition period policy will be implemented within the FullCAM Outputs Analysis System (OASys). FullCAM OASys is a system for the storage and analysis of FullCAM outputs. The project has reached the detailed design phase.
LULUCF	ARR 2012 72	Report revised emission estimates for soils on forest land converted to cropland and forest land converted to grassland	Implement	Resolved in Australia's 2014 inventory submission.

Sector	Report ref	ERT Recommendation	Response	Implementation
LULUCF	ARR 2012 73	Report land-use categories consistently with respect to the timing for moving lands from the conversion category to the remaining category	Review	Australia is currently reviewing the most appropriate length of conversion period for its national circumstances. Once this review is finalised the transition period policy will be implemented within the FullCAM Outputs Analysis System (OASys). FullCAM OASys is a system for the storage and analysis of FullCAM outputs. The project has reached the detailed design phase.
LULUCF	ARR 2012 74	Consistently apply the following criteria in the CRF tables and provide transparent documentation in the NIR: (a) areas of managed rangelands and pasture land where, due to climate variation, the tree crown cover permanently exceeds the forest threshold can no longer be considered grassland; they should be reported as a separate subdivision (e.g. natural forest expansion on grassland) under the subcategory land conversion to forest land; and (b) areas of managed forests where, due to climate variation, the tree crown cover is permanently below (i.e. it is not expected to exceed) the forest threshold can no longer be considered forest land; they should be reported as a separate subdivision under the sub-category forest land converted to a new land use (e.g. grassland)	Accept	Forest land area changes (and associated carbon stock changes) due to natural changes in forest cover are currently reported under Forest land, other native forests. The observed natural gains and losses in forest cover are most likely driven by climatic fluctuations. In the absence of land use change (and climatic change) these lands are expected to change back to their originally observed status (e.g. lands that have naturally lost cover will naturally re-gain forest cover). That is, in most cases, it is likely that woody vegetation that could potentially reach the threshold values used to define Forest land remains *in situ*. A key aspect of this research project will be using a new data set that has become available in Australia to identify woody vegetation that does not meet forest thresholds.
LULUCF	ARR 2012 77	Review the estimates of land converted to forest land in order to ensure accuracy and completeness, and submit recalculated estimates	Accept	As part of its review of land classification Australia has identified that the land converted to forest land classification should include land use conversion prior to 1990. Implementation of this revision is planned for the 2015 inventory submission.
LULUCF	ARR 2012 78	Review these figures in combination with the review recommended in paragraph 77 of this report, at the latest in the 2014 annual submission	Accept	The method and documentation for the estimation of Grassland converted to Forest land which is subsequently converted back to Grassland has been updated with the 2014 inventory submission. Detailed explanation is provided in Chapter 11 of the NIR.
LULUCF	ARR 2012 81	Implement and report on the new plant growth model	Accept	See Volume 2, section 7.E.5.

Sector	Report ref	ERT Recommendation	Response	Implementation
LULUCF	ARR 2012 84	Implement and report on the use of the CSIRO plant growth model used to estimate the amount of above-ground mass that is likely to be grown in arid and semi-arid regions	Accept	See Volume 2, section 7.E.5.
LULUCF	ARR 2013 draft	The ERT reiterates the recommendation made in the previous review reports that Australia consistently apply the following criteria in the CRF tables and provide transparent documentation in the NIR: Areas of managed rangelands and pasture land where, due to climate variation, the tree crown cover permanently exceeds the forest threshold can no longer be considered grassland; they should be reported as a separate subdivision (e.g. natural forest expansion on grassland) under the subcategory land conversion to forest land; Areas of managed forests where, due to climate variation, the tree crown cover is permanently below (i.e. it is not expected to exceed) the forest threshold can no longer be considered forest land; they should be reported as a separate subdivision under the subcategory forest land converted to a new land use (e.g. grassland).	Accept.	Forest land area changes (and associated carbon stock changes) due to natural changes in forest cover are currently reported under Forest land, other native forests. The observed natural gains and losses in forest cover are most likely driven by climatic fluctuations. In the absence of land use change (and climatic change) these lands are expected to change back to their originally observed status (e.g. lands that have naturally lost cover will naturally re-gain forest cover). That is, in most cases, it is likely that woody vegetation that could potentially reach the threshold values used to define Forest land remains *in situ*. A key aspect of this research project will be using a new data set that has become available in Australia to identify woody vegetation that does not meet forest thresholds.
LULUCF	ARR 2013 draft	Considering the complexity of the Australian land representation, the ERT recommends to add, in the main section, a summary table where, for each land category and subdivision, more relevant information related to land representation as the approach used, the background data and the transition period applied, is reported.	Accept	Australia will plans to present additional information and supporting material on land classification and methods in its 2015 submission.
LULUCF	ARR 2013 draft	To enhance comparability of the GHGI and its consistency with IPCC categories it is recommended to allocate CO_2 emissions from liming to CRF table 5(IV). Whether data available do not allow to disaggregate liming among land use categories, it is suggested to follow the common practice to assign all the activity data to the most relevant land use category (usually cropland) whist assigning the notation key IE to other land uses.	Accept	Implemented in 2014 inventory submission.
LULUCF	ARR 2013 draft	Considering that the Tier 1 methodology for SOM in cropland and grassland is based on changes in management practices (i.e. to any change in management practices a C stock change is associated; and only changes in management practices determine to count for changes in C stock	Accept	See Volume 2, 7.8.5, Planned Improvements.

Annexes

Table A.6.5(f): Summary of responses to UNFCCC ERT recommendations: ARTICLE 3.3 ACTIVITIES

Sector	Report ref	ERT Recommendation	Response	Implementation
KP Art. 3.3	ARR 2011 125	To improve transparency the ERT recommends that Australia present the annual area of afforestation and reforestation in chapter 11 of the NIR in its next annual submission.	Implement	This recommendation will be implemented in Australia's 2015 submission.
KP Art. 3.3	ARR 2011 126	To improve transparency the ERT recommends that Australia provide in its next annual submission more information on the estimation of the carbon stock change in the units of land harvested.	Implement	Australia has presented additional information on emissions and removals on harvested land in Table 12.13.
KP Art. 3.3	ARR 2011 127	In its NIR, Australia reported only generic qualitative information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested. In the NIR volume 2, appendix 7E, Australia provides figure 7.E2 showing the net change in forest cover that is not attributed to human-induced actions. Australia has included a review of the assessment of non-human induced forest cover change in its inventory improvement plan. The ERT welcomes this announced review, but reiterates the encouragement of the previous review report that Australia provide in its next annual submission, but certainly no later than the 2014 annual submission, a quantitative assessment of forest areas that have lost forest cover but which are not yet classified as deforested.	Accept	In the 2013 submission Australia has included estimates of the area of plantation forest that have lost forest cover but are yet to be classified as deforested. Forest land area changes (and associated carbon stock changes) due to natural changes in forest cover are currently reported under Forest land, other native forests. The observed natural gains and losses in forest cover are most likely driven by climatic fluctuations. In the absence of land use change (and climatic change) these lands are expected to change back to their originally observed status (e.g. lands that have naturally lost cover will naturally re-gain forest cover). That is, in most cases, it is likely that woody vegetation that could potentially reach the threshold values used to define Forest land remains *in situ*. A key aspect of this research project will be using a new data set that has become available in Australia to identify woody vegetation that does not meet forest thresholds.

Sector	Report ref	ERT Recommendation	Response	Implementation
KP Art. 3.3	ARR 2011 128	For the same reasons as for afforestation and reforestation activities, the land cover transitions in table 7.5 of the NIR do not match the deforestation areas for the activities under Article 3, paragraph 3, of the Kyoto Protocol. In the CRF table NIR-2 Australia reports the deforested areas for 2008 and 2009. During the review, Australia provided the ERT with a preliminary estimate of the annual area of land subject to deforestation under the Kyoto Protocol. To improve transparency the ERT encourages Australia to also present the annual deforested area since 1990 in the NIR of its next annual submission.	Accept	The Forest cover change data presented in table 7.5 of the NIR includes the effects of natural forest cover gain and loss, direct human induced deforestation and human induced forest clearing that does not qualify as deforestation.
	ARR 2012 110	Provide more information on the estimation of the carbon stock changes for the units of land harvested and not harvested in chapter 11 of the NIR.	Accept	The reporting of units of land harvested and not harvested within the Afforestation/Reforestation classification has been updated with the 2014 inventory submission.
	ARR 2012 111	Include forest land that "naturally" regrew after 1990, and that is subject to the implemented legal and regulatory framework that, in practice, results in human-induced afforestation and reforestation activities, in the reporting under Article 3, paragraph 3, of the Kyoto Protocol.	Review	Further analysis has been undertaken during 2012 and 2013 and the results of this work are presented in Chapter 11 of the NIR.
	ARR 2012 112	Reflect in the NIR that deforestation on afforestation/reforestation lands must also be accounted.	Accept	This was updated with the 2013 inventory submission.
	ARR 2012 114	Document in the NIR the approach of using a period of eight years following the year of harvest to detect whether forest land has been deforested.	Accept	The method and documentation for the estimation of emissions due to the Deforestation of Afforestation/ Reforestation land has been updated with the 2014 inventory submission. Detailed explanation is provided in Chapter 11 of the NIR.
	ARR 2012 115	Include in the accounting for deforestation the emissions from naturally regenerated forest land established since 31 December 1989 which has been subsequently deforested in the next annual submission, but at the latest in the 2014 annual submission.	Reject	Australia's implementation of the Deforestation classification is consistent with the requirements documented in the IPCC Supplementary methods and good practice guidance arising from the Kyoto Protocol (IPCC, 2003).

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2013 Draft	The ERT notes that, according with accounting rules established by the Annex to Decision 16.CMP.1, any forest land, regardless of the previous use, that has been cleared after the 31 January 1989 must be reported under the Deforestation activity. The ERT also notes that, although the exclusion of any cleared forest land from the Deforestation reporting results in an underestimation of emissions for which provisions set in the Annex to Decision 20/CMP.1 apply, the application of such provisions would not result in accounting any of those lands currently excluded since the IPCC default methodology operates the same exclusion applied by Australia. Further the ERT notes that, according with information reported by Australia, the exclusion from KP reporting of lands naturally converted to forest after the 31 December 1989 results, under Article 3.3 activities, in an underestimation of removals that is larger, in absolute terms, than the underestimation of emissions associated with the subsequent clearing of some of those lands. Nevertheless, the ERT recommend Australia to enhance the consistency of its accounting with the letter of Decision 16/CMP.1 by reporting under Deforestation each and any cleared forest land since 1990.	Reject	Australia's implementation of the Deforestation classification is consistent with the requirements documented in the IPCC Supplementary methods and good practice guidance arising from the Kyoto Protocol (IPCC, 2003).
	ARR 2013 Draft	The model does not reconcile data on C stock growth, which it simulates, in any X area of forest plantation and data on harvested stock data that come from the statistics of forest plantations. This to ensure that the model does not over-under estimate, systematically, the carbon accumulation associated with forest growth and, consequently the carbon loss associated with harvesting at the end of the cultural cycle The ERT recommends to implement such verification exercise in next inventory.	Accept	Further documentation of this verification was included in Volume 2 of the NIR.

Annexes

ANNEX 7: Uncertainty Analysis

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 usually practical or economic to do so. This leads to estimations based on samples or studies being used which carry a degree of additional uncertainty attached to them. Uncertainty also arises from the limitations of the measuring instruments, and over the complexities of the modelling of key relationships between observed variables and emissions.

The purpose of estimating the uncertainty attached to emissions estimates is principally to provide information on where inventory resources should be allocated to maximise the future improvements to inventory quality.

Assessing uncertainty is, itself, a difficult exercise, especially in the absence of quantitative data. Australia has conducted an uncertainty analysis for the individual sectors in line with the IPCC *Good Practice Guidelines*. Monte Carlo and Latin Hypercube approaches were used to estimate emission uncertainty in some sectors, which is equivalent to the IPCC tier 2 methodology.

The estimates have been mainly prepared by the judgement of the sectoral expert consultants. However, the estimates of uncertainty for the Australian inventory have been reviewed in 2005 by independent experts under protocols developed by the Australian CSIRO Atmospheric Research Division. The CSIRO report confirmed, with one or two exceptions, the quantitative judgements made in relation to uncertainty of inventory estimates and provide a strong basis for confidence in the assessments reported in this chapter.

The uncertainties for individual sectors are reported in more detail below. The estimated uncertainties tend to be low for carbon dioxide from energy consumption as well as from some industrial process emissions. Uncertainty surrounding estimates from these sources are typically as low as ± 4–5%. Uncertainty surrounding estimates of emissions are higher for agriculture, land use change and forestry, reflecting inherently high uncertainty due to the very nature of the processes involved (e.g. biological processes). A medium band of uncertainty applies to estimates from fugitive emissions, most industrial processes and non-CO_2 gases in the energy sector. The ranges presented are broadly consistent with the typical uncertainty ranges expected for each sector, as identified in the IPCC *Good Practice Report*.

The estimates of uncertainty surrounding the emissions estimates for individual sectors may be combined to present an estimate of the overall uncertainty for the inventory as a whole. Following the recommendations of the IPCC *Good Practice Guidance*, the emission estimates across the energy sector have been aggregated because of the hidden dependencies that exist between sectoral activity levels as a result of the constraint of overall consumption and since aggregate fuel consumption is more accurately known than the consumption in individual sectors. The results of the application of the IPCC tier 1 approach to estimating the uncertainty of the inventory as a whole, which identifies separately estimates of uncertainty for both activity and emission factors where available, and which does not account for correlations between variables (unlike some of the sectoral analyses), are presented in Table A7.1.

As indicated in the *IPCC Good Practice Guidance* the tier 1 approach is valid as long as a number of restrictive assumptions are met. An alternative, more flexible approach, which relies on Monte Carlo analysis and a more detailed specification of the sources of uncertainty, is currently under consideration for development by the DE for use in future national inventory reports. This analysis would be equivalent to the IPCC tier 2 approach and would take into consideration a number of refinements proposed by the CSIRO independent review.

The tier 1 results presented in Table A7.1 show the estimated uncertainty surrounding the aggregate inventory estimate for 2012 to be ±2.6%. The reported estimated uncertainty for the trend in emissions is ±3.0%. This estimate has been calculated on the assumption that the total uncertainty for parts of agriculture, land use, land use change and forestry, and the waste sectors are uncorrelated through time.

Much of the uncertainty for the UNFCCC inventory derives from the LULUCF sector. The uncertainty for the aggregate inventory excluding LULUCF is estimated at ±2.2% and the uncertainty in the trend is estimated ±1.5% (Table A7.2).

Table A.7.1: General reporting table for uncertainty (IPCC Good Practice Guidance Reporting Table 6.1) including LULUCF

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2-e	2012 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
1.A. Solid fossil fuels	CO_2	131,738	179,780	0.7	0.7	0.99	0.318	0.082	0.330	0.057	0.3	0.3	1,2
	CH_4	28	38	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	1
	N_2O	442	625	2	20	20.10	0.022	0.000	0.001	0.006	0.0	0.0	1
1.A. Liquid fossil fuels	CO_2	85,999	125,377	2	3	3.61	0.808	0.068	0.230	0.204	0.7	0.7	1
	CH_4	632	423	2	40	40.05	0.030	0.000	0.001	-0.017	0.0	0.0	1
	N_2O	823	1,697	2	60	60.03	0.182	0.002	0.003	0.094	0.0	0.1	1
1.A Gaseous fossil fuels	CO_2	32,915	64,089	2	3	3.61	0.413	0.056	0.117	0.167	0.3	0.4	1
	CH_4	29	237	2	5	5.39	0.002	0.000	0.000	0.002	0.0	0.0	1
	N_2O	20	40	2	20	20.10	0.001	0.000	0.000	0.001	0.0	0.0	1
1.A. Biomass fuels	CH_4	2,037	934	0	20	20.00	0.033	-0.002	0.002	-0.042	0.0	0.0	8
	N_2O	191	190	0	20	20.00	0.007	0.000	0.000	0.000	0.0	0.0	8
1.B.1 Fugitives coal mining	CO_2	1,179	1,568	5	20	20.62	0.058	0.001	0.003	0.013	0.0	0.0	1,3
1.B.1 Fugitives coal mining	CH_4	17,633	25,446	5	20	20.62	0.938	0.014	0.047	0.270	0.3	0.4	1,3
1.B.2 Fugitives oil	CO_2	393	230	5	5	7.07	0.003	0.000	0.000	-0.002	0.0	0.0	1,4
1.B.2 Fugitives Natural gas	CO_2	22	138	10	3	10.44	0.003	0.000	0.000	0.001	0.0	0.0	1,4
1.B.2 Fugitives venting & flaring	CO_2	5,568	6,330	5	5	7.07	0.080	0.001	0.012	0.006	0.1	0.1	1,4
1.B.2 Fugitives oil	CH_4	65	97	5	5	7.07	0.001	0.000	0.000	0.000	0.0	0.0	1,4
1.B.2 Fugitives Natural gas	CH_4	4,320	4,748	10	3	10.44	0.089	0.001	0.009	0.002	0.1	0.1	1,4

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2-e	2012 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
1.B.2 Fugitives venting & flaring	CH_4	2,678	1,334	5	5	7.07	0.017	-0.003	0.002	-0.013	0.0	0.0	1,4
1.B.2 Fugitives oil	N_2O	4	3	2	20	20.10	0.000	0.000	0.000	0.000	0.0	0.0	1
1.B.2 Fugitives Natural gas	N_2O	0	1	2	20	20.10	0.000	0.000	0.000	0.000	0.0	0.0	1
1.B.2 Fugitives venting & flaring	N_2O	32	33	2	20	20.10	0.001	0.000	0.000	0.000	0.0	0.0	1
2.A.1 Cement clinker production	CO_2	3,463	3,518	2.5	2.5	3.54	0.022	0.000	0.006	0.000	0.0	0.0	5
2.A.2 Lime production	CO_2	775	1,305	2.5	2.5	3.54	0.008	0.001	0.002	0.002	0.0	0.0	5
2.A.3 Other Limestone and Dolomite Consumption	CO_2	1,345	1,765	4	2.5	4.72	0.015	0.001	0.003	0.002	0.0	0.0	5
2.B Chemicals	CO_2	1,012	3,145	5	5	7.07	0.040	0.004	0.006	0.019	0.0	0.0	5
	CH_4	9	12	5	5	7.07	0.000	0.000	0.000	0.000	0.0	0.0	5
	N_2O	1,035	2,504	5	5	7.07	0.032	0.003	0.005	0.013	0.0	0.0	6
2.C 1 Steel	CO_2	9,018	6,577	2.5	5	5.59	0.066	-0.005	0.012	-0.024	0.0	0.0	5
	CH_4	59	51	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	5
	N_2O	22	16	2	20	20.10	0.001	0.000	0.000	0.000	0.0	0.0	6
2.C.3 Aluminium	CO_2	2,021	3,194	2.5	2.5	3.54	0.020	0.002	0.006	0.005	0.0	0.0	5
	PFCs	3,950	254	0	27	27.00	0.012	-0.007	0.000	-0.188	0.0	0.2	5
2.C.2 Ferroalloys	CO_2	316	273	2.5	5	5.59	0.003	0.000	0.000	0.000	0.0	0.0	5
2.C.5 Other	CO_2	217	293	2.5	5	5.59	0.003	0.000	0.001	0.001	0.0	0.0	5
2.D Food and drink	CO_2	83	218	0	2.5	2.50	0.001	0.000	0.000	0.001	0.0	0.0	6

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2-e	2012 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
2.F Consumption of HFCs & SF6	HFCs	0	7,945	0	27	27.00	0.401	0.015	0.015	0.411	0.0	0.4	5
	SF_6	221	134	0	27	27.00	0.007	0.000	0.000	-0.004	0.0	0.0	5
2.E Production of HFCs	HFCs	1,126		0	27	27.00	0.000	-0.002	0.000	-0.057	0.0	0.1	5
4.A Enteric fermentation	CH_4			0	27	27.00	0.000	0.000	0.000	0.000	0.0	0.0	6
4.B Manure management	CH_4	63,919	56,216	0	5.5	5.50	0.553	-0.017	0.103	0.000	0.0	0.0	6
	N_2O	1,540	1,676	0	10.5	10.50	0.031	0.000	0.003	0.000	0.0	0.0	6
4.C Rice Cultivation	CH_4	524	1,545	0	10.3	10.30	0.028	0.002	0.003	0.019	0.0	0.0	7
4.D Agricultural Soils	N_2O	490	478	5	10	11.18	0.010	0.000	0.001	0.000	0.0	0.0	7
4.E Burning of Savannas	CH_4	13,382	15,295	0	52	52.00	1.422	0.003	0.028	0.150	0.0	0.2	7
	N_2O	1,450	3,261	18	5	18.68	0.109	0.003	0.006	0.016	0.2	0.2	7
4.F Agricultural Residues	CH_4	193	298	5	20	20.62	0.011	0.000	0.001	0.004	0.0	0.0	7
	N_2O	99	137	5	20	20.62	0.005	0.000	0.000	0.001	0.0	0.0	7
5.A.1 Forest land remaining forest land	CO_2	-45,447	-23,067	0	30	30.00	-1.238	0.043	-0.042	1.295	0.0	1.3	8
	CH_4	1,348	3,284	0	77	77.00	0.452	0.003	0.006	0.268	0.0	0.3	8
	N_2O	368	896	0	88	88.00	0.141	0.001	0.002	0.084	0.0	0.1	8
5.A.2 Land Converted to Forest land	CO_2	-91	-11,528	0	10	10.00	-0.206	-0.021	-0.021	-0.210	0.0	0.2	8
5.B.1 Cropland Remaining Cropland	CO_2	2,864	2,539	0	30	30.00	0.136	-0.001	0.005	-0.022	0.0	0.0	8
5.B.2.1 Forest Land Converted to Croplands	CO_2	29,883	12,126	0	10	10.00	0.217	-0.034	0.022	-0.339	0.0	0.3	8
	CH_4	860	381	0	20	20.00	0.014	-0.001	0.001	-0.018	0.0	0.0	8
	N_2O	392	223	0	20	20.00	0.008	0.000	0.000	-0.007	0.0	0.0	8
5.C.1 Grassland Remaining Grassland	CO_2	35,779	1,405	0	30	30.00	0.075	-0.065	0.003	-1.939	0.0	1.9	8

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2-e	2012 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
5.B.2.1 Forest Land Converted to Grasslands	CO_2	105,661	30,573	0	10	10.00	0.547	-0.142	0.056	-1.423	0.0	1.4	8
	CH_4	2,588	484	0	20	20.00	0.017	-0.004	0.001	-0.080	0.0	0.1	8
	N_2O	706	132	0	20	20.00	0.005	-0.001	0.000	-0.022	0.0	0.0	8
5.G Other	CO_2	-4,878	-2,750	0	20	20.00	-0.098	0.004	-0.005	0.083	0.0	0.1	8
	N_2O	488	462	0	20	20.00	0.017	0.000	0.001	-0.001	0.0	0.0	9
6.A Solid Waste	CH_4	13,188	8,981	0	3.25	3.25	0.052	-0.008	0.016	-0.027	0.0	0.0	5
6.B Wastewater handling	CH_4	3,447	2,201	0	50	50.00	0.197	-0.002	0.004	-0.122	0.0	0.1	5
	N_2O	316	416	0	50	50.00	0.037	0.000	0.001	0.008	0.0	0.0	5
6.C Waste incineration	CO_2	73	30	0	40	40.00	0.002	0.000	0.000	-0.003	0.0	0.0	5
	N_2O	12		0	40	40.00	0.000	0.000	0.000	-0.001	0.0	0.0	6
6.D Waste other	CH_4	7	84	0	100	100.00	0.015	0.000	0.000	0.014	0.0	0.0	
	N_2O	1	11	0	100	100.00	0.002	0.000	0.000	0.002	0.0	0.0	
Total Emissions		**545,495**	**558,809**										
Total Uncertainties							**2.6**					**3.0**	

1 Energy Strategies; 2. NGER; 3. Dr David Williams, CSIRO; 4 Australian Petroleum Production & Exploration Association; 5 Burnbank Consulting; 6 Dr Mark Howden, CSIRO; 7. Dr Carl Meyer, CSIRO; 8. Dr Gary Richards, Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Table A.7.2: General reporting table for uncertainty (IPCC Good Practice Guidance Reporting Table 6.1) excluding LULUCF

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data Uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2e	2012 Gg CO_2e	%	%	%	%	%	%	%	%	%	
1.A. Solid fossil fuels	CO_2	131,738	179,780	0.7	0.7	0.99	0.327	0.017	0.433	0.012	0.4	0.4	1,2
	CH_4	28	38	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	1
	N_2O	442	625	2	20	20.10	0.023	0.000	0.002	0.002	0.0	0.0	1
1.A. Liquid fossil fuels	CO_2	85,999	125,377	2	3	3.61	0.831	0.030	0.302	0.091	0.9	0.9	1
	CH_4	632	423	2	40	40.05	0.031	-0.001	0.001	-0.039	0.0	0.0	1
	N_2O	823	1,697	2	60	60.03	0.187	0.001	0.004	0.089	0.0	0.1	1
1.A Gaseous fossil fuels	CO_2	32,915	64,089	2	3	3.61	0.425	0.050	0.154	0.151	0.4	0.5	1
	CH_4	29	237	2	5	5.39	0.002	0.001	0.001	0.003	0.0	0.0	1
	N20	20	40	2	20	20.10	0.001	0.000	0.000	0.001	0.0	0.0	1
1.A. Biomass fuels	CH_4	2,037	934	0	20	20.00	0.034	-0.004	0.002	-0.084	0.0	0.1	8
	N_2O	191	190	0	20	20.00	0.007	0.000	0.000	-0.003	0.0	0.0	8
1.B.1 Fugitives coal mining	CO_2	1,179	1,568	5	20	20.62	0.059	0.000	0.004	0.001	0.0	0.0	1,3
1.B.1 Fugitives coal mining	CH_4	17,633	25,446	5	20	20.62	0.964	0.006	0.061	0.112	0.4	0.4	1,3
1.B.2 Fugitives oil	CO_2	393	230	5	5	7.07	0.003	-0.001	0.001	-0.003	0.0	0.0	1,4
1.B.2 Fugitives Natural gas	CO_2	22	138	10	3	10.44	0.003	0.000	0.000	0.001	0.0	0.0	1,4
1.B.2 Fugitives venting & flaring	CO_2	5,568	6,330	5	5	7.07	0.082	-0.002	0.015	-0.012	0.1	0.1	1,4
1.B.2 Fugitives oil	CH_4	65	97	5	5	7.07	0.001	0.000	0.000	0.000	0.0	0.0	1,4
1.B.2 Fugitives Natural gas	CH_4	4,320	4,748	10	3	10.44	0.091	-0.002	0.011	-0.007	0.2	0.2	1,4

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data Uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2e	2012 Gg CO_2e	%	%	%	%	%	%	%	%	%	
1.B.2 Fugitives venting & flaring	CH_4	2,678	1,334	5	5	7.07	0.017	-0.005	0.003	-0.026	0.0	0.0	1,4
1.B.2 Fugitives oil	N_2O	4	3	2	20	20.10	0.000	0.000	0.000	0.000	0.0	0.0	1
1.B.2 Fugitives Natural gas	N_2O	0	1	2	20	20.10	0.000	0.000	0.000	0.000	0.0	0.0	1
1.B.2 Fugitives venting & flaring	N_2O	32	33	2	20	20.10	0.001	0.000	0.000	0.000	0.0	0.0	1
2.A.1 Cement clinker production	CO_2	3,463	3,518	2.5	2.5	3.54	0.023	-0.002	0.008	-0.006	0.0	0.0	5
2.A.2 Lime production	CO_2	775	1,305	2.5	2.5	3.54	0.008	0.001	0.003	0.002	0.0	0.0	5
2.A.3 Other Limestone and Dolomite Consumption	CO_2	1,345	1,765	4	2.5	4.72	0.015	0.000	0.004	0.000	0.0	0.0	5
2.B Chemicals	CO_2	1,012	3,145	5	5	7.07	0.041	0.004	0.008	0.022	0.1	0.1	5
	CH_4	9	12	5	5	7.07	0.000	0.000	0.000	0.000	0.0	0.0	5
	N_2O	1,035	2,504	5	5	7.07	0.033	0.003	0.006	0.014	0.0	0.0	6
2.C 1 Steel	CO_2	9,018	6,577	2.5	5	5.59	0.068	-0.013	0.016	-0.063	0.1	0.1	5
2.C.1 Steel	CH_4	59	51	2	5	5.39	0.001	0.000	0.000	0.000	0.0	0.0	5
2.C.1 Steel	N_2O	22	16	2	20	20.10	0.001	0.000	0.000	-0.001	0.0	0.0	6
2.C.3 Aluminium	CO_2	2,021	3,194	2.5	2.5	3.54	0.021	0.001	0.008	0.003	0.0	0.0	5
2.C.3 Aluminium	PFCs	3,950	254	0	27	27.00	0.013	-0.012	0.001	-0.320	0.0	0.3	5
2.C.2 Ferroalloys	CO_2	316	273	2.5	5	5.59	0.003	0.000	0.001	-0.002	0.0	0.0	5
2.C.5 Other	CO_2	217	293	2.5	5	5.59	0.003	0.000	0.001	0.000	0.0	0.0	5
2.D Food and drink	CO_2	83	218		2.5	2.50	0.001	0.000	0.001	0.001	0.0	0.0	6

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data Uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2e	2012 Gg CO_2e	%	%	%	%	%	%	%	%	%	
2.F Consumption of HFCs & SF6	HFCs	0	7,945	0	27	27.00	0.412	0.020	0.020	0.540	0.0	0.5	5
2.F Consumption of HFCs & SF6	SF6	221	134	0	27	27.00	0.007	0.000	0.000	-0.009	0.0	0.0	5
2.E Production of HFCs	HFCs	1,126	0	0	27	27.00	0.000	-0.004	0.000	-0.096	0.0	0.1	5
2.E Production of SF6	SF_6	0	0	0	27	27.00	0.000	0.000	0.000	0.000	0.0	0.0	5
4.A Enteric fermentation	CH_4	63,919	56,216	0	5.5	5.50	0.568	-0.066	0.135	0.000	0.0	0.0	6
4.B Manure management	CH_4	1,540	1,676	0	10.5	10.50	0.032	-0.001	0.004	0.000	0.0	0.0	6
4.B Manure management	N_2O	524	1,545	0	10.3	10.30	0.029	0.002	0.004	0.021	0.0	0.0	6
4.C Rice Cultivation	CH_4	490	478	5	10	11.18	0.010	0.000	0.001	-0.004	0.0	0.0	7
4.D Agricultural Soils	N_2O	13,382	15,295	0	52	52.00	1.462	-0.005	0.037	-0.282	0.0	0.3	7
4.E Burning of Savannas	CH_4	4,909	8,454	18	14	22.80	0.354	0.005	0.020	0.068	0.5	0.5	7
4.E Burning of Savannas	N_2O	1,450	3,261	18	5	18.68	0.112	0.003	0.008	0.016	0.2	0.2	7
4.F Agricultural Residues	CH_4	193	298	5	20	20.62	0.011	0.000	0.001	0.002	0.0	0.0	7
4.F Agricultural Residues	N_2O	99	137	5	20	20.62	0.005	0.000	0.000	0.000	0.0	0.0	7
6.A Solid Waste	CH_4	13,188	8,981	0	3.25	3.25	0.054	-0.020	0.022	-0.065	0.0	0.1	5
6.B Wastewater handling	CH_4	3,447	2,201	0	50	50.00	0.202	-0.006	0.005	-0.279	0.0	0.3	5

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions	Year t emissions	Activity data Uncert'y	Emission factor uncert'y	Combined uncert'y	Uncert'y in total inventory	Type A Sensit'y	Type B Sensit'y	Uncert'y in trend of EF	Uncert'y in trend of activity data	Uncert'y in trend of total emissions	footnote ref no.
		1990 Gg CO_2e	2012 Gg CO_2e	%	%	%	%	%	%	%	%	%	
6.B Wastewater handling	N_2O	316	416	0	50	50.00	0.038	0.000	0.001	0.000	0.0	0.0	5
6.C Waste incineration	CO_2	73	30	0	40	40.00	0.002	0.000	0.000	-0.006	0.0	0.0	5
6.C Waste incineration	N_2O	12	0	0	40	40.00	0.000	0.000	0.000	-0.001	0.0	0.0	6
6.D Waste other	CH_4	7	84	0	100	100.00	0.016	0.000	0.000	0.018	0.0	0.0	
Total Emissions		**414,974**	**543,648**										
Total Uncertainties							**2.2**					**1.5**	

1 Energy Strategies; 2. NGER; 3. Dr David Williams, CSIRO; 4 Australian Petroleum Production & Exploration Association; 5 Burnbank Consulting; 6 Dr Mark Howden, CSIRO; 7. Dr Carl Meyer, CSIRO; 8. Dr Gary Richards, Department of Climate Change and Energy Efficiency.

Energy

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 A7.3). The overall uncertainty in estimated emissions from *electricity generation* was ±1%. 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.

Australia has investigated the use of NGER uncertainty data in the national inventory uncertainty estimates. Uncertainty data is currently reported by companies under NGER at the corporation level. Therefore for many sectors it is difficult to identify the uncertainty associated with individual sources as company's emissions result from many sources. The sector where NGER uncertainty data is most easily applied is in the electricity generation sector. The emission profile for corporations in this sector are dominated by emissions associated with electricity generation and it is possible to apply the NGER data directly.

Under NGER CO_2 emissions from the combustion of coal or gas for electricity generation must be estimated using facility specific measurements. The use of facility specific measurements based on sampling and analysis of fuels results in relatively low uncertainty estimates as published in table A7.3.

The electricity uncertainty estimates have been applied in tables A.7.1 and A.7.2 to sector 1.A. Solid fossil fuels where the electricity sector is the dominant source. Uncertainty has been equally split between activity data and emission factor uncertainty as data on the composition of total uncertainty is not available under NGER. Australia will review uncertainty estimates reported under NGER and the incorporation of this data into the national uncertainty estimates further in the next annual inventory submission.

Table A.7.3: Quantified uncertainty values for key stationary energy subcategories

Greenhouse gas source and sink category	Uncertainty (%)[(a)]			
	CO_2	CH_4	N_2O	Total CO_2-e
1. ENERGY				
A Fuel combustion activities				
1.A.1.a Electricity	**±1**	**±9**	**±15**	**±1**
Black coal	±2	±9	±15	±2
Brown coal	±1	±9	±15	±1
Petroleum	±4	±9	±7	±4
Natural gas	±2	±9	±16	±2
Biomass	NA	±9	±4	±4
Biogas	NA	±9	±16	±4
1.A.1.b Petroleum refining	**±4**	**±9**	**±12**	**±4**
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**
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 and preliminary estimates for electricity incorporating NGER uncertainty estimates

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 A.7.4: Quantified uncertainty values for mobile source categories

Greenhouse gas source and sink category	Uncertainty (%)[(a)]		
	CO_2	CH_4	N_2O
1.A.4. Other sectors			
b. Residential			
Lawn mowers	±24.5	±45.2	±46.3
1.A.5. Other			
b. Mobile	**±16.4**	**±25.4**	**±44.7**
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.

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 judgment.

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.

The estimates also reflect the relatively higher uncertainty attached to the emission estimates for particular vehicle types, which are drawn from ABS data and its survey of motor vehicle use, than for the sector as a whole. This outcome reflects the dependency between activity variables; and because overall transport fuel consumption is more accurately known than the individual segments.

Table A.7.5: Emissions and quantified uncertainty values for key transport subcategories

Greenhouse gas source and sink category	Uncertainty (%)[a]		
	CO_2	CH_4	N_2O
1.A.3. Transport	**±4**	**±24**	**±42**
a. Civil aviation	**±9**	**±52**	**±52**
b. Road transport	**±4**	**±25**	**±42**
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**
d. Navigation	**±8**	**±59**	**±32**
e. Other transportation	**±24**	**±46**	**±63**
International bunkers			
Aviation	±10	±58	±59
Marine	±4	±47	±52

(a) Uncertainty reported at 95% confidence limits.

Fugitives

The overall uncertainty for *fugitive* emissions was estimated to be ±11% (Table A7.6). 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 A.7.6: Quantified uncertainty values for key fugitive emissions subcategories

Greenhouse gas source and sink category	Uncertainty (%)[a]			
	CO_2	CH_4	N_2O	CO_2-e
1. ENERGY				
B. Fugitive emissions	**±4**	**±14**	**±4**	**±11**
1.B.1. Solid fuels	**NE**	**±19**	**NE**	**±19**
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**
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.

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 (Latin Hypercube simulations). Uncertainty estimates of the components of each emission estimate (activity levels and emission factors) are based on expert judgement.

As the IPCC tier 1 approach is not suitable for assessing uncertainty where approximately normal distribution assumptions cannot be sustained, an analysis was undertaken using 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 Latin Hypercube analysis gave an uncertainty of ±5% (Table A7.7). The uncertainty in the *industrial processes* subsectors ranged from ±4% to ±20%.

Table A.7.7: Quantified uncertainty values for key industrial processes subsectors using different techniques

Source	Uncertainties and distribution[a]		Emission factors - uncertainties and distributions								
	Production/ use	Distribution	CO_2	Distribution	CH_4	Distribution	N_2O	Distribution	CF_4	Distribution	C_2F_6
Cement clinker	±5.00	Normal	±4.99	Normal	NA	NA	NA	NA	NA	NA	NA
Cement kiln dust	±7.01	Normal	±5.01	Normal	NA	NA	NA	NA	NA	NA	NA
Cement total organic carbon	NA	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Commercial lime	±5.00	Normal	±4.99	Normal	NA	NA	NA	NA	NA	NA	NA
In-house lime	±4.01	Normal	±5.01	Normal	NA	NA	NA	NA	NA	NA	NA
Limestone use	±8.01	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Dolomite use	±8.00	Normal	±4.99	Normal	NA	NA	NA	NA	NA	NA	NA
Soda ash production	±5.00	Normal	NA	Stoichiometry	NA	NA	NA	NA	NA	NA	NA
Soda ash use	±5.00	Normal	NA	Stoichiometry	NA	NA	NA	NA	NA	NA	NA
Magnesia	±5.00	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Ammonia	±7.02	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Nitric acid	±10.00	Normal	NA	NA	NA	NA	±9.99	Normal	NA	NA	NA
Nitrous oxide	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Synthetic rutile	±5.00	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Titanium dioxide	±20.00	Normal	±5.00	Normal	NA	NA	NA	NA	NA	NA	NA
Iron and steel	±5.01	Normal	±2.05	Triangular	±3.82	Triangular	±16.33	Triangular	NA	NA	NA
Hot briquetted iron	±5.00	Normal	±4.08	Triangular	±4.34	Triangular	±9.07	Triangular	NA	NA	NA
Aluminium	±5.01	Normal	±5.00	Normal	NA	NA	NA	NA	±16.22	Triangular	Function of CF_4

(a) Uncertainty reported at 95% confidence limits assuming approximately normal distributions. Source: Burnbank Consulting 2007.

Agriculture

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 (Table A7.10). 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 A7.8) 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 A.7.8: Relative uncertainty in emission estimates for the livestock subsector

Greenhouse gas source and sink categories	Uncertainty (%)[a]	
	CH_4	N_2O
A. Enteric fermentation	–5.1 to +5.9	
B. Manure management	–9.8 to +11.1	–10.1 to +10.6

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

Other Agriculture

Estimates of uncertainties in the emissions for the *other agriculture* subsectors were determined using a Latin Hypercube analysis (Table A7.9). 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 (Table A7.10). 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.

There is large relative uncertainty in the emission estimates from all subcategories, including approximately –40 to +60% for methane in the *field burning of residues* subsector and approximately –50 to +100% 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 relatively minor contributor to overall uncertainty. Partly 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 A.7.9: Relative uncertainty in emission estimates for other agriculture subsectors

Greenhouse gas source and sink categories	Uncertainty (%)[a]	
	CH_4	N_2O
4. AGRICULTURE		
C. Rice cultivation	**–20 to 23**	
1. Irrigated	–20 to 23	
D. Agricultural soils		**–46 to 97**
1. Direct soil emissions		–30 to 40
2. Animal production		–53 to 90
3. Indirect		–67 to 156
E. Prescribed burning of savannas	**–28 to 29**	**–29 to 33**
F. Field Burning of agricultural residues	**–41 to 58**	**–39 to 56**
1. Cereals	–45 to 68	–45 to 69
2. Pulse	–59 to 100	–60 to 98
3. Tuber and root	NO	NO
4. Sugar cane	–42 to 62	–46 to 74
5. Other	–57 to 96	–59 to 104

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

Table A.7.10: Probability density functions used in the uncertainty analysis for agriculture subsectors

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4AB	Enteric/ Manure Mgt	Beef cattle		Animal Numbers	Proportional change	Triangle	1	1.15	0.95	
4AB	Enteric/ Manure Mgt	Dairy Cattle		Animal Numbers	Proportional change	Triangle	1	1.10	0.95	
4AB	Enteric/ Manure Mgt	Feedlot Cattle		Animal Numbers	Proportional change	Triangle	1	1.20	0.8	
4AB	Enteric/ Manure Mgt	Dairy Cattle		Milk Production	Proportional change	Triangle	1	1.1	0.95	
4AB	Enteric/ Manure Mgt	Sheep		Wool Production	Proportional change	Triangle	1	1.1	0.95	
4AB	Enteric/ Manure Mgt	Beef Cattle and Sheep	ACT, NSW, SA, TAS, VIC, WA (Pilbara and South-West)	DMD and CP	Proportional change	Triangle				
					Spring		1	1.24	0.82	
					Summer		1	1.12	0.77	
					Autumn		1	1.12	0.83	
					Winter		1	1.10	0.82	
4AB	Enteric/ Manure Mgt	Beef Cattle and Sheep	QLD, NT and WA (Kimberley)	DMD and CP	Proportional change	Triangle				
					Spring		1	1.07	0.86	
					Summer		1	1.15	0.82	
					Autumn		1	1.15	0.77	
					Winter		1	1.11	0.71	
4AB	Enteric/ Manure Mgt	Dairy Cattle		DMD and CP	Proportional change	Triangle	1	1.15	0.8	
4AB	Enteric/ Manure Mgt	Beef Cattle and Sheep		Liveweight	Proportional Change	Triangle	1	1.25	0.85	
4AB	Enteric/ Manure Mgt	Dairy Cattle		Liveweight	Proportional Change	Triangle	1	1.15	0.85	

Sector name		Source Category	Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4AB	Enteric/ Manure Mgt	Feedlot Cattle	Liveweight	Proportional Change	Triangle	1	1.1	0.9	
4AB	Enteric/ Manure Mgt		Liveweight Gain	Proportional Change	Triangle	1	1.25	0.75	
4AB	Enteric/ Manure Mgt	Beef Cattle	Increase in DMI with milk production in season of birth	Proportional change	Triangle	1.3	1.4	1.2	
4AB	Enteric/ Manure Mgt	Beef Cattle	Increase in DMI with milk production in season following birth	Proportional change	Triangle	1.1	1.16	1.06	
4AB	Enteric/ Manure Mgt	Dairy Cattle	Increase in DMI with milk production	Proportional change	Triangle	1	1.2	0.8	
4AB	Enteric/ Manure Mgt	Sheep	Increase in DMI with milk production in season of birth	Proportional change	Triangle	1.3	1.4	1.2	
4AB	Enteric/ Manure Mgt	Beef and Dairy Cattle	DMI		1.1349 (0.0845)*DMI-0.6457 (0.4064) with a correlation between the slope and intercept of –0.969[(a)]				
4AB	Enteric/ Manure Mgt	Feedlot Cattle	DMI	Proportional change	Triangle	1	1.2	0.9	
4AB	Enteric/ Manure Mgt	Sheep	DMI	Proportional change	Triangle	1	1.05	0.95	
4AB	Enteric/ Manure Mgt	Pigs	DMI	Proportional change	Triangle	1	1.1	0.9	

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4AB	Enteric/ Manure Mgt	Beef and dairy cattle		Blaxter and Clapperton (1965)		1.48 (1.01)*RI+0.0769 (0.0247) DMI -0.0296 (0.0152) RI*DMI +2.15 (1.56). Correlation matrix for factors detailed below [(a)(b)].				
4A	Enteric Fermentation	Beef Cattle	Tropical	Kurihara et al (1999)		41.4991 (3.2866) * DMI -36.3737 (18.5316) with a correlation between intercept and slope of -0.944[(a)]				
4A	Enteric Fermentation	Feedlot Cattle		Methane Emissions	Proportional change	Normal	1			0.15
4A	Enteric Fermentation	Sheep		Howden et al (1994)		0.018252 (0.000927)*DMI +0.0018 (0.0008555) with a correlation between intercept and slope of –0.969[(a)]				
4A	Enteric Fermentation	Pigs		Methane Emissions	Proportional change	Triangle	1	1.2	0.8	
4A	Enteric Fermentation	Other		Emission Factors	Proportional change	Triangle	1	1.25	0.75	
4B	Manure Management	All Animals		Methane Emissions	Proportional change	Triangle	1	1.3	0.7	
4B	Manure Management	All Animals		N excretion	Proportional change	Triangle	1	1.3	0.7	
4B	Manure Management	All Animals		Nitrous Oxide Emissions	Proportional change	Triangle	1	1.3	0.7	

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4C	Rice Cultivation	Irrigated Rice		Area	Ha	normal				0.05
4C	Rice Cultivation	Irrigated Rice		CH_4 emission factor	Kg CH_4 -C/ha	lognormal	225			0.10
4D	Agricultural Soils	1. Direct emissions	Synthetic fertiliser	Total fertiliser used	Gg N	normal				0.10
4D	Agricultural Soils	1. Direct emissions	Synthetic fertiliser	Fraction used in each state	dimensionless	normal				0.10
4D	Agricultural Soils	1. Direct emissions	Synthetic fertiliser	Fraction used in each crop class	dimensionless	normal				0.10
4D	Agricultural Soils	1. Direct emissions	Synthetic fertiliser	N_2O emission factor	Gg N_2O-N/Gg N	lognormal	Table 6.22	-	-	0.50
4D	Agricultural Soils	1. Direct emissions	Animal waste	Manure used	Gg N	triangular		10%	-30%	
4D	Agricultural Soils	1. Direct emissions	Animal waste	N_2O emission factor	Gg N_2O-N/Gg N	lognormal	0.01			0.50
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	State annual crop production	Gg	normal				0.05
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	N_2O emission factor		lognormal	0.0125			0.50
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	carbon mass fraction in crop residues	dimensionless	truncated normal	Appendix 6.I.1	1	0	0.10
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	dry matter content	dimensionless	truncated normal	Appendix 6.I.1	1	0	0.10
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	Fraction-removed	dimensionless	truncated lognormal	Appendix 6.I.1	1	0	0.20
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	Fraction-burned	dimensionless	truncated lognormal	Appendix 6.I.1,2	1	0	0.20
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	N:C ratio in crop residue	dimensionless	truncated normal	Appendix 6.I.1	1	0	0.10

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4D	Agricultural Soils	1. Direct emissions	Crop Residues/ N Fixing	residue to crop ratio	dimensionless	lognormal	Appendix 6.I.1			0.10
4D	Agricultural Soils	1. Direct emissions	Histosols	State area of cultivated histosols	Gg	normal				0.50
4D	Agricultural Soils	1. Direct emissions	Histosols	Nitrous Oxide emissions factor	kg N_2O-N/ha	lognormal	8			0.50
4D	Agricultural Soils	2. Animal Production	N Excretion on Pasture Range and Paddock	Urinary N to agricultural soils	Gg N	triangular		10%	-30%	
4D	Agricultural Soils	2. Animal Production	N Excretion on Pasture Range and Paddock	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.004			0.50
4D	Agricultural Soils	2. Animal Production	N Excretion on Pasture Range and Paddock	Faecal N to agricultural soils	Gg N	triangular		10%	-30%	
4D	Agricultural Soils	2. Animal Production	N Excretion Pasture Range and Paddock	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.005			0.50
4D	Agricultural Soils	3. Indirect	Atmospheric Deposition	Fraction of N fertiliser volatilised						
4D	Agricultural Soils	3. Indirect	Atmospheric Deposition	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.01			0.50
4D	Agricultural Soils	3. Indirect	Atmospheric Deposition	Mass of N deposited volatilised	Gg N	triangular		10%	-30%	
4D	Agricultural Soils	3. Indirect	Atmospheric Deposition	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.01			0.50
4D	Agricultural Soils	3. Indirect	Atmospheric Deposition	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.01			0.50
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Fraction of N available for leaching and runoff	% N deposited	truncated normal		100	0	0.10

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Fraction of available N leached	dimensionless	normal	0.3			0.50
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Nitrous oxide emission factor	g N_2O-N/g N	lognormal	0.0125			0.50
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Total animal N deposited	Gg	triangular		10%	-30%	
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Fraction of N available for leaching and runoff	% N deposited	truncated normal		100	0	0.10
4D	Agricultural Soils	3. Indirect	N Leaching and Run-Off	Fraction of available N leached	dimensionless	normal	0.3			0.50
4E	Savanna Burning			Area	ha	lognormal	Annual Activity			0.1
4E	Savanna Burning	Early Dry Season		Patchiness		Triangle	1	1	0	
		Late Dry Season		Patchiness		Triangle	1	1	0.8	
4E	Savanna Burning	Low severity	fine	BEF		Logistic	0.69			0.06
			coarse	BEF		Logistic	0.06			0.49
			heavy	BEF		Logistic	0.12			0.07
			shrub	BEF		Logistic	0.27			0.20
4E	Savanna Burning	moderate severity	fine	BEF		Logistic	0.84			0.07
			coarse	BEF		Logistic	0.34			0.36
			heavy	BEF		Logistic	0.20			0.38
			shrub	BEF		Logistic	0.24			0.09
4E	Savanna Burning	high severity	fine	BEF		Logistic	0.97			0.003

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
			coarse	BEF		Logistic	0.58			0.06
			heavy	BEF		Logistic	0.58			0.11
			shrub	BEF		Logistic	0.68			0.06
4E	Savanna Burning			Fire Intensity Distribution		Truncated Normal	Table 6.41	1	0	0.2
4E	Savanna Burning			Carbon content		Normal	Table 6.43	1	0	0.02
4E	Savanna Burning			N:C ratios		Normal	Table 6.44	1	0	0.1
4E	Savanna Burning	EOF	Coarse	Fuel Loads		Lognormal	1.43			0.11
			Heavy	Fuel Loads		Lognormal	4.81			0.54
			Shrubs	Fuel Loads		Lognormal	1.46			0.20
		EW	Coarse	Fuel Loads		Lognormal	0.90			0.09
			Heavy	Fuel Loads		Lognormal	2.18			0.36
			Shrubs	Fuel Loads		Lognormal	0.49			0.05
		SW	Coarse	Fuel Loads		Lognormal	0.58			0.08
			Heavy	Fuel Loads		Lognormal	1.68			0.30
			Shrubs	Fuel Loads		Lognormal	1.77			0.33
		SH	Coarse	Fuel Loads		Lognormal	1.23			0.18
			Heavy	Fuel Loads		Lognormal	3.42			0.67
			Shrubs	Fuel Loads		Lognormal	1.71			0.18

Sector name		Source Category		Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4E	Savanna Burning	EOF,EOW,SW	Fine	CH_4 emission factor		Truncated Normal	0.0031	0.05	0	0.06
			Coarse	CH_4 emission factor		Truncated Normal	0.0031	0.05	0	0.06
			Heavy	CH_4 emission factor		Truncated Normal	0.0101	0.05	0	0.23
			Shrubs	CH_4 emission factor		Truncated Normal	0.0031	0.05	0	0.06
		Sandstone heath	Fine	CH_4 emission factor		Truncated Normal	0.0015	0.05	0	0.16
			Coarse	CH_4 emission factor		Truncated Normal	0.0015	0.05	0	0.16
			Heavy	CH_4 emission factor		Truncated Normal	0.0101	0.05	0	0.23
			Shrubs	CH_4 emission factor		Truncated Normal	0.0015	0.05	0	0.16
		Rangeland	Grass	CH_4 emission factor		Truncated Normal	0.0012	0.05	0	0.08
		EOF,EOW,SW	Fine	N_2O emission factor		Truncated Normal	0.0075	0.015	0	0.03
			Coarse	N_2O emission factor		Truncated Normal	0.0075	0.015	0	0.03
			Heavy	N_2O emission factor		Truncated Normal	0.0036	0.015	0	0.19
			Shrubs	N_2O emission factor		Truncated Normal	0.0075	0.015	0	0.03
		Sandstone heath	Fine	N_2O emission factor		Truncated Normal	0.0066	0.015	0	0.03
			Coarse	N_2O emission factor		Truncated Normal	0.0066	0.015	0	0.03
			Heavy	N_2O emission factor		Truncated Normal	0.0036	0.015	0	0.14
			Shrubs	N_2O emission factor		Truncated Normal	0.0066	0.015	0	0.03
		Rangeland	Grass	N_2O emission factor		Truncated Normal	0.0066	0.015	0	0.03

Sector name		Source Category	Data	Unit/ Measure	Distribution	Mean/ most likely value	Max	Min	CV/ SE
4F	Field Burning Agric Residues		fraction of crop residue remaining at time of burning	dimensionless	truncated lognormal	Appendix 6.I.1	1	0	0.20
4F	Field Burning Agric Residues		Burning efficiency	dimensionless	truncated normal	0.96	1	0.8	0.05
4F	Field Burning Agric Residues		Methane emission factor	Gg CH_4-C/Gg C	lognormal	0.0035			0.20
4F	Field Burning Agric Residues		CO emission factor	Gg CO-C/Gg C	lognormal	0.078			0.20
4F	Field Burning Agric Residues		VOC emission factor	Gg NMVOC-C/Gg C	lognormal	0.0091			0.20
4F	Field Burning Agric Residues		N_2O emission factor	Gg N_2O-N/Gg N	lognormal	0.0076			0.20
4F	Field Burning Agric Residues		NO_x emission factor	Gg NO_x-N/Gg N	lognormal	0.21			0.20

Notes: (a) The figures in brackets are the standard deviation of a normal distribution around the mean figure for the slope or intercept. The correlation is included as the slope and intercept vary with each other given uncertainty in both.

(b)

	RI	DMD	Interaction	Intercept
RI	1	0.813	-0.988	-0.842
DMD	0.813	1	-0.843	-0.985
Interaction	-0.988	-0.843	1	0.85
Intercept	-0.842	-0.985	0.85	1

Land Use, Land Use Change and Forestry

Australia's uses tier 3 methods (ecosystem model) of emissions estimation and an Approach 3 (full spatial enumeration) method of representing land (IPCC 2003) for most of the LULUCF sector. Unlike the tier 1 and tier 2 methods, tier 3 uses complex modelling to estimate emissions in a way that fully represents both annual and spatial variability. Tier 3 and Approach 3 methods were chosen because the causes of most emissions in Australia (forest conversion) are from rare events (a small fraction of the forest estate). Tier 3 methods allow more complex forms of sensitivity and uncertainty analysis, and in concert with verification activities give an ability to identify any potential bias.

The verification processes focus on the detailed checking of land areas and modelled emissions estimates. That is, testing of results is typically against actual measures that have a 'certain' outcome. The benefits of verification by direct measurement are, first, the detailed data derived can be used to determine the model and land area estimation performances in general (e.g. by region, soil type, vegetation type) and in detail, for example, by carbon pool (e.g. litter, fast turnover soil organic matter). Second, having actual measures allows for continuous improvement whereby the verification data can subsequently be used to enhance calibration, which is then tested again in subsequent verification. This ensures a growing base of data for model calibration while also ensuring that calibration and verification data remain independent.

Extensive independent verification programs of the land cover change and plantation mapping via remote sensing techniques have been continuously applied throughout the time-series updates. The methods applied to verification of the land cover change results are published in the NCAS Technical Reports (Lowell *et al.* 2003 and Jones *et al.* 2004) and in peer review literature (Lowell *et al.* 2005). This program initially relied on verification against historic air photographs, and more recently, by using very high resolution satellite data (1m). The verification of the plantations mapping (MBAC Consulting *in prep.*) was based on on-site field inspection. This alternative approach was used because it was able to provide a definite date of planting (from signage or company records) and could accurately provide parameters such as species, stocking rate, condition etc. that could not be derived with certainty from remote techniques. This program was based on several hundred sites throughout Australia, selected to be representative of geographic regions, plantation types and plantation ages.

The direct measurement of forest biomass is rare, and as destructive sampling is required, no time-series growth data based on whole mass measurement is available. However, through the use of allometric equations from measurable forest stand parameters of basal area, height etc. it is possible to model total stand biomass. As these measures are widely used in a forest inventory, there is a wealth of industry data available at both a single point in time and time-series (permanent plot) measurements against which growth and biomass estimates have been verified. In addition, research site data comparisons and select whole-stand mass measurements have been applied. The benefits of comparisons with research data has been that additional to commonly available stand biomass estimates are data on site conditions and management. Because of the cost and logistical difficulty in actually measuring total stand biomass, the approach taken was to destructively sample and weigh forest plots of a single species across a productivity gradient (Ximenes *et al.* 2005). This approach could then test both the biomass predictions and replication of the gradient in forest productivity and carrying capacity by model estimates.

Much like the verification activities for forest biomass, a tiered approach was applied to the verification of modelled soil carbon change estimates. Most geographically widespread and representative data were taken from paired site samples, before and after land use change. The change in total soil organic carbon was compared to modelled estimates. Soil fractionations were also completed to test the model performance in predicting turnover in various soil carbon pools. Wherever possible, models were also compared to research site data (Skjemstad and Spouncer 2002). This again had the benefit of multiple pool, time-series measurements for comparison, along with the recorded impacts of detailed site condition and management.

The methods of uncertainty analysis described by the IPCC *Good Practice Guidance* 2003 are typically designed for tier 1 and tier 2 emissions factor based approaches. More complex methods for dealing with potential error propagation and inter-correlation of parameter uncertainties needs to be applied to the process model forms of inventory used in tier 3. However, the fundamental approach of using *Monte Carlo* forms of analysis for both sensitivity and uncertainty analysis remains relevant and are applied.

Sensitivity and uncertainty analyses are used to determine:

- that the best estimate (most likely outcome) is not subject to bias;
- the parameter sensitivity, in order to understand the drivers of uncertainty and guide improvement programs and verification priorities; and,
- to determine the probability distribution of possible outcomes.

The sensitivity and uncertainty analyses undertaken are described in detail in each of the methods Appendices 7.B, 7.C and 7.D. To enable these analyses a *Monte Carlo* analysis capability has been integrated into the modelling framework and is routinely applied.

Uncertainty analyses using *Monte Carlo* techniques are also supplemented by the determination of accuracies of spatial data through verification programs. Verification can also be used to identify if there is any potential bias in the spatial inputs to the emissions modelling.

Table A.7.11: Estimation of uncertainties in components of the land use change and forestry subsectors

Greenhouse gas source and sink categories	Uncertainty (%)		
	CO_2	CH_4	N_2O
A.1 Forest land remaining forest land	± 30	-46 +77	-47 +88
A.2 Land converted to forest land	± 10		
B.1/C.1 Cropland/Grassland remaining	± 30		
B. 2/C.2 Forest land converted to Cropland/Grassland	± 10	± 20	± 20

Waste

Estimates for uncertainty for emissions from solid waste disposal were estimated by Burnbank Consulting. The full implications of non-linearities in the solid waste methodology are still to be satisfactorily explored, however, and further work into the solid waste estimates are likely in future.

Table A.7.12: Relative uncertainty in emission estimates for key waste subsectors

Greenhouse gas source and sink categories	Uncertainty (%)				
	CH_4	N_2O	NO_x	CO	NMVOC
6. Waste					
A. Solid waste disposal on land a	± 3.25	NA	NA	NA	NA
B. Wastewater	± 50				
C. Incineration	NA				

a Source Burnbank Consulting 2007

Annexes

Table A.7.13: Specific distributions, parameters and results: Solid Waste

Variable	Distribution and parameters	2sd	M-2sd	M+2sd	2sd/M	M-/2.5%	M+/97.5%
Emission Generated / 2004 - ACT		0.70	12.85	14.26	5.19%	1.00	1.00
Emission Generated / 2004 - NSW		16.55	277.85	310.95	5.62%	1.00	1.00
Emission Generated / 2004 - NT		0.26	4.63	5.14	5.26%	1.00	1.00
Emission Generated / 2004 - QLD		7.84	163.61	179.30	4.57%	1.00	1.00
Emission Generated / 2004 - SA		4.92	45.95	55.79	9.68%	1.00	1.00
Emission Generated / 2004 - TAS		1.72	15.75	19.19	9.84%	1.00	1.01
Emission Generated / 2004 - VIC		16.57	163.14	196.29	9.22%	1.00	1.00
Emission Generated / 2004 - WA		8.94	78.13	96.01	10.27%	1.00	1.00
Emissions Generated - Australia		26.59	792.84	846.03	3.25%	1.00	1.00
DOCfood	Normal (0.15,0.05*0.15)	0.01	0.13	0.16	10.00%	1.00	1.00
DOCpaper&text / DOCpaper&text	Normal (0.4,0.05*0.4)	0.04	0.36	0.44	10.00%	1.00	1.00
DOgGarden / DOgGarden	Normal (0.17,0.05*0.17)	0.02	0.15	0.19	10.00%	1.00	1.00
DOCwood / DOCwood	Normal (0.43,0.05*0.43)	0.04	0.39	0.47	10.00%	1.00	1.00
Standard Mix - MSW- food	Triangle (0.15,0.21,0.27)	0.05	0.16	0.26	23.33%	0.99	1.01
Standard Mix - MSW-p&t / Standard Mix - MSW-p&t	Triangle (0.07,0.11,0.15)	0.03	0.08	0.14	29.69%	0.98	1.01
Standard Mix - MSW-gg / Standard Mix - MSW-gg	Triangle (0.14,0.19,0.24)	0.04	0.15	0.23	21.49%	0.99	1.01
Standard Mix - MSW-wood / Standard Mix - MSW-wood	Triangle (0.02,0.03,0.04)	0.01	0.02	0.04	27.22%	0.98	1.01
Standard Mix - MSW-other / Standard Mix - MSW-other	Triangle (0.38,0.46,0.54)	0.07	0.39	0.53	14.20%	0.99	1.01
DDOC	Normal (0.5,0.1*0.5)	0.10	0.40	0.60	20.00%	1.00	1.00
Half-life	Triangle (3,4,6)	1.25	3.09	5.58	28.78%	0.94	0.99
Half-life	Triangle (10,12,14)	1.63	10.37	13.63	13.61%	0.99	1.01
Half-life	Triangle (6,7,9)	1.25	6.09	8.58	17.01%	0.97	1.00
Half-life	Triangle (17,23,35)	7.48	17.52	32.48	29.93%	0.94	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	55.99%	0.98	1.01
Half-life	Triangle (3,4,6)	1.25	3.09	5.58	28.78%	0.94	0.99

Variable	Distribution and parameters	2sd	M-2sd	M+2sd	2sd/M	M-/2.5%	M+/97.5%
Half-life	Triangle (10,12,14)	1.63	10.37	13.63	13.61%	0.99	1.01
Half-life	Triangle (6,7,9)	1.25	6.09	8.58	17.01%	0.97	1.00
Half-life	Triangle (17,23,35)	7.48	17.52	32.48	29.93%	0.94	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	56.00%	0.98	1.01
Half-life	Triangle (1,2,4)	1.25	1.09	3.58	53.45%	0.85	0.99
Half-life	Triangle (8,10,12)	1.63	8.37	11.63	16.33%	0.99	1.01
Half-life	Triangle (3,4,5)	0.82	3.18	4.82	20.41%	0.99	1.01
Half-life	Triangle (14,20,23)	3.74	15.26	22.74	19.69%	1.01	1.03
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	55.99%	0.98	1.01
Half-life	Triangle (1,2,4)	1.25	1.09	3.58	53.45%	0.85	0.99
Half-life	Triangle (8,10,12)	1.63	8.37	11.63	16.33%	0.99	1.01
Half-life	Triangle (3,4,5)	0.82	3.18	4.82	20.41%	0.99	1.01
Half-life	Triangle (14,20,23)	3.74	15.26	22.74	19.69%	1.01	1.03
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	56.00%	0.98	1.01
Half-life	Triangle (9,12,14)	2.05	9.61	13.72	17.61%	1.00	1.02
Half-life	Triangle (14,17,23)	3.74	14.26	21.74	20.79%	0.96	1.00
Half-life	Triangle (12,14,17)	2.05	12.28	16.39	14.34%	0.98	1.00
Half-life	Triangle (23,35,69)	19.48	22.85	61.82	46.02%	0.86	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	55.99%	0.98	1.01
Half-life	Triangle (9,12,14)	2.05	9.61	13.72	17.61%	1.00	1.02
Half-life	Triangle (14,17,23)	3.74	14.26	21.74	20.79%	0.96	1.00
Half-life	Triangle (12,14,17)	2.05	12.28	16.39	14.34%	0.98	1.00
Half-life	Triangle (23,35,69)	19.48	22.85	61.82	46.02%	0.86	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	56.00%	0.98	1.01
Half-life	Triangle (9,12,14)	2.05	9.61	13.72	17.61%	1.00	1.02
Half-life	Triangle (14,17,23)	3.74	14.26	21.74	20.79%	0.96	1.00
Half-life	Triangle (12,14,17)	2.05	12.28	16.39	14.34%	0.98	1.00
Half-life	Triangle (23,35,69)	19.48	22.85	61.82	46.02%	0.86	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	55.99%	0.98	1.01
Half-life	Triangle (9,12,14)	2.05	9.61	13.72	17.61%	1.00	1.02
Half-life	Triangle (14,17,23)	3.74	14.26	21.74	20.79%	0.96	1.00
Half-life	Triangle (12,14,17)	2.05	12.28	16.39	14.34%	0.98	1.00
Half-life	Triangle (23,35,69)	19.48	22.85	61.82	46.02%	0.86	0.99
Time Delay	Normal(7,0.28*7)	3.92	3.08	10.92	55.99%	0.98	1.01

Source: Burnbank Consulting 2007

ANNEX 8: Description of Australia's National Registry

The description of Australia's national registry follows the reporting guidance set down in Decision 15/CMP.1, part II (Reporting of supplementary information under Article 7, paragraph 1, E. National registries) under the Kyoto Protocol.

Name and contact information of the registry administrator designated by the Party to maintain the national registry

Shaun Calvert
Registry Administrator
Clean Energy Regulator
GPO Box 621
CANBERRA ACT 2601
Tel: +61 2 6159 3398
Email: shaun.calvert@cleanenergyregulator.gov.au

Names of any other party with which the party cooperates by maintaining their respective registries in a consolidated system

The ANREU is not operated in a consolidated system with any other party's registry.

A description of the database structure and capacity of the national registry

The following is an extract from the Software Specifications for the ANREU.

Front end server

The ANREU runs Microsoft Internet Information Services 7 (IIS) for its front-end web server. All incoming requests will enter and outgoing responses will exit though the IIS server. The IIS server rewrites URLs, then either passing it to the application server or back to the client. SSL termination happens on this tier. Secure Socket Layer (SSL) provides a secure connection between the ANREU and a client's web browser or the ITL. SSL uses a certificate which has been issued by a security authority to encrypt data moving over the unsecured internet. Beyond this point data will travel unencrypted between this front-end server and the application server. This is considered internal to the application. The IIS server converts all inbound and outbound HTTP communication to HTTPS secure communications.

Requests from the ITL and responses from the ANREU follow the same pattern. However, the front end server is not used for outgoing connections to the ITL initiated by the ANREU.

Application server

The middle tier serves the ANREU web application and uses Apache Tomcat 7.0. Apache Tomcat is an open source implementation of the Java Servlet and JavaServer Pages specifications that originally started as Sun Microsystems' original reference implementation. Tomcat runs the compiled Java Bytecode and allows for external access to application. Tomcat also provides externalized configuration for the application such as database connection details.

For outgoing requests to the ITL initiated by the ANREU web application, SSL origination occurs in the ANREU web application itself. Encrypted responses from the ITL return directly to the web application.

Database

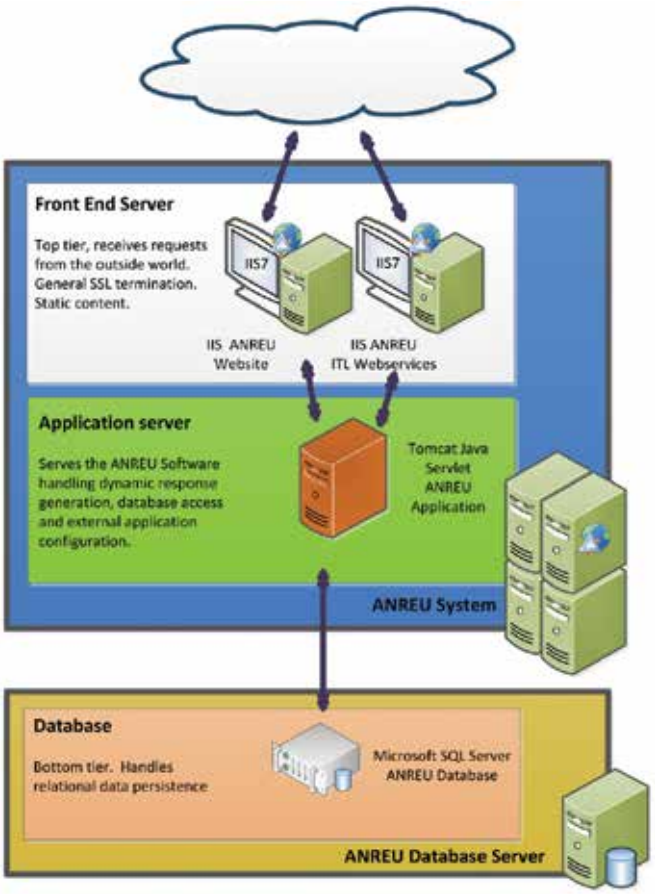
Microsoft SQL Server 2008 provides a relational database back-end for persistent storage of data for the application.

International Transaction Log Services

Transactions performed between the ANREU and the ITL take place through web service interfaces, following the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES). These web service interfaces are implemented using Apache Axis1 (Axis) which is an open source implementation of the Simple Object Access Protocol (SOAP). Axis supports generation of Java stub code based on the RPC/Encoded Web Service Definition Language (WSDL) specified by the DES. SOAP web services map to an internal service layer, isolating the web service code from the application code so that chances to the application can be made without affecting the ITL web service contract.

There are two web service interfaces that run, the client interface which allows the sending of messages to the ITL, and the server interface which allows the ANREU to receive messages from the ITL. Both of these interfaces are defined as WSDLs in the DES.

Figure A.8.1: ANREU Logical Network Topology (Production Environment)



Annexes

A description of how the national registry conforms to the technical standards for the purpose of ensuring the accurate, transparent and efficient exchange of data between national registries, the clean development registry and the independent transaction log, including (i) to (vi) below

The ANREU contains the functionality to perform issuance, conversion, external transfer, (voluntary) cancellation, retirement and Reconciliation processes using XML messages and web-services as specified in the latest version of the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES).

In addition, the ANREU also contains: 24 Hour Clean-up, Transaction Status enquiry, Time Synchronisation, Data Logging requirements (including, Transaction Log, Reconciliation Log, Internal Audit Log and Message Archive) and the different identifier formats as specified in the UNFCCC DES document.

(i) A description of the formats used in the national registry for account numbers, serial numbers for ERUs, CERs, AAUs, and RMUs, including project identifiers and transaction numbers

The formats used in the ANREU are as specified in Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES). Annex F — Definition of identifiers.

(ii) A list, and the electronic format, of the information transmitted electronically when transferring ERUs, CERs, AAUs, and/or RMUs to other registries

The formats used in the ANREU to transmit information to other registries are specified in the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES).

(iii) A list, and the electronic format, of the information transmitted electronically when acquiring ERUs, CERs, AAUs, and/or RMUs from other national registries or the CDM registry

The formats used in the ANREU to acknowledge the messages transmitted to other registries are specified in the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES).

(iv) A list, and the electronic format, of the information transmitted electronically from the national registry to the independent transaction log when issuing, transferring, acquiring, cancelling and retiring ERUs, CERs, AAUs, and/or RMUs

Information will be transmitted to the ITL in the message formats specified in the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES).

(v) An explanation of the procedures employed in the national registry to prevent discrepancies in the issuance, transfer, acquisition, cancellation and retirement of ERUs, CERs, AAUs, and/or RMUs

In order to minimise discrepancies between the ANREU and the ITL, the following approach has been adopted:

- Communications between the registry and the ITL are via web-services using XML messages — as specified in the Data Exchange Standards for Registry Systems under the Kyoto Protocol (DES). These web services, XML message format and the processing sequence are checked by the registry to ensure the compliance with the DES;

- The registry validates data entries against the formats of information as specified in Annex F of the DES;
- The registry implements internal controls in accordance with the checks performed by the ITL — as documented in Annex E of the DES.
- All units that are involved in a transaction are earmarked internally within the registry; thereby preventing the units from being involved in another transaction until a response has been received from the ITL and the current transaction has been completed;
- The web service that sends the message to the ITL for processing will ensure that a message received acknowledgement is received from the ITL before completing the submission of the message. Where no acknowledgement message has been received following a number of retries, the web-service would terminate the submission and roll back any changes made to the unit blocks that were involved;
- Where a 24 hour clean-up message is received from the ITL, the existing web service would roll back any pending transactions for the units that were involved, thereby preventing any discrepancies in the unit blocks between the registry and the ITL;
- Finally, if an unforeseen failure were to occur, the data discrepancies between our registry and the ITL can be corrected via a manual intervention function. Following this, reconciliation will be performed to validate that the data is in sync between the registry and the ITL. If a discrepancy reoccurs in the registry, the following measures will be applied:
  - Identification, and registration of the discrepancy;
  - Identification of the source of the discrepancy (DES, registry specifications, erroneous programming code);
  - Elaboration of a resolution plan and testing plan;
  - Correction and testing of the software;
  - Release and deployment of the corrected software.

(vi) An overview of the security measures employed in the national registry to deter unauthorised manipulations and minimize operator error

Below is a brief description of security measures implemented by the ANREU. For more detailed information, please refer to the formal readiness documentation which has been submitted as required to the ITL.

Identification and Authentication

All applicants looking to open an account in the ANREU are required to provide specified proof of identity documentation, along with completing a "fit and proper" person test. These identity requirements are defined in the *Australian National Registry of Emissions Unit Act 2011* and the *Australian National Registry of Emissions Unit Regulations 2011.*

Access to the registry is allowed via a personal username and password – allocated as a part of a Registration process performed by the Clean Energy Regulator. Passwords have an expiry date and any reset requires revalidation of the user's identity. Password configuration is as per Australian Government guidelines.

Access control

Users of the ANREU are divided into four security groups. These groups control the access and security at the application level. A user's login information is assigned to a user group, which determines what the user can and cannot do within the system.

The Registry supports the following user groups:

System Administrator

The System Administrator group has global authority throughout the Registry. This user is responsible not only for the day-to-day functionality of the system, but also for administrative support. This may include user management, managing and setting batch jobs, and reviewing audit and transaction logs

Account Administrator

This role is limited to selected users within the Clean Energy Regulator and allows access to account administration functions within the ANREU (creation/editing/deletion or account holders, accounts and users). An Account Administrator is unable to perform any transactions (e.g. unit transfers) in the ANREU.

Systems Auditor

A Systems Auditor has read only access to ANREU Account and Transaction information. A Systems Auditor is unable to update any information on an Account, nor is able to perform any transactions. Systems Auditor access is only available to personnel employed by the Clean Energy Regulator.

Industry User/Account Holders

Industry Users are external persons who require access to specific accounts within the ANREU. Users at this level are established when an ANREU account is initially created, and can be updated by the Account Holder. All Industry Users must pass required Proof of Identity and Fit and Proper person validations prior to being associated with an account. Additional security permissions are maintained for each Industry User associated with each account e.g. the ability to initiate or approve transactions for that account. These permissions are set by the Clean Energy Regulator upon advice from the account holder. A Read Only option is available, which requires management of the permissions – a read only Industry User would have access to view the holdings and transaction history of an account they are associated with, but is unable to initiate or approve any transactions for that account.

Access protection

In order to prevent operator errors, the ANREU incorporates validations on all user inputs to ensure that only valid details are submitted for processing; The ANREU displays confirmation of user input to help the user to spot any errors that had been made and implements an internal approval process (input of relevant password details) for secondary approval for relevant operations before submitting the details to the ITL for processing.

Additional Security measures

In addition to the above, the ANREU incorporates an initiator / approver design to assist in mitigating the risks associated with high risk unit transfer functions. The initiator / approver function requires a transaction to be initiated by one identity (authorised representative) and be approved by another (authorised representative). The approval step includes validating the transaction by entering a single use PIN issued to the approver when the "initiate" transaction component is completed.

This measure supports the recommendations as outlined by the ITL Change Advisory Board.

A list of the information publicly accessible through the user interface to the national registry

Non-confidential information has been made accessible to the public in line with the requirements of 13/CMP.1 annex II.E on the National Registry website under the Public Reports menu.

Up to date information on accounts as required by paragraph 45 has been included under Public Reports > Accounts. No ERUs have been issued to date so no information is available.

Information available to the public includes:

- Account name: the holder of the account;
- Account type: the type of account;
- Commitment period;

Information relating to projects as required by paragraph 46 has been included under Public Reports > Joint Implementation Project Information Report.

Holding and transaction information as required by paragraph 47 is published as described below:

a) The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year is available under Public Reports > Account Information Report, with Unit Block Holdings for each account

b) The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8 is available at Public Reports > Annual Holding and Transaction Summary Report

c) The total quantity of ERUs issued on the basis of Article 6 projects is available at Public Reports > Annual Holding and Transaction Summary Report

d) The total quantity of ERUs, CERs, AAUs, and RMUs acquired from other registries and the identity of the transferring accounts and registries is available at Public Reports > Annual Holding and Transaction Summary Report.

e) The total quantity of RMUs issued on the basis of each activity under Article 3 paragraphs 3 and 4 is available at Public Reports > Annual Holding and Transaction Summary Report

f) The total quantity of ERUs, CERs, AAUs, and RMUs transferred to other registries and the identity of the acquiring accounts and registries is available at Public Reports > Annual Holding and Transaction Summary Report.

g) The total quantity of ERUs, CERs, AAUs, and RMUs cancelled on the basis of activities under Article 3, paragraphs 3 and 4 is available at Public Reports > Annual Holding and Transaction Summary Report.

h) The total quantity of ERUs, CERs, AAUs, and RMUs cancelled following determination by the Compliance Committee that the party is not in compliance with its commitment under Article 3, paragraph 1 is available at Public Reports > Annual Holding and Transaction Summary Report.

i) The total quantity of other ERUs, CERs, AAUs and RMUs cancelled is available at Public Reports > Annual Holding and Transaction Summary Report.

j) The total quantity of ERUs, CERs, AAUs and RMUs retired is available at Public Reports > Annual Holding and Transaction Summary Report

k) The total quantity of ERUs, CERs and AAUs carried over from the previous commitment period is available at Public Reports > Annual Holding and Transaction Summary Report.

l) Current holdings of ERUs, CERs, AAUs and RMUs in each account.

An explanation of how to access information through the user interface of the national registry

Access to the ANREU is available through the internet at https://nationalregistry.cleanenergyregulator.gov.au/

Measures to safeguard, maintain and recover data in the event of a disaster

The servers (main and backup sites) that host the ANREU are in physically secure data centres fitted with secure access control systems. All data centres are fitted with smoke detection and automatic fire suppression systems. Anti-virus software upgrades are downloaded and installed autonomously on to the servers as soon as they are released.

A full backup of each database and an hourly transaction log backup during business hours take place every day with the back-up media being held at an offsite third party secure storage facility. The database content will also be replicated at a minimum of 30 minute intervals to a secondary data centre location when the clustering environment is implemented. This will serve as the hosting platform for Disaster Recovery.

In the event of a disaster a decision will be taken (between the Clean Energy Regulator and the IT contract supplier) to invoke disaster recovery. This will involve:

- Stopping all transactions to the main platform.
- Ensuring that the committed transactions are replicated to the DR site.
- Switching all external interaction with the main site over to the secondary location.

The IT contract supplier is committed to resuming the service for the Regulator operators within 8 hours of the decision being made.

Results of previous test procedures

Comprehensive testing information has been submitted as part of the ITL readiness documentation in December 2013. Please refer to this documentation for details.

Australia's independent assessment reports are available from the UNFCCC website http://unfccc.int/kyoto_protocol/registry_systems/independent_assessment_reports/items/4061.php

ANNEX 9: Glossary and Abbreviations

9.1 Glossary

Accounting quantity	The accounting quantity for the Kyoto Protocol *land use, land use change and forestry* activities represents the addition to or subtraction from a Party's assigned amount for a given year of the commitment period. A net removal will be added to the assigned amount while a net source will be subtracted from the assigned amount. For the afforestation/reforestation activities the accounting quantity must take into consideration the harvested forest sub-rule of the Kyoto Protocol (paragraph 4 of the annex to decision 16/CMP.1). Under this accounting rule "debits resulting from harvesting during the first commitment period following afforestation and reforestation since 1990 shall not be greater than credits accounted for on that unit of land". In other words, whenever emissions on harvested land units are greater than the removals on those land units, a net balance of zero is assumed for those units of land.
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.
Afforestation	Afforestation is the direct human-induced conversion of land that has not been forested land for a period of at least 50 years to forested land through planting, seeding and/or human-induced promotion of natural seed sources. Under the Kyoto Protocol afforestation is limited to afforestation activities occurring on those lands that did not contain forest on 31 December 1989.
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.
Calibration	Model calibration is the estimation and adjustment of model parameters and constants to improve the agreement between model outputs and a data set. Calibration requires high quality data that represent the range of conditions under which the model is required to perform so as to avoid possible bias in emission estimates.
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.
Deforestation	Deforestation is the direct human-induced conversion of forested land to non-forested land. Under the Kyoto Protocol deforestation is limited to deforestation activities that have occurred since 1990 on land that was forest on 1 January 1990.
Dolomite	A naturally occurring mineral ($CaCO_3$.mg CO_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. Australia 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	Fugitive emissions involve the release of non-combustion greenhouse gases arising from the production and delivery of fossil fuels. Fugitive emissions from solid fuels arise from the production, transport and handling of coal, and emissions from decommissioned mine and coal mine waste gas flaring. Fugitive emissions from oil and gas extraction, production and transport involve venting, flaring, leakage, evaporation and storage loss.
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.
Initial Assigned Amount	Represents Australia's emissions target for the first commitment period of the Kyoto Protocol (before adjustments are made for purchases of net credits from international sources). The initial assigned amount is calculated as 108% of the base year emissions and is established as 591.5 Mt CO_2-e a year for each year of the first commitment period 2008-2012.
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 Category	The IPCC *Good Practice* report (IPCC 2000) introduces the concept of key categories for prioritising the inventory development process. A key 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 category analysis identifies categories that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms. Tier 2 analysis identified categories 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).
Reforestation	The direct human-induced conversion of non-forested land to forested land through planting, seeding and/or human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.
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 that 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 ultimate aim of stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.
Validation	Model validation is a demonstration that a model, within its domain of applicability, possesses a satisfactory range of accuracy consistent with the intended application of the model. Validation compares simulated system output with real system observations using data not used in model development. It is used to test the model performance and that the calibration of the model has not produced biased emission estimates.
Verification	In terms of the inventory verification refers to the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help establish its reliability for the intended application of that inventory. Typically methods external to the inventory are used to verify the truth of the inventory, including comparisons with estimates made by other bodes. Verification as it pertains to modelling is a demonstration that the modelling formalism is correct. It is a check that calculations, inputs, and computer code is correct.
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.

9.2 Abbreviations

AAA	Aerosol Association of Australia
AAC	Australian Aluminium Council
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABARE	Australian Bureau of Agricultural and Resource Economics
ABR	Australian Business Register
ABS	Australia Bureau of Statistics
ACARP	Australian Coal Association Research Program
ACT	Australian Capital Territory
AD	Activity Data
ADB	Asian Development Bank
ADC	Aluminium Development Council
ADO	Automotive Diesel Oil
ADR	Australian Design Rule
AEMO	Australian Energy Market Operator
AES	Australian Energy Statistics
AEZ	Agro Ecological Zones
AFIC	Australian Feeds Information Centre
AFRC	Agriculture and Food Research Council
AGA	Australian Gas Association
AGEIS	Australia Greenhouse Emissions Information System
AGO	Australian Greenhouse Office
AIHW	Australian Institute of Health and Welfare
ALFA	Australian Lot Feeders Association
ANAO	Australian National Audit Office
ANREU	Australian National Registry of Emissions Units
ANU	Australian National University
ANZSIC	Australia New Zealand Standard Industrial Classification
APEC	Asia Pacific Economic Corporation
API	American Petroleum Institute

APPEA	Australian Petroleum Production and Exploration Association
APS	Australian Petroleum Statistics
ARC	Agricultural Research Council
ARRBTR	Australian Road Research Board Transport Research
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.
ASRIS	Australian Soil Resource Information System
ASS	Acid Sulphate Soils
AUASB	Auditing and Assurance Standards Board
AUSLIG	Australian Surveying and Land Information Group
AVHRR	Advanced Very High Resolution Radiometer
Avtur	Aviation turbine fuel
BEF	Burning Efficiency
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BoM	Bureau of Meteorology
BTX	Benzene, Toluene, Xylene
BREE	Bureau of Resources and Energy Economics
BRS	Bureau of Rural Science
C&D	Construction and Demolition waste
C&I	Commercial and Industrial waste
CAAANZ	Conservation Agriculture Alliance of Australia and New Zealand
CAB	Change Advisory Board
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Use and Storage
CEF	Clean Energy Future package
CEM	Clean Energy Ministerial
CER	Clean Energy Regulator
CERI	Clean Energy Research Institute
CFTT	Centre for Forest Tree Technology
COBIT	Control Objectives for Information and related Technology
COD	Chemical Oxygen Demand

CPN	Conditional Probability Network
CRC SI	Cooperative Research Centre for Spatial Information
CRES	Centre for Resource and Environmental Studies
CRF	Common Reporting Format
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CUEDC	Composite Urban Emissions Drive Cycle
DAFF	Department of Agriculture, Fisheries and Forestry
DCC	Department of Climate Change
DCCEE	Department of Climate Change and Energy Efficiency
DE	Department of the Environment
DEEDI	Department of Employment, Economic Development and Innovation
DEM	Digital Elevation Model
DES	Data Exchange Standards
DEWHA	Department of Environment, Water, Heritage and the Arts
DI	Department of Industry
DIT	Department of Infrastructure and Transport
DM	Dry Matter
DMD	Dry Matter Digestibility
DMITRE	Department of Manufacturing, Innovation, Trade, Resources and Energy
DMP	Department of Mines and Petroleum
DNRM	Department of Natural Resources and Mines
DOC	Degradable Organic Carbon
DOC_f	fraction of Degradable Organic Carbon dissimilated
DOM	Database Operations Manager
DRET	Department of Resources, Energy and Tourism
DSDBI	Department of State Development, Business and Innovation
E&P Forum	Exploration and Production Forum
EDC	Emission Decay Curve
EDS	Early Dry Season
EF	Emission Factor

EGCFE	Expert Group on Clean Fossil Energy
EIS	Environmental Impact Statements
EITEI	Emissions Intensive Trade Exposed Industries
EPA	Environmental Protection Agency
ERIC	Environmental Research and Information Consortium Pty Ltd
ERT	Expert Review Team
ESAA	Energy Supply Association of Australia
ESAS	Electricity Sector Adjustment Scheme
EU ETS	European Union Emissions Trading Scheme
EVAO	Estimated Value of Agricultural Operations
FAO	Food and Agriculture Organisation
FITR	Fourier Transform Infrared Spectroscopy
FOD	First Order Decay
FORS	Federal Office of Road Safety
FPA	Forest Practices Authority
FullCAM	Full Carbon Accounting Model
G8	The Group of Eight
GCL	Geosynthetic Clay Liner
GCV	Gross Calorific Equivalents
GE	Gross Energy
GEDO	Greenhouse and Energy Data Officer
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GRDC	Grains Research and Development Corporation
GWA	George Wilkenfeld and Associates
GWP	Global Warming Potential
HDPE	High Density Polyethylene
IBRA	Interim Biogeographic Regionalisation for Australia
IDF	Industrial Diesel Fuel
IEA	International Energy Agency

IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
IAR	Initial Assessment Report
ISC	Interspecies correlation
ISO	International Organization for Standardization
IUFRO	International Union of Forest Research Organizations
JCP	Jobs and Competitiveness Program
JCPAA	Joint Committee of Public Accounts and Audit
KP	Kyoto Protocol
LDS	Late Dry Season
LKD	Lime Kiln Dust
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
LTO	Landing/Takeoff
LULUCF	Land use, land use change and forestry
M2M	Methane to Markets
MCF	Methane Correction Factor
MDI	Metered Dose Inhaler
MDP	Metropolitan Development Program
ME	Metabolizable Energy
MEF	Manure Emission Factor
MMS	Manure Management Systems
MRT	Mineral Resources Tasmania
MSW	Municipal Solid Waste
MVG	Major Vegetation Groups
MWTP	Municipal Wastewater Treatment Plants
NAILSMA	North Australian Indigenous Land & Sea Management Alliance
NATA	National Association of Testing Authorities
NCAS	National Carbon Accounting System
NEA	National Energy Administration

NFI	National Forest Inventory
NG	Natural Gas
NGERS	National Greenhouse and Energy Reporting Scheme
NGGI	National Greenhouse Gas Inventory
NGGIC	National Greenhouse Gas Inventory Committee
NIAES	National Institute for Agro-Environmental Sciences
NIR	National Inventory Report
NLWRA	National Land and Water Resources Audit
NORP	Nitrous Oxide Research Program
NRC	National Research Council
NSW	New South Wales
NT	Northern Territory
OECD	Organisation for Economic and Co-operation Development
OLI	Operational Land Imager
OSCAR	Online System for Comprehensive Activity Reporting
PCC	Post Combustion Capture
PVC	Polyvinyl Chloride
QA/QC	Quality assurance/Quality control
QDME	Queensland Department of Mines and Energy
QLD	Queensland
RET	Department of Resources, Energy and Tourism
RIRDC	Rural Industries Research and Development Corporation
ROU	Recycled Organics Unit
RRA	Refrigerant Reclaim Australia
RSA	Registry System Administrators
SA	South Australia
SCA	Standing Committee on Agriculture
SCaRP	Soil Carbon Research Program
SECV	State Electricity Commission of Victoria
SEF	Standard Electronic Format

SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SIAR	Standard Independent Annual Review
SUV	Sports Utility Vehicle
SWDS	Solid Waste Disposal Site
TAS	Tasmania
TOC	Total Organic Carbon
UAG	Unaccounted for Gas
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VIC	Victoria
VKT	Vehicle Kilometres Travelled
VOC	Volatile Organic Compounds
WA	Western Australia
WALFA	Western Arnhem Land Fire Abatement
WBCSD	World Business Council for Sustainable Development
WMAA	Waste Management Association of Australia
WRI	World Resource Institute
WSAA	Water Services Association of Australia
YSLB	Years Since Last Burnt

ANNEX 10: References

AAC (Australian Aluminium Council) 2007, *Sustainability Report 2006*, AAC Canberra

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) 1990-2008, *Australian Commodity Statistics*, ABARE, Canberra.

- 2009e, *'Australian crop report December 2009 no. 152'*. Australian Bureau of Agricultural and Resource Economics, Canberra.
- 2013, *Forest Product Statistics*, Canberra

ABS (Australian Bureau of Statistics) 1991a, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra.

- 1991b, *Census of Population and Housing, 1991*. Catalogue No. 2101.0, Canberra.
- 2000, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra.
- 2004, *Detailed Energy Statistics, Australia, 2001-02*. Catalogue No. 4648.0.55.001, Canberra.
- 2006, Survey of Motor Vehicle Use – An Investigation into Coherence, Research paper 9208.0.55.005, Commonwealth of Australia, Canberra.
- 2007, *'Year Book Australia, 2007: Water Use and Irrigation'*. Catalogue No. 1301.0, Canberra.
- 2008a, *Australian Demographic Statistics*, Catalogue No. 3101.0, Canberra.
- 2008b, *Environmental Issues, people's views and practices*. Catalogue No. 4602.0, Canberra.
- 2008d, *'Year Book Australia, 2008: Agricultural Environment'*. Catalogue No. 1301.0, Canberra.
- *2008e, 'Year Book Chapter, 2008: Feature Article – Irrigation on Australian Farms'*. Catalogue No. 1301.0, Canberra.
- 2009d, *Land Management and Farming in Australia.* Catalogue no. 4627.0, Canberra
- 2009e, *Australian Demographic Statistics*, Catalogue No. 3101.0, Canberra.
- 2010a, *Australian Industry – Mining Commodities*. Catalogue No. 8155, Canberra.
- 2010b, *Water use on Australian Farms, 2008-09*.Catalogue No. 4618.0, Canberra.
- 2011, Water use on Australian Farms, 2009-10.Catalogue No. 4618.0, Canberra.2011d, Land Management and Farming in Australia. Catalogue no. 4627.0, Canberra
- 2012, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra.
- 2012a, *Motor Vehicle Census, Australia, 31 January 2012*. Catalogue No. 9309.0, Canberra.
- 2012b, *Survey of Motor Vehicle Use Australia, 12 months ended 30 June 2012*, Catalogue No. 9208.0, Canberra
- 2013, Motor Vehicle Census, Australia, 31 January 2012. Catalogue No. 9309.0, Canberra.
- 2013a, Survey of Motor Vehicle Use Australia, 12 months ended 30 June 2012, Catalogue No. 9208.0, Canberra
- 2014, *International Trade Merchandise [data available on request],* Canberra.

ACARP (Australian Coal Association Research Program), 2011. *Guidelines for the implementation of NGER method 2 or 3 for open cut coal mine fugitive GHG emissions reporting*. ACARP project C20006.

AEC (Australian Environment Council), 1988. *Air Emission Inventories (1985) for the Australian Capital Cities*, Report No. 22, Australian Government Publishing Service, Canberra.

AEMO (Australian Energy Market Operator) 2013. *National Electricity Market Review Tool*.

AFIC (Australian Feeds Information Centre) 1987, *Australian Feed Composition Tables: National Collection (1970–1987),* ed. Ostrowski-Meissner, H. T., AFIC publication No.7/87, AFIC-CSIRO, Sydney.

AFRC (Agriculture and Food Research Council) 1990, '*Nutritive requirements of ruminant animals: energy. Agriculture and Food Research Council Technical Committee on Responses to Nutrients, Report Number 5*', *Nutrition Abstracts and Reviews* (Series B), vol. 60, pp. 729–804.

AGA (Australian Gas Association) 1988–94, *Gas Distribution Industry Performance Indicators* (annual), AGA, Canberra.

– 1988–2002, *Gas Industry Statistics* (annual), AGA, Canberra.

AGO (Australian Greenhouse Office) 2000a, *Land clearing: A social history*. National Carbon Accounting System Technical Report No. 4. Australian Greenhouse Office, Canberra.

– 2000b, *International Review of the Implementation Plan for the 1990 Baseline*. National Carbon Accounting System Technical Report No. 11 (16pp). Australian Greenhouse Office, Canberra.

– 2002, *Greenhouse Gas Emissions from Land Use Change in Australia: an Integrated Application of the National Carbon Accounting System*, Australian Greenhouse Office, Canberra.

– 2004, A*GO Factors and Methods Workbook*, August 2004.Canberra, ACT.

– 2005 *National Carbon Accounting System, Development Plan 2004–2008,* Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

– 2006a, *Technical Guidelines, Generator Efficiency Standards*, Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

– 2006b, *Coal mine methane.* Unpublished report prepared for the Australian Greenhouse Office by Barlow Jonker Pty Ltd. Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

– 2007, *Energy Efficiency in Government Operations (EEGO) Policy*, Department of the Environment and Water Resources, Canberra.

AIHW (Australian Institute of Health and Welfare) 2002, *Apparent Consumption of Nutrients Australia 1997-98*, Canberra

Allen, D.E.; Kingston, G., Rennenberg, H., Dalal, R.C., and Schmidt, S. 2009. 'Effect of nitrogen fertilizer management and waterlogging on nitrous oxide emissions from subtropical sugar cane soils', *Agriculture, Ecosystems and Environment* 136, 209-217.

Amlinger, F., Peyr, S. and Cuhls, C. 2008, *Greenhouse gas emissions from composting and mechanical biological treatment;* Waste Management and Research 26:47.

Andreae, M.O., E. Atlas, H. Cachier, W.R. Cofer III, G.W. Harris, G. Helas, R. Koppmann, J-P Lacaux and D.E. Ward 1996. *'Trace gas emissions from savanna fires', In: Biomass burning and global change*, Ed. J.S. Levine, M.I.T Press, Cambridge, Ma, USA, pp 279–295.

– and Merlot, P. 2001, '*Emission of trace gases and aerosols from biomass burning*', Global Biogeochemical Cycles, 15(4): 955-966.

Apelbaum Consulting Group 2006, *Australian Transport Facts 2004*, report prepared for the Australian Transport Energy Data and Analysis Centre, ACG, Melbourne

API (American Petroleum Institute) 2004, Compendium of greenhouse gas emissions methodologies for the oil and gas industry, Washington.

– 2009, *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry.* URS Corporation, Texas, USA.

APPEA (Australian Petroleum Production and Exploration Association) 1990-2013. *Quarterly Drilling Statistics*. http://www.appea.com.au/industry-in-depth/industry-statistics/

– 1997, *Greenhouse Gas Emissions and Action Plan Report 1990–95*, Canberra.

– 1998–2006, *APPEA Greenhouse Gas Emissions and Action Plan* Report (annual), Canberra.

ARC (Agricultural Research Council) 1980, 'The *nutrient requirements of ruminant livestock', Agricultural Research Council Technical Review*, Commonwealth Agricultural Bureau, Farnham Royal.

Armstrong, W, Lunarzewski, L and Creedy, D 2006, *Australian decommissioned mine gas prediction,* report for the Australian Coal Association Research Programme, ACARP project C14080.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc) 2001, *ASHRAE Handbook Fundamentals Inch-Pound Edition,* ISBN 1-883413-87-7, 2001.

AUSLIG (Australian Surveying and Land Information Group) 2001, *Digital Elevation Model of Australia, version 2.0*. Canberra, Australia.

Australian Institute of Petroleum 1996, pers. Comm. Hugh Saddler.

Australian Macadamia Society http://www.australian-macadamias.org/about-aussie-macadamias/about-macadamias?lang=enandr=1andItemid=95, Accessed 1 December 2013.

Australian Plantation Products and Paper Industry Council 2006, *Australian Paper Industry Statistics* 2004-2005, http://www.a3p.asn.au/statistics/

Baker, T.G., and Attiwill, P.M. 1985 *'Above-ground nutrient distribution and cycling in* Pinus radiata *D. Don and* Eucalyptus obliqua *L'Herit. forests in southeastern Australia'*, Forest Ecology and Management 13:41-52.

Baldwin, G. and Scott, P.E. 1991, '*Investigations into the Performance of Landfill Gas Flaring Systems in the UK'*, Proceedings Sardinia 91, 3rd International Landfill Symposium, Sardinia, Italy, 14–18 October 1991.

Bange, H., 2006, *Nitrous Oxide and Methane in European Coastal Waters*, Estuarine Coastal and Shelf Science, vol 70 (3), pp361-374.

Barker-Reid, F., Gates, W.P., Wilson, K., Baigent, R., Galbally, I.E., Meyer, C.P., Weeks, I.A. and Eckard, R.J 2005, 'Soil nitrous oxide emissions from rainfed wheat in SE Australia' In *Fourth International Symposium Non-CO_2 Greenhouse Gases (NCGG-4): Science, Control, Policy and Implementation*, pp 25-32. Millpress, Rotterdam, Netherlands.

Barlaz, M.A 1998, *Carbon Storage during Biodegradation of Municipal Solid Waste Components in Laboratory-scale Landfills*, Global Biochemical Cycles, 12(2), 373-380.

– 2005, Note to ICF consulting, dated June 29, 2005.

– 2008, *Corrections to Previously Published Carbon Storage Factors,* Note to Parties Interested in Carbon Sequestration from Municipal Solid Waste, dated February 28, 2008.

Barnes, J. and Owens, N. J. P., 1998, *Denitrification and nitrous oxide concentrations in the Humber estuary, UK, and adjacent coastal zones*, Marine Pollution Bulletin, vol 37 (3-7), pp247-260.

Barton, L., Butterbach-Bahl, K., Kiese, R., Murphy, D.V., 2010, 'Soil nitrous oxide and methane fluxes are low from a bioenergy crop (canola), grown in a semiarid climate', *Global Change Biology*, Vol. 2, pp 1-15

Barton, L., Kiese, R., Gatter, D., Butterbach-Bahl, K., Buck, R., Hinz, C., Murphy, D.V., 2008, 'Nitrous oxide emissions from a cropped soil in a semi-arid climate', *Global Change Biology,* Vol. 14, 177–192.

Bateman, S. 2009, *Evaluation of Landfill Gas Collection Efficiency at the Wollert Landfill, Melbourne*, presented at the 3rd National Landfill and Transfer Stations Conference, Hobart

Beyond Neutral 2008, '*Greenhouse Gas Inventory for Industrial Processes – Cement, Aluminium, Lime and Titanium Dioxide/Synthetic Rutile – 2007 Inventory.'* Unpublished report submitted to the Australian Greenhouse Office. O'Brien Consulting Greenhouse, Energy, Environment, Canberra.

BITRE (Bureau of Infrastructure, Transport and Regional Economics) 2002, *Report 107, Greenhouse Gas Emissions from Transport, Australian Trends to 2020*, Canberra

– 2013 *Airport traffic data 1985-86 to 2012-13,* Canberra.

Blaxter, K.L and Clapperton, J.L., 1965, '*Prediction of the amount of methane produced by ruminants*', *British Journal of Nutrition*, vol 19, pp511–522.

Blue Environment, 2010, *Review of DOC_f factors outlined in National Inventory Report 2008*, Report for the Department of Climate Change and Energy Efficiency

Bluescope steel 2011, *Financial/Production History*, http://www.bluescopesteel.com/investors/financial-/-production-history

Bolinder, M.A., Janzen, H.H., Gregorich, E.G., Angers, D.A. and VandenBygaart A.J. 2007. *An approach for estimating net primary productivity and annual carbon inputs to soil for common agricultural crops in Canada.* Agriculture, Ecosystems and Environment 118: 29-42.

Boomsma, D.B., and Hunter, I.R. 1990 *'Effects of water, nutrients and their interactions on tree growth, and plantation forest management practices in Australasia: a review'*. Forest Ecology and Management 30: 455-476.

Bouwman, A.F., Boumans, L.J.M. and Batjes N.H. 2002, 'Emissions of N2O and NO from fertilized fields: Summary of available measurement data'. *Global Biogeochemical Cycles* 16, 1058, doi:10.1029/2001GB001811.

Brack, C.L. and Richards, G.P. 2002, 'Carbon Accounting Model for Forests in Australia*'*. *Environmental Pollution* 116: 187–194.

– Richards, G.P. and Waterworth, R.M. 2006. 'Integrated and comprehensive estimation of greenhouse gas emissions from land systems'. *Sustainability Science* 1: 91-106.

BREE (Bureau of Resources and Energy Economics) 2013a, *Australian Energy Statistics – Australian Energy Update 2013*, Canberra

– 2013b, *Beyond the NEM and the SWIS: 2011-12 regional and remote electricity in Australia, Canberra*

– 1996-2013, monthly series: *Australian Petroleum Statistics (APS)*. http://www.bree.gov.au/publications/australian-petroleum-statistics

Brouwer, E. 1965, *'Report of Sub-committee on Constants and Factors* in *Energy Metabolism*', *Proceedings of the 3rd International Symposium on Energy Metabolism*, ed. K.L. Blaxter, European Association for Animal Production, Scotland 1964, Publication No.11, pp. 441–443.

Buonicore A.J. and Davis W.T. 1992, *Air Pollution Engineering Manual*, Van Nostrand Reinhold, USA.

Burnbank Consulting 2000, *Synthetic gas use in non-Montreal Protocol industries,* Australian Greenhouse Office April 2000.

– 2002, *Inventories and projections of ozone depleting substances and synthetic greenhouse gases used in Montreal Protocol industries.* Environment Australia, Canberra.

– 2007, Uncertainty analysis – solid waste. Burnbank Consulting Pty. Ltd, 15 January 2007.

Burrows, W., Hoffman, B., Compton, J., and Back, P. 2001 '*Allometric Relationships and Community Biomass Stocks in White Cypress Pine (*Callitris glaucophylla*) and Associated Eucalypts of the Carnarvon Area - South Central Queensland*'. National Carbon Accounting System Technical Report No. 33, Australian Greenhouse Office, Canberra.

– Henry, B.K., Back, P.V., Hoffmann, T.B., Tait, L.J., Anderson, E.R., Menke, N., Danaher, T., Carter, J.O., McKeon, G.M., 2002. Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. Global Change Biology 48, 769-784.

Caccetta, P.A. 1997. '*Remote sensing, geographic information systems (GIS) and Bayesian knowledge-based methods for monitoring land condition*', PhD thesis, Curtin University of Technology, pp 184–203.

– Bryant, G., Campbell, N.A., Chia, J., Furby, S., Kiiven, H.J., Richards, G.P., Wallace, J. and Wu, X. 2003 '*Notes on Mapping and Monitoring Forest Change in Australia Using Remote Sensing and Other Data*'. In 30th International Symposium of Remote Sensing and the Environment, Hawaii, November 10-14.

– and Chia, J. 2004 '*Remote Sensing Methods for Plantation Attribution - Experiments and results for Mapsheet Si50*'. CSIRO Mathematical and Information Sciences.

– and Furby, S. 2004 '*Monitoring Sparse Perennial Vegetation Cover*'. In The 12th Australasian Remote Sensing and Photogrammetry Conference Proceedings, Fremantle, Western Australia, 18–22 October.

Campbell, R.G. (compiler) 1997. *Evaluation and development of sustainable silvicultural systems for multiple purpose management of Mountain Ash forests. A discussion paper.* VSP Technical Report no. 28. Centre for Forest Tree Technology. Forests Service. Department of Natural Resources & Environment, Victoria.

Carnovale, F., Alviano, P., Carvalho, C., Deitch, G., Jiang, S., Macaulay, D, and Summers, M., 1991, '*Air Emissions Inventory. Port Phillip Region: Planning for the Future*', Report SRS 91/001, Environment Protection Authority, Victoria, Melbourne

Carter, J.O., and Henry, B., 2003, '*Savannah Burning in Queensland, Biomass, Nitrogen Content and Charcoal Formation*', Unpublished Report, Department of Natural Resources and Mines, Queensland, 15pp

CASA (Civil Aviation Safety Authority) 2010-2013, *Civil Aircraft Register*, (http://www.casa.gov.au/)

Casey, K.D., McGahan, E.J., Atzeni, M.A., Garner, E.A and Frizzo, R.E., 1996, '*PigBal; A nutrient balance model for intensive piggeries*'. Queensland Department of Primary Industries. (Version 2.14, 10 February 2000).

Chatto, K.1997, '*Inventory of areas burnt and fuels consumed by bushfires in Australia 1983 to 1996*', A report prepared for CSIRO Division of Atmospheric Research. Centre for Forest Tree Technology (CFTT), Creswick, Victoria, Australia, 17 pp.

Christensen, K. and Thorbek, G. 1987, '*Methane excretion in the growing pig*', from *British Journal of Nutrition*, vol. 57, pp. 355–361.

CIF (Cement Industry Federation) 2003, '*Cement Industry Environment Report*', Cement Industry Federation.

– 2009, '*Australian Cement Industry sustainability Report 2009*', Cement Industry Federation.

Coal Services Pty Ltd 2013, *Australian Black Coal Statistics*, unpublished. http://www.coalservices.com.au/

Coogee Chemicals company website, www.coogee.com.au/op_meth.html

Coops, N.C., Waring, R.H. and Landsberg, J.J. 1998 '*Assessing forest productivity in Australia and New Zealand using a physiologically-based model driven with averaged monthly weather data and satellite derived estimates of canopy photosynthetic capacity*'. Forest Ecology and Management 104:113–127.

– Waring, R.H. Brown, S. and Running, S.W. 2001 '*Comparisons of predictions of net primary productivity and seasonal patterns in water use derived with two forest growth models in south-western Oregon*'. Ecological Modelling. 142:61–8.

– and Waring, R.H. 2001 *'The use of multiscale remote sensing imagery to derive regional estimates of forest growth capacity using 3-PGS'*. Remote Sensing of Environment 75: 324-334.

Crutzen, P.J., Aselmann, I. & Seiler, W. 1986, '*Methane production by domestic animals, wild ruminants, other herbivorous fauna and humans*', from *Tellus*, vol. 38 B, pp. 271–284.

CSIRO (Commonwealth Scientific and Industrial Research Organisation) 2012, *Australian PFC, HFC and SF6 emissions*, CSIRO Light Metals Flagship and Marine and Atmospheric Research, Victoria

– 2011, *Review of Confidential Data Handling Practices l*, CSIRO Mathematics, Informatics and Statistics, Canberra 2011b, *Review of Confidential Data Handling Practices l*, CSIRO Mathematics, Informatics and Statistics, Canberra

– 2009, *An Analysis of Greenhouse Gas Mitigation and Carbon Biosequestration Opportunities from Rural Land Use*, CSIRO Flagships, Sustainable Agriculture, St Lucia Queensland.

– 2005, *Australian Greenhouse Information System: Quantitative Estimates of Uncertainty*, CSIRO Atmospheric Research, Aspendale Victoria.

DAFF (Department of Agriculture, Fisheries and Forestry) 2005 '*Australian agriculture and food sector stocktake*'. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.

– 2009b, *Survey of the Australian Wastewater Treatment Industry 2009*, Department of Climate Change, Canberra.

Dalal, R., and Wang, W., Robertson, P., Parton, W.J. (2002) '*Emission Sources of Nitrous Oxide from Australian Agriculture and Mitigation Options*'. National Carbon Accounting System Technical Report No. 36 (56pp), Australian Greenhouse Office, Canberra.

DCC (Department of Climate Change) 2010, *Australia's fifth National Communication to the UNFCCC*, Department of Climate Change, Canberra.

– 2009, *Survey of the Australian Wastewater Treatment Industry 2009*, Department of Climate Change, Canberra.

– 2006, *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006*, Department of Climate Change, Canberra.

DCCEE (Department of Climate Change and Energy Efficiency)

– 2011 *Energy use in the Australian Government's operations* Department of Resources, Energy and Tourism, Canberra.

– 2012, *National Inventory Report 2010*, Department of Climate Change and Energy Efficiency, Canberra.

DE (Department of the Environment) 1998-2012, National Pollutant Inventory. http://www.npi.gov.au

DEEDI (Department of Employment, Economic Development and Innovation), 2011. *Coal Statistics.* Queensland Government. http://mines.industry.qld.gov.au/mining/coal-statistics.htm

de Klein, C A. M., Barton, L. Sherlock, R.R.; Li, Zheng; Littlejohn, R. P. 2003, '*Estimating a nitrous oxide emission factor for animal urine from some New Zealand pastoral soils*', from *Australian Journal of Soil Research*, 41(3), 381 – 399.

Delmas, R. 1994 *'An overview of present knowledge on methane emission from biomass burning'*. Fertilizer Research 37: 181-190.

– Lacaux, J.P., and Brocard, D. 1995 *'Determination of biomass burning emission factors: methods and results'*. Environmental Monitoring and Assessment 38, 181-204.

de Looper, M. and Bhatia, K. 1998, '*International health—how Australia compares*', Australian Institute of Health and Welfare, Commonwealth of Australia, Canberra, Australia.

De Maria, S. 1992, Unpublished report on Vehicle & Engine Monitoring & Analysis System (VEPMAS) by Energy and Engines Research Group, for buses running on compressed natural gas in Adelaide, Sydney and Brisbane.

Denmead, O. T., Macdonald, B.C.T., Bryant, G., Naylor, T., Wilson, S., Griffith, D.W.T., Wang, W.J., Salter, B., White, I., and Moody, P. 2010. Emissions of methane and nitrous oxide from Australian sugarcane soils. *Agricultural and Forest Meteorology*, 150(6): 748-756. doi:10.1016.

Department of Defence 2010-2012, *pers comm. regarding domestic fuel data consumption*, Department of Defence, Canberra, ACT.

Department of National Development 1969, *Compendium of Australian forest products 1935-36 to 1966-67*, Canberra.

DEWHA (Department of the Environment, Water, Heritage and the Arts) 2005-2008, unpublished data on hydrofluorcabon imports: in bulk and pre-charged equipment, Canberra.

– 2009 - *National Waste Overview 2009 (http://www.ephc.gov.au/sites/default/files/WasteMgt_Nat_Waste_Overview_PRINT_ver_200911.pdf)*

Deslandes J, and Kingston E, 1997, *Energy and Greenhouse Gas Data & Conversion Factors Relevant to BHP Operations*, BHP Technical Note, April 1997.

Dever, S. Roberts, A. and Cooksley, G. 2009, *Evaluation of Landfill Gas Emissions at Newcastle City Council's Summerhill WMC Landfill via Direct Measurement and using NGER Method-1,* presented at the 3rd National Landfill and Transfer Stations Conference, Hobart.

DHV 2010, *Update of emission factors for N2O and CH_4 for composting, anaerobic digestion and waste incineration*, Netherlands.

DIICCSRTE 2013 (Department of Industry, Innovation, Climate Change, Science Research and Tertiary Education) *National Inventory Report 2011*, Canberra.

DIRD (Department of Infrastructure and Regional Development) 1969-1988. *Australian Design Rules*. http://www.infrastructure.gov.au/roads/motor/design/

DIR (Department of Industry and Resources), 2006. *Petroleum Guidelines – Drilling Fluid Management*, Western Australia.

DIT (Department of Infrastructure and Transport) accessed 2012a, *Summary of Emission Requirements for New Petrol Passenger Cars 1972-2018* http://www.infrastructure.gov.au/roads/environment/files/Emission_Standards_for_Petrol_Cars_1972_2018.pdf

– accessed 2012a, *Emission Requirements for Diesel Heavy Duty Vehicles* http://www.infrastructure.gov.au/roads/environment/files/Standards_for_Diesel_HDVs.pdf

Dixon, B. 1990, '*Methane losses from the Australian natural gas industry*', in D.J. Swaine (ed.) *Greenhouse and Energy*, CSIRO 1990.

DMITRE (Department for Manufacturing, Innovation, Trade, Resources and Energy) 2013. Coal mining production data, Mineral Resources Division, South Australia. http://outernode.pir.sa.gov.au/minerals/publications_and_information/resource_production_statistics

DMP (Department of Mines and Petroleum) 2013. Coal mining production data, Western Australia. http://www.dmp.wa.gov.au/

DNRM (Department of Natural Resources and Mines) 2013. Coal mining production data, Mines and Energy, Brisbane. http://mines.industry.qld.gov.au/mining/coal.htm

– 2013b, Well drilling data, Brisbane, Qld. https://webgis.dme.qld.gov.au/webgis/webqmin/shapes/agreement.htm

Doorn, M.R.J. and Barlaz, M.A. 1995, *Estimate of Global Methane Emissions from Landfills and Open Dumps*. USEPA, Washington.

DPI (Department of Primary Industries), 2012. *Victoria's Minerals, Petroleum and Extractive Industries: Statistical Review 2010-2011*, Victoria.

DRET (Department of Resources, Energy and Tourism) 2012 *Energy use in the Australian Government's operations* Department of Resources, Energy and Tourism, Canberra.

Driscoll, D., Milkovits, G. and Freudenberger, D. 2000 '*Impact of Use of Firewood in Australia*'. CSIRO Sustainable Ecosystems, Canberra.

DSDBI (Department of State Development, Business and Innovation), 2013. Coal production data, Energy and Earth Resources, Victoria. http://dpistore.efirst.com.au/categories.asp?cID=46&c=181223

DTI (Department of Trade and Investment), 2013. Well drilling data, Division of Resources and Energy, NSW. http://dwh.minerals.nsw.gov.au/CI/warehouse

Duffy, Nelson and Williams 1995, '*Trace Organic Composition of Landfill Gas'.* Report to NSW Environmental Research Trusts. CSIRO. Sydney.

Dyer, R., Café, L., and Craig, A., 2001, '*Australian Grassland and Rangeland Assessment by Spatial Simulation (Aussie GRASS) Northern Territory and Kimberly Sub-project*', QNR9, Final Report for the Climate Variability in Agriculture Program, Department of Natural Resources and Mines, Queensland.

Eamus, D., McGuiness, K. and Burrows, W. 2000 '*Review of Allometric Relationships for Woody Biomass for Queensland, the Northern Territory and Western Australia*'. National Carbon Accounting System Technical Report No. 5a (60pp). Australian Greenhouse Office, Canberra.

E and P (Exploration and Production) Forum 1994, *Methods for Estimating Emissions from E&P Operations*, The Oil Industry International Exploration and Equipment Forum, London.

EASA (European Aviation Safety Agency) 1975-2013, *International Civil Aviation Organization (ICAO) Aircraft Engine Emissions Databank*. http://www.easa.europa.eu/environment/edb/aircraft-engine-emissions.php

EEA (European Environment Agency) 2011. *COPERT 4 – Estimating emissions from road transport*. http://www.eea.europa.eu/publications/copert-4-2014-estimating-emissions

EITEIs 2007,2008 – Data collated by the Department of Climate Change under Emissions Intensive Trade Exposed Industries Program.

EnerGreen Consulting 2009, *2008 Greenhouse Gas Inventory for Industrial Processes and Solvents and Other Product Use*, EnerGreen Consulting, Nov 2009.

– 2011 *Nitrous Oxide Emissions from Nitric Acid Production: A Review of Emissions Abatement Technology,* EnerGreen Consulting April 2011.

Energy Strategies 2005, '*Review of methodology for estimating Australia's unaccounted for gas (UAFG) as calculated in the NGGI*', report to the Australian Greenhouse Office.

– 2007, *Report on Chemical activity data collection and analysis,* report to the Australian Greenhouse Office.

EPA (Environment Protection Authority), NSW, 1995, '*Metropolitan Air Quality Study - Air Emissions Inventory*', Environment Protection Authority NSW.

– 2000, '*State of the Environment 2000'*, Environment Protection Authority, NSW. (http://www.environment.nsw.gov.au/soe/soe2000/ch/ch_fig_2.27.htm)

EPA (Environment Protection Authority), Victoria 1991, *Air Emissions Inventory for the Port Phillip Control Region, SRS 91/001*, Environment Protection Authority, Victoria, Melbourne.

ERIC (Environmental Research and Information Consortium Pty Ltd) 2001, '*Rates of Clearing of Native Woody Vegetation 1997–2000'*. (22pp) Report to the NSW Department of Land and Water Conservation, Parramatta.

ESAA (Energy Supply Association of Australia) 2005-2013, *Electricity Gas Australia* (Annual), Canberra.

EEA (European Environment Agency) 2009, *'EMEP/EEA air pollutant emission inventory guidebook'.* Copenhagen.

Expert Group 2013, Cold Hard Facts 2, A study of the refrigeration and air conditioning industry in Australia. Report to the Department of Sustainability and Environment, Water, Population and Communities, Canberra.

Farrington, V. 1988, '*Air Emission Inventories (1985) for the Australian Capital Cities*', Australian Environment Council Report 22, AGPS, Canberra.

Fensham, R.J., Fairfax, R.J., and Ward, D.P. 2008, *'Drought-induced tree death in savanna'*, Global Change Biology 15 (2): 380-387.

Ferguson, I., Fox, J.C., Baker, T., Stackpole, D., and Wild, I. 2002 *'Plantations of Australia – Wood Availability 2001-2004'*. Bureau of Rural Sciences, Canberra, Australia.

Fernández-Puriatch, H., Oliver-Villanueva, J. V., Alfonso-Solar, D. and Peñalvo-López, E. (2013) Quantification of potential lignocellulosic biomass in fruit trees grown in Mediterranean regions. *Bioresources.com*, **8 (1)**, 88-103.

Fisher and Paykel 2010, *Annual Report 2010*, http://www.fisherpaykel.com/global/investors/Investors-PDFs/Annual%20Reports/Annual%20Review%20Year%20Ended%2031%20March%202010.pdf

Flessa, H. P. Dorsch, F. Beese, H. Konig and A.F. Bouwman 1996, '*Influence of cattle wastes on nitrous oxide and methane fluxes in pasture land'*, J. Environ. Qual., 25, pp 1366–1370.

Florence, R. G. 1996, '*Ecology and silviculture of eucalypt forests*', CSIRO Publishing, Collingwood, Victoria.

Foley, J. and Lant, P., 2007, *Fugitive Greenhouse Gas Emissions from Wastewater Systems,* Water Services Association of Australia, WSAA Literature Review No.1, December 2007.

Ford, A. 2004 *'Site quality for* Pinus radiata *D. Don: Southern Tablelands NSW'*. School of Resources, Environment and Society, Australian National University, Canberra, ACT.

FORS (Federal Office of Road Safety) 1996, Motor Vehicle Pollution in Australia – Report on the National In-Service Vehicle Emissions Study, FORS Canberra.

FPA (Forest Practices Authority) 2007 *'The Annual Report of the Forest Practices Authority 2006-07'*. Tasmania, Australia.

Forestry Tasmania 2008 *'2008 Report – Sustainable forest management'*. Forestry Tasmania, Hobart, Tasmania.

Forests NSW 2008 *'Forests NSW: Annual Report 2007-08'*. Forests NSW, Sydney, New South Wales.

Freer, M., Moore, A.D. and Donnelly, J.R., 1997, '*GRAZPLAN: Decision support systems for Australian gazing enterprises II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS*', from *Agricultural Systems*, vol 54, pp 77–126.

Furby, S. 2002 '*Land Cover Change: Specifications for Remote Sensing Analysis*'. National Carbon Accounting System Technical Report No. 9 (236pp), Australian Greenhouse Office, Canberra.

- and Woodgate, P. 2002. '*Pilot Testing of Remote Sensing Methodology for Mapping Land Cover Change*'. National Carbon Accounting System Technical Report No. 16 (354pp), Australian Greenhouse Office, Canberra.
- and Campbell, N.A. 2001 *'Calibrating images from different dates to 'like value' digital counts'*. Remote Sensing of Environment 77: 186-196.

Galbally, I.E., P.J. Fraser, C.P. Meyer, and D.W.T. Griffith 1992, '*Biosphere/Atmosphere exchange of trace gases over Australia* in *Australia's Renewable Resources: Sustainability and Global Change*', R.M. Gifford and M.M. Barson eds., Bureau of Rural Resources, Canberra p. pp 117—149.

- C.P. Meyer, S. Bentley, I. Weeks, R. Leuning, K. Kelly, F. Phillips, F. Barker-Reid, W. Gates, R. Baigent, R. Eckard and P. Grace, 2005, '*A study of environmental and management drivers of non-CO_2* greenhouse gas emissions in Australian agro-ecosystems', in *Environmental Sciences 2*, 133–142.
- C.P. Meyer, Y-P. Wang, I.A. Weeks, C. Smith, S,M. Howden, C.M. Elsworth, C.M., B. Petraitis, E. Johnson, G. McLachlan, G. Huang and D.L. McKenney 1994, RIRDC Project CSD-47A—The role of legume pasture in greenhouse gas emissions from Australia. Final report, CSIRO Division of Atmospheric Research, Aspendale, Victoria, Australia 56 pp.

Gardner, W.D., Ximenes, F., Cowie, A., Marchant, J.F., Mann, S., and Dods, K., 2004 'Decomposition of Wood Products in the Lucas Heights Landfill Facility', 3rd Intercontinental Landfill Research Symposium. Japan (2004).

George Wilkenfeld and Associates (GWA) 2009, 'National Greenhouse Gas Inventory: 2009 Electricity sector emissions, Prepared for the Department of Climate Change, George Wilkenfeld and Associates Pty Ltd, December 2009.

GHD 2010*, Report for Review of DOC_f values used in the Australian National Greenhouse Accounts,* report to the Department of Climate Change.

- 2009a, *Report for National Greenhouse Accounts 2008: Methane Capture from Landfills,* report to the Department of Climate Change.
- 2009b, '*Lime usage in Australian planted forests*'. A report for NCAS Technical Services, Canberra, ACT.
- 2009c, '*Report for emissions from the production of cement, lime, magnesia, synthetic rutile and aluminium in the industrial processes sector*', report to the Department of Climate Change.
- 2008, '*Report for review of current municipal waste and commercial and industrial waste mix composition in the NGER Measurement Determination*' report to the Department of Climate Change, January 2008.

– 2006a, '*Review of liquid fuels CO_2* emissions factors', report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.
– 2006b, '*Review of Sectoral Models*', report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

Gifford, R. 2000a '*Carbon Content of Woody Roots: Revised Analysis and a Comparison with Woody Shoot Components (Revision 1)'*. National Carbon Accounting System Technical Report No. 7 (10pp). Australian Greenhouse Office, Canberra.
– 2000b '*Carbon Content of Aboveground Tissues of Forest and Woodland Trees*'. National Carbon Accounting System Technical Report No. 22 (28pp). Australian Greenhouse Office, Canberra.
– and Howden, M. 2001, '*Vegetation thickening in an ecological perspective: significance to national greenhouse gas inventories*'. Environmental Science and Policy 4 (2-3): 59-72.

Golder Associates, 2009, *Kimbriki Recycling and Waste Facility – Landfill Gas Emissions Assessment,* Report for Kimbriki recycling and waste management facility, NSW.

Gonzalez-Avalos, E. and Ruiz-Suarez, L.G. 2001, '*Methane emissions factors from cattle manure in Mexico*', from *Bioresource Technology*, vol 80, pp 63–71.

Gower, S.T., Gholz, H.L., Nakane, K., and Baldwin, V.C. 1994 '*Production and allocation patterns of pine forests*'. Ecological Bulletins 43: 115-135.

Grace, PR, Post, WM, Godwin, DC, Bryceson, KP, Truscott, MA and Hennessy, KJ (1998). Soil carbon dynamics in relation to soil surface management and cropping systems in Australian agroecosystems. In: , *Management of Carbon Sequestration in Soil. Symposium on Carbon Sequestration in Soils*, Columbus Oh, (175-193). Jul, 1996

Grace, PR, Rowlings, D., Rochester, I., Kiese, R. and Butterbach-Bahl K. 2010, Nitrous oxide emissions from irrigated cotton soils in northern Australia, In *19th World Congress of Soil Science, Soil Solutions for a Changing World,* 1 – 6 August 2010, Brisbane, Australia, pp 179-182.

Graham, N. McC. 1964a, '*Energetic efficiency of fattening sheep. I. Utilization of low-fibre and high-fibre food mixtures*', from *Australian Journal of Agricultural Research*, vol 15, pp 100–112.
– 1964b, '*Energetic efficiency of fattening sheep. II. Effects of undernutrition*', from the *Australian Journal of Agricultural Research*, vol 15, pp 113–126.
– 1967, '*The net energy value of three subtropical forages*', from the *Australian Journal of Agricultural Research*, vol 18, pp 137–147.
– 1969, '*The net energy value of artificially dried subterranean clover harvested before flowering*', from the *Australian Journal of Agricultural Research*, vol 20, pp 365–373.

Gras, J.L, 2002, *Emissions from Domestic Solid Fuel Burning Appliances, Technical Report No. 5*; CSIRO Report for Environment Australia, available at: http://www.environment.gov.au/atmosphere/publications/index.html

Grierson, P.F., Williams, K. and Adams, M.A. 2000 '*Review of Unpublished Biomass Related Information: Western Australia, South Australia, New South Wales and Queensland*'. National Carbon Accounting System Technical Report No. 25 (114pp). Australian Greenhouse Office, Canberra.

Griffin, E. A., Verboom, W. H. and Allen, D. 2002 '*Paired Site Sampling for Soil Carbon Estimation – WA*'. National Carbon Accounting System Technical Report No. 38, Australian Greenhouse Office, Canberra.

Grjotheim, K. and Welch B.J. 1980, '*Aluminium Smelter Technology: A Pure and Applied Approach*', Aluminium Verlag GMBH, Dusseldorf.

Guendehou, S. 2010, *Australia's National Greenhouse Gas Inventory 2008: Solid Waste Review – Fraction of DOC dissimilated* DOC_f, report to the Department of Climate Change.

– 2009, *Australia's National Greenhouse Gas Inventory 2007: Solid Waste Quality Assurance Review,* report to the Department of Climate Change.

Hall, W.B., Brook, G.M., McKeon, K.A., and Paull, C.J., 2000, '*Aussie GRASS: Australian Grassland and Rangeland Assessment by Spatial Simulation*', in *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – The Australian Experience*, edited by G. Hammer, N. Nicholls and C. Mitchell, Kluwer Academic Press, The Netherlands, pp 329–349.

Harms, B. and Dalal, R. 2003 '*Paired Site Sampling for Soil Carbon Estimation – Qld*'. National Carbon Accounting System Technical Report No. 37, Australian Greenhouse Office, Canberra.

– Dalal, R.C. and Cramp, A.P. 2005 '*Changes in Soil Carbon and Soil Nitrogen after Tree Clearing in the Semi-arid Rangelands of Queensland*'. Australian Journal of Botany (53) 639–650.

Haynes C. D. (1985). '*The pattern and ecology of munwag: traditional Aboriginal fire regimes in north-central Arnhem Land*'. Proceedings of the Ecological Society of Australia, 13, pp 203–214.

Haynes, R. J. and Goh, K. M. (1980) Distribution and budget of nutrients in a commercial apple orchard. *Plant and Soil*, 56, 445-457.

Heanes, D. L. (1984) *Determination of total organic-C in soils by an improved chromic acid digestion and spectrophotometric procedure.* Communications in Soil Science and Plant Analysis. 15, 1191-1213.

Heenan, D.P., McGhie, W.J., Thomsons, F.M., Chan, K.Y., 1995, Decline in soil organic carbon and total nitrogen in relation to tillage, stubble management, and rotation, Australian Journal of Experimental Agriculture,35, 877-84 877

Heathcote in, Camm, J.C.R., McQuilton, J., editors, 198, Australians : A Historical Atlas, Broadway, NSW, Fiarfax, Syme and Weldon Associates, pp 62-63.

Henzell, T., 2007, Australian Agriculture Its History and Challenges, CSIRO Publishing.

Hickey, J.E. 1994 *'A floristic comparison of vascular species in Tasmanian oldgrowth mixed forest with regeneration resulting from logging and wildfire'*. Australian Journal of Botany 42: 383-404.

Hingston, F.J., Dimmock, G.M., and Turton, A.G. 1981 *'Nutrient distribution in a jarrah (Eucalyptus marginate Donn Ex Sm.) ecosystem in south-west Western Australia'*. Forest Ecology and Management 3: 183-207.

Hoekman, S.K. 1992, '*Speciated Measurements and Calculated Reactivities of Vehicle Exhaust Emissions from Conventional and Reformulated Gasolines*', Environmental Science and Technology, Vol. 26, No. 10, p 2036, American Chemical Society.

Houlder, D., Hutchinson, M.F., Nix, H.A., and McMahon, J.P., 2000 ANUCLIM, User's Guide. CRES, ANU, Canberra.

Howden, S.M. 1991, '*Methane production from livestock*' in *Draft Australian Greenhouse Gas Emission Inventory 1987–88'*, Greenhouse Study Number 10, Department of the Arts, Sport, the Environment and Territories, Commonwealth of Australia, pp 15–22.

– 2001. '*Analysis of National Livestock Statistics: Assessment for systematic reporting bias*' in F. Ghassemi, D.H. White, S. Cuddy and T. Nakanishi (eds) '*Integrating models for natural resources Management across disciplines, issues and scales.* Proceedings of the International Congress on Modelling and Simulation, December 2001, Canberra. Modelling and Simulation Society of Australia and New Zealand, Canberra. p 1841-1846.

– and Barret, D. 2003. '*Review of Australian methodology for estimating greenhouse gas emissions from livestock: Analysis of Tasmania and National Beef and Dairy Herd Data*', CSIRO, report prepared for the Australian Greenhouse Office.

– White, D.H., Hegarty, R. 2002. '*The review of the National Greenhouse Gas Inventory for Australian Livestock*', CSIRO Sustainable Ecosystems, report prepared for the Australian Greenhouse Office.

– White, D.H., McKeon, G.M., Scanlan, J.C and Carter J.O., 1994, '*Methods for Exploring Management Options to Reduce Greenhouse Gas Emissions from Tropical Grazing Systems*', *Climatic Change*, vol 27 pp 49–70.

HRL, 2013, *Latrobe Valley Brown Coal Mine Method One Default Fugitive Greenhouse Gas Emission Factor*. Unpublished report.

Hughes, K. A., Gandar, P. W. and de Silva H. N. (1995) Exploration and exploitation of soil by apple, kiwifruit, peach, Asian pear and grape roots. *Plant and Soil*, **175**, 301-309.

Hunter, R.A, 2007, 'Methane production by cattle in the tropics', *British Journal of Nutrition*, Vol 98, pp 657.

Hurst, D.F., Griffith D.W.T., Carras, J.N., Williams, D.J., and Fraser, P.J. 1994a, '*Measurements of trace gases emitted by Australian savanna fires during the 1990 dry season*', *J. Atmos. Chem.*, 18, pp 33–56.

– Griffith, D.W.T. and Cook, G.D. 1994b, '*Trace gas emissions from biomass burning in tropical Australian savannas*', *J. Geophys. Res.* 99, pp 16441—16456.

– Griffith, D.W.T and Cook, G.D. 1996, '*Trace gas emissions from biomass burning in Australia*', In: Biomass Burning and Global Change, Ed. J.S. Levine, M.I.T Press, USA. Vol 2 p787-792.

Hutchinson, M.F., Stein, J.A., and Stein, J.L. 2001. *Upgrade of the 9 second Digital Elevation Model for Australia*. Centre for Resource and Environmental Studies, Australian National University, Canberra.

Hutchinson N., Piffl R., Bavaro M., Lehner M. & Pack D. 1993, '*Environmental committee on natural gas leakage, position report on methane emissions*', AGA, Canberra.

Hyder Consulting 2007a, '*AGO Factors and Methods Workbook – Waste Chapter Review*', unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

– 2007b, '*Review of Methane Recovery and Flaring from Landfills*', unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

– 2008, '*Composition of commercial & industrial and municipal waste to landfill*', report to the Department of Climate Change, January 2008.

– 2009, *Review of first order decay model parameters Fraction of degradable organic carbon dissimilated (DOC_f)* report to the Department of Climate Change.

– 2010, *Greenhouse Accounts: Emissions from solid waste disposal – DOC_f*, Report to the Department of Climate Change and Energy Efficiency.

IEA (International Energy Agency) 1992, Coal Industry Advisory Board, , *Global methane and the coal industry, OECD, Part 1*, pp 34. http://www.iea.org/textbase/nppdf/free/1990/ciab1994.pdf

– 1993, Coal Research, N_2O from Fuel Combustion. IEAPER/06, ISMN 92-9029-227-X.

– 2005, *Energy Statistics Manual*, France. http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1461

Ilic, J., Boland, D.J., McDonald, M. and Downes, G. 2000, '*Wood Density - State of Knowledge*'. National Carbon Accounting System Technical Report No. 18 (55pp). Australian Greenhouse Office, Canberra.

International Aluminium Institute 2005, '*The International Aluminium Institutes Report on the Aluminium Industry's Global Perfluorocarbon Gas Emissions Reduction Programme – Results of the 2003 Anode Effect Survey*'. International Aluminium Institute, New Zealand House, London.

2006, *The Aluminium Sector Greenhouse Gas Protocol*, Addendum to the WRI/WBCSD GHG Prototcol, International Aluminium Institute.

– USEPA, 2008. *Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production*), Washington, D.C. and London, U.K.

International Civil Aviation Organisation, 2004, *ICAO Aircraft Engine Emissions Databank*, January 2012 http://easa.europa.eu/environment/edb/aircraft-engine-emissions.php

IPCC (Intergovernmental Panel on Climate Change) 1996, *Climate Change 1995: The Science of ClimateCchange. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Unversity Press, Cambridge.

– 1997, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories:* Volume 1, *Greenhouse Gas Inventory Reporting Instructions*; Volume 2, *Greenhouse Gas Inventory Workbook;* Volume 3, *Greenhouse Gas Inventory Reference Manual* IPCC/OECD/IEA, Paris, France.

– 2000, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Japan.

– 2003, *Good Practice Guidance on Land Use, Land Use Change and Forestry*, Japan.

– 2006, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Japan.

Jaakko Pöyry Consulting 1999, *National Carbon Accounting System – Usage and Lifecycle of Wood Products*. NCAS Technical Report No.8. Canberra.

– 2000, *Analysis of Wood Product Accounting Options for the National Carbon Accounting System*. National Carbon Accounting System Technical Report No. 24 (37pp). Australian Greenhouse Office, Canberra.

Janik, L., Spouncer, L., Correll, R. and Skjemstad, J. 2002, '*Sensitivity analysis of the Roth-C soil carbon model (Ver. 26.3 Excel©)'*. National Carbon Accounting System Technical Report No. 30, Australian Greenhouse Office, Canberra.

Jenkinson, D.S., 1990 The turnover of organic carbon and nitrogen in soil. Philisophical Transactions of the Royal Society B 329: 361-368.

Jenkinson, D.S., Adams, D.E. and Wild, A. 1991, '*Model Estimates of CO_2* Emissions from Soil in Response to Global Warming'. Nature 351: 304-306.

– Hart, P.B.S., Rayner, J.H. and Parry, L.C. 1987, '*Modelling the Turnover of Organic Matter in Long-Term Experiments at Rothamsted'*. INTERCOL Bulletin 15: 1–8.

Joint Coal Board 1988–2000, *Australian Black Coal Statistics* (annual), Sydney.

Jones, S., Lowell, K.E., Woodgate, P., Buxton, L., Mager, A. and Liebchen, S. 2004, '*Update on the National Carbon Accounting System Continuous Improvement and Verification Methodology*'. National Carbon Accouting System Technical Report 46, Australian Greenhouse Office.

Keith, H., Barrett, D. and Keenan, R. 2000, '*Review Allometric Relationships for Woody Biomass for New South Wales, the Australian Capital Territory, Victoria, Tasmania and South Australia*'. National Carbon Accounting System Technical Report No. 5b (119pp). Australian Greenhouse Office.

Kennedy, P.M. and Charmley, E., 2012, ' Methane yields from Brahman cattle fed tropical grasses and legumes', *Animal Production Science*, Vol 52, pp. 225-239.

Kesteven, J., Landsberg, J. and URS Consulting 2004, '*Developing a national forest productivity model*'. National Carbon Accounting System Technical Report No.23, Australian Greenhouse Office, Canberra.

King, R.H. & Brown, W.G. 1993, '*Interrelationships between dietary protein level, energy intake and nitrogen retention in pregnant gilts*', Journal of Animal Science, vol. 71, pp. 2450–2456.

- Toner, M.S., Dove, H., Atwood, C.S. & Brown, W.G. 1993, *The response of first-litter sows to dietary protein level during lactation*', *Journal of Animal Science*, vol. 71, pp.2457–2463.

Kirchgessner, M., Kreuzer, M., Muller, H.L., Windisch, W. 1991, '*Release of methane and of carbon dioxide by the pig*', *Agribiological Research*, vol. 44, pp. 103–113.

Kiiveri, H. Caccetta, P. Campbell, N. Evans, F. Furby, S. Wallace, J. 2003, '*Environmental Monitoring Using a Time Series of Satellite Images and Other Spatial Data Sets*', in D. D. Denison , M. H. Hansen, C. Holmes, B. Mallick, B. Yu (Eds), Nonlinear Estimation and Classification, Lecture Notes In Statistics, New York, Springer Verlag, 2003, ISSU 171, pages 49-62.

- Caccetta, P.A., and Evans, F. 2001, '*Use of conditional probability networks for environmental monitoring*', International Journal of Remote Sensing, Volume 22: 1173-1190.

Kirk-Othmer (1999), *Concise Encyclopedia of Chemical Technology*, Fourth Edition, John Wiley & Sons, Inc. USA.

Kroodsma, D. A. and Field, C. B. (2006), Carbon sequestration in Californian agriculture. *Ecological Applications*, 16 (5), 1975-1985.

Kruger, I, Taylor, G. and Ferrier M., 1995, *Australian Pig Housing Series: Effluent at Work*, NSW Agriculture, Australia, 211pp.

Kurihara, M., Magner, T., Hunter, R.A., and McCrabb G.J., 1999, '*Methane production and energy partition of cattle in the tropics*', British Journal of Nutrition vol 81, pp 263–272.

- Magner, T., Hunter, R.A., and McCrabb G.J., 2006, '*Methane production and energy partition of cattle in the tropics*', *British Journal of Nutrition, unpublished corrigendum.*

Lamborn, J. 2009, *Characterisation of municipal solid waste composition into model inputs*. Third international workshop "Hydro-Physico-Mechanics of Landfills" Braunschweig, Germany, March 2009.

Landsberg, J.J. (1986) '*Coupling of Carbon, Water and Nutrient Interactions in Woody Plant Soil Systems*'. Tree Physiology 2.

- and Gower, S.T. 1997 '*Applications of Physiological Ecology to Forest Management*'. Academic Press: San Diego Press. 354pp.
- and Waring, R.H. 1997 '*A generalized model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance, and partitioning*'. Forest Ecology and Management, 95: 209–228.

Law, B.E., Sun, O.J., Campbell, J., Van Tuyl, S., and Thornton, P.E. 2003 *'Changes in carbon storage and fluxes in a chronosequence of ponderosa pine'*. Global Change Biology 9: 510-524.

Leung, L 2001, BHP, *pers comm. regarding emission factor analysis of Port Kembla and Whyalla coking coals.*

Leuning, R., Baker, S.K., Jamie, I.M, Hsu, C.H., Klien, L., Denmead, O.T. and Griffith, D.W.T. 1999, '*Methane emissions from free-range sheep: a comparison of two measurement methods*'. *Atmospheric Environment*, vol 33, pp 1357–1365.

Lewis, N.B., Keeves, A., and Leech, J.W. 1976 *'Yield regulation in South Australian Pinus radiata plantations'*. Woods and Forests Department Bulletin (South Australia) 23.

Llewellyn, R.S., D'Emden, F., and Gobbett, D. 2009 'Adoption of no-till and conservation farming practices in Australian grain growing regions: current status and trends'. Preliminary report for SA No-till Farmers Association and CAAANZ, South Australia.

Lloyds' Register of Shipping 1995, '*Marine Exhaust Emissions Research Programme - Steady State Operation*', Lloyds' Register of Shipping, London, UK.

Lovatt, C. J. (1996) Nitrogen allocation within the 'Hass' avocado. *Californian Avocado Society 1996 Yearbook*, 80, 75-83.

Lowell, K., Buxton, L., Fintelman, R., Ching, J., Arya, T., and Jones, S. *Update of the national carbon accounting system continuous improvement and verification methodology*: 2002-2010 unpublished research report by the Cooperative Research Centre for Spatial Information and RMIT University Australia, November 2012

Lowell, K.E., Woodgate, P., Jones, S. and Richards, G.P. 2003, '*Continuous Improvement of the National Carbon Accounting System Land Cover Change Mapping*'. National Carbon Accounting System Technical Report 39, Australian Greenhouse Office, p. 36.

– Richards, G.P., Woodgate, P., Jones, S. and Buxton, L. 2005, '*Fuzzy Reliability Assessment of Multi-Period Land-cover Change Maps*'. Photogrammetric Engineering and Remote Sensing. 71:939–945.

Lucas, R.M., King, S., *et al.,* 1997, *'The role of Australia's native forests in carbon sequestration: Tasmania as a case study'*. Report to the Department of Environment, Sports and Territories, Canberra, Australia.

Lunarzewski, L 2005 *Gas Emission Curves for Sealed Goafs or Abandoned Mines*, report for the Australian Coal Association Research Programme, ACARP project C13007.

– 2006, *Review of the Draft Australian Methodology for Estimating Greenhouse Gas Emissions from Flooding Decommissioned Coal Mines*, unpublished report to the Department of Environment and Heritage.

Mackensen, J. and Bauhus, J. 1999, '*The Decay of Coarse Woody Debris*'. National Carbon Accounting System Technical Report No. 6 (41pp). Australian Greenhouse Office, Canberra.

– Bauhus, J., and Webber, E. 2003 *'Decomposition rates of coarse woody debris - A review with particular emphasis on Australian species'*. Australian Journal of Botany 51: 23-37.

Margan, D.E., Graham, N. McC. and Searle, T.W. 1985, '*Energy values of whole lucerne (Medicago sativa) and of its stem and leaf fractions in immature and fully grown sheep*', *Australian Journal of Experimental Agriculture*, vol. 25, pp 783–790.

– Graham, N. McC. and Searle, T.W. 1987, '*Energy values of whole oats grain in adult wether sheep*', *Australian Journal of Experimental Agriculture*, vol. 27, pp 223–230.

– Graham, N. McC., Minson, D.J. and Searle, T.W. 1988, '*Energy and protein values of four forages, including a comparison between tropical and temperate species*', *Australian Journal of Experimental Agriculture*, vol. 28, pp 729–736.

Marini, R. P. and Sowers, D. S. (2000), Peach tree growth, yield and profitability as influenced by tree form and tree density. *Horticultural Science*, **35 (5)**, 837-842.

Marsden-Smedley, J.B. and W.R. Catchpole, 1995a, '*Fire modelling in Tasmanian buttongrass moorlands I. Fuel characteristics*'. *International Journal of Wildland Fire* 5, pp 203–214.

– and W.R. Catchpole 1995b, '*Fire modelling in Tasmanian buttongrass moorlands II. Fire behaviour*'. *International Journal of Wildland Fire* 5, pp 215–228.

MBAC Consulting (in prep.) *CSIRO Plantation Imagery Verification*. Australian Greenhouse Office, Canberra, Australia.

McKenzie, N. J., Ryan, P. J., Fogarty, P. and Wood, J. 2000b '*Sampling Measurement and Analytic Protocols for Carbon and Litter Estimation*'. National Carbon Accounting System Technical Report No. 14 (66pp). Australian Greenhouse Office, Canberra.

– Jacquier, D.W., Ashton, L.J. and Cresswell, H.P. 2000a '*Estimation of Soil Properties Using the Atlas of Australian Soils*'. CSIRO Land and Water Technical Report 11/00.

McMeniman, J.P., Defoor, P. J., and Gaylean, M.L. 2009. *Evaluation of the National Research Council (1996) dry matter intake predictions and relationships between intake and performance by feedlot cattle.* Journal of Animal Science, 87.3:1138-1146.

McMurtrie, R.E., Leuning, R., Thompson, W.A. and Wheeler, A.M. 1992 '*A Model of Canopy Photosynthesis and Water-Use Incorporating a Mechanistic Formulation of Leaf* CO_2 Exchange'. Forest Ecology and Management. 52:261–278.

Meyer, C.P., 2004, '*Establishing a consistent time-series of greenhouse gas emission estimates from savanna burning in Australia*', Final report to the Australian Greenhouse Office, December 2004, CSIRO Division of Atmospheric Research, Aspendale, Victoria, Australia, 58pp.

– 2011, '*Review of the National Greenhouse Gas Emissions Methodology for Savanna Burning*'. Report to the Commonwealth Department of Climate Change and Energy Efficiency, 52 p.

– And Cook G.D., 2011. '*Seasonality in Greenhouse Gas Emission Factors from Savanna fires*'. Final Report to NAILSMA, February 2011, CSIRO Marine and Atmospheric Research, Aspendale, Vic, AUSTRALIA, 60 p.

Micales, J.A and Skog, K.E. 1996 *The decomposition of forest products in landfills*, International Biodeterioration and Biodegradation 39 (2-3): pp 145- 158.

Milthorpe F.L. 1982, '*Interaction of biogeochemical cycles in nutrient-limited environments: wheat-pasture and forest systems*' in *The Cycling of Carbon, Nitrogen, Sulfur and Phosphorous in Terrestrial and Aquatic Ecosystems,* I.E. Galbally and J.R. Freney eds., Australian Academy of Science, Canberra pp 35–45.

Ministry for the Environment, 2011. Unpublished report to DCCEE, *Review of components of Australia's national inventory system*. New Zealand Government.

Minson, D.J. and McDonald, C.K., 1987, '*Estimating forage intake from the growth of beef cattle*', *Tropical Grasslands* vol 21, pp 116–122.

MLA (Meat and Livestock Australia) 2002, *'2002 Lamb Survey'*, Market Information Services, Meat and Livestock Australia.

Moe, P.W. and Tyrrell, H.F., 1979, '*Methane production in dairy cows*', *Journal of Dairy Science*, vol 62, pp 1583–1586.

Mohren, G.M.J and Goldewijk, K.C.G.M. 1990 'CO_2Fix*: a dynamic model of the CO_2* fixation in forest stands'. Rapport 624, De Dorschkamp, Research Institute of Forestry and Urban Ecology, Wageningen, 96pp.

Mokany, K., Raison, R.J., and Prokushkin, A.S. 2006 '*Critical analysis of root:shoot ratios in terrestrial biomes*'. Global Change Biology 12: 84-86

Montreal Process Implementation Group for Australia (2008) '*Australia's State of the Forests Report*.' Bureau of Rural Sciences, Canberra. http://adl.brs.gov.au/forestsaustralia/publications/sofr2008.html

Moorhead, D.L. and Reynolds, J.F. 1991 '*A General Model of Litter Decomposition in the Northern Chihuahuan Desert'*. Ecological Modelling 59: 197–219.

– Currie, W.S., Rastetter, E.B., Parton, W.J. and Harmon, M.E. 1999 '*Climate and Litter Quality Controls on Decomposition: An Analysis of Modelling Approaches'*. Global Biogeochemical Cycles 13: 575–589.

Morgan, K.T., Scholberg, J. M. S., Obreza, T. A. and Wheaton, T. A. (2006) Size, biomass and nitrogen relationships with sweet orange tree growth. *Journal of the American Society of Horticultural Science*, 131 (1), 149-156. Moss, A.R. 1993, '*Methane: Global warming and production by animals'*. Chalcombe Publications, Canterbury, UK, 105pp.

MRT (Mineral Resources Tasmania) 2012. Coal production data, Department of Infrastructure, Energy and Resources, Tasmania. http://www.mrt.tas.gov.au/

Mulholland, J.G., J.B.Coombe, M.Freer and W.R. McManus, 1976, '*An Evaluation of Cereal Stubbles for Sheep Production*'. *Aust. J. Agric. Res.,* 1976, 27, pp 881–893.

Murphy, T., Jones, G., Vanclay, J. and Glencross, K. (2013) Preliminary carbon sequestration modelling for the Australian macadamia industry. *Agroforestry Systems*, **87**, 689-698.

Murphy, B., Rawson, A., Ravenscroft, L. Rankin, M. and Millard, R. (2002) '*Paired Site Sampling for Soil Carbon Estimation – NSW'*. National Carbon Accounting System Technical Report No. 34, Australian Greenhouse Office, Canberra.

Myers, B.J., Theiveyanathan, S., O'Brien, N.D., and Bond, W.J. 1996 *'Growth and water use of* Eucalyptus grandis *and* Pinus radiata *plantations irrigated with effluent'*. Tree Physiology 16:211-219.

National Forest Inventory 1997a *National Plantation Inventory of Australia*. BRS, Canberra.

– 1997b *Forecasting of Wood Flows from Australia's Plantations*. A report to the 1997 National Plantation Inventory. Bureau of Resource Sciences, Canberra. 22pp.

National Greenhouse and Energy Reporting (Audit) Determination 2009 (Cwlth), ComLaw, viewed 9 March 2012, http://www.comlaw.gov.au/Details/F2010L00053/

National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Cwlth), ComLaw, viewed 9 March 2012, http://www.comlaw.gov.au/Details/F2011C00469

NGER 2009-2012 – Data collated by the Clean Energy Regulator under the National Greenhouse and Energy Reporting system. http://www.cleanenergyregulator.gov.au/National-Greenhouse-and-Energy-Reporting/Pages/default.aspx

NGGIC (National Greenhouse Gas Inventory Committee), 1994a, The Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Agriculture, Workbook for Non-Carbon Dioxide Gases from the Biosphere, National Greenhouse Gas Inventory Committee, Workbook 5.0 , Canberra.

– 1994b, *The Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook for Livestock,* National Greenhouse Gas Inventory Committee Workbook 6.0, Canberra.

– 1995, *The Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook for Landfill, Wastewater and Other Waste Activities*, National Greenhouse Gas Inventory Committee Workbook 8.0, Canberra.

– 1996, *The Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook for Livestock,* National Greenhouse Gas Inventory Committee Workbook 6.1, Canberra.

– 2006, *National Inventory Report and Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks: Energy (Fugitive Fuel Emissions)*, Canberra.

Netherlands Environment Assessment Agency 2010, *Greenhouse Gas Emissions in the Netherlands 1990-2008, National Inventory Report 2010*, Bilthoven, Netherlands.

New South Wales Department of Minerals 1988–94, *New South Wales coal industry profile* (annual), Sydney.

New Zealand Ministry for the Environment 2010, *New Zealand's Greenhouse Gas Inventory 1990-2008,* Wellington, New Zealand

NLWRA (National Land and Water Resources Audit) 2001. *Australian Native Vegetation Assessment 2001*, National Land and Water Resources Audit, Canberra.

Nut Producers Australia http://nutproducers.com.au/pistachio-products/australian-pistachio-history/, Accessed 1 December 2013.

NRC (National Research Council) 1994, '*Nutrient requirements of poultry*', Ninth Revised Edition, National Academy Press.

O'Brien 2006a, '*Review of Onsite Industrial Wastewater Treatment',* O'Brien Consulting Greenhouse, Energy, Environment, report to the Australian Government Department of the Environment and Heritage, Canberra.

– 2006b, *Solvent and Clinical Waste Incineration in Australia*, O'Brien Consulting Greenhouse, Energy, Environment, report to the Australian Government Department of the Environment and Heritage, Canberra.

O'Connell, A.M. 1997 *'Decomposition of slash residues in thinned regrowth eucalypt forest in Western Australia'*. Journal of Applied Ecology 34: 111-122.

OECD (Organisation for Economic and Co-operation Development) 1991, '*Estimation of Greenhouse Gas Emissions and Sinks*', Final Report from the OECD Experts Meeting, February 1991 (Revised August 1991), prepared for the IPCC, OECD.

Oenema, O., G.L. Velthoft, S. Yamulki and S.C. Jarvis 1997, '*Nitrous oxide emissions from grazed grassland', Soil Use and Management*, 13, pp 288–295.

Officer, S.F., Phillips, F., Armstrong, R. and Graham, C., 2010, Nitrogen fertiliser increases nitrous oxide emissions from a semi arid Vertosol, In: *19th World Congress of Soil Science, Soil Solutions for a Changing World,* 1 – 6 August 2010, Brisbane, Australia, pp168-171.

Olives Australia http://www.oliveaustralia.com.au/About_Olive_Trees/about_olive_trees.html, Accessed 1 December 2013.

Onesteel 2009, *2009 Annual Report*, http://www.onesteel.com/images/db_images/annualreports/OneSteel%20Limited%20-%20Annual%20Report%202009.pdf

Orbital Australia 2010, *Emissions Factor Derivation from NISE2 Measurements of Vehicles from the Australian Fleet,* internal report to the Department of Climate Change and Energy Efficiency, December 2010.

- 2011a, *Literature Review of Uncertainty in Fuel Properties*, internal report to the Department of Climate Change and Energy Efficiency, June 2011.
- 2011b, *Preparation of Weighted GHG Results from Additional Data Sources,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.
- 2011c, *Additional Data Analysis for Greenhouse Gas Inventory - Search for Ethanol, LPG and Diesel Deterioration Rate Information,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.

Palisade Corporation 1997 *@Risk for Windows*. Version 3.5.2.

Parton, W.J., Schimel, D.S., Cole, C.V. and Ojima, D.S. 1987 '*Analysis of factors controlling soil organic matter levels in Great Plains grasslands*'. Soil Science Society of America Journal. 51:1173–1179.

Paul, K., Polglase, P., Coops, N., O'Connell, T., Grove, T., Medlam, D., Carlyle, C., May, B., Smethurst, P. and Baillie, C. 2002a '*Modelling Change in Soil Carbon Following Afforestation or Reforestation: Preliminary Simulations Using GRC3 and Sensitivity Analysis*'. National Carbon Accounting System Technical Report No. 29 (106pp), Australian Greenhouse Office, Canberra.

- Polglase, PJ, Nyakuengama, JG and Khanna, PK 2002b '*Change in soil carbon following afforestation*'. Forest Ecology and Management. 168: 241–257.
- Polglase, PJ and Richards, GP 2003a '*Sensitivity analysis of predicted change in soil carbon following afforestation*'. Ecological Modelling. 164:137–152.
- Polglase, P.J. Richards G.P. 2003b '*Predicting Change in Soil Carbon following Afforestation or Reforestation*'. Forestry Ecology and Management 177: 485–501.
- and Polglase, P.J. 2004a *'Prediction of decomposition of litter under eucalypts and pines using the FullCAM model'*. Forest Ecology and Management 191: 73-92.
- and Polglase P.J. 2004b *Calibration of the Roth C model to turnover of soil carbon under eucalypts and pines*. Australian Journal of Soil Research 42, 883-895.
- 2013 S. Roxburgh, J. Raison, J. Larmour, J. England, S. Murphy, J. Norris, P. Ritson, K. Brooksbank, T. Hobbs, C. Neumann, T. Lewis, Z. Read, D. Clifford, L. Kmoch, M. Rooney, D. Freudenberger, J. Jonson, A. Peck, R. Giles, J. Bartle, G. McAurthur, D. Wildy, A. Lindsay, N. Preece, S. Cunningham, T. Powe, J. Carter, R. Bennett, D. Mendham, R. Sudmeyer, B. Rose, D. Butler, L. Cohen, T. Fairman, R. Law, B. Finn, M. Brammar, G. Minchin, P. van Oosterzee and A. Lothian. *Improved estimation of biomass accumulation by environmental planting and mallee plantings using FullCAM*, report for the Department of the Environment. CSIRO Sustainable Agriculture Flagship, Canberra, Australia.

Pekol Traffic and Transport 2013, selected tables purchased from the *Australian Transport Facts*.

PCI Geomatics 2000, PCI Geomatics Corporation, USA

Phillips, F.A., Leuning, R., Baigent, R., Kelly, K.B., and Denmenad, O.T., 2007, Nitrous oxide flux measurements from an intensively managed irrigated pasture using micrometeorological techniques, *Agricultural and Forest Meteorology,* 143:92–105

Pitt and Sherry, 2013. *Independent Technical Review of a Proposed Brown Coal Mine Default Fugitive Emissions Factor*. Report for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Prince, S.D., Haskett, J., Steininger, M., Strand, H., and Wright, R. 2001. *Net primary production of US Midwest croplands from agricultural harvest yield data.* Ecological Applications 11: 1194-1205.

Polglase, P.J., Paul, K.I., Khanna, P.K., Nyakuengama, J.G., O'Connell, A.M., Grove, T.S. and Battaglia, M. (2000) *Change in Soil Carbon Following Afforestation and Reforestation*. National Carbon Accounting System Technical Report No. 20 (89pp) Australian Greenhouse Office, Canberra.

– Snowdon, P, Theiveyanathan, T, Paul, KI, Raison, RJ, Grove, T and Rance, SJ 2004 *Calibration of the FullCAM model to* Eucalyptus globulus *and* Pinus radiata *and uncertainty analysis*. Nation Carbon Accounting System Technical Report No. 40, Australian Greenhouse Office, Canberra.

Potter, C.S., Randerson, J.T., Field, C.B., Matson, P.A., Vitousek, P.M., Mooney, H.A. and Klooster, S.A. 1993 '*Terrestrial ecosystem production: a process model based on global satellite and surface data*'. Global Biogeochemical Cycles 7:811–841.

Protiviti 2007, *Review of Management of the National Greenhouse Gas Inventory Database,* internal report to the Department of Environment and Water Resources.

Punshon, S. and Moore, R. M., 2004, *Nitrous oxide production and consumption in a eutrophic coastal embayment*, Marine Chemistry, vol 91(1-4), pp37-51.

QDNRME (Queensland Department of Natural Resources, Mines and Energy) 1979-2009. *Annual coal statistics*.

Queensland Transport 2001, *Transport 2007, An action plan for South East Queensland*, Queensland Transport. http://www.transport.qld.gov.au/Home/Projects_and_initiatives/Plans/Integrated_transport_plans/Transport_2007/

Queensland Coal Board 1988–94*, Queensland coal industry annual review* (annual), Brisbane.

Raison, R.J., Keith, H., Barrett, D., Burrows, W. and Grierson, P.F. 2003 *Spatial Estimates of Biomass in 'Mature' Native Vegetation*. National Carbon Accounting System Technical Report 44, Australian Greenhouse Office, Canberra, Australia, p. 56.

– and Squire, R. 2008, *'Forest Management in Australia: Implications for Carbon Budgets'*. National Carbon Accounting System Technical Report No 32, Australian Greenhouse Office, Canberra, Australia.

Raupach M, Kirby M, Briggs P and Barrett D 2000, Balancing the Australian biosphere: continental budgets of water, carbon, nitrogen and phosphorus . Project 5.4A. Final report to the National Land and Water Resources Audit, Canberra

Reay, D.S., K.A. Smith and A.C. Edwards, 2004, '*Nitrous oxide in agricultural drainage waters following field fertilisation*'. *Water, Air, Soil Pollution: Focus*, vol 4, pp 437–451.

Recycled Organics Unit, University of New South Wales, 2008, 'Recycling organics: industry statistics 2007', Report prepared for Compost Australia by the Recycled Organics Unit. Internet publication www.compostaustralia.com.au and previous issues.

– 2009, *Organics recycling in Australia - Industry statistics 2009*, Recycled Organics Unit, Sydney.

Resource Assessment Commission 1991 *Forest and Timber Inquiry Draft Report*. Volumes 1 and 2. Commonwealth of Australia, Canberra.

– 1992a *Forest and Timber Inquiry: Final Report Part I.* Australian Government Publishing Service, Canberra.

– 1992b *A survey of Australia's forest resource*. Australian Government Publishing Service, Canberra.

Richards, G.P., ed. 2002, *Biomass Estimation: Approaches for Assessment of Stocks and Change*. National Carbon Accounting System Technical Report No. 27. Australian Greenhouse Office, Canberra.

– 2001, *The FullCAM Carbon Accounting Model: Development, Calibration and Implementation for the National Carbon Accounting System*. National Carbon Accounting System Technical Report No. 28 (50pp), Australian Greenhouse Office, Canberra.

– and Brack, C. 2004a, *A continental biomass stock and stock change estimation approach for Australia*. Australian Forestry. 67:284–288.

– and Brack, C., 2004b, '*A modelled carbon account for Australia's post-1990 plantation estate*', *Australian Forestry* vol 67, no 4, pp289–300 2005.

– and Evans, D. 2004, *Development of a carbon accounting model (FullCAM Vers. 1.0) for the Australian continent*. Australian Forestry. 67:277–283.

– and Evans, D.W. 2000a, CAMFor *User Manual v 3.35*. National Carbon Accounting System Technical Report No. 26 (47pp), Australian Greenhouse Office, Canberra.

– and Evans, D.W. 2000b, *CAMAg* National Carbon Accounting System (electronic model) Australian Greenhouse Office, Canberra.

– and Evans, D.W. 2000c, *GRC3* National Carbon Accounting System (electronic model) Australian Greenhouse Office, Canberra.

– Borough, C., Evans, D., Reddin, A., Ximenes, F. and Gardner, D. 2007, *Developing a carbon stocks and flows model for Australian wood products*. Australian Forestry. 70 (2): 108-119.

Rio Tinto 2009, *2009 Annual report*, http://www.riotinto.com/annualreport2009/production/metals.html

Robinson, D.W. and C.A. Kirkby 2002, '*Maize stubble management survey: summary of results*', CSIRO Land and Water Technical Report 13/02, CSIRO Land and Water.

Ruimey, A., Saugier, B. and Dedieu, G. 1994, '*Methodology for the estimation of terrestrial net primary production from remotely sensed data*'. J. Geophys. Res. 99:5263–5283.

Russell-Smith, J. Lucas D, Gapindi M, Gunbunuka B, Kapirigi N, Namingum G, Lucas K, Giuliani P, Chaloupka G, 1997. *Aboriginal resource utilization and fire management practice in western Arnhem Land, monsoonal northern Australia: notes for prehistory and lessons for the future.* Human Ecology 25, 159–195. doi:10.1023/A:1021970021670

– Edwards, A.C., Cook, G.D., Brocklehurse, P., and Schatz, J., 2004, '*Improving greenhouse emissions estimates associated with savanna burning northern Australia: Phase 1'*, Final Report to the Australian Greenhouse Office, June 2004, 27 pp

– Whitehead P.J., Smith R., Craig R.,Allan G.E.,Thackway R., Frakes I., Cridland S., Meyer C.P., Gill A.M. 2007. '*Bushfires 'Down Under': patterns and implications of Australian landscape burning*'. International Journal ofWildland Fire 16, 361–377. doi:10.1071/WF07018

– Murphy B.P., Meyer C.P., Cook G.D., Maier S., Edwards A.C., Schatz J., and Brocklehurst, 2009. '*Improving estimates of savanna burning emissions for greenhouse accounting in northern Australia: limitations, challenges, applications*'. International Journal of Wildland Fire, 18(1), pp1-18.

Ryan, M.G., Binkley, D., and Fownes, J.H. 1997 '*Age-related decline in forest productivity: pattern and process*'. Advances in Ecological Research 27: 213-262.

Ryan, W.G. and Samarin, A. 1992, '*Australian Concrete Technology',* Longman Cheshire, Melbourne.

Saffigna, P.G., Cogle, A.L., Strong, W.M. and Waring, S.A. 1982, '*The Effect of Carbonaceous residue on 15 fertiliser nitrogen transformations in the field',* in *The Cycling of Carbon Nitrogen, Sulfur and Phosphorous in Terrestrial and Aquatic Ecosystems*, I.E. Galbally and J.R. Freney eds., Australian Academy of Science Canberra, Australia, pp 83–87.

Sanderman, J., Farquharson, R., and Baldock, J. 2009. Soil carbon sequestration potential: a review for Austrlaian agriculture. Report for the CSIRO National Research Flagships Sustainable Agriculture.

Sanfelipe Olives http://www.sanfelipeoliveco.com/facts.html, Accessed 1 December 2013.

Sass R.L. 1994, '*Short Summary Chapter for Methane'* in *CH_4 and N_2O : Global Emissions and Controls from Rice Fields and Other Agricultural and Industrial Sources,* Eds.: K. Minami, A. Mosier and R. Sass, NIAES, NIAES, Tsukuba, Japan, pp 1–7.

– and F.M. Fisher 1994, '*CH_4 Emission from Paddy Fields in the United States Gulf Coast Area* in *CH_4 and N_2O – Global Emissions and Controls'* from *Rice Fields and Other Agricultural and Industrial Sources*. Eds.: K. Minami, A. Mosier and R. Sass, NIAES Series 2, NIAES, Tsukuba, Japan, pp 65–77.

Sawamoto, T, Y. Nakajima, M. Kasuya, H. Tsuruta and K. Yagi, 2005, '*Evaluation of emission factors for indirect N_2O emission due to nitrogen leaching in agro-ecosystems'. Geophysical Research Letters*, 32(3), doi:10.1029/2004GL021625.

SCA (Standing Committee on Agriculture) 1990; '*Feeding standards for Australian livestock, Ruminants*', SCA Ruminant Sub-Committee, CSIRO Australia.

Scheer, C., Grace, P.R, Rowlings, D.W and Payero, J. 2012, Nitrous oxide emission from irrigated wheat in Australia: impact of irrigation management, *Plant Soil*, 359:351-362

Schlamadinger, B., Canella, L., Marland, G. and Spitzer, J. 1997 '*Bioenergy strategies and the global carbon cycle*'. Sciences Geologiques. 50:157–182.Schwenke, G., Haigh, B., McMullen, G. and Herridge, D. 2010, Soil nitrous oxide emissions under dryland N-fertilised canola and N_2-fixing chickpea in the northern grains regions, Australia, In *19th World Congress of Soil Science, Soil Solutions for a Changing World,* 1 – 6 August 2010, Brisbane, Australia, pp228-231.

Sheriff, D.W., Mattay, J.P. and McMurtrie, R.E. 1996 *'Modeling productivity and transpiration of Pinus radiata: climatic effects'*. Tree Physiology 16: 183-186.

Singh, G.A., A.P. Kershaw, and R.Clark, 1981, '*Quaternary vegetation and fire history in Australia* in *Fire and the Australian Biota'* A.M. Gill, R.H. Groves, J.R. Noble eds, Australian Academy of Science, Canberra, Chapter 2, pp 23—54.

Skjemstad, J. and Spouncer, L. 2002 *Estimating Changes in Soil Carbon Resulting from Changes in Land Use*. National Carbon Accounting System Technical Report No. 36, Australian Greenhouse Office, Canberra.

– and Spouncer, L., 2003. *Integrated Soils Modelling for the National Carbon Accounting System*. National Carbon Accounting System Technical Report No. 36, Australian Greenhouse Office, Canberra, Australia.

– Spouncer, L.R. and Beech, T.A. 2000 *Carbon Conversion Factors for Historical Soil Carbon Data*. National Carbon Accounting System Technical Report No. 15 (17pp). Australian Greenhouse Office, Canberra.

– Spouncer, LR, Cowie, B and Swift, RS. 2004. *Calibration of the Rothamsted organic carbon turnover model (RothC ver. 26.3), using measurable soil organic carbon pools.* Australian Journal of Soil Research (2004), 42, 79-88.

Snowdon, P. 2002 'Modeling Type 1 and Type 2 growth responses in plantations after application of fertilizer or other silvicultural treatments'. Forest Ecology and Management 163: 229-244.

- Eamus, D., Gibbons, P., Khanna, P.K., Keith, H., Raison, R.J. and Kirschbaum, M.U.F. 2000, *Synthesis of allometrics, review of root biomass, and design of future woody biomass sampling strategies*. National Carbon Accounting System Technical Report No. 17 (142pp). Australian Greenhouse Office.
- Raison, J., Keith, H., Ritson, P., Grierson, P., Adams, M., Montagu, K., Bi, H., Burrows, W., and Eamus, D. 2002 *Protocol for Sampling Tree and Stand Biomass*. National Carbon Accounting System Technical Report No. 31 (72pp), Australian Greenhouse Office, Canberra.
- Ryan, P., Raison, J. 2005 *Review of C:N Ratios in Vegetation, Litter and Soil under Australian Native Forests and Plantations*. National Carbon Accounting System Technical Report No. 45 (60pp), Australian Greenhouse Office, Canberra.
- and Waring, H.D. 1984 *'Long-term nature of growth responses obtained to fertilizer and weed control applied at planting and their consequences for forest management'*. In: Grey, D.C., Shonau, A.P.G., Shutz, C.J. (Eds.), Proceedings of the IUFRO Symposium on Site and Productivity of Fast Growing Plantations, April 30-May 11, Pretoria and Pietermaritzberg, South Africa. Forest Research Institute, Pretoria, pp 701-711.
- and James, R. 2008 *'Historical development of silvicultural practices in plantations'*. In: Raison, R.J. and Squire, R. (Eds.), 'Forest management in Australia: Implications for carbon budgets'. National Carbon Accounting System Technical Report No. 32, Australian Greenhouse Office, Canberra, Australia.

Spencer, R., Keenan, R., Ranatunga, K. and Wood , M. 2001 *Plantation Projections in Australia*. (unpublished report).

Stewart, J.B., Smart, R.V., Barry, S.C. and Veitch, S.M. (2001) 1996/97 Land Use of Australia - Final Report for Project BRR5, National Land and Water Resources Audit, Canberra.

Swift, R. and Skjemstad, J. 2002 *Agricultural Land Use and Management Information*. National Carbon Accounting System Technical Report No. 13 (446pp). Australian Greenhouse Office, Canberra.

Sydney Water, Wastewater network map, http://www.sydneywater.com.au/SW/water-the-environment/how-we-manage-sydney-s-water/wastewater-network/index.htm

Thackway, R. and Cresswell, I.D. eds. 1995 '*An Interim Biogeographic Regionalisation for Australia: a framework for establishing the national system of reserves*'. Version 4.0. Australian Nature Conservation Agency, Canberra.

Thomson, S. 2010; *Gas layering in the subsurface: Implications for greenhouse gas emissions, Proceedings of the 37th symposium on the geology of the Sydney basin*. Hunter Valley May 6-7, 2010.

Todd, J, Gibbons, A., King, R. and Kinrade, P. 1989a, *Measurement of Air Pollutants from Woodheaters*; NERDP Project Number 1186; Centre for Environmental Studies, University of Tasmania, Hobart.

- Gray, KM and King LR. 1989b, *National Fuelwood Study, the Commissioned Study on Fuelwood Use and Supply in Australia*; Department of Primary Industries and Energy, Canberra.
- 1991; Emissions and Performance of Woodheaters When Burning Softwoods, Fuelwood Report No. 3; Centre for Environmental Studies, University of Tasmania, Hobart
- 1993 *Carbon dioxide emissions from firewood combustion*, Inhouse Fuelwood Report No. 55, Centre for Environmental Studies, University of Tasmania.
- 2001, *Factors Influencing Residential Wood-Smoke Emissions: Hobart Survey*, Report for the Department of Primary Industries, Water and Environment, Hobart, January 2001
- 2003, *Estimating Greenhouse Gas Emissions from Residential Firewood Use Australia 1989/65 to 2000/01*, Report for Energy Strategies Pty Ltd and the Australian Greenhouse Office, Eco-Energy Options.

– 2005, *Carbon dioxide emissions from firewood combustion*, unpublished report to the Australian Greenhouse Office.

– 2008: *Woodheater Operation and Firewood Parameters: Australia*, prepared for the Department of the Environment and Water Resources, EEO Report 08/01

– 2011. *Estimating Greenhouse Gas Emissions from Residential Firewood Use: Australia 1989/90 to 2010/11*. Eco-Energy Options Pty Ltd.

Tolhurst, K.G. 1994, '*Assessment of Biomass Burning in Australia: 1983 to 1992'*, in *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Agriculture, Workbook for Non-Carbon Dioxide Gases from the Biosphere*, National Greenhouse Gas Inventory Committee, Workbook 5.0 1994.

Treadrea, P. 1995, '*The Environmental Consequences of Urban and Rural Bituminous Practices'*, Australian Road Research Board Transport Research (ARRBTR), Melbourne.

Tsaranu, M. 2007 *Report of quality assurance review of the Australia's National Greenhouse Gas Inventory 2006: Industrial Processes Sector*. Report to the Australian Greenhouse Office.

Turner, B. 1984 *'Potential productivity gains in Australian east coast* Pinus radiata *plantations'*. In: Grey, D.C., Shonau, A.P.G., Shutz, C.J. (Eds.), Proceedings of the IUFRO Symposium on Site and Productivity of Fast Growing Plantations, April 30-May 11, Pretoria and Pietermaritzberg, South Africa. Forest Research Institute, Pretoria, pp 947-956.

– and James, R. 1997 *'Forecasting of wood flows from Australia's plantations - a report to the 1997 National Plantation Inventory'.* Bureau of Rural Sciences, Canberra, Australia.

– and James, R. 2002. *Derivation of indicative yields for major plantation species.* In: Richards, G. (Ed) Biomass Estimation: Approaches for Assessment of Stocks and Change. National Carbon Accounting System Technical Report no. 27, Australian Greenhouse Office, Canberra, pp 71-77.

– Lambert, M.J., Hopmans, P., and McGrath, J. 2001 *'Site variation in* Pinus radiata *plantations and implications for site specific management'*. New Forests 21: 249-282.

Unkovich, M., Baldock, J., and Marvanek, S. 2009 *'Which crops should be included in a carbon accounting system for Australian agriculture?'.* Crop and Pasture Science 60: 617-626.

– Baldock, J. A. and Farquharsan R. (2014). Estimating historical crop yields on a regional scale using a simple water-driven productivity model. *CSIRO publications*, Australia (*In Prep.*)

– Baldock, J., and Forbes, M. 2006. *'Australian crop yields and harvest Indices (Microsoft Access Database)'.* CSIRO Land and Water, Adelaide.

– Baldock, J. and Forbes, M. 2010. *Variability in harvest index of grain crops and potential significance for carbon accounting: examples from Australian agriculture*. Advances in Agronomy 105: 173-219.

USEPA (United States Environment Protection Agency) 1985, *Compilation of Air Pollutant Emission Factors*, Vol 1, Stationary Point and Area Sources, Fourth Edition, Research Triangle Park, North, USA.

– 1989, *Compilation and Speciation of National Emissions Factors for Consumer/Commercial Solvent Use,* EPA-450/2-89-008.

– 1991a, *Nonroad Engine and Vehicle Emission Study - Report*, Office of Air and Radiation, USEPA, Washington, DC.

– 1991b, *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone. Volume 1: General Guidance for Stationary Sources.* EPA-450/4–91–016. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

– 1992, *Procedures for Emission Inventory Preparation, Vol IV: Mobile Sources*. Research Triangle Park, North Carolina, USA.

– 1995a, *Highway Vehicle Emission Estimates -- II*, Office of Mobile Sources, USEPA, Research Triangle Park, North Carolina, USA.

– 1995b, *of Air Pollutant Emission Factors, Vol 1, Stationary Point and Area Sources*, Fifth Edition, Research Triangle Park, NC, USA.

– 1996, *AP-42 Compilation of Air Pollutant Emission Factors Vol 1 Stationary Point and Area Sources*, United States Environmental Protection Agency, available at www.epa.gov/ttn/chief/index.html

– 1997, *Emission Inventory Improvement Program,* Document Series Volume 3 – Chapter 6, http://www.epa.gov/ttn/chief/eiip/techreport/volume03/index.html

van Sliedregt, H., McGahan, E. and Casey, K. 2000, '*Predicting Waste Production From Feedlot Cattle*', Unpublished Confidential Report prepared for Cattle and Beef CRC (Meat Quality) Sub-Program 6 - Feedlot Waste Management, DPI Intensive Livestock Environmental Management Services, Toowoomba, Qld.

Vic Forests 2008 *'Vic Forests: Annual Report 2008'*. Victoria, Australia.

VicHealth 1999, *Moving to Healthier People and Healthier Places – Trends in Transportation*, (http://www.vichealth.vic.gov.au/assets/contentFiles/vhtransch3.pdf), Victorian Health Promotion Foundation.

Villalobos, F. J., Testi, L., Hidalgo, J., Pastor, M. and Orgaz, F. (2006) Modelling potential growth and yield of olive (*Olea europaea* L.) canopies. *European Journal of Agronomy*, **24**, 296-303.

Vinyl Council Australia website, www.vinyl.org.au/manufacturingprocess

WA Department of Industry and Resources, 2006. *Petroleum Guidelines, Drilling Fluids Management*. Environment Division, Perth.

Western Australia Department of Agriculture and Food http://www.agric.wa.gov.au/PC_92665.html Accessed 1 December 2013.

Walkley, A., and Black, I. A. 1934. *An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method*. Soil Science. 37: 29–38.

Wang, X. J., Smethurst, P. J., and Herbert, A. M. 1996*, Relationships between three measures of organic matter or carbon in soils of eucalypt plantations in Tasmania*. Australian Journal of Soil Research. 34, 545 – 553.

Wang WJ, Moody PW, Reeves SH, Salter B, Dalal RC, 2008. Nitrous oxide emissions from sugarcane soils: effects of urea forms and application rate. In *Proceedings of the Australian Society of Sugar Cane Technologists,* Vol 30: 87–94.

– Dalal, R.C., Reeves, S.H., Butterbach-Bahl, K. and Kiese R., 2011, Greenhouse gas fluxes from an Australian subtropical cropland under long-term contrasting management regimes. *Global Change Biology*, 17(10):3089-3101.

Waterworth, R.M., Brookhouse, M.T., Kesteven, J., 2005. '*Use of tree ring data to test a broad-scale model of forest productivity in Australia*'. In: Innes, J.L., Edwards, I.K., Wilford, D.J. (Eds.), IUFRO 2005. The International Forestry Review, Brisbane, Australia, p. 76.

– Richards, G.P., Brack, C.L. and Evans, D.M.W., 2007. *A generalised process-empirical hybrid model for predicting forest growth*. Forest Ecology and Management 238, 231-243.

– and Richards, G.P. 2008 *'Implementing Australian forest management practices into a full carbon accounting model'*. Forest Ecology and Management 255: 2434-2443.

Watson, I.W., McKeon, G.M., Wilcox, D.G., 2004. Modelling climate and management effects on shrub populations in the Gascoyne region of Western Australia and the north east district of South Australia. In: *Pasture degradation and recovery in Australia's rangelands*. Eds: G. McKeon, W. Hall, B. Henry, G. Stone and I. Watson. Department of Natural Resources, Mines and Energy, Queensland, Australia.

WBCSD (World Business Council for Sustainable Development) 2005, Cement Sustainability Initiative, Climate Protection Task Force, *'The Cement CO_2 Protocol, CO_2 accounting and Reporting Standard for the Cement Industry'*, Protocol Guidance Document Version 2.0.

Webb, A. 2002 *Pre-clearing soil carbon levels in Australia,* National Carbon Accounting System Technical Report No. 12 (204pp). Australian Greenhouse Office.

Webbnet Land Resource Services Pty. Ltd. 2000 *Estimation of Changes in Soil Carbon Due to Changed Land Use*. National Carbon Accounting System Technical Report No. 2 (92pp) Australian Greenhouse Office, Canberra.

Weeks, I.A., Galbally, I.E., Huang Guo-hong, 1993, '*Nitrous Oxide Emissions from Motor Vehicles in Australia*', Research Report to ANZECC, Final Report, CSIRO, Victoria.

West, P.W. and Mattay, J.P. 1993 '*Yield prediction models and comparative growth rates for 6 eucalypt species*'. Australian Forestry 56(3): 211–225.

White, D.H., Bowman, P.J., Morley, F.H.W., McManus, W.R. & Filan, S.J., 1983, '*A simulation model of a breeding ewe flock*', *Agricultural Systems* vol 10 pp 149–189.

– 2002, '*A check of the internal consistency of pasture and livestock data used to estimate levels of greenhouse gas emissions from the sheep and beef cattle industries*', unpublished report to the Australian Greenhouse Office and CSIRO Sustainable Ecosystems, ASIT Consulting.

Whittemore, C. 1993, '*Energy value of feedstuffs for pigs*, in *The Science and Practice of Pig Production*'. Longmans Scientific and Technical Publications, USA.

Wilkerson V.A, Casper, D.P, and Mertens, D.R., 1995, 'The prediction of methane production of Holstein cows by several equations' *Journal of Dairy Science*, Vol 78, pp 2402–2414.

Williams D.J. 1993, '*Methane emissions from the manure of free-range dairy cows*', *Chemosphere,* vol. 26, pp. 179–187.

Williams, D.J., Saghafi A., Lange A., and Drummond, M.S. 1993, '*Methane emissions from open-cut mines and post-mining emissions from underground coal',* CSIRO Investigation report CET/IR173.

– Lama, R.D., and Saghafi, A., 1996, '*Methane Emissions from Coal Mining*', International Energy Agency, Paris.

Williams, Y. and Wright, A. 2005, '*Variation in methane output between sheep*', in Abstracts *Greenhouse 2005: Action on Climate Change*, Melbourne, Victoria, 13–17 November 2005. CSIRO, Australia, pg 110.

WMAA (Waste Management Association of Australia) 2007, *National landfill survey results*, http://www.wmaa.asn.au/uploads/documents/State%20Summary%20June%202007.pdf

Woldendorp, G., and Keenan, R.J. 2005 *'Coarse woody debris in Australian forest ecosystems: A review'*. Austral Ecology 30: 834-843.

WSAA (Water Services Association of Australia) 2005 '*Facts 2005 - The Australian Urban Water Industry*'., Melbourne.

– 2011, *National Greenhouse and Energy Reporting System - Guidelines for the Water Industry*. Draft

Wu, X., Furby, S. and Wallace, J. 2004 '*An Approach for Terrain Illumination Correction*'. In The 12th Australasian Remote Sensing and Photogrammetry Conference Proceedings, Fremantle, Western Australia, 18–22 October.

Yamulki, S. and S.C. Jarvis 1997. '*Nitrous oxide emissions from excreta form a simulated grazing pattern and fertiliser application to grassland*', from *Gaseous emissions from grasslands*, Eds.: S.C. Jarvis and B.F. Pain, CAB International, Wallingford, UK, pp 195–199.

Ximenes, F. and Gardner, D. 2005 *'Recovery of Biomass as Green Sawn Boards after Milling of Spotted Gum (Corymbia maculata) Sawlongs from NSW South Coast Forests*'. National Carbon Accounting System Technical Report No. 48, Australian Greenhouse Office, Canberra, Australia.

- Gardner, D., and Marchant, J. 2005 '*Total biomass measurement and recovery of biomass in log products in Spotted Gum (Corymbia maculata) forests of SE NSW'*. National Carbon Accounting System Technical Report No. 47, Australian Greenhouse Office, Canberra.
- Gardner, D. and Richards, G.P. 2006 *Total above-ground biomass and biomass in commercial logs following the harvest of Spotted Gum (Corymbia maculata) forests of SE NSW*. Australian Forestry 69: 213-222.
- Gardner, W.D., and Kathuria, A. 2008a. *Proportion of aboveground biomass in commercial logs and residues following the harvest of five commercial forest species in Australia.* Forest Ecology and Management 256: 335-346.
- Gardner, W.D. and Cowie, A.L 2008b '*The decomposition of wood products in landfills in Sydney, Australia,* Waste Management 2008, doi:10.1016/j.wasman.2007.11.006.

Zhang, G., Zhang, J., Ren, J., Li, J. and Liu, S., 2008, *Distributions and sea-to-air fluxes of methane and nitrous oxide in the North east China sea in summer*, Marine Chemistry, vol 110, pp42-55.

environment.gov.au

CC16.0214C