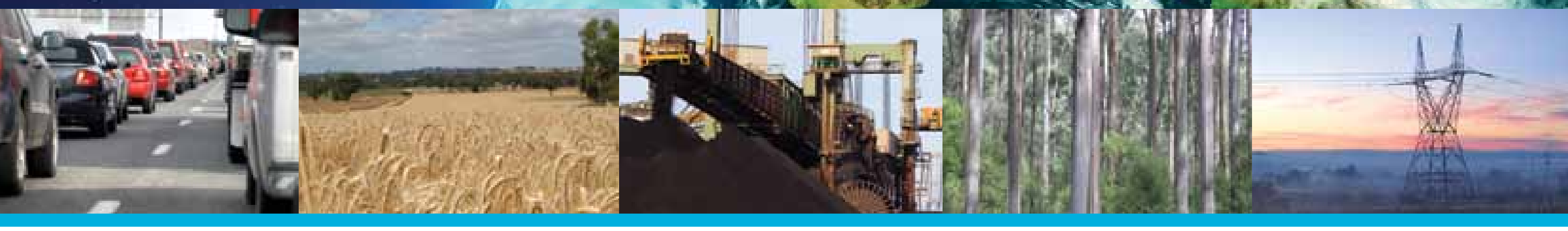
Australian Government

Department of Climate Change and Energy Efficiency



AUSTRALIAN NATIONAL GREENHOUSE ACCOUNTS

National Inventory Report 2010 Volume 3

The Australian Government Submission to the United Nations Framework Convention on Climate Change April 2012

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8.1 OVERVIEW

Total estimated *waste* emissions for 2010 were 14.1 Mt CO_2-e, or 2.5% of total net national emissions (excluding LULUCF) (Table 8.1). The majority of these emissions were from *solid waste disposal on land*, contributing 11.1 Mt or 79.1% of waste emissions. *Wastewater handling* contributed a further 2.8 Mt (20.1%) of waste emissions while *waste incineration* and *biological treatment of solid waste* contributed 0.03 Mt (0.2%) and 0.1 (0.6%) 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, 2010

Greenhouse gas source and sink categories	CO_2-e emissions (Gg)			
	CO_2	CH_4	N_2O	Total
6 WASTE	**30**	**13,625**	**421**	**14,076**
A. Solid waste disposal on land	NA	11,140	NA	11,140
B. Wastewater handling	NA	2,414	412	2,826
C. Waste incineration	30	NA	NE	30
D. Other waste	NA	71	9	81

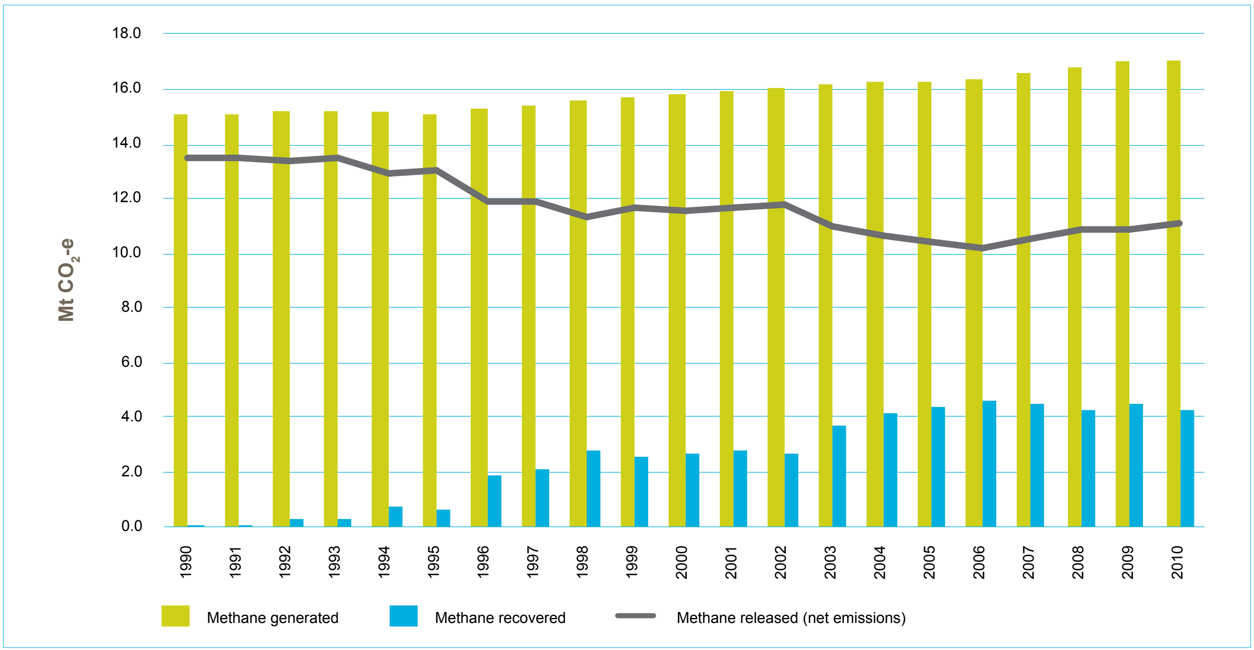
Trends

Waste emissions were 19.1% (3.3 Mt CO_2-e) lower in 2010 than they were in 1990 and 2.2% (0.3 Mt CO_2-e) higher than in 2009.

Emissions from municipal *solid waste disposal on land* decreased by 17.8% (2.4 Mt CO_2-e) over the period 1990 to 2010 (Figure 8.1) and were 2.6% (0.3 Mt CO_2-e) higher than in 2009. As waste degradation is a slow process, estimates of methane generation for 2010 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 4.3 Mt CO_2-e of methane in 2010.

Figure 8.1 Emissions from solid waste disposal on land, 1990–2010



Wastewater handling emissions decreased by 24.9% (0.9 Mt CO_2-e) over the period 1990 to 2010, with an increase of 0.4% (0.01 Mt CO_2-e) since 2009. 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.

Emissions of CO_2 from the incineration of solvents and clinical waste decreased by 65.1% (0.1 Mt) between 1990 and 2010.

Emissions from the biological treatment of solid waste have increased by 871.4% (0.1 Mt CO_2-e) between 1990 and 2010 and 13.1% (0.01 Mt CO_2-e) since 2009.

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	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.

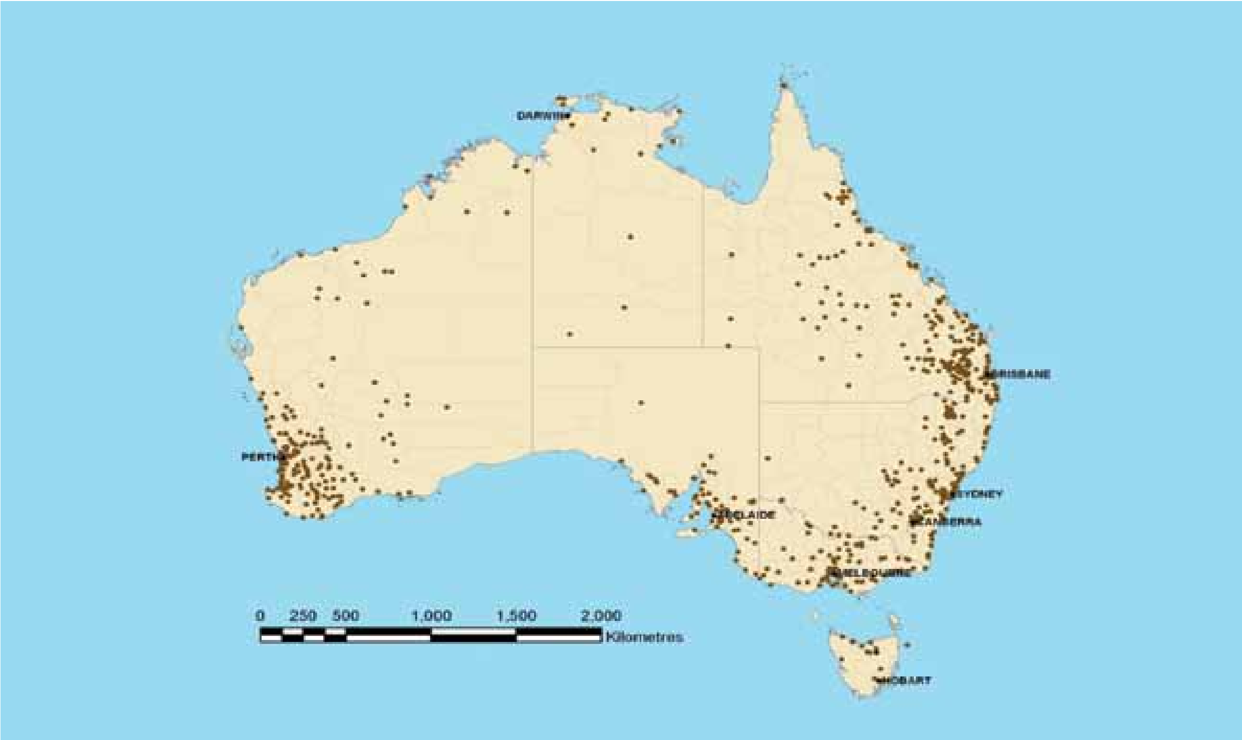
Solid waste treatment in Australia

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 report 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.

Figure 8.2 Australian landfill locations



Source: Geoscience Australia

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 (ie 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.

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.

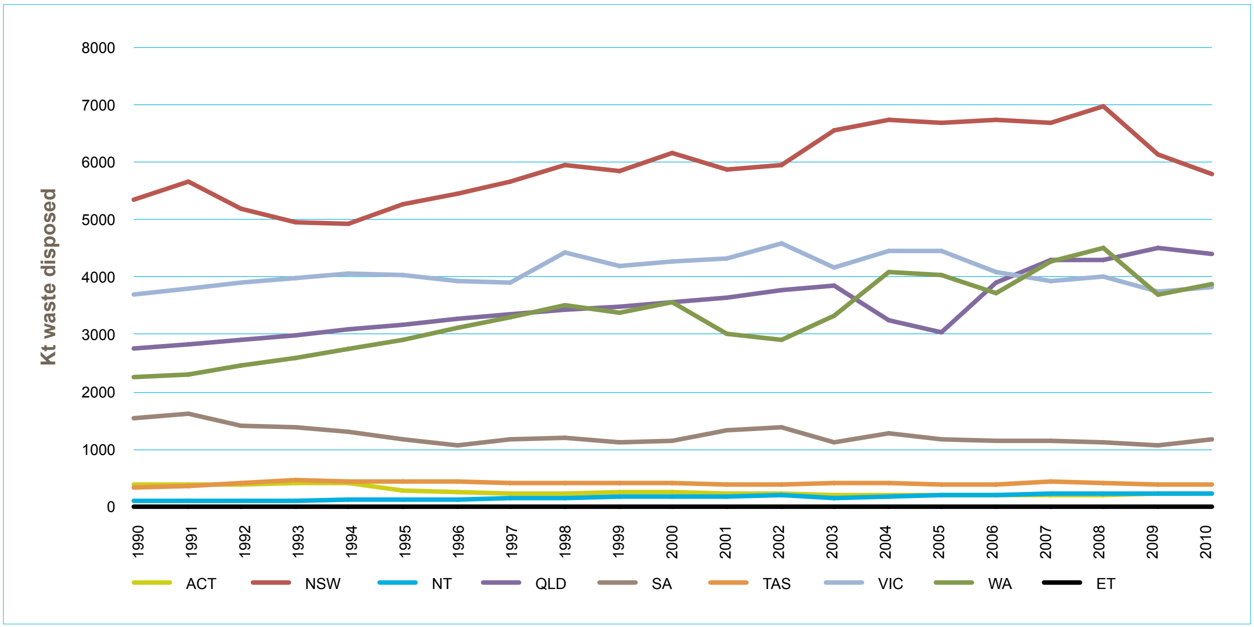
8.3.2 Activity data

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. 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).

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

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 data have been used to determine the stream percentages. Where disaggregated historical data cease, the stream shares have been held constant back to 1940. In Table 8.3 the stream percentages for each State and Territory, as applied for 2009, are reported.

Table 8.3 Waste streams: municipal, commercial and industrial, construction and demolition: percentages by State: 2010

	NSW[a]	VIC[b]	QLD[c]	NT[d]	SA[e]	WA[f]	TAS[g]	ACT[h]
Municipal Solid Waste	33%	43%	39%	39%	36%	26%	41%	40%
Commercial and Industrial	34%	34%	31%	31%	19%	20%	52%	41%
Construction and Demolition	33%	23%	30%	30%	46%	54%	7%	18%

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.

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

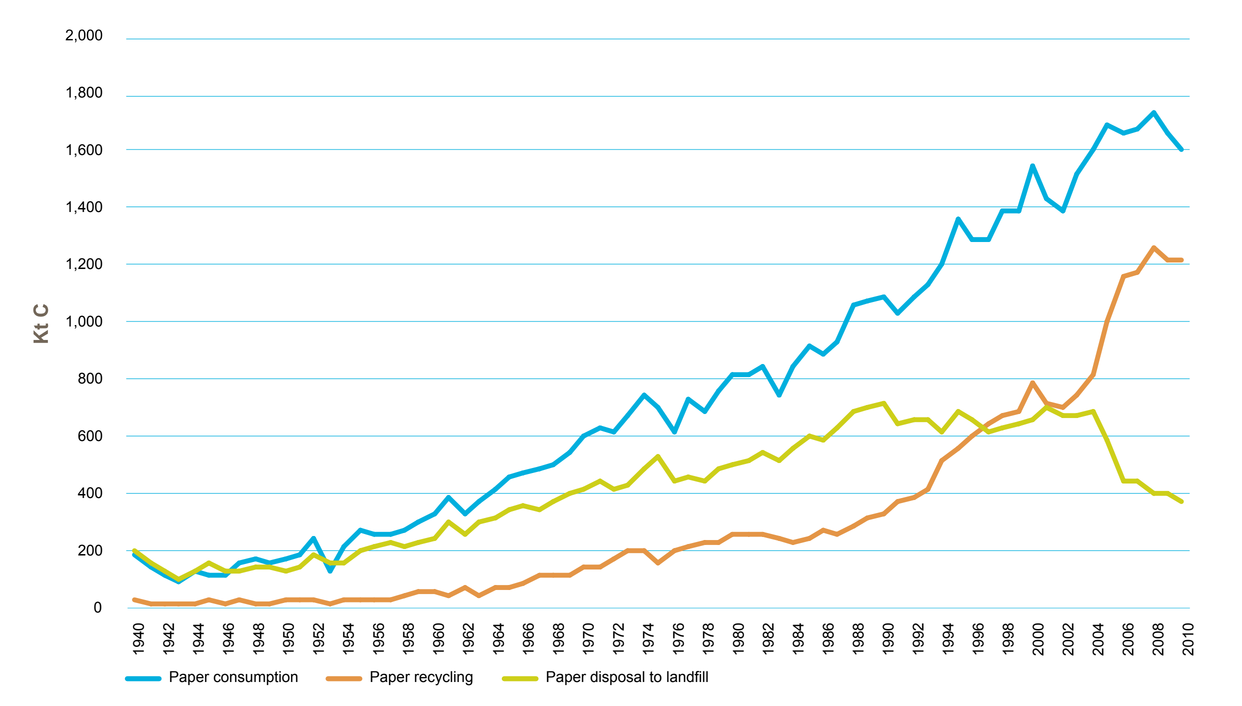
Each waste stream is further disaggregated into a mix of individual waste type categories that contain significant fractions of biodegradable carbon. The categories considered are as follows:

- 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).

Paper, wood and wood waste generation and disposal

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: 1940-2010



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 4,030 kt in 2010 (ABARES 2011c) 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 1,612 kt C in 2010 (Table 8.4). Per capita consumption of paper has increased from an estimated 26 kg C per person in the 1940s to 72 kg C per person in 2010. Reflecting the growth in paper consumption, waste paper generation is estimated to have increased from 245 kt C in 1940 to 1,642 kt C in 2010.

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 lead 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 75% in 2010, 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 2010, 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 (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 (Table 8.5).

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.

Figure 8.5 Estimated wood product wastes production, recycling, aerobic treatment processes and disposal to landfill – Australia: 1990-2010

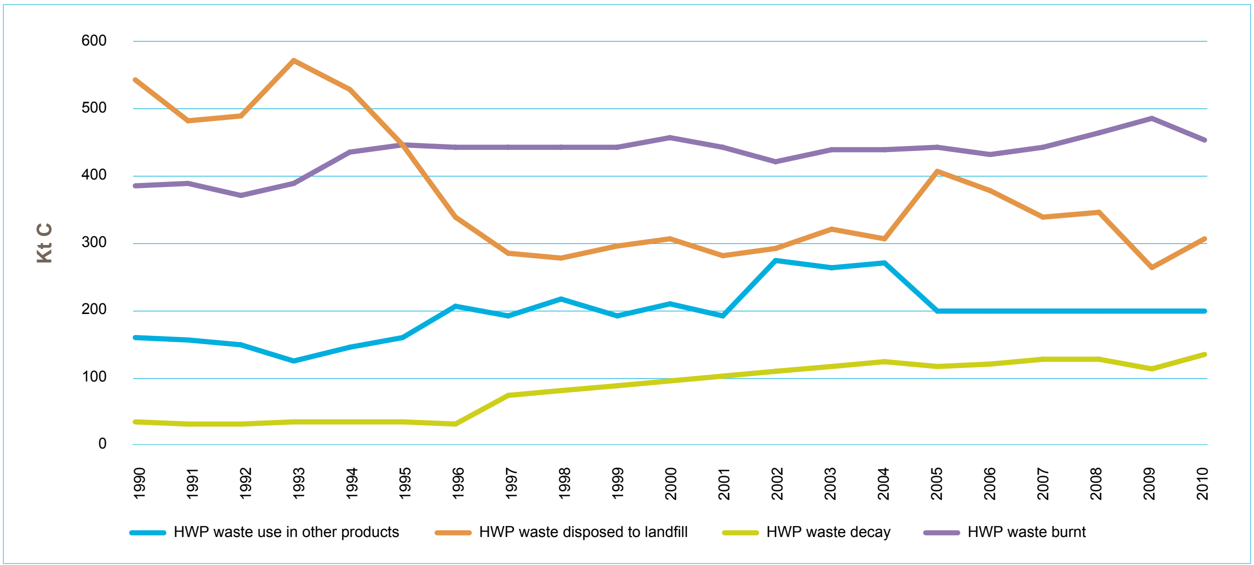


Table 8.4 Paper consumption, waste generation and disposal: Australia

	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	1,666	76	935	1,685	1,226	408	0.73	0.24
2010	1,612	72	905	1,642	1,226	367	0.75	0.22

Source: DCCEE estimates: derived from ABARES 2011c, 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	3,961	1,060	0.27	0.46	0.25	0.11	0.19
2010	4,009	1,089	0.27	0.41	0.28	0.12	0.18

(a) Includes waste generation but excludes roundwood log and woodchip exports.
Source: Department of Climate Change and Energy Efficiency: derived from ABARES 2011c, 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 2011c; Jaakko Pöyry 2000, Department of National Development 1969.	Not applicable.	ABARES 2011c; 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).
Recycling	Source: ABARES 2011c, 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: ABARES 2011a and 2011c) 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 Tables 8.4 and 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 2011c and the Department of National Development 1969) and paper recycling (ABARES 2011c). 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 2011c and the Department of National Development 1969) and on the combustion of wood and wood waste (ABARES 2011a). 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: 2010

	kt C
Additions to the HWP carbon stock	
Apparent consumption of HWP	3,352
Generation of HWP wastes	1,071
Total additions	4,423
Deductions from the HWP carbon stock	
Disposal to landfill	1,005
Disposal through combustion for energy/waste incineration	563
Disposal through aerobic decay	181
Recycling/use in other products	1,466
Total deductions	3,215
Net increment in HWP stock	**1,208**

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 2010, the reduction in carbon stock from combustion for energy of HWP and wastes generated from harvested wood product production is estimated at 563 kt C. 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 harvested wood products 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 2010, the reduction in carbon stock from disposal to landfill is estimated at 1,005 kt C. 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 HWP. 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.

Waste mixes disposed to landfill

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 2010 are reported in Table 8.8.

Table 8.8 Individual waste type mix: percentage share of individual waste streams disposed to landfill 2010

	Municipal Solid Waste	Commercial & Industrial	Construction & Demolition
Food	37.8%	22.1%	0.0%
Paper (a)	6.2%	6.7%	1.2%
Garden and Green	17.8%	4.1%	2.0%
Wood (a)	1.1%	7.1%	6.0%
Waste from HWP production (a)		12.2%	
Textiles	2.2%	4.1%	0.0%
Sludge	0.0%	1.5%	0.0%
Nappies	4.3%	0.0%	0.0%
Rubber and Leather	0.5%	3.6%	0.0%
Inert (concrete, metal, plastics and glass, soil etc)	30.2%	38.5%	90.8%

Sources: Derived from GHD 2008 and Hyder Consulting 2008; (a) DCCEE 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 (kilotonnes): 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	509	933	1,878	421	4,726
1990	16,425	2,948	1,797	1,283	2,002	719	7,677
2000	19,594	3,569	1,637	1,438	1,657	976	10,317
2001	19,021	3,581	1,746	1,462	1,544	954	9,734
2002	19,390	3,641	1,684	1,565	1,547	913	10,040
2003	19,818	3,411	1,698	1,474	1,677	871	10,686
2004	20,587	3,510	1,726	1,525	1,675	894	11,256
2005	20,225	3,547	1,468	1,535	1,899	900	10,875
2006	20,396	4,022	1,117	1,643	1,840	1,067	10,706
2007	21,215	4,078	1,115	1,694	1,782	1,071	11,474
2008	21,794	4,199	1,005	1,706	1,855	1,133	11,897
2009	19,999	4,015	1,020	1,640	1,547	1,066	10,712
2010	19,916	3,987	917	1,644	1,642	1,047	10,679

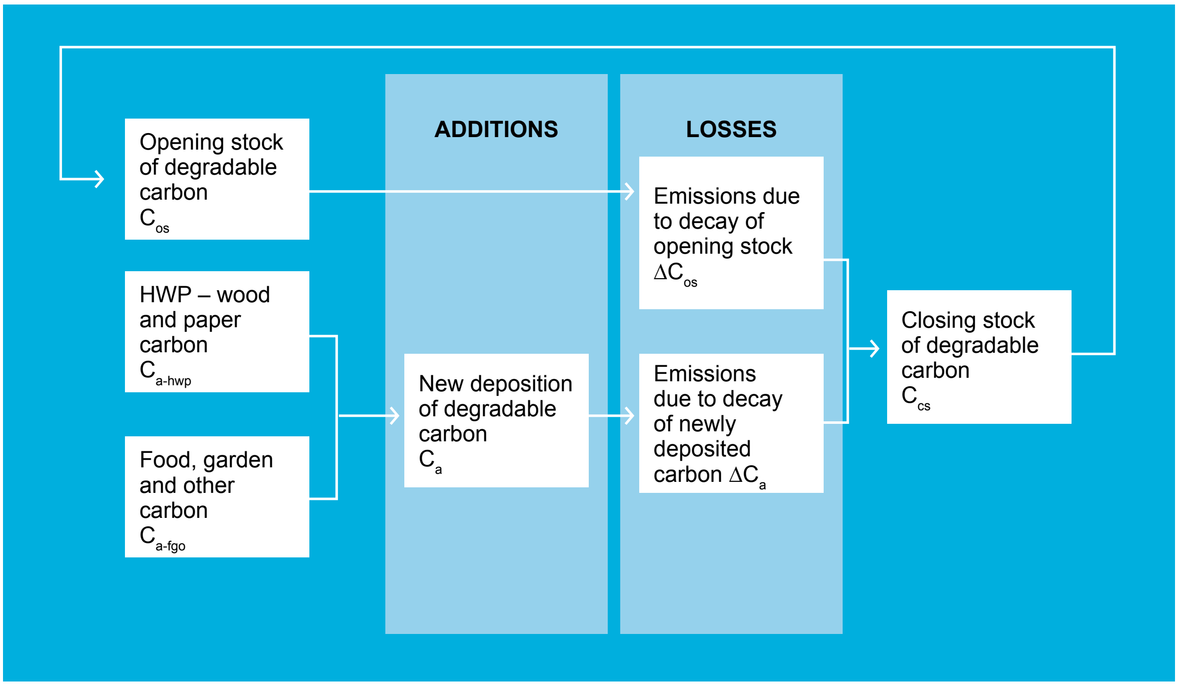
(a) State Government Agencies; (b) DCCEE estimates.

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 2006 IPCC *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.

Ccs = Cos – Δ Cos (emissions lost from opening stock) + Ca - Δ Ca (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 have been determined based on default half lives reported in IPCC 2006 and 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 8.12, 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 50.0 for 2010.

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) 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.

8.2.1.3.7 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 NGERS for 2009 onwards and industry survey for the years 1990-2008. 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.

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 8.15. 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 2010

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	1,078	719	2	645
1991	2,422	1,078	718	2	645
1992	2,398	1,082	721	11	639
1993	2,446	1,083	722	11	640
1994	2,383	1,081	720	35	617
1995	2,397	1,080	720	28	622
1996	2,319	1,083	722	91	568
1997	2,282	1,090	727	98	566
1998	2,367	1,097	731	130	541
1999	2,351	1,106	737	121	554
2000	2,444	1,111	741	129	550
2001	2,440	1,121	747	131	555
2002	2,434	1,130	753	128	562
2003	2,432	1,139	760	176	525
2004	2,474	1,141	761	197	507
2005	2,476	1,139	759	207	496
2006	2,447	1,140	760	222	484
2007	2,441	1,156	771	216	500
2008	2,465	1,170	780	205	518
2009	2,280	1,183	789	215	517
2010	2,271	1,190	794	204	530

Source: DCCEE 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 8.7.

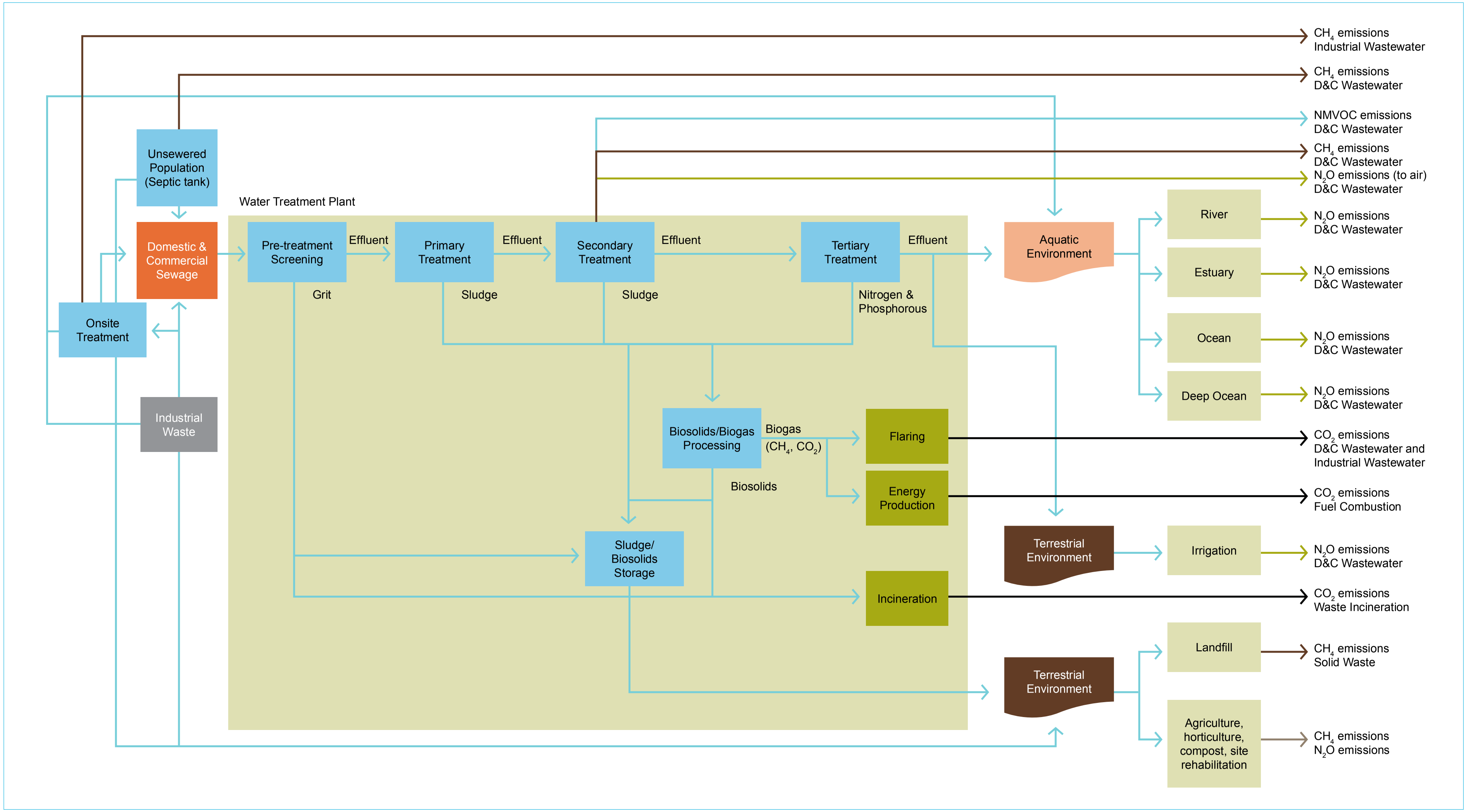
Consistent with IPCC *good practice*, methane emissions from effluent discharge to receiving waters is not reported in the inventory. Similarly, N_2O emissions from any form of industrial wastewater discharge and from discharge of municipal wastewater to ocean and deep ocean waters or used in irrigation 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 8.7 Pathways for Wastewater



Wastewater treatment in Australia

A survey of the Australian wastewater industry was conducted by the Department of Climate Change (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 2008b.
(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 8.17 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 2008b.
(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 8.8 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 8.8 Sydney Water Wastewater Systems

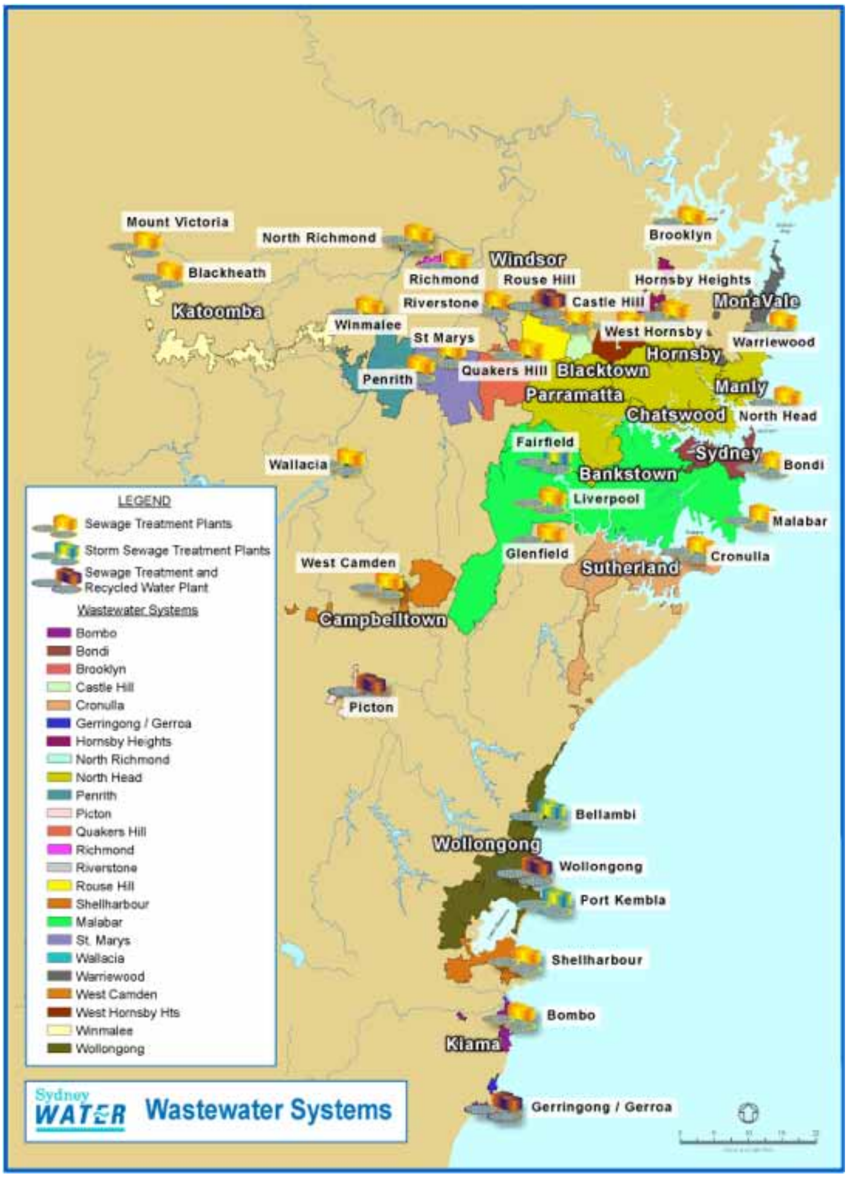


Table 8.19 Sydney Water Corporation Wastewater Treatment Plants 2008

	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
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
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 NGERSs and used for the first time in this inventory. Around 60% of facilities reporting under NGERS (numbering 79 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 0.06432 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 NGERS 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, NGERS 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 NGERS 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 NGERS 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

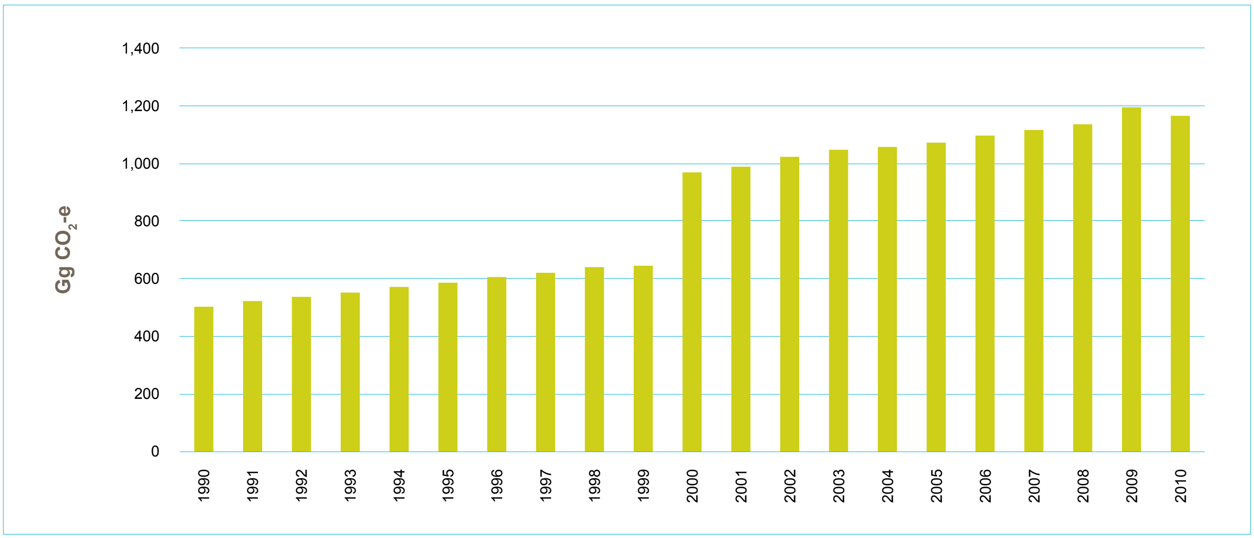
Source: WSAA 2011

Emission factors for each facility for wastewater and sludge are derived using equation 6.2 in the IPCC *Good Practice Guidance*, (2000). The IPCC default maximum methane producing capacity (Bo) 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 NGERS for the years 2009 and 2010. 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 8.9 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 8.9 Methane capture from domestic and commercial wastewater treatment 1990 – 2010



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 net emissions from wastewater are not negative.

Choice of emission factor

There is a proportion of the wastewater treatment sector where no facility-specific data is available under NGERS. 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 NGERS 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 NGERS was available.

Time-series consistency

The use of NGERS data for the first time in this submission has required careful consideration of time-series consistency issues. Facility-level activity data and emission factors are available for 2009 and 2010 only. In order to preserve time-series consistency, facility-level activity data obtained under NGERS 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 NGERS utilise well established infrastructure and treatment processes that have not undergone significant changes since 1990.

The residual portion of the sector, for which no NGERS 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 N_2O 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 NGERS and, in addition, DCC 2009 yielded nitrogen treatment and discharge data for a group of utilities not captured under NGERS. In total, facility level data obtained under NGERS 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 NGERS or DCC 2009 and the average nitrogen input received by the wastewater plants per person serviced by the plants derived from NGERS and DCC 2009 facility data. Together with the IPCC good practice assumption for the fraction of nitrogen in protein, 0.16kg N/kg protein, the facility level data translates into a per capita protein consumption level of 35.9 kg per person per year in 2009 and 31.9 kg per person per year in 2010.

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 NGERS 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 2010 is obtained by facility under NGERS 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 ($EF_{5\text{-}r}$).	0.0075 kg N_2O-N/kg N
Estuary ($EF_{5\text{-}e}$).	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 NGERS 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).

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 NGERS for the first time in this inventory. Where available, the quantity of COD treated at each facility has been taken from direct measurements reported under NGERS. Where facility-specific data under NGERS are unavailable, estimates are based on country-specific wastewater and COD generation rates shown in Table 8.22.

NGERS data were only used where industry coverage was considered sufficient to provide a complete picture of wastewater treatment practices in a given industry. Coverage was considered sufficient for the pulp and paper, beer and sugar industries.

Table 8.22 Country-specific COD generation rates for industrial wastewater, 2010

Commodity	Wastewater generation rate (m^3 wastewater/t commodity produced)	COD generation rate (kg COD/m^3 wastewater generated)
Dairy	5.7	0.9
Pulp and Paper	26.7[b]	0.4
Meat and Poultry	13.7	6.1
Organic Chemicals	67.0[a]	3.0
Sugar	0.4	3.8
Beer[c]	C	C
Wine	23.0[a]	1.5
Fruit	20.0	0.2
Vegetables	20.0	1.2

Source: O'Brien 2006a unless otherwise stated. (a) NGGIC 1995, (b) Australian Plantation Products and Paper Industry Council 2006, (c) facility-level parameters obtained for beer production under NGERS 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 NGERS 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, 2010

Commodity	MCF
Dairy	0.4
Pulp and Paper	0
Meat and Poultry	0.4
Organic Chemicals	0.1[a]
Sugar	0.3
Beer [b]	C
Wine	0
Fruit	1
Vegetables	1

Source: O'Brien 2006a unless otherwise stated. (a) NGGIC 1995, (b) facility-level parameters obtained for beer production under NGERS 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 paper, sugar and beer industries from NGERS. For the remaining industries, 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 NGERS for pulp and paper, beer and sugar facilities for 2009 onwards and derived from facility-level data in O'Brien (2006a) and NGGIC (1995) for the years 1990-2008. For the industries for which NGERS 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 same proportions as domestic and commercial wastewater treatment.

Table 8.24 Methane recovered as a percentage of industrial wastewater treatment 2010

Commodity	Fraction of methane recovered/flared (%)
Dairy [(b)]	6%
Pulp and Paper [(c)]	64%
Meat and Poultry [(b)]	6%
Organic Chemicals [(b)]	6%
Sugar [(c)]	0%
Beer [(a), (c)]	57%
Wine [(b)]	0%
Fruit [(b)]	100%
Vegetables [(b)]	100%

Source: (a) O'Brien 2006a, (b) NGGIC 1995 (c) NGERS 2010.

Time-series consistency

Time-series consistency has been maintained through the interpolation of MCF values and proportions of methane captured for pulp and paper and sugar 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 NGERS 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 industries where NGERS 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 DCCEE.

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 NGERS, 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

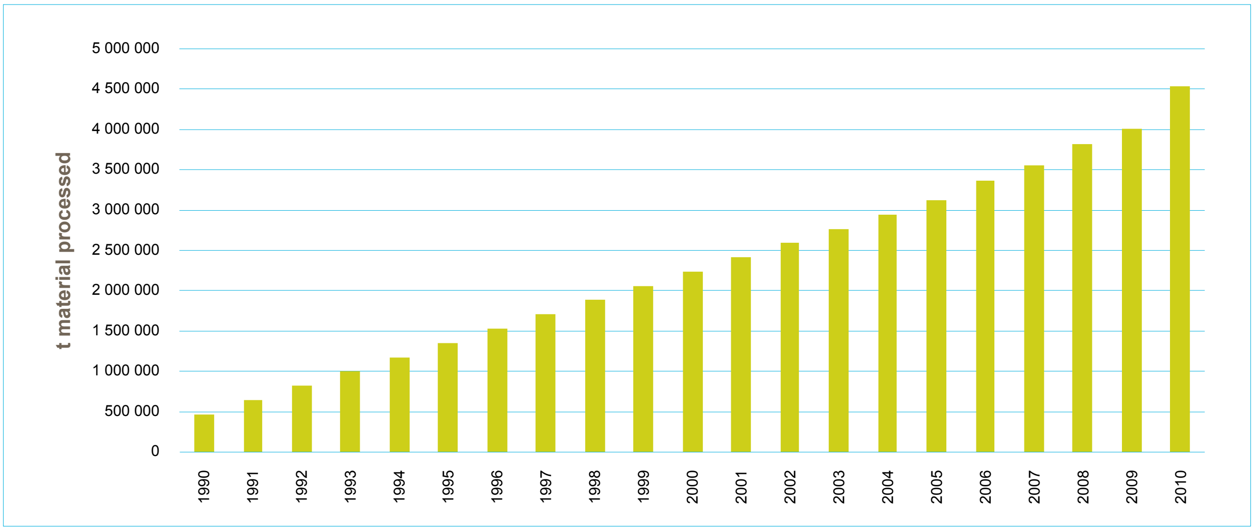
Estimates of emissions from the biological treatment of solid waste (for example, composting and anaerobic digestion) have been included for the first time in this submission. Emissions from the biological treatment of solid waste were 81 Gg CO_2-e in 2010.

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 NGERS 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 NGERS 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 8.10.

Figure 8.10 quantities of material processed via composting 1990-2010



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

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 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 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 NGERS. 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. A preliminary number for 2011 is included based upon NGERS facility reports.

Table 8.27 Estimates of implied protein per capita: Australia: 1990-2011

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 (p)	86.1

Sources: de Looper and Bhatia 1998 (1990-1993), AIHW 2002 (1994 – 1998), DCC 2009 (2008), NGERS 2009, 2010 and 2011.
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.

Sensitivity testing of the waste type specific factors adopted showed that the average DOC_f value for Australia between 1990 and 2010 was 0.48 compared with the IPCC default of 0.5. The sensitivity testing confirms that the Australian parameters used in this inventory are generally consistent with the IPCC default DOC_f value of 0.5.

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

As NGERS data were used for methane capture for the first time in this submission, 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 NGERS 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 NGERS). Therefore, this portion of flaring activity data had to be estimated for 2009 based on previously reported data.

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

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 8.28 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 2010 inventory, derived from NGERS facility data, has decreased to 87.3 g/day. Facility data received under NGERS for the first two 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. N_2O 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. N_2O 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 mg N 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 2010. The range of estimates for each year was found to be very large. In 2010, the minimum quantity of wet sludge sent to landfill from wastewater treatment was 464 kt while the maximum quantity was estimated to be 930 kt. These values are significantly higher than the estimate of wet sludge disposed to landfills estimated under the solid waste sector (less than 200 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 2009 INVENTORY

8.9.1 Solid waste disposal on land

Recalculations have been performed for solid waste as a result of a revision to wood and paper disposal in the harvested wood products model for the years 1990 – 2009.

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

	2011 Submission	2012 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.A Solid Waste Disposal on Land				
1990	14,216	13,545	-672	-4.7%
1991	14,151	13,536	-615	-4.3%
1992	13,991	13,425	-567	-4.1%
1993	13,955	13,431	-523	-3.7%
1994	13,442	12,957	-485	-3.6%
1995	13,525	13,072	-453	-3.3%
1996	12,349	11,926	-423	-3.4%
1997	12,274	11,879	-395	-3.2%
1998	11,725	11,362	-362	-3.1%
1999	11,971	11,636	-335	-2.8%
2000	11,873	11,560	-313	-2.6%
2001	11,944	11,648	-295	-2.5%
2002	12,089	11,808	-281	-2.3%
2003	11,287	11,025	-262	-2.3%
2004	10,879	10,635	-245	-2.2%
2005	10,641	10,419	-222	-2.1%
2006	10,367	10,164	-203	-2.0%
2007	10,685	10,496	-189	-1.8%
2008	11,044	10,868	-176	-1.6%
2009	11,024	10,860	-164	-1.5%

8.9.2 Wastewater handling

Recalculations have been performed for the whole time-series in wastewater handling as a result of a revision facility-level methane capture under NGERS for 2008. A review of methane capture capacity in domestic and commercial wastewater has also resulted in revisions to estimates covering the years 1990 to 2007.

Methane capture in industrial wastewater has also been revised for some specific commodities resulting in recalculations shown in Table 8.31.

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

	2011 Submission	2012 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.B.2 Domestic and Commercial Wastewater				
1990	1,826	1,792	-34	-1.9%
1991	1,829	1,802	-27	-1.5%
1992	1,829	1,808	-21	-1.1%
1993	1,826	1,812	-15	-0.8%
1994	1,813	1,805	-9	-0.5%
1995	1,803	1,800	-3	-0.2%
1996	1,807	1,811	3	0.2%
1997	1,821	1,831	10	0.5%
1998	1,818	1,835	17	0.9%
1999	1,838	1,854	16	0.9%
2000	1,867	1,563	-304	-16.3%
2001	1,886	1,579	-308	-16.3%
2002	1,912	1,579	-333	-17.4%
2003	1,934	1,586	-348	-18.0%
2004	1,956	1,604	-351	-18.0%
2005	1,975	1,621	-354	-17.9%
2006	2,009	1,650	-359	-17.9%
2007	2,042	1,678	-364	-17.8%
2008	2,092	1,721	-371	-17.7%
2009	2,087	1,727	-361	-17.3%

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

	2011 Submission	2012 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.B.1 Industrial Wastewater				
1990	1,889	1,973	84	4.5%
1991	1,845	1,926	81	4.4%
1992	1,782	1,861	79	4.4%
1993	1,704	1,779	75	4.4%
1994	1,642	1,715	73	4.5%
1995	1,530	1,597	67	4.4%
1996	1,401	1,462	61	4.4%
1997	1,317	1,373	56	4.3%
1998	1,233	1,286	53	4.3%
1999	1,174	1,223	49	4.2%
2000	1,125	1,173	48	4.3%
2001	1,243	1,297	54	4.3%
2002	1,178	1,228	50	4.2%
2003	1,063	1,108	45	4.2%
2004	1,081	1,126	45	4.2%
2005	952	1,128	176	18.5%
2006	932	1,082	150	16.1%
2007	962	1,104	142	14.8%

	2011 Submission	2012 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
2008	947	1,097	150	15.8%
2009	934	1,086	152	16.3%

8.2.7.3 Waste incineration

There have been no recalculations in incineration in the 2011 inventory.

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

	2011 Submission	2012 Submission	Change	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e	%
6.C Waste Incineration				
1990	85	85	–	0.0%
1991	85	85	–	0.0%
1992	85	85	–	0.0%
1993	85	85	–	0.0%
1994	86	86	–	0.0%
1995	91	91	–	0.0%
1996	66	66	–	0.0%
1997	28	28	–	0.0%
1998	28	28	–	0.0%
1999	29	29	–	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%

8.2.7.4 Biological treatment of solid waste

Emissions from the composting of solid waste have been included in this inventory for the first time.

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

	2011 Submission	2012 Submission	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e
6.D Biological Treatment of Solid Waste			
1990	0	8	8
1991	0	11	11
1992	0	15	15
1993	0	18	18
1994	0	21	21
1995	0	24	24
1996	0	27	27
1997	0	30	30

	2011 Submission	2012 Submission	Change
	Gg CO_2-e	Gg CO_2-e	Gg CO_2-e
1998	0	33	33
1999	0	37	37
2000	0	40	40
2001	0	43	43
2002	0	46	46
2003	0	49	49
2004	0	52	52
2005	0	55	55
2006	0	60	60
2007	0	63	63
2008	0	68	68
2009	0	71	71

8.10 SOURCE SPECIFIC PLANNED IMPROVEMENTS

8.10.1 Solid waste disposal on land

Australia plans to move towards the development of tier 3 methods for the estimation of emissions from solid waste disposal in future submissions. Underpinning this development will be the use of data as it becomes available under the NGER system combined with the development of new measurement systems operated by landfill operators and supplemented by ongoing research activities.

The availability of facility-level data collected under the NGER system will enable a facility-specific and spatially explicit approach to be adopted for the largest landfills which will supplement the current State-based approach. As an interim step, the DCCEE aims to represent the largest 39 landfills, which receive an estimated 55% of total waste, in the next inventory and will enable waste received to be tracked at a geospatial level. The method for collection of waste data received for the balance of landfills will not change, however, ensuring time-series consistency is maintained. Methane capture estimates obtained under NGERS have been used in this submission.

Under NGERS, 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. This data will replace the current approach where IPCC default values for particular climatic conditions are applied to whole states and territories where the conditions for a complete state or territory are based on climate data for the capital city of that state or territory. The current approach ignores differences in climate across individual states and generates anomalies for landfills close to borders and also ignores differences in management practices across the state or territory. 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 method to be used to determine ‘k’ is provided in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008*.

In the future, consideration is being given to the development of methods to be used in NGERS to enable measurements to be undertaken by landfill operators to better understand oxidation rates at Australian landfills and to obtain direct measurements of methane under continuous or periodic monitoring mechanisms. Draft methods for the measurement of oxidation rates have been prepared by GHD in (2010) and consideration will be given to their elaboration in the future.

The field measurement program will be supported by additional research activities. 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

A limited subset of NGERS data has been used for industrial wastewater in this submission. The DCCEE plans to expand the use of NGERS facility data to additional industries for future submissions. The inventory will be built around facility-specific and spatially explicit data for the largest treatment plants. Improved data on a range of parameters will be collected under NGERS including estimates of capture of methane, methane correction factors (the amount of effluent or sludge that undergoes anaerobic decomposition) and data on the quantity of COD in sludge. The quality of the inventory for the industrial wastewater sector will also continue to be similarly improved through the incorporation of facility information obtained under NGERS.

The facility-specific approach will also be supported by the development of new methods and the results of international research. In particular, methods for the direct measurement of emissions at certain types of plants will be explored while Australian industry is actively participating in international research efforts designed to improve understanding of nitrous oxide emission processes.

8.10.3 Waste incineration

As with wastewater handling, only a limited subset of NGERS data has been used for incineration in this submission. The DCCEE will review NGERS reports for the 2010-11 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 2010 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 1990–2009 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 ABARES Australian energy statistics. This is due to ABARES revisions to estimates in response to improved activity data available under the NGER system. This has resulted in revisions to fuel consumption and the reallocation of fuel use between source categories, particularly for 2009. As a result of this, a step change now exists in some time series for individual fuel types within certain source categories. This step change is particularly evident in the reallocation of natural gas and diesel from 1.A.2 Manufacturing to 1.A.1.c Manufacture of Solid Fuels and Other Energy Industries. See under the Planned Improvements sections in Volume1for discussion regarding plans to revise the pre-2009 portions of times series affected by the step change in future submissions.

Table 10.1 Reasons for the recalculations for the 2010 inventory (compared with the 2009 inventory)

Sector		Category	Reason for Recalculation
1.A	Energy		
	Stationary Combustion	1.A.1	Electricity Generation: a reallocation of a significant portion of bagasse consumption from 1.A.2.e Food, beverages and tobacco affects the entire Electricity Generation time series.
			Oil and Gas Extraction: an increase in natural gas for 2009 which incorporates a reallocation from Mining (Non-Energy) and Non-Ferrous Metals. Minor revisions to natural gas in 2006 to 2008.
			Coal Mining: an increase in diesel due to reallocation from Mining (Non-Energy) and Non-Ferrous Metals.
		1.A.2	Iron and steel: Increase in solid fuel activity data for iron and steel in 2009.

Sector		Category	Reason for Recalculation
			Non ferrous metals: Reallocation of coke to iron and steel, natural gas to coal mining and a reduction in black coal for 2009.
			Chemicals: Increase in black coal, natural gas, LPG and minor increases in other fuels for 2009.
			Pulp, paper and print: A reduction of black coal in 2009.
			Food, beverages and tobacco: For 2009; an increase in black coal and brown coal briquettes, a decrease in natural gas. For the entire time series; a reallocation of a significant portion of bagasse consumption to electricity generation.
			Other: In Mining (Non-Energy); a large reallocation of natural gas and diesel to Coal Mining in 1.A.1.c.
			Non-Metallic Mineral Products; a reduction in black coal consumption
		1.A.4	Commercial and institutional: Minor ABARES revision in natural gas and diesel for 2009
			Residential: For 2009; a minor decrease in LPG and increase in natural gas consumption. For the entire time series; an increase the CH_4 and N_2O emission factors for residential wood heaters arising from Todd (2011) report.
			Agriculture/fisheries/forestry: For 2009; a decrease in gasoline and diesel consumption.
	Transport	1.A.3	ABARES revision to aviation turbine fuel consumption in the Northern Territory in 2005.
			ABARES revision to LPG and petrol consumed in the road transport sector in 2009.
			Emission factors and deterioration rates were updated for a range of vehicle types in light of two new studies (Orbital 2011b and Orbital 2011c). These updated factors generally had a downward effect on non-CO_2 emissions due to the lower calculated deterioration factors. A number of other parameters including average trip length and urban VKT percentage were updated after the collection of new activity data.
			Minor ABARES revision to ADO activity data in New South Wales in 2005.
			ABARES revision to navigation fuel consumption data in 2009.
			The allocation of IDF between military transport (Sector 1.A.5.b) and navigation (1.A.3.d) has been updated to be consistent with the allocation for ADO.
		1.A.5	For 2009, a minor increase in lubricant consumption activity data due to a revision of the ABARES Australian Energy Statistics.
			The allocation of IDF between military transport (Sector 1.A.5.b) and navigation (1.A.3.d) has been updated to be consistent with the allocation for ADO.
	Fugitive Emissions	1.B.1	Emissions increased for 2009 due to the inclusion of flaring emissions for years 2009 and 2010, facilitated by the availability of flare data reported by mines to the NGERS.
			Revisions of historical mine data resulted in increases in emissions for the years 1991 to 1994 and 1997 to 2003.
	Industrial Processes	2.A	Inclusion of emissions from the production of clay bricks and pavers for all years (reported in 2.A.3 Limestone and Dolomite Use).
		2.B	Revision to nitric acid activity data for 2009.
		2.C	Revision to CO_2 for coke consumption in iron and steel production for 2009.

Sector		Category	Reason for Recalculation
		2.D	Revision to historic time-series of CO_2 extracted from wells and used in food and drink manufacture
		2.F	Revision to motor vehicle stock and disposal estimates based on updated vehicle census data from the ABS.
			Use of NGERS data for the use of SF6 in electricity supply and distribution for 1990-2009.
4.	Agriculture	4.A-F	End of time-series recalculations due to 3 year averaging of reported emissions
		4.A,B, D	Update to preliminary milk production for 2008, 2009 and 2010
			There was a complete time series recalculation to the emissions for agricultural soils due to the new method for prescribed burning of savannas as explained section 6.7.
			The new prescribed burning of savannas method resulted in changes to emission estimations for atmospheric deposition (section 6.6.2.7).
			Animal input and activity data have also been revised as described in section 6.4.5.
5	LULUCF	5.A.1	Updated activity data for *harvested native forests*. Revision of *fuelwood consumed* for 2009 due to revised activity data. *Other native forests* areas revised following updated forest extent data.
		5.A.2	*Grassland converted to forest land* areas revised following annual update of the forest extent data.
		5.B.1	Revisions to the estimation of *cropland remaining cropland* involved: The assignment of crop harvest events to annual crops previously modelled as continuous 3 or 5 year events. New function to allow animals to graze on crop stubbles. Simulation resolution reduced from 100m to 25m. Carbon stock change reported for perennial woody crops and soil only. Simulation start date extended back to 1800 to more accurately reflect land clearing for agriculture. Everforest mask introduced to account for updated forest extent data.
		5.B.2	Revisions due to improved management data for *forest land converted to cropland* and *grassland*. Improved attribution of forest cover change where fire had occurred. Revised areas for *forest land converted to cropland* and grassland due to updated forest extent data.
		5.C.1	Revised areas for *grassland remaining grassland* due to updated forest and shrub extent data. Updated yield data for 2009. Revision due to improved yield mapping. Other improvements to the estimation of grassland remaining grassland involved: The assignment of a senescence event to reduce pasture growth over summer months. Allocation of generic pasture regimes for the arid, semi-arid and marginal rangeland pastures. Simulation start date extended back to 1800 and 1500 in rangeland regions to more accurately reflect land clearing for agriculture and soil carbon under native vegetation in rangeland Australia. Reporting of the soil carbon and perennial woody biomass pools.
		5.C.2	Revisions due to improved management data for *forest land converted to cropland and grassland*. Improved attribution of forest cover change where fire had occurred. Revised areas for *forest land converted to cropland* and grassland due to updated forest extent data.
		5.G	HWP – Revision to activity data used to determine the disposal of HWP stocks
6	Waste	6.A	Revisions to the estimates of wood and paper disposal from the harvested wood products model

Sector	Category	Reason for Recalculation
	6.B	Revision to estimates of methane capture from wastewater treatment
	6.D	Inclusion of emissions from biological treatment for all years

(a) Recalculation in response to UNFCCC ERT recommendations.

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 0.32 Mt or -0.1% in 1990 and an increase in emissions of 1.69 Mt or 0.3% in 2009 compared with estimates presented in the *National Inventory Report 2009* (see Table 10.2). The changes associated with the LULUCF sector were more significant with an increase in the estimate of total emissions of 49.58 Mt or 11.0% in 1990 and a decrease in emissions of 6.47 Mt or -1.1% in 2009.

Table 10.2 Recalculations for the 2010 inventory by sector (compared with the 2009 inventory): 1990, 2005-2009

Sector	1990	2005	2006	2007	2008	2009
	Mt	Mt	Mt	Mt	Mt	Mt
1.A Fuel Combustion	0.32	0.02	-0.02	-0.02	-0.15	2.41
1.A.1, 2, 4, 5 Stationary Energy	0.42	0.16	0.15	0.15	0.002	3.17
1.A.3 Transport	-0.10	-0.13	-0.17	-0.17	-0.16	-0.75
1.B Fugitives	0.12	0.15	0.16	0.30	0.28	0.55
2 Industrial Processes	0.20	0.26	0.19	0.14	0.13	-0.22
4 Agriculture	-0.35	-0.06	-0.52	-0.96	-1.28	-0.76
6 Waste	-0.61	-0.35	-0.35	-0.35	-0.33	-0.30
Total recalculation (excluding LULUCF)	-0.32	0.03	-0.54	-0.89	-1.35	1.69
5 Land use, land use change and forestry	49.89	-38.59	-34.48	-248.61	-106.93	-8.15
Total recalculation (including LULUCF)	49.58	-38.56	-35.02	-249.50	-108.28	-6.47

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 small as the recalculations have been applied throughout the time series 1990 to 2009. 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 the 2010 inventory; 1990-2009

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	418.3	418.0	-0.3	-0.1%	461.5	511.0	49.6	10.7%
1991	419.5	419.6	0.2	0.0%	585.9	566.2	-19.7	-3.4%
1992	424.2	424.1	-0.1	0.0%	548.8	503.4	-45.4	-8.3%
1993	426.6	425.9	-0.7	-0.2%	403.7	448.4	44.7	11.1%
1994	428.3	426.5	-1.8	-0.4%	408.6	434.6	26.0	6.4%
1995	440.7	439.5	-1.2	-0.3%	545.5	455.7	-89.8	-16.5%
1996	446.9	446.5	-0.4	-0.1%	445.2	474.2	29.0	6.5%
1997	458.3	459.0	0.7	0.1%	449.0	480.5	31.6	7.0%
1998	472.7	473.5	0.8	0.2%	600.0	525.2	-74.8	-12.5%
1999	483.2	483.2	0.0	0.0%	493.7	494.3	0.6	0.1%
2000	496.1	494.3	-1.8	-0.4%	482.6	554.2	71.6	14.8%
2001	507.6	505.0	-2.6	-0.5%	465.1	492.7	27.6	5.9%
2002	509.2	506.4	-2.8	-0.5%	842.2	591.7	-250.4	-29.7%
2003	517.8	516.5	-1.3	-0.2%	684.9	763.9	79.0	11.5%
2004	525.8	524.7	-1.0	-0.2%	330.4	487.1	156.7	47.4%
2005	527.7	527.8	0.0	0.0%	572.6	534.0	-38.6	-6.7%
2006	533.1	532.5	-0.5	-0.1%	581.3	546.2	-35.0	-6.0%
2007	542.1	541.2	-0.9	-0.2%	884.6	635.1	-249.5	-28.2%
2008	550.8	549.5	-1.4	-0.2%	620.3	512.0	-108.3	-17.5%
2009	545.8	547.5	1.7	0.3%	599.8	593.3	-6.5	-1.1%

Source: Previous estimate – DCCEE 2011.

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.

DCCEE 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 by 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 sectors as, for the most part, the 2006 IPCC *Guidelines* have already been implemented in other sectors.

Changing international practice

The DCCEE actively monitors the implementation of inventory guidelines by other parties to the UNFCCC/Kyoto Protocol to ensure comparability of national inventories. More specifically, the DCCEE 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 DCCEE 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 mutual Australia-New Zealand review conducted in 2011, 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 DCCEE had not received the final ERT report of the centralised review of Australia's 2009 Inventory). Areas for inventory improvement are identified each year in the DCCEE's *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 System (NGERS). Estimation methods used for NGERS are governed by the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* and are designed to be consistent with the national inventory estimation methods.

From 1 July 2012, Australian companies that meet specified thresholds will be subject to a carbon price where the estimates of company liabilities will be based on company reports submitted under the NGERS. The introduction of a carbon price in Australia establishes not only a price on carbon but also a price on measurement error. Consequently there is considerable investment being undertaken into private measurement systems across Australia which will lead to improved accuracy of data submitted under NGERS. Improvements are expected, for example, in company monitoring systems and in the operation of laboratory analyses of key emission parameters. Similarly, the establishment of the Carbon Farming Initiative will also generate improvements in the accuracy of measurements on a project basis in the land sectors.

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. In 2011-12, in collaboration with the Grains Research and Development Corporation (GRDC), the DCCEE will support 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. This research is most often focussed on the land sector given the land sector contributes significant key categories, the extent of the sector, the relatively high cost of private measurement and the relatively high variability of spatial and temporal emission processes.

In Australia, specific funding for research programs on the land is managed by the Department of Agriculture, Fisheries and Forestry (DAFF) (see http://www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research). The Climate Change Research Program funds research projects and on–farm demonstrations to help prepare Australia's primary industries for climate change and build the resilience of the agricultural sector into the future.

Between 2009 and 2012, the Climate Change Research Program has been focussed on three priority areas:

- reducing greenhouse gas emissions such as methane, nitrous oxide and carbon dioxide;
- improving soil management and determining the potential of sequestering of carbon in agricultural soils, in a variety of agricultural soil types in different locations under different management practices; and
- research into alternative management practices and the development of adaptation management practices and techniques.

From 2012, in conjunction with the commencement of a carbon price in Australia, the DAFF will administer a four year, $201 million *Filling the Research Gap* Program which will provide competitive grants funding to support research into emerging abatement technologies, strategies and innovative management practices that improve soil carbon and reduce greenhouse gas emissions from the land sector and enhance sustainable agricultural practice.

Research and development tasks involve State government research agencies, CSIRO and universities across Australia.

The work is co-ordinated by science experts representing a range of scientific agencies. Current representation involves Universities (Melbourne University and Queensland University of Technology) and the Commonwealth Scientific and Industrial Organisation (CSIRO) – Sustainable Agriculture Flagship. The CSIRO Flagship has as part of its mission the development of science, technology, measurement and management systems to help reduce net greenhouse gas emissions from Australian lands while increasing the storage of new carbon in our lands (see http://www.csiro.au/en/Organisation-Structure/Flagships/Sustainable-Agriculture-Flagship/Carbon-Land-use-Theme.aspx).

The key ways in which the co-ordinated research programs will support emissions reduction are through:

- measuring carbon stocks and greenhouse gas emissions from Australian lands;
- predicting changes in carbon stocks over time;
- identifying and demonstrating emission reduction practices and associated social, economic and environmental benefits and interactions;
- developing new technologies and practices for emissions reduction and generation of carbon sinks; and
- assisting adoption of mitigation options and the institutional arrangements that support them.

With this research and development the research agencies (Universities, State departments and CSIRO) aim to support the development of reliable estimates of emission sources and carbon sinks from agricultural and forestry lands, the design of permanent and measurable greenhouse gas offsets (i.e. in conjunction with the Carbon Farming Initiative) and to support the development of models to enable the scaling-up from the animal, plant or paddock level to regional and continental scales.

National Inventory quality control systems

The DCCEE 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 NGERS, 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 with the results available in 2012.

The DCCEE 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 DCCEE will invest in enhanced quality control and output reporting systems for the LULUCF and Forestry 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* model for LULUCF is a critical part of the improvement plan. In 2012/13, 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

DCCEE 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 NGERS and data for the land sector.

10.4.3.1 National Greenhouse and Energy Reporting System (NGERS)

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 NGERS 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 DCCEE 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 NGERS will differ depending on the current data collection processes. A summary of the expected relative benefits of NGERS for various IPCC sectors is provided in Table 10.4.

Table 10.4 Principal benefits of the NGERS 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	

10.4.3.2 Other sectors – improvements in inventory activity data

Outside the sectors covered by NGERS and the carbon Farming Initiative, the DCCEE 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 DCCEE is collaborating with CSIRO to evaluate use of multi-sensor data for time series analysis and also with Geoscience Australia to ensure continuity of satellite data given the technical problems with Landsat 5 and 7 satellites.

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

Funding managed by the Department of Agriculture, Fisheries and Forestry is being used to support the Australian Bureau of Statistics development and ongoing conduct of national surveys of agricultural management practices. The surveys will provide valuable input into benchmarking at a regional level agricultural practices that affect, inter alia, soil carbon outcomes and make possible the monitoring of changes in practices over time.

Soils

Data inputs into the Grasslands and Croplands categories will be systematically reviewed and updated where possible to improve the accuracy and coherency of emission estimates of these categories. In particular, it is intended to use the Australian Soil Resource Information System (ASRIS), developed by the CSIRO Land and Water Division, which is an integrated set of soil databases including site specific, local, regional and national data.

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

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

Data made available under NGERS 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 NGERS 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 NGERS, 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 NGERS 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	Yes
1.A.1b	Petroleum refining	Implemented	Potentially	Potentially	Yes	Yes
1.A.1c	Coke production	Potentially	Potentially	Potentially	No	Yes
1.A.2	Manufacturing	Potentially	Potentially	Potentially	No	Yes
1.A.3	Transport	No	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	Partially implemented	Partially implemented	Potentially	No	Yes
1.B.2	Oil & Gas	Partially implemented	Potentially	Potentially	No	Yes
2	**Industrial Processes**					
2.A.1	Cement	Implemented	Potentially	Potentially	No	Yes
2.A.2	Lime	Implemented	Potentially	Potentially	No	Yes
2.A.3	Limestone and Dolomite use	Implemented	Potentially	Potentially	Yes	Yes
2.A.4	Soda ash production and use	Implemented	Implemented	NA	No	Yes
2.B.1	Ammonia	Implemented	Potentially	Potentially	No	Yes
2.B.2	Nitric acid	Implemented	Implemented	NA	No	Yes
2.B.5	Synthetic rutile and titanium dioxide	Implemented	Potentially	Potentially	No	Yes
2.C.1	Iron and steel	Potentially	Potentially	Potentially	No	Yes
2.C.2	Ferro-alloy metals	Implemented	Potentially	Potentially	No	Yes
2.C.3	Aluminium	Implemented	Potentially	Potentially	No	Yes
2.C.4	Other metals	Implemented	Potentially	Potentially	No	Yes
2.E	HFC production	No	No	No	No	No
2.F	HFC consumption	No	No	No	No	No

Category		Facility – level activity data	Tier 2/3	Verification test for tier 2 parameters	Completeness/ sectoral improvement	Improved uncertainty estimates
2.F	SF_6 consumption	Implemented	Potentially	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**	Waste				
6.A	Solid waste	No	Potentially	Potentially	No	Yes
6.B.1	Domestic and Commercial Wastewater	No	Potentially	Potentially	No	Yes
6.B.2	Industrial Wastewater	Partially implemented	Potentially	Potentially	Yes	Yes
6.C	Waste incineration	Yes	Potentially	Yes	Yes	Yes
6.D	Biological treatment of solid waste	Yes	Potentially	Yes	Yes	Yes

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 NGERs 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 NGERS 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	Yes	Yes
4.A.	Enteric Fermentation Feedlot beef	Yes (feeds)	Potentially	No	Yes	Yes
4.A	Enteric Fermentation Swine	Yes (methane capture)	Potentially	No	Yes	Yes
4.B	Manure Management	Yes	No	No	Yes	Yes
5.A	Grasslands conversion to forests	Yes	Yes	Yes	Yes	Yes

10.4.4.2 Using data from public research for 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 or to consider changes to the tier of the method selected or to the model structure.

Major areas of inventory where data are being applied for the validation and calibration of model parameters include the following.

Enteric fermentation from cattle herds in northern Australia (enteric fermentation)

The research program is funded by the Department of Agriculture, Fisheries and Forestry and results will become increasingly available from 2012.

The enteric livestock research is co-ordinated through the Reducing Emissions from Livestock Research Program, and has three major areas of research: the use of and testing of measurement techniques to provide fundamental emissions data from livestock; adapting rumen function (feed quality, feed additives, genetics, and rumen microbial populations) that could govern abatement actions, and managing and measuring emissions from manure and urine to reduce emissions. Final conclusions and more complete assessments of management practice data is expected in 2012.

Manure production predictions from intensive pig operations

Queensland University in conjunction with Queensland Primary Industries and Fisheries are upgrading the PigBal model to improve the accuracy of manure production predictions from intensive pig operations. This project is due for completion in December 2012 and as such a review of the method for estimating emissions from intensive pig operations will be conducted in 2012 and 2013

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 research program is managed by the Department of Agriculture, Fisheries and Forestry and results will become increasingly available from 2012. 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.

Emission factor for sugar cane

The current emission factor used for sugarcane crops in Australia's national inventory is 1.25% of applied nitrogen emitted as nitrous oxide. Recently completed research programs funded by Federal and State Government departments, CSIRO and Universities have identified that this EF is lower than the measured values for emissions of nitrous oxide, A proposal for revision of the emission factor applied to sugar cane is currently before an independent expert panel for assessment with a view to implementation in the 2012 submission.

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

The DCCEE 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, DCCEE held a stakeholder workshop on the 27th October 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 will begin in early 2012.

The growth function for environmental plantings (grasslands conversion to forests)

The CSIRO has been commissioned by DCCEE to conduct research into the growth dynamics of environmental plantings (for uses other than wood production) in order to review and update existing relationships. Work will be completed during 2012.

Soil carbon response functions for changes in management practices (croplands remaining croplands and grasslands remaining grasslands)

New empirical research funded by the Department of Agriculture, Fisheries and Forestry is focussed on the generation of data in relation to soil carbon with particular emphasis on gaining a better understanding of the effects of various management practices on soil carbon levels.

New empirical research funded by the Department of Agriculture, Fisheries and Forestry is focussed on the generation of data in relation to soil carbon with particular emphasis on gaining a better understanding of the effects of various management practices on soil carbon levels.

The CSIRO Sustainable Agriculture Flagship is responsible for scientific leadership and coordination of all soil carbon activities associated with the Soil Carbon Research Program (SCaRP) project which has received over $20 million in funding between 2009-2012. Partners other than CSIRO involved in the project include University of Western Australia; Department of Primary Industries, Victoria; Department of Natural Resources and Water, Queensland; University of New England, New South Wales; Murray Catchment Management Authority; University of Tasmania; and the Department of Water, Land and Biodiversity, South Australia.

The objectives of the SCaRP project include development of a nationally consistent assessment of soil carbon condition across the major land-use/soil type combinations used for agricultural production across Australia; identification of land-uses and management strategies with the potential to build soil carbon at a regional level; quantification of the inputs of carbon to soils under agricultural systems based on perennial vegetation; development of rapid and cost-effective means for quantifying soil carbon stocks and measuring soil bulk density; and provision of data for further development of FullCAM, Australia's national inventory.

The program supports a comprehensive research effort that will identify the impacts of farm management practices on soil carbon sequestration or loss. Current activities involve the analysis of more than 13,000 soils from key regional areas within each state.

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, emissions factors for carbon and nitrogen trace gasses are currently based on a limited source of data – more information will become available to determine the relationship between emission factors and fire behaviour and fuel type from empirical work from a Pyrotron at CSIRO. The new empirical data will be assessed for use to estimate parameters for fires in all native forests.

Solid waste disposal parameters

The DOCf 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 DCCEE 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
- grasslands 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, which matches the definition used for UNFCCC reporting (see section 7.3.2.1):

- 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			R	IE	R	R
	Deforestation	R	R	R	R	R			R	NO	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	NA
	Grazing Land Management	NA	NA	NA	NA	NA				NA	NA	NA	NA
	Revegetation	NA	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 the NCAS 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 of the National Carbon Accounting System (NCAS). 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: Afforestation and Reforestation	Article 3.3 activities: Deforestation	Article 3.4 activities: Forest Management (if elected)	Article 3.4 activities: Cropland Management (if elected)	Article 3.4 activities: Grazing Land Management (if elected)	Article 3.4 activities: Revegetation (if elected)	Other(4)	Total area at the beginning of the current inventory year(5)
		(kha)							
Article 3.3 activities	Afforestation and Reforestation	1,122.27	0.00						1,122.27
	Deforestation		6,286.85						6,286.85
	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)		19.36	116.44	NA	NA	NA	NA	NA	761,590.88
Total area at the end of the current inventory year		1,141.64	6,403.29	NA	NA	NA	NA	NA	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 Appendices 7.A and 7.D). 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.A). 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.

KYOTO PROTOCOL LULUCF

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

(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.A and 7.F) but with additional data to meet the requirements of the Kyoto Protocol. 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 only 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.

To ensure that only lands that were forest in 1990 are included in the *deforestation* account, the 1990 forest extent layer (created from satellite data available at the end of 1989) derived from the FullCAM remote sensing program is used as a base map to mask areas of non-forest in 1990. All *deforestation* activities 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). Only forest areas that were present in 1990 and cleared after 1990 are included in the emissions estimates to meet these requirements. The location of land included in the *deforestation* account for 2010 is shown in Figure 11.1.

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. These differences are due to the exclusion from the deforestation account of:

- the ongoing emissions and removals from land cleared prior to 1990 that has remained cleared (non-forested); and,
- areas of land which were not forest in 1990 but have subsequently naturally regrown (i.e. not directly human induced and therefore not included as *afforestation/reforestation*) and then re-cleared as part of cyclic regrowth and reclearing cycles.

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.

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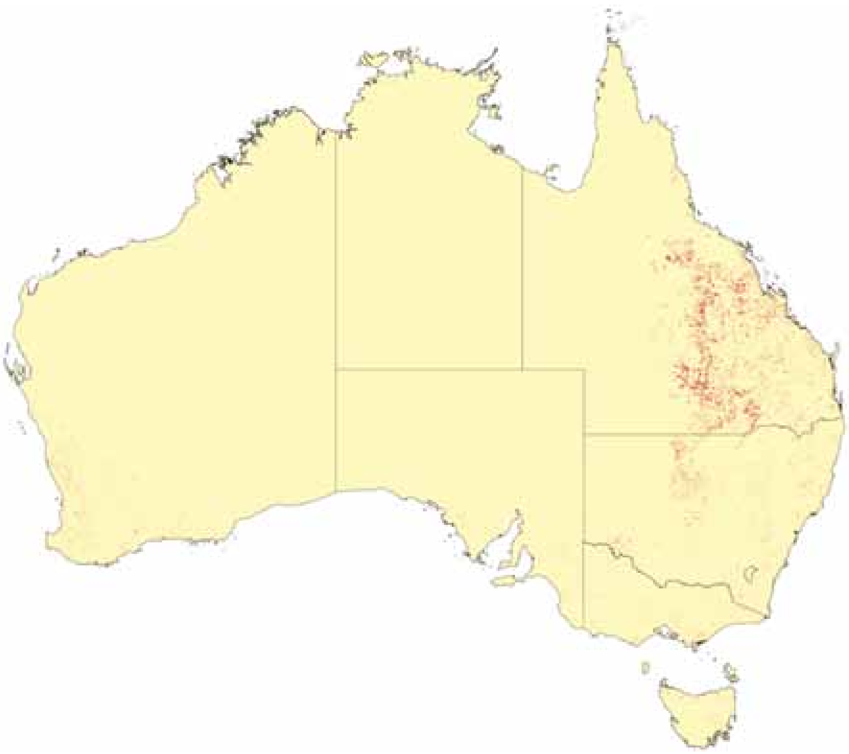
Figure 11.1 Location (in red) of land included in the deforestation account for 2010

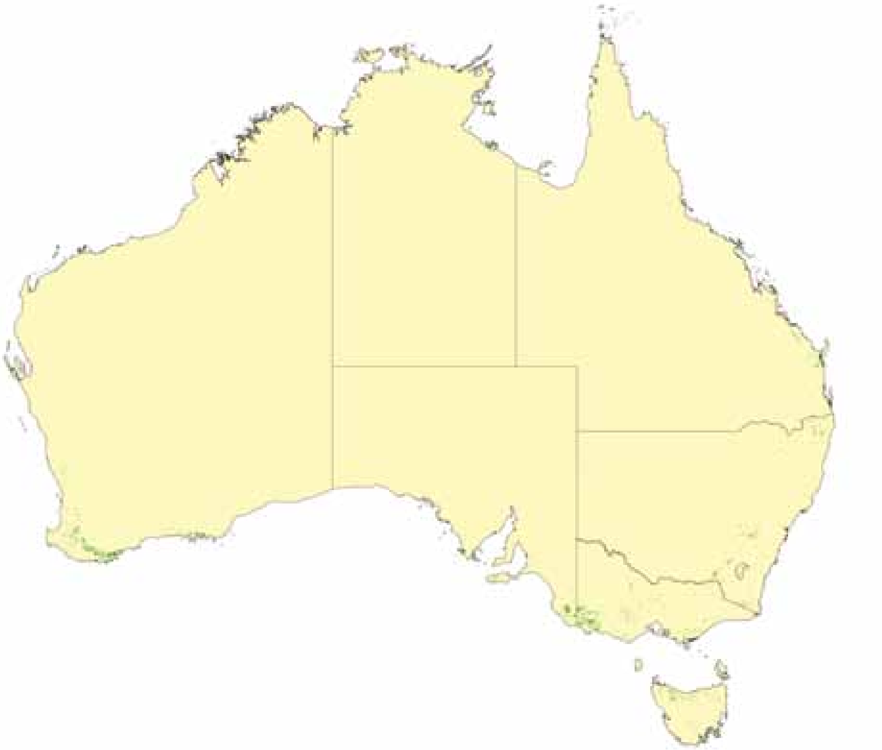


Afforestation & Reforestation

For *afforestation/reforestation*, Australia applied the same tier 3, Approach 3 method as that used to report emissions and removals from *land converted to forest land* under the UNFCCC inventory (see Appendix 7.A and 7.D). 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 the FullCAM 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 according to the base map are included in the emissions estimates. The location of land included in the *reforestation* account for 2010 is shown in Figure 11.2.

Figure 11.2 Location (in green) of land included in the afforestation/reforestation account for 2010



To ensure that only direct human-induced change is reported for Article 3.3 activities tenures which are protected from human-induced change, e.g. national parks and reserves, are masked out from the detected forest change prior to analysis as are lands affected by fire. In addition, 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. This ensures that only direct human-induced change is included under Article 3.3.

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 regionally and species specific management information.

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. CO_2 and non-CO_2 emissions due to wildfires are calculated using the methods described in Appendix 7.E. The CO_2 emissions from wildfires and CO_2 removals from recovery are included in the change in dead organic matter. No CO_2 recovery is estimated following wildfires on harvested forests as it is assumed that these fires will lead to salvage harvesting and re-establishment and therefore these CO_2 removals are already included in the C stock changes.

Liming

Emissions from liming (CaCO3) activities in Australia are only estimated for hardwood plantations. A survey conducted for the DCCEE 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

The NCAS Landsat data has been updated to include the most recent satellite data. This is consistent with the annual update process for the NCAS 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*, *reforestation* and *deforestation* in this submission are the same as those applied in the previous submission.

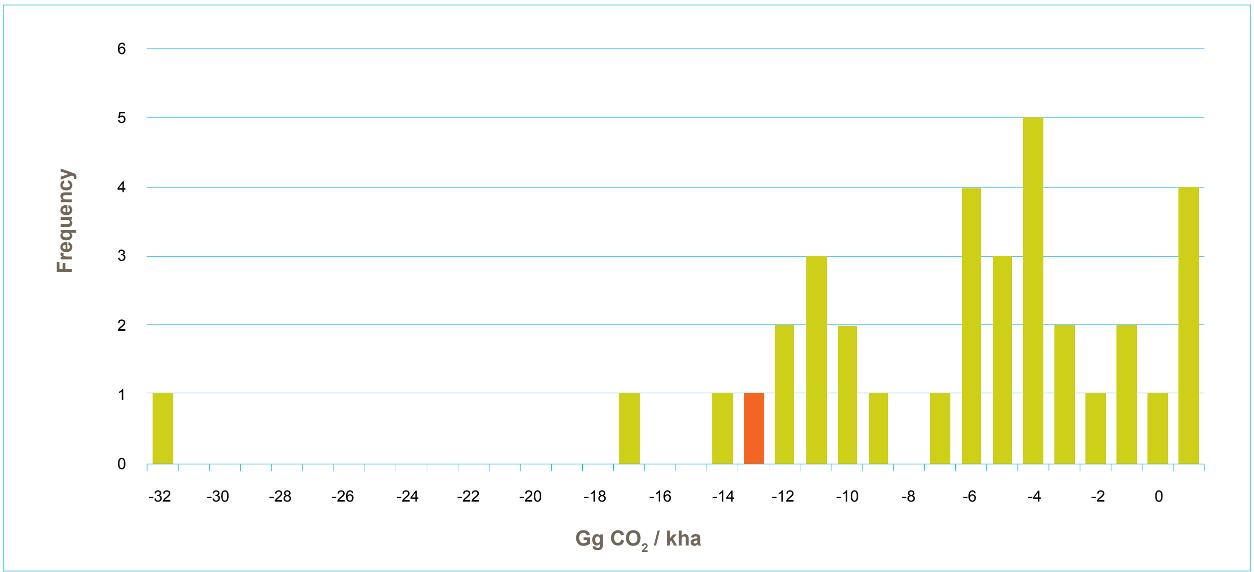
11.3.1.5 Uncertainty estimates and quality control

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 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.A and Attachment 7.A.1). 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. Details of sensitivity and uncertainty analyses carried out on the NCAS model are provided in Appendix 7.J.

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 11.3 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.

In Australia many areas of forest have regrown after previous clearing or abandonment of lands. In other areas natural dieback and recovery occur. To ensure that only direct human-induced change is reported for Article 3.3 activities tenures which are protected from human-induced change, e.g. national parks and reserves, are masked out from the detected forest change prior to analysis, as are lands affected by fire. In addition, 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 through time. 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 (i.e. regrowth and dieback) or human induced. This is determined by studying the geometry and temporal pattern of change. This ensures that only direct human-induced change is included under Article 3.3.

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. 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, as also excluded during the attribution process.

Two processes are used to ensure that areas of forest that are temporarily de-stocked due to forest harvesting are excluded from the *afforestation/reforestation* and *deforestation* estimates:

1. application of masks that identify tenures in which forest harvesting is known to occur (State forests). This includes both native and non-endemic plantations; and,
2. a detailed attribution process which excludes areas of land cover change that are identified as forest harvesting by studying the time-series data to ensure that a land use change has occurred.

These processes are applied consistently across all Article 3.3 activities.

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 mixture of climate (e.g. drought), grazing, fire, natural dieback and regrowth of forests identified are linked to specific land areas and the regional differences in these processes gives rise to variability in forest cover over time. The typical fluctuations in those areas of forest cover that occur around the prescribed canopy cover definition of a forest (20% in Australia) are accounted for under the UNFCCC other native forests category (Appendix 7.E). They are not counted as either *deforestation* or *afforestation/reforestation*.

11.5 ARTICLE 3.4

Not applicable as Australia has not elected Article 3.4 activities.

11.6 OTHER INFORMATION

11.6.1 KEY CATEGORY ANALYSIS

The key category analysis for Article 3.3 activities are reported in Annex 1 and in Table 11.5.

Table 11.5 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			
		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

11.7 INFORMATION RELATING TO ARTICLE 6

Australia has not approved any Joint Implementation activities (Article 6). Therefore Australia does not identify any Article 3.3 activities as subject to Article 6.

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	2,957,579,143	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	NO	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	2,957,579,143	NO	NO	NO	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			23,032,901				NO	NO	NO	NO		
3.3 Deforestation			NO				49,650,531	NO	NO	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							NO	NO	NO	NO	NO	NO
Sub-total		NO	23,032,901				49,650,531	NO	NO	NO	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												
CDM	NO	NO	NO	25,846	NO	NO	NO	NO	NO	NO	NO	NO
GB	NO	NO	NO	71,000	NO	NO	NO	NO	NO	75,846	NO	NO
NZ	NO	NO	NO	30,005	NO	NO	NO	NO	NO	5	NO	NO
Sub-total	NO	NO	NO	126,851	NO	NO	NO	NO	NO	75,851	NO	NO
				Additional information								
Independently verified ERUs								NO				

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

Total (Sum of Tables 2a and 2b)	NO	NO	23,032,901	126,851	NO	NO	49,650,531	NO	NO	75,851	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

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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	2,907,928,612	NO	23,032,901	NO	NO	NO
Entity holding accounts	NO	NO	NO	51,000	NO	NO
Article 3.3/3.4 net source cancellation accounts	49,650,531	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	NO	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	2,957,579,143	NO	23,032,901	51,000	NO	NO

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

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Issuance pursuant to Article 3.7 and 3.8				2,957,579,143								
Non-compliance cancellation								NO	NO	NO	NO	
Carry-over			NO	NO		NO						
Sub-total	2,957,579,143	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	23,032,901	126,851	NO	NO	49,650,531	NO	NO	75,851	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	NO	23,032,901	126,852	NO	NO	49,650,531	NO	NO	75,852	NO	NO
Total	2,957,579,143	NO	23,032,901	126,852	NO	NO	49,650,531	NO	NO	75,852	NO	NO

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Table 12.8 – SEF Table 5(b), Summary information on replacement

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

Table 12.9 – SEF Table 5(c), Summary information on retirement

	Retirement					
	Unit type					
Year	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 12.10 – 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 12.11 – 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 12.12 – SEF Table 6(c), Memo item: corrective transactions relating to retirement

	Replacement					
	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 12.13.

Table 12.13 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 at https://nationalregistry.climatechange.gov.au/ 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% of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol, or 100% of five times its most recently reviewed inventory, whichever is lowest'.

Australia's commitment period reserve is 2,661,821,229 t CO_2-e 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 12.14 shows the accounting quantity for 2008, 2009 and 2010.

Table 12.14 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 2008	2009	2010	Total[5]	Accounting Parameters[6]	Accounting Quantity[7]
	(Gg CO_2 equivalent)						
A. Article 3.3 activities							
A.1. Afforestation and Reforestation							
A.1.1. Units of land not harvested since the beginning of the commitment period[1]		-23,081.08	-22,100.09	-25,766.52	-70,947.69		-70,947.69
A.1.2. Units of land harvested since the beginning of the commitment period[1]							0.00
ACT_Softwood		-0.23	-0.82	7.16			0.00
NSW_Hardwood		123.97	125.20	326.65			0.00
NSW_Softwood		639.98	558.13	32.95			0.00
NT_Hardwood		215.51	342.97	237.65			0.00
QLD_Hardwood		0.79	5.29	-17.32			0.00
QLD_Softwood		99.65	61.86	-7.27			0.00
SA_Hardwood		135.45	188.91	216.31			0.00
SA_Softwood		129.99	78.18	93.50			0.00
TAS_Hardwood		534.01	640.02	882.51			0.00
TAS_Softwood		210.89	183.73	158.64			0.00
VIC_Hardwood		922.21	1149.50	1395.77			0.00
VIC_Softwood		237.37	194.66	201.94			0.00
WA_Hardwood		3516.18	3775.55	4920.99			0.00
WA_Softwood		161.24	157.61	74.63			0.00
A.2. Deforestation		56,245.46	47,874.19	43,849.04	147,968.69		147,968.69
B. Article 3.4 activities							
B.1. Forest Management (if elected)		NA	NA	NA	NA		NA
3.3 offset[2]						NA	NA
FM cap[3]						NA	NA

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	BY(4)	Net emissions/removals				Accounting Parameters(6)	Accounting Quantity(7)
		2008	2009	2010	Total(5)		
	(Gg CO_2 equivalent)						
B.2. Cropland Management (if elected)	0.00	NA	NA	NA	NA	0.00	0.00
B.3. Grazing Land Management (if elected)	0.00	NA	NA	NA	NA	0.00	0.00
B.4. Revegetation (if elected)	0.00	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 2010 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	Change to Designated representative with overall responsibility for the national inventory (Volume 1, section 1.2.1 refers) Assistant Secretary National Inventory Systems and International Reporting Branch Department of Climate Change and Energy Efficiency Australian Government GPO Box 854 Canberra ACT 2601 AUSTRALIA nationalgreenhouseaccounts@climatechange.gov.au
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	No change in this submission
15/CMP.1 annex II.E paragraph 30 (c) Changes in the process of inventory compilation	Continuing on from the improvements in the 2011 submission the process of inventory compilation continues to incorporate more facility specific data obtained under the National Greenhouse and Energy Reporting System (NGERS). Recalculations flowing from the change have been identified in the relevant chapters.
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 2011 inventory submission additional QA/QC activities and procedures have been implemented as identified in the relevant chapters.
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 1.1 of the ANREU was released into production on 28 October 2011. The hosting configuration remains unchanged, but enhancements to the registry web application have lead to increased capacity in terms of the ability to handle transactions and the reconciliation involving large numbers of unit blocks.
15/CMP.1 annex II.E paragraph 32 (d) Change of conformance to technical standards	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 now 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 now 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	In coordination with the release of v1.1 of the ANREU, several new security measures have been implemented. Phishing attacks on European registries in 2010 lead the Registry System Administrators (RSA) Change Advisory Board (CAB) to require that Kyoto national registries adopt either two-factor authentication or "the two man rule" to secure registries against potential fraudulent transactions. The ANREU now incorporates a hybrid of these measures – using an initiator and approver design which requires 2 distinct authorisation steps to be undertaken in the approval of high risk transfer transactions. This measure supports the recommendations as outlined by the ITL Change Advisory Board.
15/CMP.1 annex II.E paragraph 32 (g) Change of list of publicly available information	Australia has changed the information available under the Public Reports function. 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 revised non confidential public information can now be found at https://nationalregistry.climatechange.gov.au/ under the Public Reports facility.
15/CMP.1 annex II.E paragraph 32 (h) Change of Internet address	No change in this submission

Reporting Item	Annual Report
15/CMP.1 annex II.E paragraph 32 (i) Change of data integrity measure	In coordination with the release of v1.1 of the ANREU, several data integrity measures have been enhanced. To enhance data availability and recovery, the ANREU has implemented a transactional data replication scheme. Replication in this instance means that any change made to the production server will automatically be copied to a backup disaster recovery server. If anything were to happen to the production server, the backup server could immediately be brought up in its place with all the data intact. No changes have occurred to the data integrity measures implemented at the server/hosting level.
15/CMP.1 annex II.E paragraph 32 (j) Change of test results	There has been no change in the test results originally submitted for the ANREU. However, additional test cases and testing approaches have been performed in addition to those already submitted prior to Australia's initial IAR. With the release of v1.1 of the ANREU, the ANREU vendor (SRA International, Inc.), in coordination with the ITL Service Desk and the Australian registry administrator, successfully performed the Annex H test plan. These tests were performed on 3 October 2011, and the test results were submitted to ITL Service desk, together with the required SOAP/XML files and a backup of the database at the conclusion of the tests – as per the Annex H test protocols. No issues or defects were discovered as part of the testing process.
Response to previous Annual Review recommendations	No issues were identified through the 2011 Standard Independent Annual Review (SIAR) process.

15. MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3.14

Australia is pleased to provide an update of 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 serious about tackling climate change, and actively engages in a range of key multilateral, regional and bilateral forums and discussions relevant to international cooperation on climate change and related economic, environmental and social issues. Australia is taking a range of actions to reduce greenhouse gas emissions, and ensure reliable and affordable energy supply. Australia has a renewable energy target to ensure 20% of Australia's electricity supply will come from renewable sources by 2020 and has passed the Clean Energy Future (CEF) package of legislation, which introduces a price on carbon from 1 July 2012.

Australia's CEF includes in its design effective measures to address the domestic social and economic impact of action to mitigate climate change, including through assistance to households and industries most affected by the legislation. The CEF will cut Australia's carbon pollution by at least 5% compared with 2000 levels by 2020. As part of the CEF, the carbon price will create a powerful incentive for businesses across the economy to cut their pollution by investing in clean technology and finding more efficient ways of operating. This includes promoting more gas-fired and renewable energy electricity generation in place of emissions-intensive coal-fired generation.

Australia has a market-based energy system and an ongoing co-operative reform agenda aimed at increasing transparency and flexibility in the wholesale and retail energy markets. These reforms aim to ensure reliable and affordable energy supply for consumers, and the setting of energy prices which reflect the costs of supply.

Australia is also conducting a large-scale demonstration of smart grid technology. The $100 million Smart Grid, Smart City project was announced as part of the 2009 Federal Budget and will deliver the world's first fully-integrated, commercial-scale smart grid. It will test the business case and build corporate and public awareness of smart grid technologies. This project will be an important source of learning, which the Australian Government intends to share with other countries through the International Smart Grid Action Network, established under the US-led Clean Energy Ministerial process, and other international fora.

CARBON CAPTURE AND STORAGE

CCS technology provides an important avenue for climate change mitigation to occur by minimising emissions potential from existing energy infrastructure. As such, important steps were taken at COP 17 in Durban to include CCS as an eligible activity in the Clean Development Mechanism.

In cooperation with many nations, from the developed and developing world, Australia is contributing to global efforts underway in the development, diffusion, and transfer of advanced technologies, which capture and store greenhouse gases, and encourage their wider use.

Australia facilitates the participation of least developed countries and other non-Annex I Parties in this effort. This includes working to strengthen the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention to assist them to participate in efforts that improve efficiency in upstream and downstream activities relating to fossil fuels. Australia's activities to achieve this are set out below.

AUSTRALIA-CHINA JOINT COORDINATION GROUP ON CLEAN COAL TECHNOLOGY (JCG)

The JCG was established in 2007 to facilitate and enhance the mutually beneficial development, application and transfer of low emissions coal technology and is supported by $20 million of Australian Government funding drawn from the National Low Emissions Coal Initiative. Under the JCG the Australian Government, Department of Resources, Energy and Tourism (RET) is working closely with China's National Energy Administration (NEA). The JCG meets annually and funding is allocated to specific projects that are announced publicly.

In December 2010, China's NEA signed a MoU with RET to collaborate on a feasibility study for a full scale post combustion capture (PCC) project with CCS in China. The feasibility study will draw on $12 million committed under the JCG, and focus on a commercial-scale (600 MW), integrated CCS demonstration project using the PCC process. Work on the project is underway with an initial scoping study undertaken by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and China's Clean Energy Research Institute (CERI). Once the scoping study stage has been completed, one site will be identified and the feasibility study stage will commence.

At the last JCG meeting in September 2011, three proposals building on successful projects conducted between Australia and China under the Asia-Pacific Partnership on Clean Development and Climate were endorsed. These projects include stage two of the PCC Pilot Project conducted by CSIRO and CERI; an extension of the China-Australia Geological Storage Project conducted by Geoscience Australia and the Administrative Centre for China's Agenda 21; and the Enhanced Coal Bed Methane Project conducted by CSIRO and China United Coal Bed Methane. Financial support will be made available for these projects. JCG funding is also being used to support six collaborative research projects with approximately $3 million over two financial years.

GLOBAL CARBON CAPTURE AND STORAGE INSTITUTE

The Global Carbon Capture and Storage (CCS) Institute was announced by the Australian Government in 2008, and has total Australian Government funding of A$315 million. The Australian Government recently extended the term of the funding agreement with the Institute to June 2017, which more clearly ties the work of the Institute with the 2015-2020 deployment goal for CCS which was agreed by the G8. The Institute is an important measure taken by Australia that will assist carbon intensive economies reduce their exposure to the impact of the implementation of response measures.

The Institute will help deliver the G8's goal of developing at least 20 fully integrated industrial-scale CCS demonstration projects around the world. CCS technology is vital to assist countries reduce the carbon intensity of their economic base, and therefore their vulnerability to global efforts to reduce carbon emissions. The Institute connects parties around the world to solve problems, address issues and learn from each other to accelerate the deployment of CCS projects by providing a fact-based advocacy for CCS, assisting projects, and sharing knowledge.

Since its official opening in April 2009, the Institute has attracted strong and widespread support from governments, corporations, industry bodies and research organisations from key markets around the globe, and has built a diversified membership profile that represents a healthy cross-section of these international stakeholders. There are currently 330 members, including 27 national governments. The Institute's members account for over 80% of the world's carbon dioxide emissions from energy and industrial sources.

The Institute has undertaken many activities since the last report under this item that support the acceleration of CCS globally.

The Institute's capacity development activities continue to focus on developing countries, helping to build an 'enabling environment', addressing the many different barriers to CCS deployment, and developing appropriate in-country expertise.

A Member-based Capacity Development Steering Group was established to help guide these activities. Based on analysis of relevant criteria and advice from the Steering Group, the Institute identified six 'countries of focus' for the capacity development program: China, India, Indonesia, Malaysia, Mexico and South Africa. Active engagement with these countries is now underway.

Substantial progress has been made in developing and implementing an integrated and tailored capacity development program for Malaysia and Mexico.

The Institute, in partnership with the Malaysian Ministry of Energy, Green Technology and Water (KeTTHA) and the Clinton Climate Initiative, produced a Malaysia CCS Scoping Study which was formally handed over on 24 January 2011. In addition, a CCS Capacity Assessment has been completed and the first stage of a tailored work program has been developed. In September 2011, the Institute developed a Capacity Assessment and program in partnership with Mexican stakeholders. The Institute is currently helping the Mexican Government draft a National CCS Strategy.

In support of South Africa's work towards a test injection project, the Institute sponsored and facilitated a South African delegation of policy, legal and non-government representatives to visit Australia in mid-2011. The focus of the trip was to learn about the CO_2CRC's experience in running a test injection demonstration project in Australia.

In China, the Institute has agreed with the National Development and Reform Commission in China on a program of activities; including an enhanced oil recovery workshop in March 2012.

There was also significant progress in the capacity development programs of the Institute's Strategic Partners. As part of the Institute's financial contribution towards the ADB CCS Trust Fund, it is supporting CCS scoping studies in Indonesia, Philippines, Thailand and Vietnam. Representatives from these countries gave an update on this work at the CCS Ready Workshop in Manila in June 2011. The Institute is working closely with the ADB on the development of this work in Indonesia, and working closely with relevant ministries to identify areas where the Institute can support the deployment of CCS in Indonesia. The World Bank CCS Trust Fund, which the Institute has supported financially, will implement country specific technical assistance programs in ten countries.

As part of its ongoing support of the IEAGHG, the Institute sponsored their CCS Summer School, held in Norway in August 2010. The Institute also provided ten scholarships to early career professionals and post graduate students from the Asia-Pacific region to attend the CO_2CRC's CCS School held in Brisbane in July 2010.

The Institute supplemented its development of a definition on 'CCS Ready' from early 2010 with an issues paper published in November 2010 setting out the key elements necessary to support implementing the definition.

The Institute is also actively engaged with a number of governments considering implementing a CCS Ready policy and ran a CCS Ready Workshop in association with the ADB's Clean Energy Forum in Manila in June 2011.

A Regulatory Test Toolkit was published in February 2011 to provide assistance to regulators in developing early-stage regulatory regimes. The toolkit was developed in conjunction with Edinburgh University and builds upon a test exercise to assess the existing regulatory and consenting framework for CCS in Scotland.

The toolkit can be applied by governments anywhere, enabling them to determine present regulatory ability and what is further required to enable the deployment of CCS technology in a regulatory-efficient manner. The toolkit exercise embodies a regulatory simulation or 'dry-run' of a real or simulated CCS scheme, thereby tracking the approvals processes for a project from the initial planning stages, through the operational phase, and into the decommissioning period.

The Institute continues to roll out the toolkit process, targeting a number of jurisdictions worldwide throughout 2011 and 2012.

CARBON SEQUESTRATION LEADERSHIP FORUM

The Carbon Sequestration Leadership Forum (CSLF) is a Ministerial-level international climate change initiative that is focused on cooperation to develop and apply technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the CSLF is to make CCS technologies broadly available internationally, and to identify and address wider issues relating to its deployment. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology.

Australia is a foundation member of the CSLF, which has a membership comprising twenty one countries and the European Commission. Australia has been actively involved in the CSLF since it was formed in June 2003 and is a member of a number of CSLF task forces. Australia is an active participant in the CSLF Capacity Building Program, which is designed to assist CSLF members to develop the information, tools, skills, expertise and institutions required to implement CCS demonstrations and then move to commercial operation. To date, Australia has made the highest contribution to the CSLF Capacity Building Fund (US$968,160.00) and ten projects have been approved.

ASIA PACIFIC PARTNERSHIP ON CLEAN DEVELOPMENT AND CLIMATE

In the five years of its existence, the APP enhanced partnerships between the public and private sectors, promoted best practices and technologies across a range of key sectors, and deepened cooperation among its seven partner countries. The APP achieved considerable success and benefited all partners, and the Partnership has become a model of public-private partnerships to drive the development of clean technologies.

Following the launch of APP in 2006, a number of partnerships have emerged which are undertaking public-private cooperation involving APP countries and other partners. APP Partner Countries share the view that the APP's activities may be further enhanced, expanded, and shared with a broader group of countries by incorporating them into the work of these other multilateral and bilateral efforts.

The APP has agreed that the most efficient and effective way to help these efforts grow and prosper and expand to a broader group of partners would be to transition the active programming into other relevant partnerships or bodies. As such, the APP formally concluded on 5 April 2011 in Bangkok, Thailand. However, Australia and other APP Partner Countries remain committed to current and ongoing APP projects that will continue and transition to new international fora.

GLOBAL METHANE INITIATIVE

The Methane to Markets Partnership involving 41 member countries was re-launched as the Global Methane Initiative (the Initiative) at the Ministerial Meeting held in Mexico City on 1 October 2010. The Initiative aims to encourage, through collaboration, the development and use of low emissions technology and services in different sectors. Projects under the Initiative will accelerate deployment of methane emission-reducing technologies and practices, stimulating economic growth and energy security in Partner countries and helping them to minimise exposure to measures taken to mitigate climate change. Since re-launching as the Global Methane Initiative, members are now addressing methane abatement as well as commercial use of fugitive emissions, and targeting additional emission sources such as wastewater.

Two successful expos have been held in China in 2007 and India in 2010 to demonstrate methane technologies, practices and projects. The next expo will be held in Vancouver in 2013.

The Initiative now has 41 members including all of the 10 largest methane emitters in the world (Australia is the 10th largest methane emitter). A large number of its members are developing countries with a broad geographical spread, including Argentina, Brazil, Chile, China, Colombia, the Dominican Republic, Ecuador, Ethiopia, Ghana, India, Indonesia, Mexico, Mongolia, Nicaragua, Nigeria, Pakistan, Peru, the Philippines, Republic of Korea, Thailand and Vietnam.

In the five years since its inception, the former M2M has supported more than 300 projects that will reduce emissions by 63 Mt CO_2-e when the projects are fully implemented. Australia was one of the 14 founding members of the former M2M and nominated members to all four subcommittees. The Initiative is a cross-portfolio issue in the Australian Government covering responsibilities of the Department of Resources, Energy and Tourism (RET), the Department of Agriculture Fisheries and Forestry (DAFF) and the Department of Climate Change and Energy Efficiency (DCCEE). The Steering Committee is the key decision making body responsible for determining the new direction, policies and procedures of the Initiative. The first official cross-partnership meeting of the GMI was held in Poland in October 2011.

Australia has facilitating the participation of the least developed countries and other non-Annex I Parties in these processes through the involvement of developing country Parties as listed above.

ASIA PACIFIC ECONOMIC COOPERATION (APEC) EXPERT GROUP ON CLEAN FOSSIL ENERGY (EGCFE)

The EGCFE is an Expert Group under the APEC Energy Working Group (EWG). Membership covers the 21 member economies (developing and developed) of the APEC region. India is also invited to EGCFE events and regularly sends a representative.

The EGCFE's mission is to encourage the use of clean fuels and energy technologies that will both contribute to sound economic performance and achieve high environmental standards. The EGCFE undertakes activities to concurrently enhance economic development and mitigate, at the local, regional, and global levels, the environmental impact (e.g. air emissions, water and waste management) related to the production, preparation, transport, storage, and use of fossil fuels.

Australia is hosting the EGCFE Business Meeting and annual seminar in February 2012. The Business Meeting will facilitate planning of the group's forward work program, including a focus on building knowledge, awareness and capacity in APEC developing economies for CCS and advanced coal power generation technologies. The seminar will facilitate knowledge sharing and cooperation among government, industry and research representatives from APEC economies on technical and policy issues in the development and diffusion of cleaner fossil fuel technologies.

CLEAN ENERGY MINISTERIAL

Carbon Capture Use and Storage (CCUS) Action Group

At the first Clean Energy Ministerial (CEM) in 2010, Ministers established the Carbon Capture Use and Storage (CCUS) Action Group to facilitate political leadership and provide recommendations to the CEM on concrete, near-term actions to accelerate the deployment of CCS.

The CCUS Action Group, which brings together governments, businesses and CCS organisations, developed a set of eight recommendations, which were endorsed by Ministers at the second CEM in 2011. One of these recommendations was to 'identify and advance appropriate funding mechanisms to support the demonstration of large-scale CCS projects in developing economies' recognising that in order to realistically achieve domestic $C0_2$ reduction targets, many developing countries with a heavy reliance on fossil fuel based energy sources will need CCS as part of their technology mitigation portfolios.

A working group, chaired by the Global CCS Institute and including the International Energy Agency (IEA), Clinton Climate Initiative, World Bank, Asian Development Bank, World Resources Institute, the Australian Department of Resources, Energy and Tourism and the UK Department of Energy and Climate Change, was charged with implementing this recommendation and is due to report key messages and recommendations to the next CEM, scheduled for April 2012.

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)*, 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 2010. The full results for the 2010 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 2010 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.

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 A1.1: Key categories for Australia's 2010 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	177,303	0.25	0.25
1.A.3.b	Road Transportation\Liquid Fuels	CO_2	53,138	69,558	0.10	0.35
4.A.1	Enteric Fermentation\Cattle	CH_4	39,017	43,452	0.06	0.41
5.C.2	Land converted to Grassland	CO_2	105,993	42,493	0.06	0.48
5.A.1	Forest Land remaining Forest Land	CO_2	47,060	35,618	0.05	0.53
5.C.1	Grassland remaining Grassland	CO_2	604	27,041	0.04	0.57
1.A.1.a	Public Electricity and Heat Production\Gaseous Fuels	CO_2	8,239	20,379	0.03	0.59
5.A.2	Land converted to Forest Land	CO_2	152	17,259	0.02	0.62
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Gaseous Fuels	CO_2	4,593	16,869	0.02	0.64
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,312	0.02	0.66
5.B.2	Land converted to Cropland	CO_2	29,832	11,642	0.02	0.68
6.A.1	Managed Waste Disposal on Land	CH_4	13,545	11,140	0.02	0.70
4.A.3	Enteric Fermentation\Sheep	CH_4	24,595	10,144	0.01	0.71
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	3,385	9,712	0.01	0.73
5.B.1	Cropland remaining Cropland	CO_2	1,754	7,434	0.01	0.74
1.A.4.b	Residential\Gaseous Fuels	CO_2	4,613	7,383	0.01	0.75
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	7,338	0.01	0.76
4.E	Prescribed Burning of Savannas	CH_4	4,909	6,560	0.01	0.77
1.A.2.b	Non-Ferrous Metals\Gaseous Fuels	CO_2	4,140	6,261	0.01	0.78
1.A.3.a	Civil Aviation\Liquid Fuels	CO_2	2,895	6,101	0.01	0.78
1.A.4.c	Agriculture/Forestry/Fisheries\Liquid Fuels	CO_2	3,372	6,025	0.01	0.79
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Liquid Fuels	CO_2	958	5,199	0.01	0.80
1.A.1.b	Petroleum Refining\Liquid Fuels	CO_2	5,243	4,611	0.01	0.81
5.G	Other (Harvested Wood Products)	CO_2	5,048	4,428	0.01	0.81
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	–	4,397	0.01	0.82
1.A.2.f	Other (please specify)\Mining\Liquid Fuels	CO_2	1,741	3,973	0.01	0.83
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,600	0.01	0.83

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,580	0.01	0.84
2.A.1	Cement Production	CO_2	3,463	3,549	0.01	0.84
1.A.2.b	Non-Ferrous Metals\Solid Fuels	CO_2	3,845	3,521	0.01	0.85
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,337	0.00	0.85
2.B	Chemical Industry	N_2O	1,035	3,264	0.00	0.86
1.A.2.f	Other (please specify)\Mineral industry\Gaseous Fuels	CO_2	2,950	3,156	0.00	0.86
2.C.3	Aluminium Production	CO_2	2,021	3,140	0.00	0.86
1.A.2.b	Non-Ferrous Metals\Liquid Fuels	CO_2	2,822	3,134	0.00	0.87
1.A.2.c	Chemicals\Liquid Fuels	CO_2	3,263	3,096	0.00	0.87
4.D.3.1	Atmospheric Deposition	N_2O	3,144	3,091	0.00	0.88
1.A.1.a	Public Electricity and Heat Production\Liquid Fuels	CO_2	2,878	2,747	0.00	0.88
1.A.3.c	Railways\Liquid Fuels	CO_2	1,728	2,574	0.00	0.88
4.D.1.1	Synthetic Fertilizers	N_2O	1,530	2,561	0.00	0.89
2.B	Chemical Industry	CO_2	599	2,560	0.00	0.89
1.A.4.a	Commercial/Institutional\Gaseous Fuels	CO_2	1,811	2,528	0.00	0.90
1.A.2.f	Other (please specify)\Mineral industry\Solid Fuels	CO_2	2,168	2,474	0.00	0.90
1.A.2.a	Iron and Steel\Solid Fuels	CO_2	1,196	2,466	0.00	0.90
1.A.4.a	Commercial/Institutional\Liquid Fuels	CO_2	1,233	2,412	0.00	0.91
5.A.1	Forest Land remaining Forest Land	CH_4	1,385	2,325	0.00	0.91
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Solid Fuels	CO_2	2,353	2,212	0.00	0.91
1.A.2.c	Chemicals\Gaseous Fuels	CO_2	1,441	2,159	0.00	0.92
4.E	Prescribed Burning of Savannas	N_2O	1,450	2,052	0.00	0.92
5.A.1	Forest Land remaining Forest Land\Biomass Burning\Wildfires	CH_4	813	1,848	0.00	0.92
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,477	1,764	0.00	0.92
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,653	0.00	0.93
1.A.2.e	Food Processing, Beverages and Tobacco\Gaseous Fuels	CO_2	1,246	1,601	0.00	0.93
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	–	1,557	0.00	0.93
1.A.2.f	Other (please specify)\Construction\Liquid Fuels	CO_2	2,809	1,522	0.00	0.93

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
1.A.3.b	Road Transportation\Liquid Fuels	N_2O	698	1,515	0.00	0.94
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CO_2	–	1,421	0.00	0.94
1.A.2.a	Iron and Steel\Gaseous Fuels	CO_2	1,383	1,366	0.00	0.94
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CO_2	3,601	1,339	0.00	0.94
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	250	1,312	0.00	0.94
1.A.2.d	Pulp, Paper and Print\Gaseous Fuels	CO_2	817	1,269	0.00	0.94
5.G	Agricultural Liming	CO_2	170	1,257	0.00	0.95
1.B.1.c	Fugitives\Coal mining\Decommissioned Mines	CH_4	356	1,216	0.00	0.95
1.A.1.a	Public Electricity and Heat Production\Solid Fuels	CO_2	117,909	177,303	0.25	0.25
1.A.3.b	Road Transportation\Liquid Fuels	CO_2	53,138	69,558	0.10	0.35
4.A.1	Enteric Fermentation\Cattle	CH_4	39,017	43,452	0.06	0.41
5.C.2	Land converted to Grassland	CO_2	105,993	42,493	0.06	0.48
5.A.1	Forest Land remaining Forest Land	CO_2	47,060	35,618	0.05	0.53

Table A1.2: Key categories for Australia's 2010 inventory–trend assessment including LULUCF

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
5.C.2	Land converted to Grassland	CO_2	105,993	42,493	0.12	0.22	0.22
1.A.1.a	Public Electricity and Heat Production\Solid Fuels	CO_2	117,909	177,303	0.06	0.12	0.34
5.C.1	Grassland remaining Grassland	CO_2	604	27,041	0.04	0.07	0.41
5.B.2	Land converted to Cropland	CO_2	29,832	11,642	0.03	0.06	0.47
5.A.1	Forest Land remaining Forest Land	CO_2	47,060	35,618	0.03	0.05	0.52
4.A.3	Enteric Fermentation\Sheep	CH_4	24,595	10,144	0.03	0.05	0.57
5.A.2	Land converted to Forest Land	CO_2	152	17,259	0.03	0.05	0.62
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Gaseous Fuels	CO_2	4,593	16,869	0.02	0.03	0.65

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.1.a	Public Electricity and Heat Production\Gaseous Fuels	CO_2	8,239	20,379	0.02	0.03	0.68
1.A.3.b	Road Transportation\Liquid Fuels	CO_2	53,138	69,558	0.01	0.03	0.71
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	3,385	9,712	0.01	0.02	0.72
5.B.1	Cropland remaining Cropland	CO_2	1,754	7,434	0.01	0.02	0.74
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	–	4,397	0.01	0.01	0.75
6.A.1	Managed Waste Disposal on Land	CH_4	13,545	11,140	0.01	0.01	0.76
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Liquid Fuels	CO_2	958	5,199	0.01	0.01	0.77
2.C.3	Aluminium Production	CF_4	3,337	211	0.01	0.01	0.78
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	7,338	0.00	0.01	0.79
1.A.3.a	Civil Aviation\Liquid Fuels	CO_2	2,895	6,101	0.00	0.01	0.80
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CO_2	3,601	1,339	0.00	0.01	0.81
1.A.4.c	Agriculture/Forestry/Fisheries\Liquid Fuels	CO_2	3,372	6,025	0.00	0.01	0.81
5.C.2	Land converted to Grassland	CH_4	2,587	782	0.00	0.01	0.82
1.A.4.b	Residential\Gaseous Fuels	CO_2	4,613	7,383	0.00	0.01	0.83
2.B	Chemical Industry	N_2O	1,035	3,264	0.00	0.01	0.83
1.A.2.f	Other (please specify)\Mining\Liquid Fuels	CO_2	1,741	3,973	0.00	0.01	0.84
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,580	0.00	0.01	0.84
2.B	Chemical Industry	CO_2	599	2,560	0.00	0.01	0.85
1.A.2.f	Other (please specify)\Construction\Liquid Fuels	CO_2	2,809	1,522	0.00	0.00	0.85
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	–	1,557	0.00	0.00	0.86
1.A.2.b	Non-Ferrous Metals\Gaseous Fuels	CO_2	4,140	6,261	0.00	0.00	0.86
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CO_2	–	1,421	0.00	0.00	0.87
1.A.4.b	Residential\Biomass	CH_4	2,018	875	0.00	0.00	0.87
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,600	0.00	0.00	0.87
1.A.1.b	Petroleum Refining\Liquid Fuels	CO_2	5,243	4,611	0.00	0.00	0.88
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,337	0.00	0.00	0.88
5.G	Other (Harvested Wood Products)	CO_2	5,048	4,428	0.00	0.00	0.88
2.E.1.1	Production of HCFC-22	HFC-23	1,126	–	0.00	0.00	0.89

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
6.B.1	Industrial Wastewater \ Wastewater	CH_4	1,901	995	0.00	0.00	0.89
1.A.2.a	Iron and Steel\Solid Fuels	CO_2	1,196	2,466	0.00	0.00	0.89
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	878	0.00	0.00	0.90
1.A.3.d	Navigation\Liquid Fuels\Residual Oil	CO_2	1,369	481	0.00	0.00	0.90
5.G	Agricultural Liming	CO_2	170	1,257	0.00	0.00	0.90
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,477	1,764	0.00	0.00	0.91
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	250	1,312	0.00	0.00	0.91
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CH_4	944	50	0.00	0.00	0.91
1.A.4.a	Commercial/Institutional\Liquid Fuels	CO_2	1,233	2,412	0.00	0.00	0.91
4.E	Prescribed Burning of Savannas	CH_4	4,909	6,560	0.00	0.00	0.92
4.A.1	Enteric Fermentation\Cattle	CH_4	39,017	43,452	0.00	0.00	0.92
5.A.1	Forest Land remaining Forest Land\ Biomass Burning\Wildfires	CH_4	813	1,848	0.00	0.00	0.92
1.A.2.b	Non-Ferrous Metals\Solid Fuels	CO_2	3,845	3,521	0.00	0.00	0.93
2.C.3	Aluminium Production	CO_2	2,021	3,140	0.00	0.00	0.93
4.D.1.1	Synthetic Fertilizers	N_2O	1,530	2,561	0.00	0.00	0.93
1.B.1.c	Fugitives\Coal mining\Decommissioned Mines	CH_4	356	1,216	0.00	0.00	0.93
4.B.13	Manure Management\Solid storage and dry lot	N_2O	202	1,001	0.00	0.00	0.93
5.A.1	Forest Land remaining Forest Land	CH_4	1,385	2,325	0.00	0.00	0.94
1.A.2.f	Other (please specify)\Mining\Solid Fuels	CO_2	658	19	0.00	0.00	0.94
1.A.3.b	Road Transportation\Liquid Fuels	N_2O	698	1,515	0.00	0.00	0.94
2.C.3	Aluminium Production	C_2F_6	613	33	0.00	0.00	0.94
1.A.2.c	Chemicals\Solid Fuels	CO_2	1,079	603	0.00	0.00	0.94
1.A.2.c	Chemicals\Liquid Fuels	CO_2	3,263	3,096	0.00	0.00	0.95
1.A.3.c	Railways\Liquid Fuels	CO_2	1,728	2,574	0.00	0.00	0.95
5.C.2	Land converted to Grassland	N_2O	707	213	0.00	0.00	0.95

Table A1.3: Key categories for Australia's 2010 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
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
1.A.2.a	Iron and Steel\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,Trend
1.A.2.b	Non-Ferrous Metals\Liquid Fuels	CO_2	YES	Level
1.A.2.c	Chemicals\Liquid Fuels	CO_2	YES	Level,Trend
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.d	Pulp, Paper and Print\Gaseous Fuels	CO_2	YES	Level
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.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	N_2O	YES	Level, Trend
1.A.3.c	Railways\Liquid Fuels	CO_2	YES	Level, Trend

A		B	C	D
IPCC Source Categories		Direct Greenhouse Gas	Key Source Category Flag	If Column C is Yes, Criteria for Identification
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	YES	Level, Trend
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, 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.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
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	YES	Level, Trend
1.B.1.c	Fugitives\ Coal mining\Decommissioned Mines	CH_4	YES	Level, 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	Trend
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CO_2	YES	Level, Trend
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CO_2	YES	Level, Trend
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\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
2.B	Chemical Industry	N_2O	YES	Level
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

A	B	C	D
IPCC Source Categories	**Direct Greenhouse Gas**	**Key Source Category Flag**	**If Column C is Yes, Criteria for Identification**
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.D.1.1 Synthetic Fertilizers	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
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	N_2O	YES	Level
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.1 Forest Land remaining Forest Land\Biomass Burning\Wildfires	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, Trend
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.C.2 Land converted to Grassland	N_2O	YES	Trend
5.G Other (Harvested Wood Products)	CO_2	YES	Level, Trend
5.G Agricultural Liming	CO_2	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 A1.4: Key categories for Australia's 2010 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	177,303	0.33	0.33
1.A.3.b	Road Transportation\Liquid Fuels	CO_2	53,138	69,558	0.13	0.45
4.A.1	Enteric Fermentation\Cattle	CH_4	39,017	43,452	0.08	0.53
1.A.1.a	Public Electricity and Heat Production\Gaseous Fuels	CO_2	8,239	20,379	0.04	0.57
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Gaseous Fuels	CO_2	4,593	16,869	0.03	0.60
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,312	0.03	0.63
6.A.1	Managed Waste Disposal on Land	CH_4	13,545	11,140	0.02	0.65
4.A.3	Enteric Fermentation\Sheep	CH_4	24,595	10,144	0.02	0.67
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	3,385	9,712	0.02	0.69
1.A.4.b	Residential\Gaseous Fuels	CO_2	4,613	7,383	0.01	0.70
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	7,338	0.01	0.72
4.E	Prescribed Burning of Savannas	CH_4	4,909	6,560	0.01	0.73
1.A.2.b	Non-Ferrous Metals\Gaseous Fuels	CO_2	4,140	6,261	0.01	0.74
1.A.3.a	Civil Aviation\Liquid Fuels	CO_2	2,895	6,101	0.01	0.75
1.A.4.c	Agriculture/Forestry/Fisheries\Liquid Fuels	CO_2	3,372	6,025	0.01	0.76
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Liquid Fuels	CO_2	958	5,199	0.01	0.77
1.A.1.b	Petroleum Refining\Liquid Fuels	CO_2	5,243	4,611	0.01	0.78
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	–	4,397	0.01	0.79
1.A.2.f	Other (please specify)\Mining\Liquid Fuels	CO_2	1,741	3,973	0.01	0.79
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,600	0.01	0.80
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,580	0.01	0.81
2.A.1	Cement Production	CO_2	3,463	3,549	0.01	0.81
1.A.2.b	Non-Ferrous Metals\Solid Fuels	CO_2	3,845	3,521	0.01	0.82
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,337	0.01	0.83
2.B	Chemical Industry	N_2O	1,035	3,264	0.01	0.83
1.A.2.f	Other (please specify)\Mineral industry\Gaseous Fuels	CO_2	2,950	3,156	0.01	0.84
2.C.3	Aluminium Production	CO_2	2,021	3,140	0.01	0.84

A		B	C	D	E	F
IPCC Source Category		Gas	Base Year Estimate	Current Year Estimate	Level Assessment	Cumulative Total
1.A.2.b	Non-Ferrous Metals\Liquid Fuels	CO_2	2,822	3,134	0.01	0.85
1.A.2.c	Chemicals\Liquid Fuels	CO_2	3,263	3,096	0.01	0.86
4.D.3.1	Atmospheric Deposition	N_2O	3,144	3,091	0.01	0.86
1.A.1.a	Public Electricity and Heat Production\Liquid Fuels	CO_2	2,878	2,747	0.01	0.87
1.A.3.c	Railways\Liquid Fuels	CO_2	1,728	2,574	0.00	0.87
4.D.1.1	Synthetic Fertilizers	N_2O	1,530	2,561	0.00	0.88
2.B	Chemical Industry	CO_2	599	2,560	0.00	0.88
1.A.4.a	Commercial/Institutional\Gaseous Fuels	CO_2	1,811	2,528	0.00	0.89
1.A.2.f	Other (please specify)\Mineral industry\Solid Fuels	CO_2	2,168	2,474	0.00	0.89
1.A.2.a	Iron and Steel\Solid Fuels	CO_2	1,196	2,466	0.00	0.90
1.A.4.a	Commercial/Institutional\Liquid Fuels	CO_2	1,233	2,412	0.00	0.90
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Solid Fuels	CO_2	2,353	2,212	0.00	0.90
1.A.2.c	Chemicals\Gaseous Fuels	CO_2	1,441	2,159	0.00	0.91
4.E	Prescribed Burning of Savannas	N_2O	1,450	2,052	0.00	0.91
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,477	1,764	0.00	0.91
2.A.3	Limestone and Dolomite Use	CO_2	1,345	1,653	0.00	0.92
1.A.2.e	Food Processing, Beverages and Tobacco\Gaseous Fuels	CO_2	1,246	1,601	0.00	0.92
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	–	1,557	0.00	0.92
1.A.2.f	Other (please specify)\Construction\Liquid Fuels	CO_2	2,809	1,522	0.00	0.93
1.A.3.b	Road Transportation\Liquid Fuels	N_2O	698	1,515	0.00	0.93
1.B.2.c.2.1	Fugitives\ Oil and Natural Gas\ Venting and Flaring\ Flaring\ Oil	CO_2	–	1,421	0.00	0.93
1.A.2.a	Iron and Steel\Gaseous Fuels	CO_2	1,383	1,366	0.00	0.93
1.B.2.c.2.2	Fugitives\ Oil and Natural Gas\ Venting and Flaring\ Flaring\ Gas	CO_2	3,601	1,339	0.00	0.94
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	250	1,312	0.00	0.94
1.A.2.d	Pulp, Paper and Print\Gaseous Fuels	CO_2	817	1,269	0.00	0.94
1.B.1.c	Fugitives\ Coal mining\Decommissioned Mines	CH_4	356	1,216	0.00	0.94
1.A.2.e	Food Processing, Beverages and Tobacco\Solid Fuels	CO_2	1,190	1,194	0.00	0.95
4.B.8	Manure Management\Swine	CH_4	1,050	1,111	0.00	0.95
4.B.13	Manure Management\Solid storage and dry lot	N_2O	202	1,001	0.00	0.95

Table A1.5: Key categories for Australia's 2010 inventory–trend assessment excluding LULUCF

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.1.a	Public Electricity and Heat Production\Solid Fuels	CO_2	117,909	177,303	0.03	0.14	0.14
4.A.3	Enteric Fermentation\Sheep	CH_4	24,595	10,144	0.03	0.12	0.26
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Gaseous Fuels	CO_2	4,593	16,869	0.02	0.06	0.33
1.A.1.a	Public Electricity and Heat Production\Gaseous Fuels	CO_2	8,239	20,379	0.01	0.06	0.38
4.A.1	Enteric Fermentation\Cattle	CH_4	39,017	43,452	0.01	0.04	0.42
6.A.1	Managed Waste Disposal on Land	CH_4	13,545	11,140	0.01	0.04	0.46
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	3,385	9,712	0.01	0.03	0.49
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-134a	-	4,397	0.01	0.03	0.51
2.C.1.4	Iron and Steel\Coke	CO_2	9,018	7,338	0.01	0.03	0.54
2.C.3	Aluminium Production	CF_4	3,337	211	0.01	0.02	0.56
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Liquid Fuels	CO_2	958	5,199	0.01	0.02	0.59
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CO_2	3,601	1,339	0.00	0.02	0.60
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CH_4	13,948	15,312	0.00	0.02	0.62
4.D.2	Pasture, Range and Paddock Manure	N_2O	4,881	3,580	0.00	0.02	0.64
1.A.3.a	Civil Aviation\Liquid Fuels	CO_2	2,895	6,101	0.00	0.01	0.65
1.A.1.b	Petroleum Refining\Liquid Fuels	CO_2	5,243	4,611	0.00	0.01	0.66
1.A.2.f	Other (please specify)\Construction\Liquid Fuels	CO_2	2,809	1,522	0.00	0.01	0.67
1.B.2.b.4	Fugitives\Natural Gas\Distribution	CH_4	4,093	3,337	0.00	0.01	0.69
2.B	Chemical Industry	N_2O	1,035	3,264	0.00	0.01	0.70
2.B	Chemical Industry	CO_2	599	2,560	0.00	0.01	0.71
1.A.4.b	Residential\Biomass	CH_4	2,018	875	0.00	0.01	0.72
1.A.2.f	Other (please specify)\Mining\Liquid Fuels	CO_2	1,741	3,973	0.00	0.01	0.73
1.A.4.c	Agriculture/Forestry/Fisheries\Liquid Fuels	CO_2	3,372	6,025	0.00	0.01	0.74
2.F.1	Refrigeration and Air Conditioning Equipment	HFC-125	–	1,557	0.00	0.01	0.74
6.B.1	Industrial Wastewater\Wastewater	CH_4	1,901	995	0.00	0.01	0.75

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.2.b	Non-Ferrous Metals\Solid Fuels	CO_2	3,845	3,521	0.00	0.01	0.76
2.E.1.1	Production of HCFC-22	HFC-23	1,126	–	0.00	0.01	0.77
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	2,477	1,764	0.00	0.01	0.78
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CO_2	–	1,421	0.00	0.01	0.79
1.A.4.b	Residential\Gaseous Fuels	CO_2	4,613	7,383	0.00	0.01	0.79
1.B.2.c.1.2	Venting and Flaring, Venting	CH_4	1,734	878	0.00	0.01	0.80
1.A.3.d	Navigation\Liquid Fuels\Residual Oil	CO_2	1,369	481	0.00	0.01	0.81
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CH_4	944	50	0.00	0.01	0.82
1.A.2.c	Chemicals\Liquid Fuels	CO_2	3,263	3,096	0.00	0.01	0.82
1.B.2.c.1.2	Venting and Flaring, Venting	CO_2	1,966	3,600	0.00	0.01	0.83
4.D.3.1	Atmospheric Deposition	N_2O	3,144	3,091	0.00	0.01	0.83
1.A.1.a	Public Electricity and Heat Production\Liquid Fuels	CO_2	2,878	2,747	0.00	0.01	0.84
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	250	1,312	0.00	0.01	0.85
2.A.1	Cement Production	CO_2	3,463	3,549	0.00	0.01	0.85
1.A.2.a	Iron and Steel\Solid Fuels	CO_2	1,196	2,466	0.00	0.01	0.86
1.A.2.b	Non-Ferrous Metals\Gaseous Fuels	CO_2	4,140	6,261	0.00	0.01	0.86
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries\Solid Fuels	CO_2	2,353	2,212	0.00	0.00	0.87
1.A.2.f	Other (please specify)\Mining\Solid Fuels	CO_2	658	19	0.00	0.00	0.87
1.A.4.a	Commercial/Institutional\Liquid Fuels	CO_2	1,233	2,412	0.00	0.00	0.88
1.A.2.c	Chemicals\Solid Fuels	CO_2	1,079	603	0.00	0.00	0.88
2.C.3	Aluminium Production	C_2F_6	613	33	0.00	0.00	0.88
1.B.1.c	Fugitives\Coal mining\Decommissioned Mines	CH_4	356	1,216	0.00	0.00	0.89
4.B.13	Manure Management\Solid storage and dry lot	N_2O	202	1,001	0.00	0.00	0.89
1.A.4.b	Residential\Liquid Fuels	CO_2	1,317	1,000	0.00	0.00	0.90
1.A.2.f	Other (please specify)\Other non-specified\Gaseous Fuels	CO_2	1,046	660	0.00	0.00	0.90

A		B	C	D	E	F	G
IPCC Source Categories		Gas	1990 Emissions	2009 Emissions	Trend Assessment	% Contribution to Trend	Cumulative Total of Column F
1.A.2.f	Other (please specify)\Mineral industry\Gaseous Fuels	CO_2	2,950	3,156	0.00	0.00	0.91
1.A.3.b	Road Transportation\Liquid Fuels	N_2O	698	1,515	0.00	0.00	0.91
4.D.1.1	Synthetic Fertilizers	N_2O	1,530	2,561	0.00	0.00	0.91
1.A.3.b	Road Transportation\Liquid Fuels	CO_2	53,138	69,558	0.00	0.00	0.92
1.A.4.a	Commercial/Institutional\Solid Fuels	CO_2	512	128	0.00	0.00	0.92
1.A.2.b	Non-Ferrous Metals\Liquid Fuels	CO_2	2,822	3,134	0.00	0.00	0.92
1.B.1.a.1.1	Fugitives/Coal Mining/Underground	CO_2	1,122	936	0.00	0.00	0.92
2.C.3	Aluminium Production	CO_2	2,021	3,140	0.00	0.00	0.93
2.B	Chemical Industry	CO_2	407	996	0.00	0.00	0.93
4.C.1.1	Rice Cultivation\Continuously Flooded	CH_4	490	175	0.00	0.00	0.93
1.A.2.a	Iron and Steel\Gaseous Fuels	CO_2	1,383	1,366	0.00	0.00	0.93
1.A.2.f	Other (please specify)\Mineral industry\Liquid Fuels	CO_2	314	825	0.00	0.00	0.94
1.A.3.d	Navigation\Solid Fuels\Coal	CO_2	307	–	0.00	0.00	0.94
1.A.2.e	Food Processing, Beverages and Tobacco\Liquid Fuels	CO_2	423	159	0.00	0.00	0.94
1.A.3.b	Road Transportation\Liquid Fuels	CH_4	479	253	0.00	0.00	0.94
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CH_4	–	355	0.00	0.00	0.95
1.A.2.e	Food Processing, Beverages and Tobacco\Solid Fuels	CO_2	1,190	1,194	0.00	0.00	0.95
1.A.2.f	Other (please specify)\Mineral industry\Solid Fuels	CO_2	2,168	2,474	0.00	0.00	0.95

Table A1.6: Key categories for Australia's 2010 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\Solid Fuels	CO_2	YES	Level, Trend
1.A.2.a	Iron and Steel\Gaseous Fuels	CO_2	YES	Level, 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, Trend
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.d	Pulp, Paper and Print\Gaseous Fuels	CO_2	YES	Level
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	Level
1.A.2.e	Food Processing, Beverages and Tobacco\Liquid 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
1.A.2.f	Other (please specify)\Construction\Liquid Fuels	CO_2	YES	Level, Trend
1.A.2.f	Other (please specify)\Mining\Solid Fuels	CO_2	YES	Trend
1.A.2.f	Other (please specify)\Other non-specified\Gaseous Fuels	CO_2	YES	Trend

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A		B	C	D
IPCC Source Categories		Gas	Key Source Category Flag	If Colum C is Yes, Criteria for Identification
1.A.2.f	Other (please specify)\Mineral industry\Liquid Fuels	CO_2	YES	Trend
1.A.2.f	Other (please specify)\Mineral industry\Solid Fuels	CO_2	YES	Level
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.b	Road Transportation\Liquid Fuels	CH_4	YES	Trend
1.A.3.c	Railways\Liquid Fuels	CO_2	YES	Level
1.A.3.d	Navigation\Liquid Fuels\Gas/Diesel Oil	CO_2	YES	Level, Trend
1.A.3.d	Navigation\Liquid Fuels\Residual Oil	CO_2	YES	Trend
1.A.3.d	Navigation\Solid Fuels\Coal	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, Trend
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	Trend
1.B.1.a.2.1	Fugitives\Coal Mining\Surface mines	CH_4	YES	Level, Trend
1.B.1.c	Fugitives\Coal mining\Decommissioned Mines	CH_4	YES	Level, 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	Trend
1.B.2.c.2.1	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Oil	CO_2	YES	Level, Trend
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CO_2	YES	Level, Trend
1.B.2.c.2.2	Fugitives\Oil and Natural Gas\Venting and Flaring\Flaring\Gas	CH_4	YES	Trend
2.A.1	Cement Production	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
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	C2F6	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	Level, Trend
4.B.8	Manure Management\Swine	CH_4	YES	Level
4.C.1.1	Rice Cultivation\Continuously Flooded	CH_4	YES	Trend
4.D.1.1	Synthetic Fertilizers	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
4.E	Prescribed Burning of Savannas	N_2O	YES	Level
6.A.1	Managed Waste Disposal on Land	CH_4	YES	Level, Trend
6.B.1	Industrial Wastewater\Wastewater	CH_4	YES	Trend

Table A1.7: Summary overview for key categories for Land use, Land-use Change and Forestry activities under the Kyoto Protocol – 2010

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

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 ABARES Australian national energy statistics balance, supplemented by specific sectoral data where available. The Australian Petroleum Statistics are used as a basis for the liquid fossil fuel data. ABARES Australian national energy statistics balance is shown below in Table A.4.1.

COMPARISON OF AUSTRALIAN METHODOLOGY WITH IPCC REFERENCE APPROACH

Total CO_2 emissions estimated using Australia's National approach methodology are 372.6 Mt. Total CO_2 emissions estimated using the reference approach are 375.9 Mt – this is a 0.88% difference between the two methods.

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Table A4.1: Australian Energy Statistics

	Black coal	Brown coal	Met. coke	Coal by–products	Natural gas, CSM	Crude oil and ORF	Propane, butane, LPG	Refined products	Liquid/gas biofuels	Biomass wood	Biomass bagasse	Wind electricity	Solar electricity	Hydro–electricity	Total electricity	Solar hotwater	U_3O_8 Uranium	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ		PJ	PJ	PJ	PJ	PJ	PJ
Supply																		
Primary indigenous	9,827.0	744.0			2,004.9	946.2	110.6		21.2	103.4	88.2	17.3	1.0	45.1		10.1	3,363.3	17,282.3
plus all imports					225.7	1,055.9	28.8	732.0										2,042.4
less all exports[a]	8,327.4				971.9	668.4	75.0	116.7									3,550.9	13,710.2
less stock changes and discrepancies	11.3	2.1	2.4	-0.9	-112.7	-92.7	14.0	33.5									-187.5	-330.5
Total primary energy supply[b]	**1,488.3**	**741.9**	**-2.4**	**0.9**	**1,371.4**	**1,426.4**	**50.4**	**581.8**	**21.2**	**103.4**	**88.2**	**17.3**	**1.0**	**45.1**		**10.1**		**5,944.9**
less conversions																		
Coke ovens	124.4		-75.5	-13.6				0.6							0.1			36.0
Petroleum refining				0.4	22.0	1,434.1	-31.6	-1,402.6							6.2			28.5
Gas manufacturing					0.3		0.1											0.4
Electricity generation	1,243.6	737.0		3.3	390.6	0.5		39.3	10.1	12.0	53.0	17.3	1.0	45.1	-869.6			1,683.2
Other conversion[c]	18.8	4.9	67.1	-23.6	187.4	-11.8	-13.1	23.9							0.5			254.0
Fuel use in conversion					31.5		0.2	97.5							110.7			240.0
Consumption																		
Total final energy consumption[d]	**101.5**		**5.9**	**34.5**	**739.6**	**3.6**	**94.8**	**1,823.0**	**11.1**	**91.4**	**35.2**				**752.2**	**10.1**		**3,702.8**
Agriculture					0.1		1.8	85.8							8.3			96.0
Mining			0.2		145.5	2.9	1.8	125.9	0.8						62.6			339.7
Food, beverages, textiles	11.5			2.6	36.2	0.6	1.2	1.8	0.2	2.3	33.6				22.0			111.9
Wood, paper and printing	4.3				24.6		0.1	0.4	0.5	28.8					17.8			76.6
Chemical	6.1		0.9	0.9	119.1		12.7	68.5	0.2	0.3	1.6				17.3			227.7
Iron and steel	0.6		1.9	28.8	23.1			1.0							13.5			69.0
Non-ferrous metals	51.2		2.7	1.0	122.4		0.1	67.4		1.4					138.4			384.6
Other industry	27.3		0.1	0.3	69.6		7.0	8.7	1.2	0.9					25.6			140.7
Construction					3.0		0.2	21.8							0.3			25.4
Road transport					2.3		55.2	999.8	7.6									1,064.9
Rail transport								37.3							8.3			45.7
Air transport[a]								245.5										245.5
Water transport[a]								60.1										60.1
Commercial and services	0.6			0.8	49.5		3.4	32.1	0.7	0.3					221.4	0.4		309.1
Residential					144.1		11.1	1.2		57.4					216.5	9.8		440.1
Lubes, bitumen, solvents								65.8										65.8

[a] Includes air and water transport bunker fuels.
[b] Total primary energy supply is a measure of the total energy supplied within the economy. It is equal to indigenous production plus imports minus exports, plus stock changes and statistical discrepancies.
[c] Includes return streams to refineries from the petrochemical industry, consumption of coke in blast furnaces, blast furnace gas manufacture, briquette manufacturing and lignite tar in char manufacture.
[d] Total final energy consumption is the total energy consumed in the final or 'end-use' sectors. It is equal to total primary energy supply less energy consumed or lost in conversion, transmission and distribution.

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.

With each new inventory, a number of emission sources and removals have been added to the national inventory, resources permitting, as the remaining outstanding sources are generally minor while at the same time resource-intensive to estimate.

In this inventory, two minor new sources have been added. These sources are:

- Flaring from underground coal mines – data for 2009 and 2010 on the recovery and flaring of CH_4 from coal mines has been made available from mines reporting under the NGERS for the first time. Prior to this, flaring data has been difficult to obtain for compilation inventory purposes, although emissions from CH_4 recovered for fuel combustion purposes (i.e. electricity production) have always been included in the inventory. Therefore, the inclusion of coal mine flaring emissions for 2009 and 2010 in this inventory submission marks the first time emissions from this source have been reported. The emissions have been reported under 1.B.1.c. Other – Flaring; and,

- 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. Australia has applied the tier 1 method from the 2006 IPCC *Guidelines* and country specific emissions factors based on research to derive estimates of emissions based upon the total amount of material processed through composting and anaerobic digestion. Emissions from the biological treatment of solid waste were 81 Gg CO_2-e in 2010.

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 DCCEE 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 DCCEE 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 report, a model has been developed to demonstrate the flows of fugitive methane and carbon dioxide associated with underground coal mines. The model shown in Figure 6.A.2 also demonstrates the effectiveness of methane capture for electricity generation in reducing the net fugitive emissions – capturing over 17% 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 A6.1: 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	DCCEE	6.7.2.2, page 6.16
1.A.2	Accuracy	Data submitted under NGERs subject to DCCEE Greenhouse and Energy Reporting Office validation unit activities	Compliance	DCCEE	6.7.2.2, page 6.16
1.B.1	Comparability	Integration of national and facility estimation methods within National Greenhouse Accounts Framework	Compliance	DCCEE	6.7.1.2 page 6.12
1.D.1	Transparency	Company level data published by the Greenhouse and Energy Data Officer (GEDO) under the NGER Act 2007	Compliance	DCCEE	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
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

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006 IPCC Guidelines Vol 1 cross reference
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	DCCEE 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	DCCEE 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 DCCEE, should reduce over time	Compliance	DCCEE 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 DCCEE website	Compliance	National Inventory Team	6.5, page 6.

* Planned for AGEIS implementation 2011-12.

A6.2 AUSTRALIA'S NATIONAL CARBON BALANCE

Table A6.2: Australia's National Carbon Balance 2010

Supply	Kt C	Uses	Kt C
Fossil fuel consumption (a)	112,081	Emissions	
Carbonate consumption (a)	2,112	1.A Combustion emissions (fossil fuels)	101,608
Hydrofluorocarbon consumption (d)	2,949	1.B Fugitive emissions	222
		2.A Industrial process fossil fuel emissions	4,024
		Memo: International bunker fuels	3,388
		2.A Mineral product carbonate emissions	2,100
Biomass consumption		2.F Hydrofluorocarbon emissions (d)	1,769
Wood and paper products (a)	4,423	Memo: Combustion emissions (wood products and waste)	563
Bagasse, ethanol, biogas (b)	1,192	Memo: Combustion emissions (bagasse, ethanol, biogas)	1,168
Firewood (b)	1,246	Memo: Combustion emissions (all wood)	2,236
		6.A Landfill emissions (methane and carbon dioxide)	1,190
Waste disposal (food, garden, textiles, rubber – landfill)(c)	1,213	Aerobic treatment processes (paper, wood and wood waste)	181
		Increment to product stocks	
		Petrochemical and steel products	91
		Carbonate products	3
		Hydrofluorocarbon products (d)	1,079
		Biomass finished products	1,208
		Biomass fibre recycled	1,466
		Increment to waste stocks and residues	
		Carbon dioxide captured for permanent storage	–
		Non-oxidised carbon	1,779
		Carbonate wastes	9
		Landfill	1,028
		Miscellaneous	
		Hydrofluorocarbons destroyed	101
		Residual	4
TOTAL SUPPLY	**125,216**	**TOTAL USES**	**125,216**

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 125,216 kt C of carbon entering the market economy, 118,448 kt C is estimated to result in greenhouse gas emissions; 3,846 kt C is estimated to result in increments of the carbon stock in products and 2,921 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 100 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 2009 is at Figure A.6.1.

Results from the carbon balance have shown that all carbon is effectively accounted for. For 2010, all carbon has been accounted for down to 0.0003% (3/10 000 of a percent). This discrepancy relates to carbon contained in carbon dioxide from biofuels, within the memo items. Further work will continue on resolving this discrepancy.

The carbon balance analysis effectively tests the integrity of the calculations within the AGEIS by checking that all carbon consumed is accounted for and has been used to uncover several errors within data entries and the emission calculation process. Although the errors were of a very minor nature, they were of the type that is difficult to trace without systematic QC tools.

Figure A6.1 balance flow chart showing carbon inputs and distribution of outputs for 2010

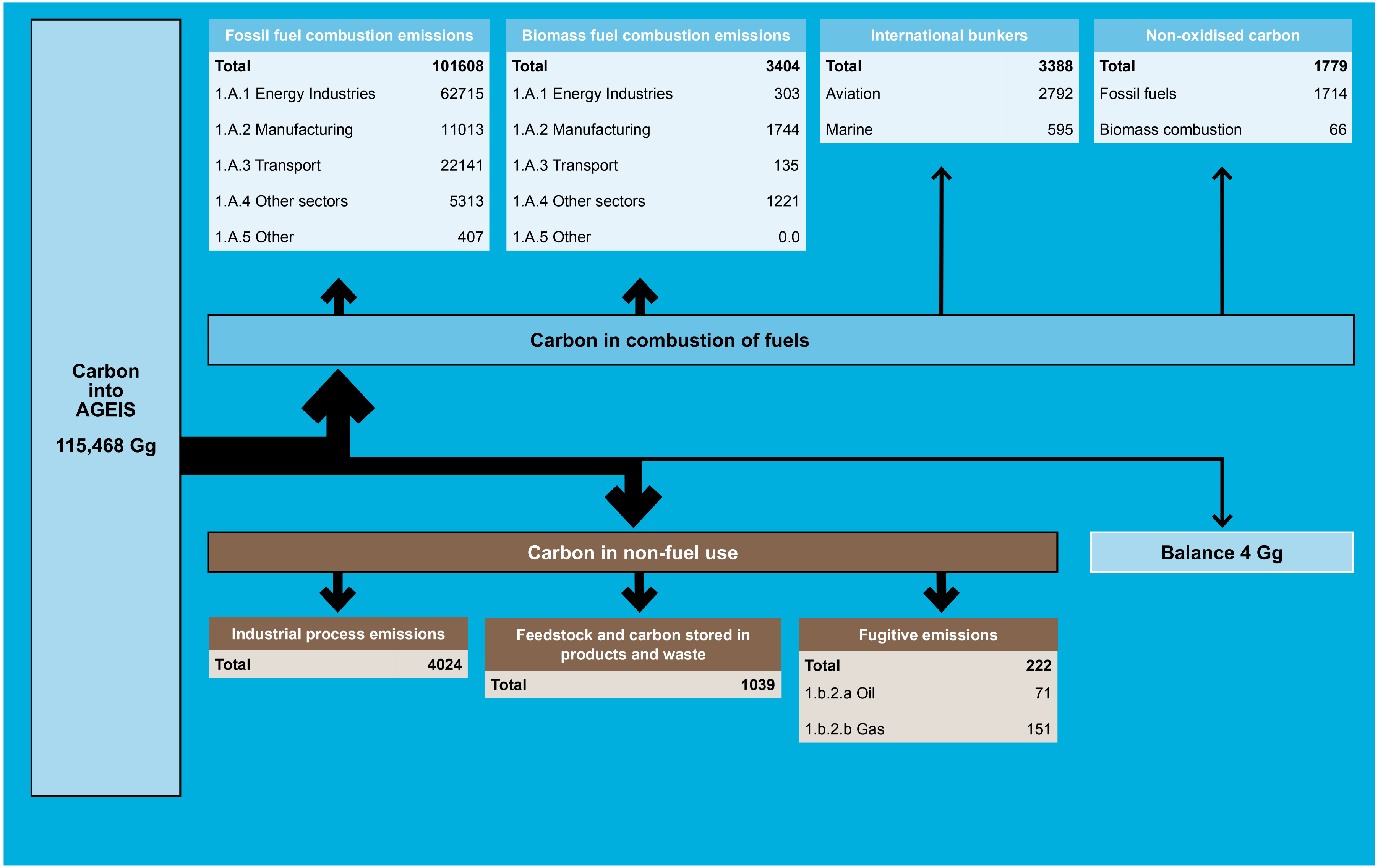
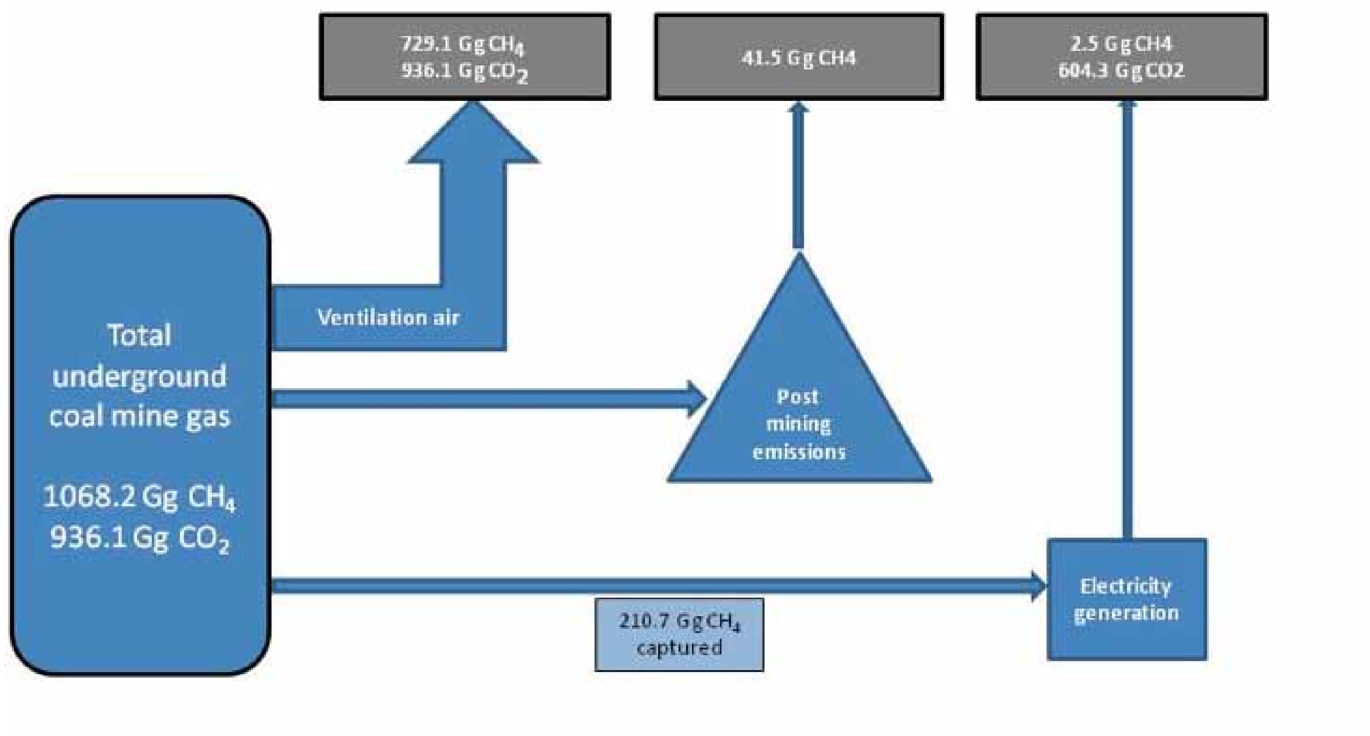


Figure A6.2 Fugitive gas balance flow chart for underground mines, 2010



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 2011 Inventory submission (ARR 2011) has not yet been finalised.

Table A.6.3a: Summary of responses to UNFCCC ERT recommendations: energy and cross cutting

Sector	Report ref	ERT Recommendation	Response	Implementation
CC	ARR 2010 37	(a) The provision of a tier 2 uncertainty analysis.	Accept subject to available resources.	Will be included in the Inventory improvement plan 2011-12
1.B	ARR 2010 42	Australia has reported fugitive CO_2 emissions from surface coal mining and CO_2 and CH_4 emissions from all post-coal mining activities as not estimated, citing “no data or IPCC methodology available” as the reasons. However, tier 3 AD are generally available for all coal mines in Australia. The ERT encourages Australia to estimate these emissions based on suitable methodologies, e.g. available in literature, and to report these emissions in its next annual submission.	Higher tier methods for the estimation of carbon dioxide emissions from open cut mines are included in the NGER. As companies adopt these methods in forthcoming years, the data will be included in the inventory. CH_4 emissions for post-mining are reported using the IPCC default method. Additional research into methodology development is being undertaken for higher tier methods for post-mining emissions.	Emissions estimated using higher tier methods for open cut coal mining and post-mining will be reported in Australia's inventory as they become available from the NGERS in forthcoming years.
1.B	ARR 2010 42	If considered necessary, the ERT encourages Australia to estimate country-specific EFs based on CH_4 and CO_2 levels in a mine before opening it for coal extraction.	The NGER Determination includes methods for estimating vented emissions from a mine prior to coal extraction. In addition, a higher tier method is available for reporting under NGERS for open cut mines which establishes that insitu gas pool within the coal mine resource prior to mining.	The CH_4 and CO_2 content profile for underground mines by coal field are published in Figure 3.3.16 of the 2012 NIR submission. The publication of the gas profile of opencut mines will be considered as higher tier data becomes available in future years.
1.A	ARR 2010 44	The ERT therefore recommends that Australia conduct and report on improved uncertainty estimates for its inventory in its next annual submission. This could also be useful for ensuring optimum resource allocation in the national system.	New data on uncertainty will be available from NGERS data is now available.	NGERS data on uncertainty will be analysed in preparation of the 2013 NIR submission.
1.A	ARR 2010 48	In response to a question from the ERT, the ABARE representative informed the ERT that ABARE is already examining this issue and is developing a plan to collect these data. The ERT encourages Australia to collect these data on a regular basis.	ABARE (now called the The Bureau of Resources and Energy Economics) implemented a plan to collect and integrate energy data below the NGERS threshold in the Australian Energy Statistics sued to compile the 2012 NIR submission.	Implemented

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Sector	Report ref	ERT Recommendation	Response	Implementation
1.A	ARR 2010 49	Although there is no direct evidence that these factors are not correct for current usage, the ERT encourages Australia to conduct fresh estimates of these EFs in order to bring them closer to those of other fuels, including through the use of NGERS reporting by refineries.	Accept. A study was undertaken to review the fuel characteristics used in the Australian inventory.	2012 Submission. Section 3.2.1 A study reviewed the appropriateness of fuel characteristics in the national inventory compared with publically available Australian and international data. The report concluded data used in the inventory is consistent with local and international data with the exception of the CO_2 EF for ethanol where further research is required – see NIR Vol 1, section 3.2.1 under Liquid fuels. Will be included in the Inventory improvement plan 2011-12.
1.A.3.b	ARR 2010 58	The ERT recommends that Australia use the information in this report to calibrate the model. The ERT also recommends that Australia examine model assumptions such as average fuel consumption rates of various vehicle types over the years, cold-start percentages, EFs, average trip length, urban, non-urban activity shares and vintage vehicle performance curves to improve the accuracy of road transportation emission estimates.	Accept. Improvements in the model parameters have been undertaken in the inventory over the last two years.	A number of parameters were reviewed and improved in the last two national inventory submissions. 2011 NIR – box 3.1 refers. 2012 NIR submission, section 3.5.2 refers.
1.A	ARR 2010 59	The ERT also encourages Australia to include reporting by the refineries on oil product specifications, such as energy content, chemical composition and carbon content, in their reporting through the NGERS. This would help to improve oil product EFs used by Australia.	Data on energy and carbon content for refinery fuel consumption is collected via NGERS and is included in the inventory submission.	A study has been undertaken to review the fuel characteristics used in the Australian inventory – see NIR Vol 1, section 3.2.1 under Liquid fuels.
1.A	ARR 2010 63	These include utilizing NGERS data for more comprehensive reporting of stationary combustion emissions, implementing the energy balance/tracking system with AGEIS, utilizing NGERS data to improve the allocation of fuel use between the energy and industrial processes sectors and further investigation into the CH_4 EF from petrol and diesel for road transportation.	Identified by Party	The implementation of the energy balance/tracking system in AGEIS has been testes and is currently under refinement. It is antipacted to be in full operation by the 2013 submission. NGERS data has been utilised in the 2011and 2012 NIR submissions to improve the allocation of fuel use between energy and industrial processes – see Vol 1, section 3.2.5. A number of parameters in the road transport model were improved as outlined in section 3.5.2 of the NIR.

Sector	Report ref	ERT Recommendation	Response	Implementation
1.A.3.b	ARR 2010 64	The ERT also recommends that Australia check the assumptions used in the road transportation model.	Accept. Improvements in the model parameters have been undertaken in the inventory over the last two years.	A number of parameters were reviewed and improved in the last two national inventory submissions. 2011 NIR – box 3.1 refers. 2012 NIR submission, section 3.5.2 refers.
1A and 2C	ARR 2009 37 (i) (a)	Cross cutting issues identified for improvement: Correctly allocating emissions from coal use between the energy and industrial processes sectors.	The reallocation of coal use associated with ferroalloy production to the industrial processes sector occurred in the 2011 submission through use of NGER data. However, NGER data is currently not available for use in reallocating the use of pulverised coal as a reducing agent in the iron and steel sector to the industrial processes sector.	Data obtained through NGERS will continue to be used to improve the allocation of emissions between the energy and industrial processes sector. New fuel types available in NGER may assist for pulverised coal in the 2013 inventory year.

Table A.6.3b: Summary of responses to UNFCCC ERT recommendations: Industrial processes –

Sector	Report ref	ERT Recommendation	Response	Implementation
2C	ARR 2010 77	The ERT reiterates the recommendation made in previous reviews 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 the NGERS could facilitate this reallocation.	Re-allocations of emissions from the use of reductants in the production of ferro-alloys and other metals have been undertaken based on NGERS data. Refer to sections 4.5.2 and 4.5.5 of NIR volume 1. The use of black coal in iron and steel production has not yet been re-allocated pending further research.	Partial in 2011 NIR submission
2F	ARR 2010 78	HFCS: The ERT encourages Australia to further increase transparency by exploring the possibility of reporting data for individual species for the other relevant subcategories (foam blowing, fire extinguishers and solvents) and by applying notation keys as appropriate.	Data are not currently available on the speciation of gases used in the production of foams, fire extinguishers and solvents.	Implementation contingent on availability of speciation data

Table A.6.3c: Summary of responses to UNFCCC ERT recommendations: Agriculture

Sector	Report ref	ERT Recommendation	Response	Implementation
4	ARR 2010 90	AD are derived using data from different governmental (e.g. ABS) and private (e.g. industrial associations) organizations. The agriculture sector inventory is complete and covers all sources of emissions, having been compiled on a state-by-state basis to better reflect the large physical, climate and management differences between states and territories. The ERT commends Australia for its effort to explain these differences but continues to encourage Australia to further explain how these differences impact the determination of the emission parameters.	Accept: Additional information included in NIR explicitly stating that some states are considered temperate and others warm hence significant differences in MCFs.	2011 NIR submission – section 6.3.2 and 6.4.2 Livestock activity data workshops will also be held to address this throughout 2012. Further outcomes will be implemented in the 2013 submission.
4	ARR 2009 69, 73	The ERT encourages Australia to update its uncertainty analysis using data from the latest research in EFs for the agriculture sector and to provide additional information to support the expert opinions.	Accept	2012 submission – See Annex 7.
4A	ARR 2009 91, 94, 95	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	Accept	See 6.4.6. Source Specific Planned Improvements pending release of publications from the Reducing Emissions from Livestock Research Program.
4B	ARR 2008 45 ARR 2009 69,71 ARR 2010 100	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 2009/2010 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.	2012 Submission – See 6.4.6. Source Specific Planned Improvements – planned 2013 implementation. Planned workshops for 2012.

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Sector	Report ref	ERT Recommendation	Response	Implementation
4E	ARR 2009 76 ARR 2010 99	The ERT recommends that Australia include information in the NIR to support the expert judgement that all savannas in Queensland can be treated as grassland.	Methodology amended to account for the effect of seasonality of burning and vegetation class specific emissions factors, fuel loads and fuel accumulation with years since last burnt.. There were also revisions to activity data that resulted in minor recalculations. Included in this revision is the re-stratification of some areas of Queensland savanna grassland to savanna woodland using a combination of validated vegetation, land use and geological data sets available in the public domain.	Section 6.7.2 refers.

Table A.6.3d: Summary of responses to UNFCCC ERT recommendations: WASTE

Sector	Report ref	ERT Recommendation	Response	Implementation
6A	ARR 2010 123	GHG emissions from biological recycling processes (e.g. composting) of solid waste were not reported as there is no methodology available in the Revised 1996 IPCC *Guidelines* and the IPCC good practice guidance. The ERT encourages Australia to explore ways of estimating the GHG emissions from the biological treatment of solid waste using country-specific and/or other available methodologies.	Australia has included estimates of emissions from the biological treatment of solid waste in its 2012 submission	2012 NIR submission
6A	ARR 2010 125	The ERT strongly encourages Australia to develop country-specific DOC values.	To undertake this exercise would be a resource-intensive research project. Will be pursued subject to available resources.	Included in improvement plan. (see section 8.2.7.1)
6A	ARR 2010 125	The ERT strongly encourages Australia to develop country-specific methane generation constant (k) values	Accept. Facility-level k data is not yet available under NGERS however this aspect of reporting will continue to be monitored as refinements are made to NGERS reporting provisions.	Included in improvement plan. (section 8.2.7.1)
6A	ARR 2010 125	The ERT also encourages Australia to improve the data quality of the past landfilled amounts to develop a functional relationship between waste generation rates and drivers (e.g. waste management policies, population, GDP and income) by applying statistical regression techniques.	Implement in future submission subject to availability of suitable data.	Included in improvement plan.

Sector	Report ref	ERT Recommendation	Response	Implementation
6A	ARR 2010 125	The ERT further encourages Australia to verify the methane conversion factor (MCF) values for the years prior to 1990 as it is probable that unmanaged landfill practices were carried out during those years.	Accept that additional data is required to be able to determine MCF values for year s prior to 1990 while noting the difficulties of obtaining this data.	Included in improvement plan. (section 8.2.7.1)
6B	ARR 2010 130	N_2O emissions from the application of sludge to agricultural soils should be reported under the agriculture sector. The ERT recommends that Australia report N_2O emissions from the application of sludge to agricultural soils in the agriculture sector in order to improve comparability.		Included in improvement plan. (section 8.2.7.2)
	ARR 2010 132	Australia plans to move towards the development of a tier 3 method to estimate emissions from solid waste disposal on land in the next annual submission. The NGERS will play a major role in supplying facility-level data. New measurement systems operated by landfill operators and supplemented by ongoing research activities will be combined with NGERS data to improve data quality in the next annual submission.	Identified by party. This work is ongoing.	Included in improvement plan – section 8.2.7.1

Table A.6.3e: Summary of responses to UNFCCC ERT recommendations: Land Use Land Use Change and Forestry

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 106	During the review, the ERT was informed that Australia is considering the separation of forest land converted to settlements from forestland converted to grassland. The ERT recommends that Australia implement this separation in the next annual submission.	Review	Ongoing research to identify and map urban areas through time is being undertaken. Included in improvement plan
	ARR 2010 107	In response to recommendations made by previous ERTs, Australia improved the documentation relating to the tier 3 approach and provided, for the first time, a comparison of the results from the tier 3 model with a tier 2 approach for the conversion categories. The ERT acknowledges the efforts made by Australia and recommends that Australia describe in a transparent manner the tier 2 approach used in its next annual submission (e.g. by explaining the method applied, AD and parameters).	Accept	Further analysis and improvements to the Tier 2 model for forestland converted to cropland and grassland have been documented in the 2012 NIR submission – see Appendix 7.J.3.2

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 108	Australia improved the transparency of its reporting by including land-use matrices for every year from 1990 to 2008. However, the ERT noted that the annual land-area matrices provided in the NIR and the land areas reported in the CRF tables were not consistent. Australia chose 50 years as the transition period for land-use conversion but this was not fully applied in its disaggregation of land use 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 improve the consistency of its reporting in its next annual submission.	Accept	Improved disaggregation of land-use included in improvement plan
	ARR 2010 109	The ERT recommends that Australia increase the transparency of its recalculations by describing any significant changes associated with its recalculations in the next annual submission.	Accept	Significant changes are described in the recalculation section of the 2012 submission – see Chapter 7
	ARR 2010 110	The ERT recommends that, for any area of managed land, Australia carefully assess if the gain or loss of forest cover due to climate variation is to be considered permanent and that Australia consistently apply the following criteria in the CRF tables and 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; (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 subcategory forest land converted to a new land use (e.g. grassland)	Review	Included in improvement plan

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Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 112	The ERT recommends that Australia disaggregate in the CRF tables the causes of conversions to forest land (e.g. due to climate-driven gain of forest cover or due to plantations) and the causes of conversions from forest land (e.g. due to climate driven loss of forest cover or due to harvest or other causes).	Review	As this relates directly to reference 110 consideration of this issue is included in improvement plan
	ARR 2010 113	The ERT noted that Australia assumes no change in the soil carbon stock in forest land remaining forest land, following the tier 1 approach of the IPCC good practice guidance for LULUCF. Since forest land remaining forest land is a key category, the ERT encourages Australia to move to higher tiers in its next annual submission.	Review. Australia aims to implement higher tier modelling of soil carbon in all forest land remaining forest land subcategories.	Australia is undertaking research and developing infrastructure to enable Tier 3 modelling of Forest land remaining Forest land. As part of this development Australia would implement dynamic modelling of soil carbon in Forestland remaining Forestland. Incorporated into the inventory improvement plan.
	ARR 2010 114	The ERT noted an inconsistency in the data of area converted to forest between table 7.D5 of the NIR and the CRF tables, and recommends that Australia ensure full consistency between the NIR and the CRF tables in its next annual submission.	Accept	Australia has improved QC processes to check for consistency between the NIR and CRF.
	ARR 2010 115	The ERT recommends that Australia disaggregate by crop type in CRF table 5.B.1 cropland remaining cropland, and document in a transparent manner in the NIR the method used to estimate CO_2 emissions and removals due to transition among crop types.	Review. Australia will investigate disaggregation of croplands and will document the methods in future submissions.	Australia has improved the method of biomass estimation to account for emissions and removals in perennial woody biomass. This will be further improved upon to account for emissions and removals due to transition among crop types and is incorporated into improvement plan.
	ARR 2010 116	The ERT recommends that Australia, in its next annual submission, disaggregate by grassland type, including grass and shrub transitions, in CRF table 5.C grassland remaining grassland.	Accept	Australia is currently developing new methods to account for emissions and removals due to transitions between grass and shrub. Incorporated into improvement plan.
	ARR 2010 118	For some years, Australia has reported an increase in carbon stock in mineral soil for forest land converted to cropland. In response to the ERT's question, Australia explained that cropland converted from forest land is primarily a crop-pasture system with a high input of dead organic matter. The ERT reiterates the recommendation made by the previous ERT that Australia provide additional documentation in the NIR to justify this pattern in its next annual submission.	Accept	The data and parameters that inform the model for Cropland remaining Cropland and Forest land converted to cropland have been comprehensively reviewed for the 2012 submission (section 7.6.4 refers). The cropland data and parameters have been improved and as a result forest land converted to cropland no longer exhibits an increase in carbon stock in mineral soil.

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 119	For transparency purposes, the ERT encourages Australia to include in future NIRs the time series of emission estimates from fires, disaggregated by gas, by land-use category, and by subdivision (e.g. .harvested native forests. .post-1990 plantations. and .other native forests.) and separated from removals due to subsequent forest recovery.	Australia currently reports fire emissions disaggregated by gas and land-use category. Australia's wildfire data is not available spatially, consequently it is currently not possible to disaggregate by subdivision.	Incorporated into the inventory improvement plan as part of the work being undertaken to enhance modelling capacity in Forest land remaining forest land.
	ARR 2010 121	Australia uses a very complex set of models and approaches in its LULUCF inventory. The ERT, while acknowledging the improvements made regarding the documentation on the QA/QC procedures for the LULUCF sector, considers that further efforts (e.g. increased transparency of model outputs and additional verification activities) are needed to allow future ERTs to fully evaluate the model outputs.	Accept	In Australia's 2012 national inventory submission (Chapter 7) additional descriptive information regarding the models and approaches which use to support land sector reporting. This is an ongoing project and future Inventory submissions will continue to improve the descriptions of the models used.

Table A.6.3f: Summary of responses to UNFCCC ERT recommendations : ARTICLE 3.3 ACTIVITIES

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 137	The ERT encourages Australia to provide in the next annual submission a quantitative assessment of forest areas that have lost forest cover but which are not yet classified as deforested.	Review. This item will be considered for future submissions in light of availability of resources.	An analysis of forest cover change that is uncertain human induced will be presented in future submissions.
	ARR 2010 139	For transparency purposes, the ERT encourages Australia to provide in the next annual submission the following information: (a) With regard to afforestation and reforestation activities, additional information on the share of thinning and final harvest in the emission estimates from lands harvested since the beginning of the commitment period; (b) With regard to deforestation activities, the non-CO_2 emission estimates from wildfires, currently reported under the agriculture sector.	Partially accept.	(a) This will be documented in future submissions (b) Australia's savanna fire data is not spatially explicit, therefore it is not possible to separately report fire emissions on grassland remaining grassland and forest land converted to grassland.

Sector	Report ref	ERT Recommendation	Response	Implementation
	ARR 2010 144	In order to increase the transparency of the inventory and to assist future ERTs to assess the outputs of the model, the ERT: (a) Recommends that Australia define the terms used for its verification activities (e.g..calibration, validation, .verification, .model evaluation.) in its next annual submission and that Australia more clearly describe and document the range of activities and the various steps carried out to verify the various components of the model in the context of the .continuous improvements. approach, including a more complete explanation of the tier 2 method applied; (b) Strongly recommends that Australia carry out additional verification activities, such as a comparison of the model's output with existing field data, the collection of additional field data, verification by independent bodies and a discussion of the differences in the results with other remote sensing programmes carried out by individual states (e.g. Queensland and New South Wales). The ERT further recommends that Australia include in its next annual submission a plan to implement these additional verification activities; (c) Recommends that Australia further increase the flexibility of the FullCAM model with regard to the possibility of producing specific parameters and intermediate outputs that could be useful to assess the model's results (e.g. emissions per year of conversion and final land use).		(a) Definition of these terms provided in the 2012 national inventory submission (Appendix 7.J refers). Australia will continue to document model verification activities and provide further explanation of the tier 2 comparison models in the 2012 and future national inventory submissions. (b) Further information on existing verification activities and comparisons has been provided in the 2012 national inventory submission (Appendix 7.J refers) and further information will be available in future NIR submissions. (c) Current and ongoing model development is enabling Australia to report on a greater range of outputs. The results will be reported in future submissions to assist in the review process.

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 DCCEE 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 2010 to be ±3.6%. 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 ±2.8% and the uncertainty in the trend is estimated ±1.9% (Table A7.2).

Table A7.1: 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	2010 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
1.A. Solid fossil fuels	CO_2	131,753	190,353	2	5	5.39	1.765	0.079	0.372	0.397	1.1	1.1	1,2
	CH_4	28	36	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	1
	N_2O	442	654	2	20	20.10	0.023	0.000	0.001	0.006	0.0	0.0	1
1.A. Liquid fossil fuels	CO_2	88,131	117,561	2	3	3.61	0.730	0.034	0.230	0.102	0.7	0.7	1
	CH_4	649	446	2	40	40.05	0.031	-0.001	0.001	-0.023	0.0	0.0	1
	N_2O	836	1,721	2	60	60.03	0.178	0.002	0.003	0.091	0.0	0.1	1
1.A Gaseous fossil fuels	CO_2	32,915	64,649	2	3	3.61	0.401	0.053	0.127	0.160	0.4	0.4	1
	CH_4	29	308	2	5	5.39	0.003	0.001	0.001	0.003	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	2,042	952	0	20	20.00	0.033	-0.003	0.002	-0.054	0.0	0.1	8
	N_2O	225	209	0	20	20.00	0.007	0.000	0.000	-0.002	0.0	0.0	8
1.B.1 Fugitives coal mining	CO_2	1,122	1,181	5	20	20.62	0.042	0.000	0.002	-0.004	0.0	0.0	1,3
1.B.1 Fugitives coal mining	CH_4	18,165	27,135	5	20	20.62	0.963	0.013	0.053	0.254	0.4	0.5	1,3
1.B.2 Fugitives oil	CO_2	393	262	5	5	7.07	0.003	0.000	0.001	-0.002	0.0	0.0	1,4
1.B.2 Fugitives Natural gas	CO_2	22	89	10	3	10.44	0.002	0.000	0.000	0.000	0.0	0.0	1,4
1.B.2 Fugitives venting & flaring	CO_2	5,568	6,360	5	5	7.07	0.077	0.000	0.012	0.000	0.1	0.1	1,4
1.B.2 Fugitives oil	CH_4	65	108	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	4,338	4,049	10	3	10.44	0.073	-0.002	0.008	-0.005	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	2010 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
1.B.2 Fugitives venting & flaring	CH_4	2,678	1,283	5	5	7.07	0.016	-0.003	0.003	-0.017	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	31	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	3,549	2.5	2.5	3.54	0.022	-0.001	0.007	-0.002	0.0	0.0	5
2.A.2 Lime production	CO_2	775	1,231	2.5	2.5	3.54	0.007	0.001	0.002	0.002	0.0	0.0	5
2.A.3 Other Limestone and Dolomite Consumption	CO_2	1,345	1,653	4	2.5	4.72	0.013	0.000	0.003	0.001	0.0	0.0	5
2.B Chemicals	CO_2	1,009	3,559	5	5	7.07	0.043	0.005	0.007	0.024	0.0	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	3,264	5	5	7.07	0.040	0.004	0.006	0.020	0.0	0.0	6
2.C 1 Steel	CO_2	9,018	7,338	2.5	5	5.59	0.071	-0.006	0.014	-0.028	0.1	0.1	5
	CH_4	59	54	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	5
	N_2O	22	17	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	3,140	2.5	2.5	3.54	0.019	0.002	0.006	0.004	0.0	0.0	5
	PFCs	3,950	244	0	27	27.00	0.011	-0.008	0.000	-0.224	0.0	0.2	5
2.C.2 Ferroalloys	CO_2	316	335	2.5	5	5.59	0.003	0.000	0.001	0.000	0.0	0.0	5
2.C.5 Other	CO_2	217	268	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	232	0	2.5	2.50	0.001	0.000	0.000	0.001	0.0	0.0	6
2.F Consumption of HFCs & SF_6	HFCs		6,658	0	27	27.00	0.310	0.013	0.013	0.352	0.0	0.4	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_2-e	2010 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
	SF_6	221	145	0	27	27.00	0.007	0.000	0.000	-0.006	0.0	0.0	5
2.E Production of HFCs	HFCs	1,126		0	27	27.00	0.000	-0.003	0.000	-0.068	0.0	0.1	5
4.A Enteric fermentation	CH_4	63,919	53,895	0	5.5	5.50	0.511	-0.037	0.105	0.000	0.0	0.0	6
4.B Manure management	CH_4	1,540	1,730	0	10.5	10.50	0.031	0.000	0.003	0.000	0.0	0.0	6
	N_2O	524	1,574	0	10.3	10.30	0.028	0.002	0.003	0.020	0.0	0.0	6
4.C Rice Cultivation	CH_4	490	175	5	10	11.18	0.003	-0.001	0.000	-0.007	0.0	0.0	7
4.D Agricultural Soils	N_2O	13,338	13,168	0	52	52.00	1.179	-0.004	0.026	-0.202	0.0	0.2	7
4.E Burning of Savannas	CH_4	4,909	6,560	18	14	22.80	0.258	0.002	0.013	0.027	0.3	0.3	7
	N_2O	1,450	2,052	18	5	18.68	0.066	0.001	0.004	0.004	0.1	0.1	7
4.F Agricultural Residues	CH_4	193	231	5	20	20.62	0.008	0.000	0.000	0.000	0.0	0.0	7
	N_2O	99	102	5	20	20.62	0.004	0.000	0.000	0.000	0.0	0.0	7
5.A.1 Forest land remaining forest land	CO_2	-47,060	-35,618	0	30	30.00	-1.840	0.035	-0.070	1.049	0.0	1.0	8
	CH_4	1,385	2,325	0	77	77.00	0.308	0.001	0.005	0.113	0.0	0.1	8
	N_2O	378	634	0	88	88.00	0.096	0.000	0.001	0.035	0.0	0.0	8
5.A.2 Land Converted to Forest land	CO_2	-152	-17,259	0	10	10.00	-0.297	-0.033	-0.034	-0.334	0.0	0.3	8
5.B.1 Cropland Remaining Cropland	CO_2	1,754	7,434	0	30	30.00	0.384	0.011	0.015	0.319	0.0	0.3	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	2010 Gg CO_2-e	%	%	%	%	%	%	%	%	%	
5.B.2.1 Forest Land Converted to Croplands	CO_2	29,832	11,642	0	10	10.00	0.201	-0.044	0.023	-0.435	0.0	0.4	8
	CH_4	899	526	0	20	20.00	0.018	-0.001	0.001	-0.028	0.0	0.0	8
	N_2O	317	203	0	20	20.00	0.007	0.000	0.000	-0.009	0.0	0.0	8
5.C.1 Grassland Remaining Grassland	CO_2	-19066	92586	0	30	30.00	4.631	0.254	0.201	7.632	0.0	7.6	8
5.B.2.1 Forest Land Converted to Grasslands	CO_2	105304	43407	0	10	10.00	0.724	-0.202	0.094	-2.020	0.0	2.0	8
	CH_4	2,587	782	0	20	20.00	0.027	-0.004	0.002	-0.084	0.0	0.1	8
	N_2O	707	213	0	20	20.00	0.007	-0.001	0.000	-0.023	0.0	0.0	8
5.G Other	CO_2	-4,878	-3,172	0	20	20.00	-0.109	0.005	-0.006	0.093	0.0	0.1	8
	N_2O	632	665	0	20	20.00	0.023	0.000	0.001	-0.002	0.0	0.0	9
6.A Solid Waste	CH_4	13,545	11,140	0	3.25	3.25	0.062	-0.008	0.022	-0.027	0.0	0.0	5
6.B Wastewater handling	CH_4	3,422	2,414	0	50	50.00	0.208	-0.003	0.005	-0.144	0.0	0.1	5
	N_2O	343	412	0	50	50.00	0.035	0.000	0.001	0.002	0.0	0.0	5
6.C Waste incineration	CO_2	73	30	0	40	40.00	0.002	0.000	0.000	-0.004	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	71	0	100	100.00	0.012	0.000	0.000	0.012	0.0	0.0	
	N_2O	1	9	0	100	100.00	0.002	0.000	0.000	0.002	0.0	0.0	
Total Emissions		511,034	580,646										
Total Uncertainties							3.6					3.0	

[1] Energy Strategies; 2. George Wilkenfeld & Associates; 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.

Table A7.2: 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	2010 Gg CO_2e	%	%	%	%	%	%	%	%	%	
1.A. Solid fossil fuels	CO_2	131,753	190,353	2	5	5.39	1.889	0.046	0.455	0.230	1.3	1.3	1,2
	CH_4	28	36	2	5	5.39	0.000	0.000	0.000	0.000	0.0	0.0	1
	N_2O	442	654	2	20	20.10	0.024	0.000	0.002	0.004	0.0	0.0	1
1.A. Liquid fossil fuels	CO_2	88,131	117,561	2	3	3.61	0.781	0.007	0.281	0.022	0.8	0.8	1
	CH_4	649	446	2	40	40.05	0.033	-0.001	0.001	-0.038	0.0	0.0	1
	N_2O	836	1,721	2	60	60.03	0.190	0.002	0.004	0.091	0.0	0.1	1
1.A Gaseous fossil fuels	CO_2	32,915	64,649	2	3	3.61	0.430	0.052	0.155	0.157	0.4	0.5	1
	CH_4	29	308	2	5	5.39	0.003	0.001	0.001	0.003	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	2,042	952	0	20	20.00	0.035	-0.004	0.002	-0.081	0.0	0.1	8
	N_2O	225	209	0	20	20.00	0.008	0.000	0.000	-0.004	0.0	0.0	8
1.B.1 Fugitives coal mining	CO_2	1,122	1,181	5	20	20.62	0.045	-0.001	0.003	-0.013	0.0	0.0	1,3
1.B.1 Fugitives coal mining	CH_4	18,165	27,135	5	20	20.62	1.031	0.008	0.065	0.170	0.5	0.5	1,3
1.B.2 Fugitives oil	CO_2	393	262	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	89	10	3	10.44	0.002	0.000	0.000	0.000	0.0	0.0	1,4
1.B.2 Fugitives venting & flaring	CO_2	5,568	6,360	5	5	7.07	0.083	-0.002	0.015	-0.010	0.1	0.1	1,4
1.B.2 Fugitives oil	CH_4	65	108	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	4,338	4,049	10	3	10.44	0.078	-0.004	0.010	-0.011	0.1	0.1	1,4
1.B.2 Fugitives venting & flaring	CH_4	2,678	1,283	5	5	7.07	0.017	-0.005	0.003	-0.026	0.0	0.0	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	2010 Gg CO_2e	%	%	%	%	%	%	%	%	%	
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	31	2	20	20.10	0.001	0.000	0.000	-0.001	0.0	0.0	1
2.A.1 Cement clinker production	CO_2	3,463	3,549	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	1,231	2.5	2.5	3.54	0.008	0.001	0.003	0.001	0.0	0.0	5
2.A.3 Other Limestone and Dolomite Consumption	CO_2	1,345	1,653	4	2.5	4.72	0.014	0.000	0.004	-0.001	0.0	0.0	5
2.B Chemicals	CO_2	1,009	3,559	5	5	7.07	0.046	0.005	0.009	0.027	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	3,264	5	5	7.07	0.043	0.005	0.008	0.023	0.1	0.1	6
2.C 1 Steel	CO_2	9,018	7,338	2.5	5	5.59	0.076	-0.010	0.018	-0.052	0.1	0.1	5
	CH_4	59	54	2	5	5.39	0.001	0.000	0.000	0.000	0.0	0.0	5
	N_2O	22	17	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	3,140	2.5	2.5	3.54	0.020	0.001	0.008	0.003	0.0	0.0	5
	PFCs	3,950	244	0	27	27.00	0.012	-0.012	0.001	-0.315	0.0	0.3	5
2.C.2 Ferroalloys	CO_2	316	335	2.5	5	5.59	0.003	0.000	0.001	-0.001	0.0	0.0	5
2.C.5 Other	CO_2	217	268	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	232		2.5	2.50	0.001	0.000	0.001	0.001	0.0	0.0	6
2.F Consumption of HFCs & SF_6	HFCs	0	6,658	0	27	27.00	0.331	0.016	0.016	0.430	0.0	0.4	5
	SF_6	221	145	0	27	27.00	0.007	0.000	0.000	-0.009	0.0	0.0	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	2010 Gg CO_2e	%	%	%	%	%	%	%	%	%	
2.E Production of HFCs	HFCs	1,126	0	0	27	27.00	0.000	-0.003	0.000	-0.094	0.0	0.1	5
4.A Enteric fermentation	CH_4	63,919	53,895	0	5.5	5.50	0.546	-0.069	0.129	0.000	0.0	0.0	6
4.B Manure management	CH_4	1,540	1,730	0	10.5	10.50	0.033	-0.001	0.004	0.000	0.0	0.0	6
	N_2O	524	1,574	0	10.3	10.30	0.030	0.002	0.004	0.022	0.0	0.0	6
4.C Rice Cultivation	CH_4	490	175	5	10	11.18	0.004	-0.001	0.000	-0.011	0.0	0.0	7
4.D Agricultural Soils	N_2O	13,338	13,168	0	52	52.00	1.262	-0.010	0.032	-0.516	0.0	0.5	7
4.E Burning of Savannas	CH_4	4,909	6,560	18	14	22.80	0.276	0.000	0.016	0.006	0.4	0.4	7
	N_2O	1,450	2,052	18	5	18.68	0.071	0.000	0.005	0.002	0.1	0.1	7
4.F Agricultural Residues	CH_4	193	231	5	20	20.62	0.009	0.000	0.001	-0.001	0.0	0.0	7
	N_2O	99	102	5	20	20.62	0.004	0.000	0.000	-0.001	0.0	0.0	7
6.A Solid Waste	CH_4	13,545	11,140	0	3.25	3.25	0.067	-0.015	0.027	-0.050	0.0	0.1	5
6.B Wastewater handling	CH_4	3,422	2,414	0	50	50.00	0.222	-0.005	0.006	-0.243	0.0	0.2	5
	N_2O	343	412	0	50	50.00	0.038	0.000	0.001	-0.004	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
	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	71	0	100	100.00	0.013	0.000	0.000	0.015	0.0	0.0	
	N_2O	1	9	0	100	100.00	0.002	0.000	0.000	0.002	0.0	0.0	
Total Emissions		417,993	542,691										
Total Uncertainties							2.8					1.9	

[1] Energy Strategies; 2. George Wilkenfeld & Associates; 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 ±5%. The highest uncertainty was for N_2O emissions, with an associated uncertainty of up to ±16%. However, as emissions of N_2O (and CH_4) account for only a small fraction, 0.4%, of the subsector's total emissions, there is a negligible impact on overall uncertainty for this sector.

Table A7.3: Quantified uncertainty values for key stationary energy subcategories

Greenhouse gas source and sink category	Uncertainty (%)[a]			
	CO_2	CH_4	N_2O	Total $CO_{2\text{-e}}$
1. ENERGY				
A Fuel combustion activities				
1.A.1.a Electricity	**±5**	**±9**	**±15**	**±5**
Black coal	±6	±9	±15	±6
Brown coal	±4	±9	±15	±4
Petroleum	±4	±9	±7	±4
Natural gas	±4	±9	±16	±4
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

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 A7.4: 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 A7.5: 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**
	±4	±23	±41
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 A7.6: 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**
1.B.1.a.i. 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 A7.7: Quantified uncertainty values for key industrial processes subsectors using different techniques

	Uncertainties and distribution[a]		Emission factors – uncertainties and distributions									
Source	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
Total emissions	26019.09										
Aggregate uncertainty	±2.88										

(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. 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 A7.8: 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. The uncertainty in emission factors and associated parameters were determined from surveys of the published international literature, with emphasis on local Australian measurements. All variables are considered to be independent except fuel load and burning efficiency, which were positively correlated. The activity data with the greatest uncertainties are the areas of savanna fires. These are collated from a large and dispersed number of state government organisations with a wide range of data quality protocols.

There is large relative uncertainty in the emission estimates from all subcategories, including approximately –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 A7.9: 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	**–52 to 80**	**–55 to 94**
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.

LAND USE, LAND USE CHANGE AND FORESTRY

Australia's National Carbon Accounting System (NCAS) uses tier 3 methods (ecosystem model) of emissions estimation and an Approach 3 (full spatial enumeration) method of representing land (IPCC 2003). 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, the testing of the NCAS 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.

The sensitivity and uncertainty analysis of the NCAS 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 A7.10: 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 A7.11: 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

Table A7.12: 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

Variable	Distribution and parameters	2sd	M-2sd	M+2sd	2sd/M	M-/2.5%	M+/97.5%
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
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
Department of Climate Change and Energy Efficiency
GPO Box 854
CANBERRA ACT 2601
Tel: +61 2 6159 3398
Email: shaun.calvert@climatechange.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

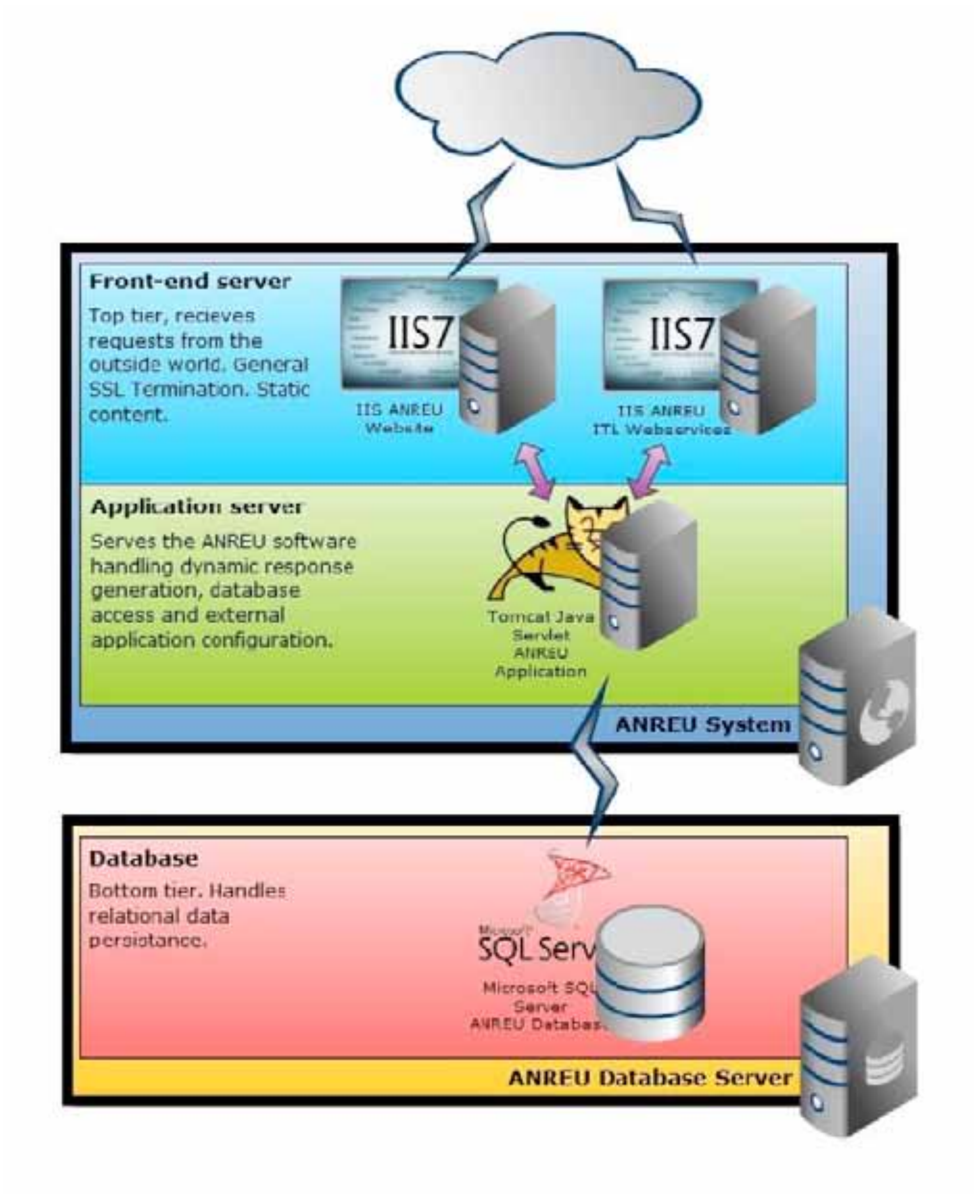
Microsoft SQL Server 2008 provides a relational database back-end for persistent storage of data for the application.

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 A8.1 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

The ANREU incorporates the following security measures.

Identification and Authentication

All applicants to open an account in the ANREU are required to provide proof of identity documentation, along with completing a "fit and proper" person test. These 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 Department of Climate Change and Energy Efficiency. Passwords have an expiry date and any reset requires revalidation of the users identity. Password configuration is as per Australian Government guidelines.

Access control

Users of the ANREU are divided into three 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. This person is responsible for maintaining the technical environment of the ANREU, including all hardware, software, and network concerns. This includes scheduling regular data backups and restoring data in the event of a system.

Program Manager/ANREU Administrator

The registry administrator, or program manager role, represents the person or persons responsible for all policy-based operations of the registry. This person will have access to all functionality that can be provided through the Registry interfaces, but will not have direct access to the database tables and the web application server. Should the need arise to access these resources, the registry administrator must coordinate with the system administrator. The registry administrator is responsible for such policy-based activities as account creation, approval of forwarding instructions, monitoring notifications and messages logs, and coordinating with the ITL for reconciliations.

Industry User/Account Holders

Provisions are made for account holders to have access to the registry web application. The ANREU provides the capability to create users with restricted levels of access by which users would only be permitted to access data relevant to their own holdings and activities. These permissions can be configured using the system administration functions.

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 now 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 nationalregistry.climatechange.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 Department of Climate Change and Energy Efficiency 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 Department operators within 8 hours of the decision being made.

Results of previous test procedures

Australia's independent assessment report is available from the UNFCCC website http://unfccc.int/resource/docs/2008/iar/aus01.pdf

ANNEX 9: 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.
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. The NCAS when assessing Australia's land use change emissions uses a criteria of 20% tree crown cover, 2 metre minimum tree height, and a minimum of 0.2 hectares in land area for inclusion. These minimum criteria are within the ranges outlined in the Marrakech Accords.
Fuel Oil	Covers all residual (heavy) fuel oils including those obtained by blending.
Fugitive Emissions	Generally deliberate but not fully controlled emissions that typically result from leaks, including those from pump seals, pipe flanges and valve stems. Fugitive emissions also include methane emitted from coal mine seams. During petroleum storage tank filling, venting loss of vapour is a fugitive emission.
Global Warming Potential (GWP)	Represents the relative warming effect of a unit mass of a gas compared with the same mass of CO_2 over a specific period. Multiplying the actual amount of gas emitted by the GWP gives the CO_2-equivalent emissions.
Greenhouse Gases	Gases that contribute to global warming, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). In addition, the photochemically important gases—NMVOCs, oxides of nitrogen (NO_x) and carbon monoxide (CO)—are also considered. NMVOC, NO_x and CO are not direct greenhouse gases. However, they contribute indirectly to the greenhouse effect by influencing the rate at which ozone and other greenhouse gases are produced and destroyed in the atmosphere.
Hydrofluorocarbons (HFCs)	Used as substitutes for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

Industrial Diesel Fuel (IDF)	A petroleum product primarily consumed in the rail and water transport sectors.
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'.
Venting	The process of releasing gas into the atmosphere without combustion. This may be done either at the production site or at the refinery or stripping plants. It is done to dispose of non-commercial gas or to relieve system pressure.

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