Australian Government
Department of Industry, Science, Energy and Resources

National Inventory Report

2019

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

Australian National Greenhouse Accounts

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VOLUME 3

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PART 2

Supplementary Information Required Under Article 7.1 of the Kyoto Protocol

11. Kyoto Protocol LULUCF

In accordance with Decision 1/CMP.8, this Part of the Report contains supplementary information to fulfil reporting requirements under Article 7 of the Kyoto Protocol (KP) (decisions 6/CMP.9, 2/CMP.8, 2 and 4/CMP.7, 15/CMP.1 and 2, 3 and 4/CMP.11) and net emissions estimates compiled using reporting rules and guidance applicable to the KP 2nd commitment period (CP2), including guidance contained in the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement, IPCC 2014).

The Australian Government submitted its instrument of acceptance to the Doha Amendment on 9 November 2016.

11.1 General Information

11.1.1 Definition of forest and other criteria

Forests include all vegetation with a vegetation height of at least 2 metres and crown canopy cover of 20 per cent or more and lands with systems with a woody biomass vegetation structure that currently fall below but which, *in situ,* could potentially[1] reach the threshold values of the definition of a forest. Young natural stands and all plantations which have yet to reach a crown density of 20 per cent or tree height of 2 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of either human intervention, such as harvesting, or natural causes, but which are expected to revert to forest.

Australia has adopted a minimum forest area of 0.2 ha (Table 11.1).

Forest use is typically evident by human disturbance, such as in commercial forest harvest, or clearly delineated by land tenure, such as conservation reserves. In extensive systems, such as grazed woodlands, there is a continuum in the intensity and intent of use.

Table 11.1 Selection of parameters for defining 'forest' under the KP

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

For the second KP commitment period, Australia will report on *forest management* and has elected to report emissions and removals from the following Article 3.4 activities:

- *cropland management;*
- *grazing land management; and*
- *revegetation.*

1 This potential is evidenced from the Landsat series in that the land has previously supported forest.

11.1.3 Precedence conditions and hierarchy among Article 3.4 activities

Australia has implemented a hierarchy of Article 3.4 activities into its land classification system. *Forest management,* as a mandatory activity takes precedence over the other Article 3.4 activities, consistent with IPCC requirements. The hierarchy of Article 3.4 activities is applied as follows:

1. forest management;
2. cropland management;
3. grazing land management; and
4. revegetation.

Australia's system for the classification of land in the UNFCCC and KP LULUCF inventories is described in more detail in section 6.3 in Volume 2 of the NIR and in section 11.2 below.

11.2 Land-related information

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

Deforestation under the KP is a subset of *forest conversion* and includes only lands where there has been direct human-induced conversion of forest to alternative land uses since 1 January 1990.

Conversion of *forest lands* to alternative land uses prior to 1990 are accounted for under *cropland management or grazing land management* to enable complete accounting under CP2.

Forest management is a subset of *forest land remaining forest land* and includes those forests managed under a system of practices designed to support commercial timber production such as harvest or silvicultural practices or practices that are designed to implement specific sink enhancement activities.

Forests included under this definition include multiple-use public forests, plantations established prior to 1990, privately managed native forest land where *forest management* activities (harvesting and silvicultural practices) have been observed to occur; and forests where regulated sink enhancement activities occur.

Forest lands outside of the multiple-use public forests and pre-1990 plantation lands are also monitored for signs of harvesting and silvicultural practices in order to achieve complete accounting for these management practices. If a harvest event is observed, the net emissions are reported under the *forest management* category and all future net emissions on that land continue to be reported under that category.

Afforestation/reforestation is a subset of *land converted to forest land* and includes only those forests established since 1 January 1990. Forests under *land converted to forest land* may be established through planting events either for commercial timber or for other reasons, known as 'environmental plantings', or by regeneration from natural seed sources on lands regulated for the protection of forests.

Cropland management includes all land that is used for continuous cropping, lands managed as crop-pasture rotations and *land converted to cropland from grassland. Forest land converted to cropland* prior to 1990 is also included under *cropland management. Land converted to forest land* is excluded from *cropland management.*

Perennial crops including orchards and vineyards are included under *cropland management.* Units of land where orchards were established on land clear of forest on 31 December 1989 are included in the *cropland management* and not the *afforestation/reforestation* classification.

Grazing land management lands include permanent *grasslands* and biomass burning in forests in northern Australia. *Forest lands* are not double counted in Australia's land classification systems as Australia has applied a 'narrow' approach to *forest management,* allowing northern forests subject to fire not identified as being managed for timber to be included under *grazing land management.*

A forest observed to be deforested, or observed to be subject to a forest management practice, is reported under *deforestation* or *forest management* categories in preference to *grazing land management* in accordance with the hierarchy used for Australia's inventory.

Revegetation includes human-induced establishment of vegetation since 1990 that covers a minimum area of 0.05 hectares and does not meet the definitions of *afforestation/reforestation.* It is restricted to sparse, sub-forest vegetation in settlements and wetlands.

While there are some essential differences between the KP and UNFCCC classification systems, it is possible to reconcile them. For the most part, the differences have become either less pronounced or less significant as the coverage of land activities adopted by the Australian Government has increased over time. In Table 11.2, a concordance between UNFCCC and KP classifications used in the preparation of net emission estimates in this Report is presented.

Table 11.2 Reconciliation table between UNFCCC and KP classifications

UNFCCC	KP
Forest land	
Forest land – multiple-use public forest	*forest management*
Forest land – pre-1990 plantations	*forest management*
Forest land – harvested private native forests	Monitored for *forest management* activity
Forest land – other native forest	Monitored for *forest management* activity
Forest land – biomass burning in non-temperate areas	*grazing land management*
New plantations since 1990	*afforestation/reforestation*
Native regeneration since 1990 – direct human-induced	*afforestation/reforestation*
Forest land previously converted to other land uses since 1990	*deforestation*
Forest land previously converted to other land uses prior to 1990	*afforestation/reforestation*
Land converted to forest prior to 1990	Monitored for *forest management* activity
Cropland	
Cropland – permanent	*cropland management*
Perennial woody horticulture	*cropland management*
Forest land converted to cropland since 1990	*deforestation*
Forest land converted to cropland prior to 1990	*cropland management*
Grassland converted to cropland	*cropland management* (crop-pasture rotations)
Grassland	
Grasslands – permanent	*grazing land management*
Forest land converted to grassland since 1990	*deforestation*
Forest land converted to grassland prior to 1990	*grazing land management*
Cropland converted to grassland	*cropland management* (crop-pasture rotations)

UNFCCC	KP
Settlements	
Settlements – sparse woody vegetation gained or lost since 1990	*revegetation*
Settlements – sparse woody vegetation gained or lost prior to 1990	not in scope of KP
Forest land converted to settlements since 1990	*deforestation*
Forest land converted to settlements prior to 1990	not in scope of KP
Wetlands	
Wetlands – sparse woody vegetation gained or lost since 1990	*revegetation*
Wetlands – sparse woody vegetation gained or lost prior to 1990	not in scope of KP
Wetlands – biomass burning in non-temperate areas	*grazing land management*
Forest land converted to wetland since 1990	*deforestation*
Forest land converted to wetlands prior to 1990	not in scope of KP

11.2.2 Identification of geographical locations

All lands under the reporting categories of *afforestation/reforestation, deforestation, cropland management* and *grazing land management* are monitored using a Reporting Method 2 land identification system (IPCC, 2014, Chapter 2.2.2) based on the Landsat time series in conjunction with ABARES Land Use Maps. The methods of mapping forest extent and change in extent are outlined in Chapter 6 (Appendix 6.A).

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.

Land is tracked and simulated in FullCAM at a pixel by pixel (25m x 25m) level and the carbon stock change on each pixel is tracked from the start of the simulation to the reporting year. The outputs of the simulations are stored in a datacube which can be queried using the FullCAM Outputs Analysis System.

The consistent tracking through time of individual units of land down to 0.2 ha results in millions of estimation units. For the purpose of reporting under Article 3.3 and Article 3.4, the areas 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 5 broad types of forest: softwood plantations, hardwood plantations, environmental plantings, natural regeneration, and regrowth on previously cleared lands. Allocations to these classifications are obtained from more detailed analysis of the Landsat data (see Appendix 6.A).

Lands subject to *forest management* are monitored using a combination of Reporting Methods 1 and 2 under IPCC (2014) Chapter 2.2. Reporting method 2 is being progressively implemented for forest harvesting and controlled burning activities as spatially-explicit data on these activities are acquired from state governments.

11.2.3 Methodology used to develop the land transition matrix

The land transition matrix is developed using the forest extent data derived from Australia's Landsat archive consistent with the data for the UNFCCC reporting categories (Table 6.3 in Section 6.3).

Table 11.3 Land area subject to KP LULUCF activities in 2019

Activity	Area in 2019 (k ha)
Afforestation and Reforestation	9,077.16
Deforestation	10,844.93
Forest Management	12,704.89
Cropland Management	39,646.72
Grazing Land Management	536,196.24
Revegetation	14,071.54
Wetland drainage and rewetting	NA
Other	146,287.21
Total	**768,828.70**

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

Land where forest cover loss is identified as being human-induced and where it is not expected that the forest will be regenerated or replanted is classified as *deforestation* land.

In cases where there is a temporary change in forest cover due to natural events (e.g. fire, drought) or where changes occur within a land tenure where it is expected that the land will revert to forest (e.g. harvested forest, national park), the land is monitored for a period of time, depending upon the land tenure and use, consistent with the guidance provided in section 2.6.2.1 of the KP Supplement.

Areas that have entered the monitoring system continue to be classified as *forest land* provided that the time since forest cover loss is shorter than the number of years within which tree establishment is expected (Table 11.4). After the specified monitoring period, however, lands that have lost forest cover due to direct human-induced actions, have undergone land use change, and failed to regenerate are classified as *deforestation.*

Table 11.4 Monitoring period for Article 3.3 and 3.4 lands

Land classification	Monitoring period (x years)
Afforestation/reforestation	8
Settlements	10
Forest management	12

11.2.3.2 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 land that have entered the monitoring system described above and have been without forest cover for less than the monitoring periods in Table 11.4, (that is, forest or plantation re-establishment has not been confirmed), amounted to 816,041 hectares in 2019 (Table 11.5).

In accordance with good practice, estimates will be made at the end of the commitment period of the proportion of these areas that are not expected to regenerate.

Table 11.5 Area of land monitored for land-use change by jurisdiction in 2019 (ha)

State	Total
Australian Capital Territory	6,681
New South Wales	180,332
Northern Territory	8,086
Queensland	238,608
South Australia	53,071
Tasmania	61,726
Victoria	249,779
Western Australia	259,128
Total	**1,057,411**

11.3 Methods for carbon stock changes and greenhouse gas emissions and removal estimates

In general, a Tier 3, Approach 3 (Reporting Method 2 under IPCC (2014)) system is used to estimate emissions and removals under Article 3.3 and 3.4 using the same methods as used to estimate the UNFCCC inventory (Chapter 6). Tier 2 methods are used for emissions and removals under *revegetation. Forest management* uses a combination of approach 2 and 3 depending on the availability of spatially-explicit data on harvesting and controlled burning, consistent with the methods used for corresponding categories in the UNFCCC inventory (Chapter 6).

Table 11.6 Summary of methodologies and emission factors –KP 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
Deforestation						
C stock changes	T3	M				
Biomass burning[a]	IE	IE	CS	CS	CS	CS
Article 3.4 activities						
Forest management						
C stock changes	T2/T3	M				
Biomass burning[a]	T2/T3	CS/M	CS	CS	CS	CS
Cropland management						
C stock changes	T2/T3	CS/M				
Biomass burning[a]	IE	IE	CS	CS	CS	CS
Grazing land management						
C stock changes	T2/T3	CS/M				
Biomass burning	T3	M	CS	CS	CS	CS

Greenhouse Gas Source And Sink	CO_2		CH_4		N_2O	
	Method applied	EF	Method applied	EF	Method applied	EF
Revegetation						
C stock changes	T2	CS				
Biomass burning[b]	IE	IE	IE	IE	IE	IE

EF = emission factor, CS = country specific, M = Model, NO = not occurring, IE=included elsewhere, T2 = Tier 2 and T3 = Tier 3.

(a) CO_2 emissions from biomass burning associated with forest harvesting or land use changes are included carbon stock changes.

(b) Emissions from biomass burning associated with fire management in northern Australia on wetlands are included in *grazing land management*.

11.3.1 Years for which carbon stock changes and non-CO_2 emissions are reported

Carbon stock changes and non-CO_2 emissions from land subject to Article 3.3 and Article 3.4 activities are reported from the start of the commitment period in 2013.

11.3.2 Information that demonstrates that Article 3.3 activities began on or after 1 January 1990 and are direct human-induced

The land is monitored using a time series of Landsat imagery since 1972 in order to be able to demonstrate the date at which the activities began.

11.3.3 Factoring out of indirect and natural emissions and removals

Indirect effects on greenhouse gas emissions and removals are not explicitly factored out although, as Australia's estimation methods utilise a process-based Tier 3 modelling approach, it is clear that the relationships between biomass, climate and atmospheric concentrations are fixed for the time series of emission estimates.

Natural emissions and removals are managed through the application of the natural disturbance provision for a range of identified natural disturbances under *forest management*.

11.3.4 Uncertainty estimates

Uncertainty estimates are provided in Annex 2.

The same methods and data are used to estimate emissions and removals in all Article 3.3 and 3.4 activities as are used for the associated UNFCCC categories.

11.4 Deforestation

11.4.1 Identification of land subject to *deforestation*

Deforestation activity (Table 11.7) is identified using methods applied to the identification of *forest conversion* under the UNFCCC and described in Appendix 6.A. *Deforestation* only includes lands where there has been direct human-induced conversion of forest to alternative land uses since 1 January 1990.

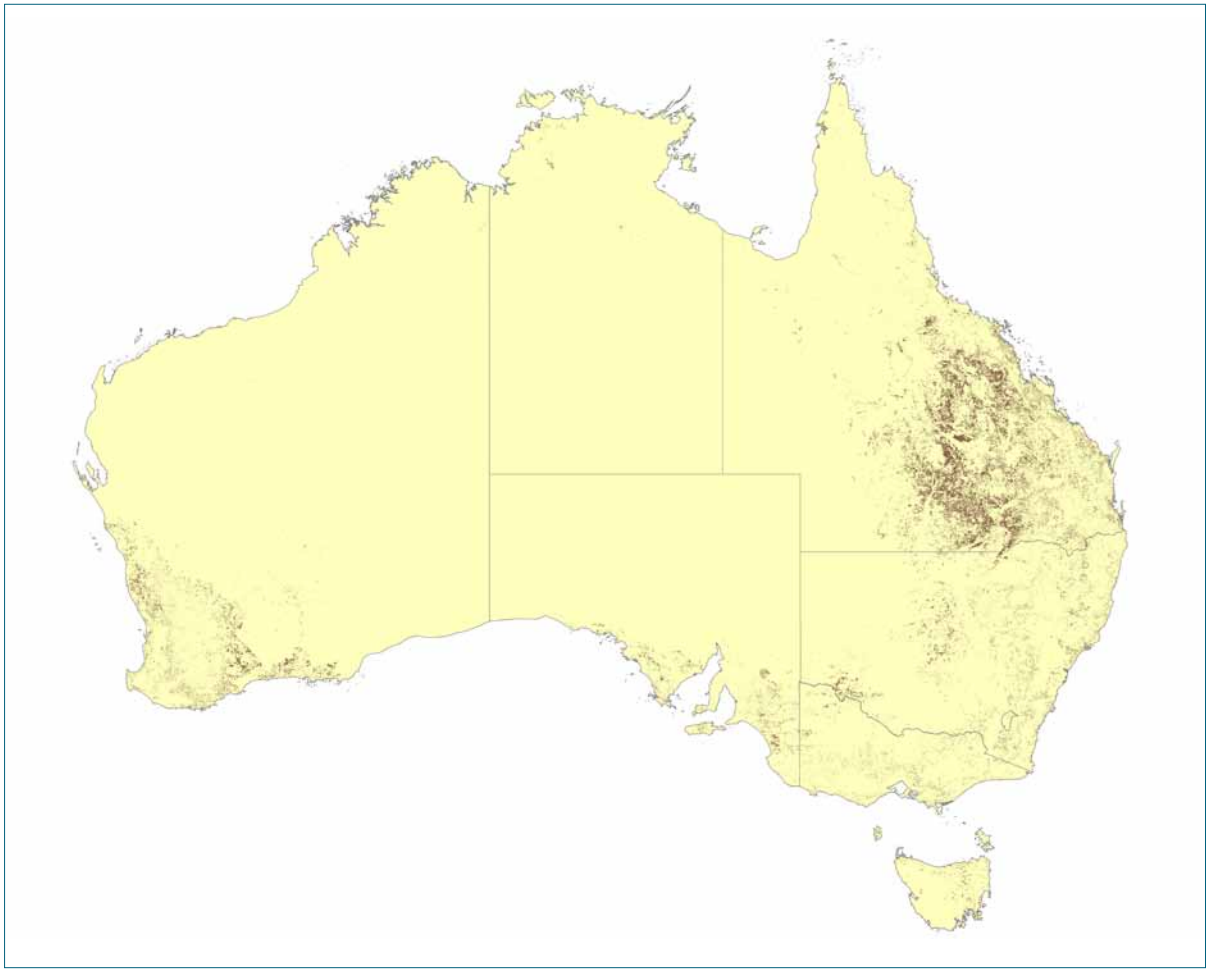
Table 11.7 Area of deforestation 1990–2019

Year	Area of deforestation (Mha)
1990	0.57
1991	1.31
1992	1.97
1993	2.46
1994	2.96
1995	3.34
1996	3.74
1997	4.14
1998	4.54
1999	5.01
2000	5.47
2001	5.99
2002	6.46
2003	6.88
2004	7.32
2005	7.87
2006	8.35
2007	8.74
2008	9.01
2009	9.23
2010	9.42
2011	9.58
2012	9.73
2013	9.93
2014	10.10
2015	10.27
2016	10.44
2017	10.59
2018	10.74
2019	10.84

11.4.1.1 Spatial identification of *deforestation* lands

The location of land included in the *deforestation* account is shown in Figure 11.1.

Figure 11.1 Location (in brown) of land included in the deforestation account



11.4.2 Methods for estimation of carbon stock changes and greenhouse gas emissions and removal estimates

11.4.2.1 Data

The same data sources are used for *deforestation* as for *forest conversion,* as detailed in Volume 2.

11.4.2.2 Methods

The same Tier 3, Approach 3 (Reporting Method 2 under IPCC (2014)) system is used for *deforestation* as that used to estimate *forest conversion* (see Appendices 6.B and 6.F).

11.4.2.3 Start year

Estimation of net emissions is undertaken from 1972 consistent with the available Landsat series.

11.4.2.4 Carbon pools

FullCAM estimates emissions from soil through a process involving all on-site carbon pools (living biomass, dead organic matter and soil).

11.4.3 Harvested wood products from deforestation events

Harvested wood products from deforestation events are separately identified and emissions reported according to instantaneous oxidation in accordance with paragraph 31 of the annex to Decision 2/CMP.7.

The Tier 3, Reporting Method 2 spatial monitoring system for *deforestation* is used to detect and differentiate deforestation events from harvesting on *afforestation / reforestation* and *forest management* lands, as described in Section 11.2.3.

These deforestation events are modelled as part of *deforestation,* where all biomass from the deforestation event is burned on site, with no products produced.

National aggregate harvesting statistics have been allocated between harvest from *afforestation / reforestation, forest management* and *deforestation* (from the deforestation event) to ensure that there is no double-counting of products produced from deforestation events. The deforestation component is excluded from the reporting of emissions estimates of the *harvested wood products* pool, as these products have already been accounted for on the basis of instantaneous oxidation.

11.4.4 Reporting of *deforestation* in 2019

11.4.4.1 Reporting of *deforestation* net emissions in 2019

Estimates of net emissions from *deforestation* are reported in Table 11.8.

Table 11.8 Estimated net emissions from deforestation (kt CO_2-e)

Year	Total
2000	68,821
2005	86,969
2008	63,300
2009	51,009
2010	53,426
2011	40,669
2012	32,788
2013	35,989
2014	38,262
2015	30,083
2016	27,657
2017	26,917
2018	29,337
2019	22,284

11.4.4.2 Estimation of AAUs to be cancelled for deforestation in 2013 to 2018

In the reporting period, 2013–2020, one Assigned Amount Unit (AAU) is to be cancelled for every tonne of emissions reported from the deforestation activity (the same approach as for emissions from sources in the energy, industrial processes and product use, agriculture, waste sectors). Estimates of AAUs to be cancelled in 2013 to 2018 are presented in Table 11.9.

Table 11.9 Estimated AAUs to be cancelled for deforestation net emissions (t CO_2-e)

Year	AAUs to be cancelled
2013	35,988,984
2014	38,262,441
2015	30,082,561
2016	27,656,725
2017	26,917,121
2018	29,336,917
2019	22,283,634

11.4.5 Quality Assurance – Quality Control

Deforestation activity is identified using methods applied to the identification of forest lands converted to grass and other lands under the UNFCCC and is described in detail in Section 6.6 of Volume 2 of the NIR.

Table 11.10 provides a reconciliation between emissions reported under the KP *deforestation* account (Table 11.10, Component A) and the UNFCCC accounts for *forest land converted to other land uses.*

Differences between these two classifications arise because the *deforestation* account considers lands with a history of anthropogenic forest loss since 1990. It includes emissions from these lands where forest has subsequently regrown and is accounted for in the UNFCCC accounts for *land converted to forest* (component E), but does not include the ongoing emissions and removals from lands cleared prior to 1990 (component B). Emissions from nitrogen leeching and run-off (component C) are not in scope of any part of the KP accounts, and emissions from non-temperate fire management (component D) are allocated exclusively to *grazing land management* irrespective of the land's conversion history.

Table 11.10 Reconciliation of emissions from UNFCCC forest conversion and KP deforestation and other classifications

Year	Deforestation	Cleared prior to 1990 and remains clear	Nitrogen leeching and runoff	Non-temperate fire management	Forest regrown on lands cleared since 1990	Total UNFCCC Forest land converted to other land uses
	(kt CO_2-e)	(kt CO_2-e)	(kt CO_2-e)	(kt CO_2-e)	(kt CO_2-e)	(kt CO_2-e)
Component	A	B	C	D	E	A+B+C+D-E
2008	63,300	4,538	43	59	-5,283	73,222
2009	51,009	3,896	40	61	-5,172	60,179
2010	53,426	7,975	66	55	-5,943	67,465
2011	40,669	4,734	80	71	-6,795	52,349
2012	32,788	5,137	50	66	-8,231	46,272
2013	35,989	6,678	38	64	-8,322	51,092
2014	38,262	5,450	51	68	-8,347	52,178
2015	30,083	4,296	38	72	-9,012	43,501
2016	27,657	2,674	40	51	-11,615	42,036
2017	26,917	3,210	32	53	-11,295	41,508
2018	29,337	4,456	25	47	-11,033	44,898
2019	22,284	1,921	25	46	-9,754	34,031

11.4.6 Recalculations

Further descriptions of the recalculations is provided in the corresponding LULUCF category in Chapter 6, namely *forest land converted to grasslands.*

Table 11.11 *Deforestation*: recalculation of total CO_2-e emissions (kt), 1990–2018

Year	Deforestation				Reasons for Recalculations			
					A. Updated spatial observations		B. Soil Cover	C. Agricultural Parameters
	2020 submission	2021 submission	Change		Terrestrial forests	Mangroves		
	(kt CO_2 -e)	(kt CO_2 -e)	(kt CO_2 -e)	%	(kt CO_2 -e)	(kt CO_2 -e)	(kt CO_2 -e)	(kt CO_2 -e)
1990	63,714	65,721	2,007	3.2%	1,617	0	390	0
1995	66,041	66,891	850	1.3%	128	-1	635	89
2000	68,115	68,821	706	1.0%	56	-2	601	51
2005	85,618	86,969	1,351	1.6%	206	6	1,019	120
2006	85,665	87,028	1,363	1.6%	207	4	1,080	72
2007	83,525	85,349	1,824	2.2%	233	-1	1,049	543
2008	62,066	63,300	1,233	2.0%	997	2	508	-273
2009	50,096	51,009	913	1.8%	319	1	446	148
2010	52,802	53,426	623	1.2%	561	5	320	-262
2011	39,758	40,669	911	2.3%	158	-2	289	466
2012	32,836	32,788	-48	-0.1%	41	2	241	-333
2013	34,484	35,989	1,505	4.4%	172	7	624	702
2014	37,454	38,262	809	2.2%	324	-5	597	-108
2015	28,283	30,083	1,800	6.4%	851	1	343	604
2016	26,858	27,657	799	3.0%	508	-6	466	-169
2017	26,145	26,917	772	3.0%	569	-5	214	-7
2018	26,853	29,337	2,484	9.2%	2,988	23	241	-769

11.5 Afforestation & reforestation

11.5.1 Identification of land subject to *afforestation/reforestation*

Afforestation/reforestation activity is identified using methods applied to the identification of *land converted to forest* under the UNFCCC and described in Appendix 6.A. Plantations for timber, environmental plantings and the promotion of natural seed sources are included within the *afforestation/reforestation* classification. Emissions from *harvested wood products* associated with hardwood plantation timber harvested since 2000 are also included.

The natural regeneration of forests from natural seed sources are identified in areas consistent with the intentions of land use regulatory systems and reflect the deliberate decisions of land managers to not maintain pasture for grazing. To qualify as a *forest land* converted from natural seed sources, the land must have been clear of forest throughout the period 1972–1989 and must have converted to forest land after 1 January 1990.

Conversions to forest land can be supported through a range of government programs and regulatory processes including from offsets created under State vegetation management acts or under major project approval processes. The Emissions Reduction Fund is used to encourage these outcomes.

The identification of regeneration of forest from natural seed sources as *afforestation/reforestation* is explained further in section 11.5.1.2 below. The area of *afforestation/reforestation* is presented in Table 11.12.

Table 11.12 Area of afforestation/reforestation 1990–2019

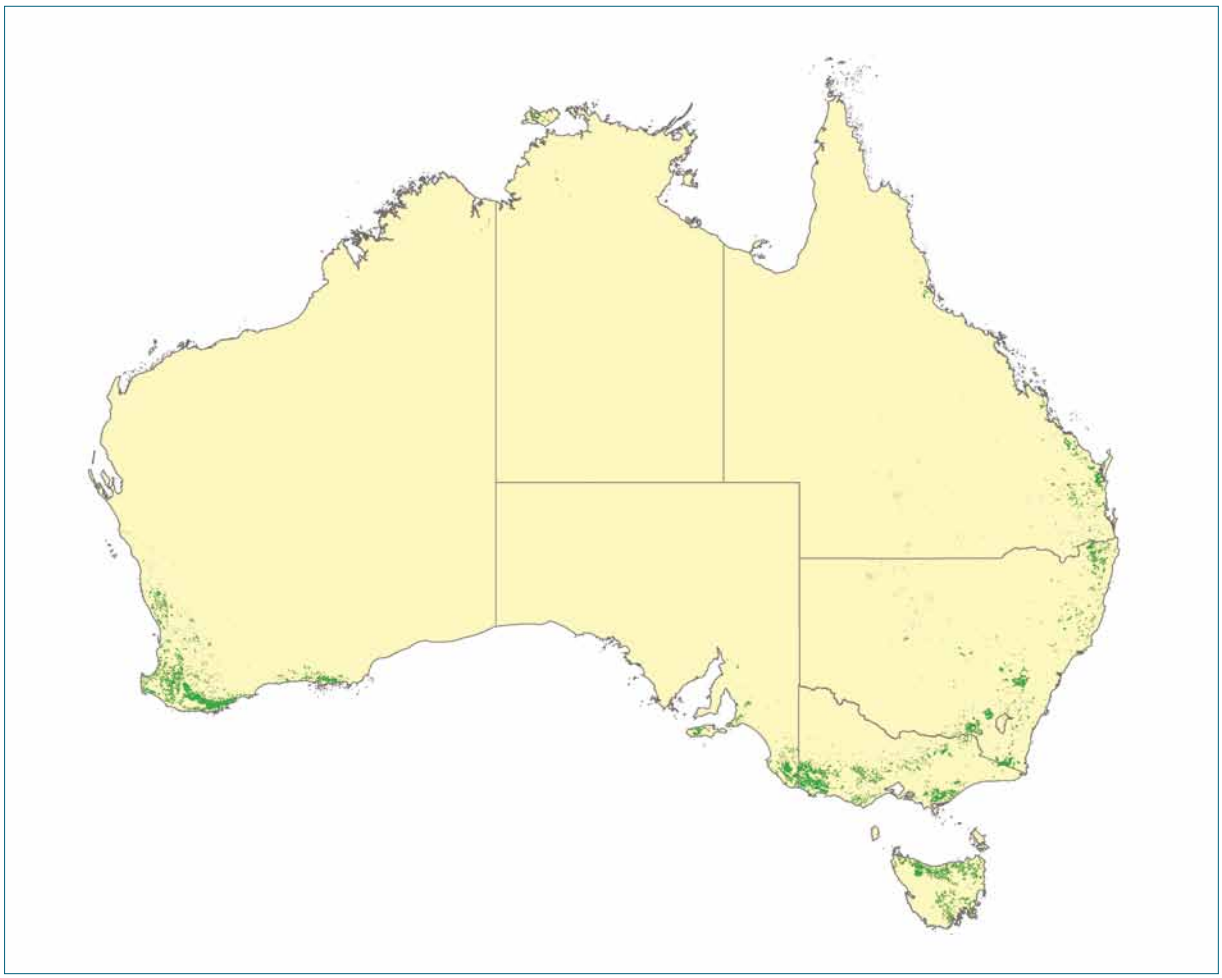
Year	Area of *afforestation/reforestation estate* (M ha)
1990	0.26
1991	0.79
1992	1.21
1993	1.50
1994	1.77
1995	2.02
1996	2.26
1997	2.50
1998	2.73
1999	3.00
2000	3.24
2001	3.49
2002	3.72
2003	3.94
2004	4.18
2005	4.46
2006	4.74
2007	5.00
2008	5.23
2009	5.46
2010	5.72
2011	6.01
2012	6.31
2013	6.64
2014	7.02
2015	7.42
2016	7.88
2017	8.34
2018	8.72
2019	9.08

Australia's *afforestation/reforestation* estate has increased in area over the period 1990–2019 (Table 11.12).

11.5.1.1 Spatial identification of *afforestation/reforestation* lands

Afforestation/reforestation activities are identified in relation to a 1990 base map of forest land derived from the land monitoring program (Appendix 6.A). The location of land from plantings included in the *afforestation/reforestation* account is shown in Figure 11.2.

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



11.5.1.2 Identification of regeneration of native forests as *afforestation/reforestation*

It is estimated that there were approximately 5.87 million hectares of land which was not forest on 31 December 1989 (and was not forested at any time between 1972 and 1989), which was subsequently converted to *forest land* through natural regeneration and remained forest.

All lands in South Australia, Tasmania, Victoria and Western Australia have been identified as subject to land clearing restrictions. In Queensland, lands mapped as high value regrowth under the *Vegetation Management Act 1999* and land that is included in the Collaborative Australian Protected Area Database (CAPAD) is considered protected. In the remaining jurisdictions (Australian Capital Territory, New South Wales and the Northern Territory) further analysis of land clearing regulations is required to include all protected lands. In NSW, in particular, the area identified as protected is likely to be a significant under estimate. The focus of current analysis is to improve the estimated area of protected land in New South Wales.

Carbon abatement projects of the Australian Government's Emissions Reduction Fund are also spatially identified and included in the protected lands irrespective of their presence in or absence from other identified protected areas.

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

CAPAD is used to provide a national perspective of the conservation of biodiversity in protected areas. It also allows Australia to regularly report on the status of protected areas to meet international obligations such as those in the Convention on Biological Diversity (CBD). Australian protected area information is also included in the World Database on Protected Areas (WDPA).

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

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

State and territory native vegetation clearance statutes

New South Wales

- *Biodiversity Conservation Act 2016*
  - previously *Native Vegetation Act 2003* and *Threatened Species Conservation Act 1995*
- *Local Land Services Act 2013*
- *Environmental Planning and Assessment Act 1979 (Local Environmental Plan)*
- *Fisheries Management Act 1994* (includes mangrove specific protections)

Victoria

- *Victorian Planning Provisions (Clause 52.17)*
- *Planning and Environment Act 1987*
- *Conservation, Forests and Lands Act 1987*
- *Flora & Fauna Guarantee Act 1988*
- *Catchment and Land Protection Act 1994*
- *Environmental Protection Act 1970*
- *Forests Act 1958*

Queensland

- *Vegetation Management Act 1999*
  - previously *Land Act 1994* and *Environmental Protection Act 1994*
- *Planning Act 2016*
  - previously *Sustainable Planning Act 2009* and *Integrated Planning Act 1997*
- *Nature Conservation Act 1992*
- *Fisheries Act 1994* (includes mangrove specific protections)

Western Australia

- *WA Environmental Protection Act 1986*

South Australia

- *SA Native Vegetation Act 1991*
- *Fisheries Management Act 2007* (includes mangrove specific protections)
- *Native Vegetation Regulations 2017*

Tasmania

- *Tasmania Forest Practices Act 1985*

Australian Capital Territory

- *ACT Planning and Development Act 2007*
- *Nature Conservation Act 2014*

Northern Territory

- *NT Planning Act 1999*
- *NT Planning Scheme 2020*
- *Pastoral Land Act 1992*

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

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

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

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

In Queensland the administrative processes are more complex. Legal consequences derive from a combination of regional ecosystem plans issued under regulation, individual property agreements and land clearing permits. A similar mix of instruments is applied in New South Wales.

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

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

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

Currently the Emissions Reduction Fund promotes regeneration from natural seed sources through a direct subsidy program.

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

11.5.2 Methods for carbon stock changes and emissions and removal estimates

11.5.2.1 Data

The same data sources are used for *afforestation/reforestation* as for *land converted to forest land* in the UNFCCC inventory (see Appendix 6.A and 6.G).

11.5.2.2 Methods

For *afforestation/reforestation,* the same Tier 3, Approach 3 system is used as for *land converted to forest land* under the UNFCCC inventory (see Appendix 6.A and 6.G). The use of the Tier 3, Approach 3 (reporting method 2 under IPCC (2014)) 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.

HWP associated with harvesting in short rotation hardwood plantation areas from 2000 onwards are assumed to have occurred in plantations established after 31 December 1990 and are included in *afforestation/reforestation,* and are calculated consistent with the methods for *forest management* set out in 11.6.3.2.

11.5.2.3 Start year

Estimation of net emissions is undertaken from 1972 consistent with the available Landsat series.

11.5.2.4 Carbon pools

FullCAM estimates emissions from soil through a process involving all on-site carbon pools (living biomass, dead organic matter and soil).

11.5.3 Reporting of *afforestation/reforestation* in 2019

11.5.3.1 Reporting of *afforestation/reforestation* net emissions in 2019

Estimates of net emissions from *afforestation/reforestation* are reported in Table 11.13.

Table 11.13 Estimated net emissions from *afforestation/reforestation* (kt CO_2-e)

Year	Total
2008	-23,149
2009	-23,085
2010	-25,920
2011	-36,348
2012	-34,250
2013	-30,110
2014	-30,672
2015	-29,188
2016	-31,830
2017	-32,896
2018	-23,556
2019	-17,660

11.5.3.2 Estimation of *afforestation/reforestation* Accounting Quantity in 2013–19

For land activity categories other than *deforestation,* credits (called RMU credits) are issued against the reduction in net emissions relative to a specified benchmark base year or reference level.

For *afforestation/reforestation* estimates of net emissions in the reporting year are used to estimate the amount of RMU credits (the accounting quantity) to be issued. The estimated quantities of RMUs to be issued for 2013–19 are contained in Table 11.14.

Table 11.14 Estimated Accounting Quantity for *afforestation/reforestation* (t CO_2-e)

Year	Accounting Quantity (RMU credits)
2013	-30,110,440
2014	-30,671,817
2015	-29,188,054
2016	-31,830,409
2017	-32,895,531
2018	-23,556,047
2019	-17,659,658

* Note: Negative values indicate that RMUs are to be issued.

11.5.4 Quality Assurance – Quality Control

Refer to Chapter 6.6.

11.5.5 Recalculations

The quantification of the recalculation components is shown in Table 11.15. Descriptions of the reasons for the recalculations are provided in the corresponding LULUCF sub-category in Chapter 6, namely *land converted to forest land* (section 6.5.5).

Table 11.15 *Afforestation/reforestation*: recalculation of total CO_2-e emissions (kt), 1990–2018

					Reasons for recalculation					
					A. Updated spatial observations					
Year	2020 submission ($kt CO_2$)	2021 submission ($kt CO_2$)	Change ($kt CO_2$)	Change (% change)	Terrestrial forests ($kt CO_2$)	Mangroves ($kt CO_2$)	B. Soil Cover ($kt CO_2$)	C. Agricultural Parameters ($kt CO_2$)	D. Harvested Wood Products ($kt CO_2$)	E. Fire Observations ($kt CO_2$)
1990	-1,081	-1,229	-148	13.7%	-69	-15	-53	-4	0.0	-7
1995	-2,743	-3,537	-794	-28.9%	-36	-25	-726	5	0.0	-12
2000	-11,846	-12,495	-649	-5.5%	-11	-31	-595	-27	0.0	15
2005	-15,598	-16,886	-1,288	-8.3%	429	-21	-1,739	11	0.0	31
2006	-19,492	-21,046	-1,554	-8.0%	-147	-21	-1,339	-47	0.0	-1
2007	-19,044	-20,222	-1,178	-6.2%	255	-20	-1,451	5	0.0	34
2008	-22,086	-23,149	-1,063	-4.8%	409	-20	-1,407	-80	0.0	34
2009	-21,974	-23,085	-1,111	-5.1%	536	-19	-1,698	38	0.0	32
2010	-24,587	-25,920	-1,333	-5.4%	1,032	-19	-2,334	-41	0.0	29
2011	-34,388	-36,348	-1,960	-5.7%	-127	-18	-1,822	-39	0.0	46
2012	-32,552	-34,250	-1,698	-5.2%	613	-18	-2,283	-51	0.0	41
2013	-28,960	-30,110	-1,150	-4.0%	875	-18	-2,204	115	0.0	82
2014	-29,580	-30,672	-1,092	-3.7%	702	-18	-1,918	23	0.0	119
2015	-28,044	-29,188	-1,144	-4.1%	747	-18	-1,997	-5	0.0	129
2016	-30,554	-31,830	-1,276	-4.2%	782	-18	-2,183	49	0.0	94
2017	-31,770	-32,896	-1,126	-3.5%	667	-17	-1,793	-21	0.0	37
2018	-22,785	-23,556	-771	-3.4%	1,054	-24	-1,795	63	-0.2	-68

11.6 Article 3.4 activities – Forest management

Forest management comprises emissions and removals from *forest lands* that are managed under a defined system of practices, and includes emissions from harvested wood products and natural disturbances relating to *forest management* lands. Forest harvesting is the key driver of anthropogenic emissions and removals from *forest management* over the medium term.

In accordance with Decision 2/CMP.7, *forest management* is accounted against an emissions reference level that represents policies and practices in place as at December 2009. Australia's forest management reference level (FMRL) was reported in its 2011 *Forest Management Reference Level Submission* (DCCEE, 2011).

A summary of responses to the reporting requirements contained in Decision 2/CMP.7 is contained in section 11.10.2.

11.6.1 Identification of land subject to *forest management*

Forest lands are identified using methods applied to the identification of forest under the UNFCCC and described in Appendix 6.A. *Forest Management* lands are a subset of *Forest lands* identified using the narrow approach in accordance with practices specified in section 11.6.2.

Forest management lands include:

- all commercial plantations not included under Article 3.3 (i.e. plantations established on or before 31 December 1989);
- all public land available for timber harvesting as at December 2009, specifically multiple-use public forests as identified by the Montreal Process Implementation Group 2008;
- other forest lands (comprising forest lands that were in formal conservation reserves as at December 2009, privately managed native forests and extensively grazed woodlands) where the following activities are observed:
  - harvesting since 1990, and
  - direct human-induced activities which aim to recover the forest from a degraded state, such as enrichment planting, conducted after December 2009.

All forest lands are monitored for harvesting since 1990 because the management intent of forest land outside of plantations, multiple-use public forests and conservation areas is not known. Once an activity is identified, the land on which it occurs is transferred to the *forest management* lands account. This enables the balanced and complete accounting of emissions and removals over time from this activity.

Table 11.16 shows the area of land included under each of these components of *forest management.*

Table 11.16 Land subject to *forest management*

Forest management sub-classifications	Modelled area (M ha)
Multiple use forests	11.1
Private native forests (where harvest has been observed and which have been included in forest management)	0.9
Pre-1990 plantations (commercial plantations not included under Article 3.3)	0.7
Total forest area	**12.7**

11.6.2 Identification of management practices

Forest management includes lands where management practices for the purpose of sustainable production of wood and wood fibre occur, such as:

- harvesting of forests, including thinning, selective harvesting and clearfell;
- silvicultural practices used for forest management;
- slash management, pest control, or fertilisation;
- protection of natural resources within the areas of land available for harvesting; and
- the application of codes of forest practice.

11.6.2.1 Policies included in the reference level projection

Australia has a comprehensive domestic framework designed to achieve the conservation and sustainable management of all of its forests. This framework includes:

- A national policy framework – Australia's 1992 National Forest Policy Statement (NFPS) promotes the conservation and sustainable management of forests.
- Regional Forest Agreements (RFAs) – RFAs have legal status via the national *Regional Forests Agreement Act 2002*. RFAs are 20-year plans underpinning regional approaches to balance conservation and production from native forests and cover the majority of production forest regions in Australia. In addition to forest conservation provisions, RFAs provide certainty for sustainable timber supply.
- Australia's Sustainable Forest Management Framework of Criteria and Indicators 2008 – this is an internationally recognised framework for sustainable forest management applied to Australia's forests.
- State and territory frameworks – jurisdictional legislation and codes of practice are applied to ensure environmentally responsible forestry practices.
- Forest certification – independent third party forest certification applies to most of Australia's production forests.

At the national level, Australia uses the international Montreal Process Criteria and Indicators as the framework for monitoring and measuring the management of forests.

Harvesting in native forests in Australia is regulated both at the national and State level. In 1992, Commonwealth and State governments agreed to a National Forest Policy statement establishing a regime for balancing ecologically sustainable forest management and harvesting with establishment of a Comprehensive, Adequate and Representative (CAR) reserve system to protect areas of environmental and heritage value such as old growth forests. This regime involved scientific research and consultation (called Comprehensive Regional Assessments) to support 20-year Regional Forest Agreements that provide certainty for forest-based industries, forest-dependent communities and conservation.

These agreements represent an important part of the policy context for regulating harvest rates in native multiple-use public forests in Australia. Regional Forest Agreements cover more than 39 million hectares, and in the four states New South Wales, Tasmania, Victoria and Western Australia nearly 17 million hectares are protected from logging under the CAR reserve system (ABARES, 2013). Additionally, the amount of wood that can be harvested from multiple-use public forests under Regional Forest Agreements is regulated using sustainable yield calculations designed to ensure the environmental attributes and the productive capacity of the forest are maintained. There are additional constraints on harvesting from native forests in areas that are reserved for conservation, water or heritage protection or other purposes. The application of codes of forest practice can also restrict harvesting in some areas (ABARES, 2013).

For native forests subject to harvesting (multiple-use public forests and harvested private native forests) inclusion of the relevant pre-2009 policies has been achieved by extrapolating the average harvest rates during the period 2002–2009 to the projection period. This projected harvest rate (Table 11.17) was used to model projected emissions during the FMRL period.

Table 11.17 Forest management reference level harvest rates

	Harvesting area (ha)
Reference Level harvesting (2002–2009 average)	90,726

For pre-1990 plantations, it is assumed in the reference level that harvesting occurs when plots reach maturity based on standard growth rates and rotation lengths, an assumption which is not affected by policy changes.

11.6.3 Methods used to establish the Forest Management Reference Level and for *forest management* reporting

11.6.3.1 Methods for estimating emissions in FMRL and reporting of *forest management*

The methods used in reporting of emissions from *forest management* and for calculation of the technical correction are described below in accordance with IPCC (2014), Chapter 2.7.2. Equivalent methods have been used for *forest management* as for the corresponding UNFCCC forest category (as described in Vol 2 Chapter 6). Consistent with *forest lands remaining forest lands,* emissions from *forest management* have been estimated using the methods described in Chapter 6.4.1. A Tier 3, Reporting method 2 spatial model for *harvested native forests* has been applied to public multiple use forest in the states of Victoria and New South Wales. This spatial method models timber harvesting using specific locations, dates and types of harvesting as provided by state government agencies (Chapter 6.4.1.2). This method also incorporates the weather record since 1970 to simulate the dynamics of the soil carbon pool.

The emissions and removals from *harvested native forests* in other states are estimated using a Tier 2, Reporting method 2 approach, based on the non-spatially explicit Estate modelling capability of FullCAM. This model enables the use of age-based growth data and incorporates the effects of differing silvicultural treatments on the generation and management of harvest slash. The forest classification and related characteristics including biomass and growth rates used to estimate carbon stock changes and emissions are the same as those described for the *harvested native forests* model in Chapter 6.4.1.1. Management and harvesting practices used in the model are also described in Chapter 6.4.1.1, and in Chapter 6.4.2 regarding emissions from post-harvest regeneration burning (slash burning).

The annual change in living biomass in native forests subject to harvesting is the net result of uptake due to forest growth (above and belowground as determined from the growth models) and losses due to forest harvesting. The forest type and harvest type influence the proportions of biomass transferred to the harvested wood products pool or residue material (including belowground biomass) moved to dead organic matter.

Emissions from consumption of fuelwood are estimated using the same methodology described in Chapter 6.4.4. It has been estimated that 19 per cent of emissions from consumption of wood and wood-waste is attributable to *forest management* lands.

The methods used to estimate carbon stock change and emissions for pre-1990 plantations are the same as those described in Chapter 6.4.2.

11.6.3.2 Harvested wood products

A Tier 3, country specific method is used to estimate harvested wood products from forest management. In accordance with IPCC (2014) section 2.8.4 and paragraph 30 of the annex to Decision 2/CMP.7, Tier 3 or country specific methods can be used provided transparent and verifiable activity data is available and methods applied are at least as detailed and accurate as the default factors described in paragraph 29 of the annex to Decision 2/CMP.7. Consistent with ERT recommendations, work is being undertaken to improve the quality controls on Australia's Tier 3 methods through comparisons with the default methods and approaches.

The general approach to estimating carbon stock changes in HWPs is set out in Chapter 6.15 (Source Category 4.G) – *harvested wood products* in Volume 2. The HWP model relies on the log harvest, HWP production and trade data contained in the Australian Forest Product Statistics (ABARES 2020). In this submission, *forest management* includes HWP derived from softwood; all native hardwood; and all plantation hardwood harvests prior to the year

2000. HWP derived from harvests from all hardwood plantations from the year 2000 onwards are included in *afforestation/reforestation.* HWP stored in solid waste disposal sites is not included.

Consistent with Decision 2/CMP.7, only HWP sourced from domestic forests are considered and exported material is included. Estimates are reported according to 3 broad HWP pools: Paper; Sawn wood; and Wood based panels. Accordingly, the 5 pool structure of HWP model used for the UNFCCC inventory is aggregated in the following way for the purposes of reporting:

- Paper and paper-board – pool 1 (very short term paper and paper products);
- Sawn wood – pool 4 and pool 5 (long and very long term products); and,
- Wood based panels – pool 2 and pool 3 (short and medium term products).

11.6.3.3 Data

The same data sources are used for *forest management* as for *forest land remaining forest land,* as detailed in Chapter 6.4.1, Appendix 6.A, 6.E and 6.G.

11.6.3.4 Start year

Estimation of net emissions is undertaken from 1970.

11.6.3.5 Carbon pools

FullCAM estimates emissions from soil through a process involving all on-site carbon pools (living biomass, dead organic matter and soil).

11.6.4 Natural Disturbances

In Australia, wildfire is the most widespread and frequent natural disturbance event which causes significant losses of carbon stock to the atmosphere.[2] Other natural disturbances include drought, storm damage, tropical cyclones, and pests and pathogens.

Decision 2/CMP.7 outlines rules for the reporting of natural disturbances in national inventories (the natural disturbances provision).[3]

The natural disturbance provision has been applied to the estimates of emissions from *forest management.* Australia applies the default approach described in Decision 2/CMP.7 and the IPCC 2013 KP Supplement.

For the Kyoto Protocol, emissions include all gases from all wildfires on lands identified as *forest management* lands. The approach differs to that used in Chapter 6 since the natural disturbance provision is applied to the estimates of emissions rather than to the disaggregation of activity data as in Chapter 6.

2 Natural disturbances are defined in Decision 2/CMP.7 as: Non-anthropogenic events or non-anthropogenic circumstances. For the purposes of this decision, these events or circumstances are those that cause significant emissions in forests and are beyond the control of, and not materially influenced by, a Party. These may include wildfires, insect and disease infestations, extreme weather events and/or geological events. These exclude harvesting and prescribed burning.

3 Annex to decision 2/CMP.7, paragraph 33.

11.6.4.1 Monitoring system for wildfires

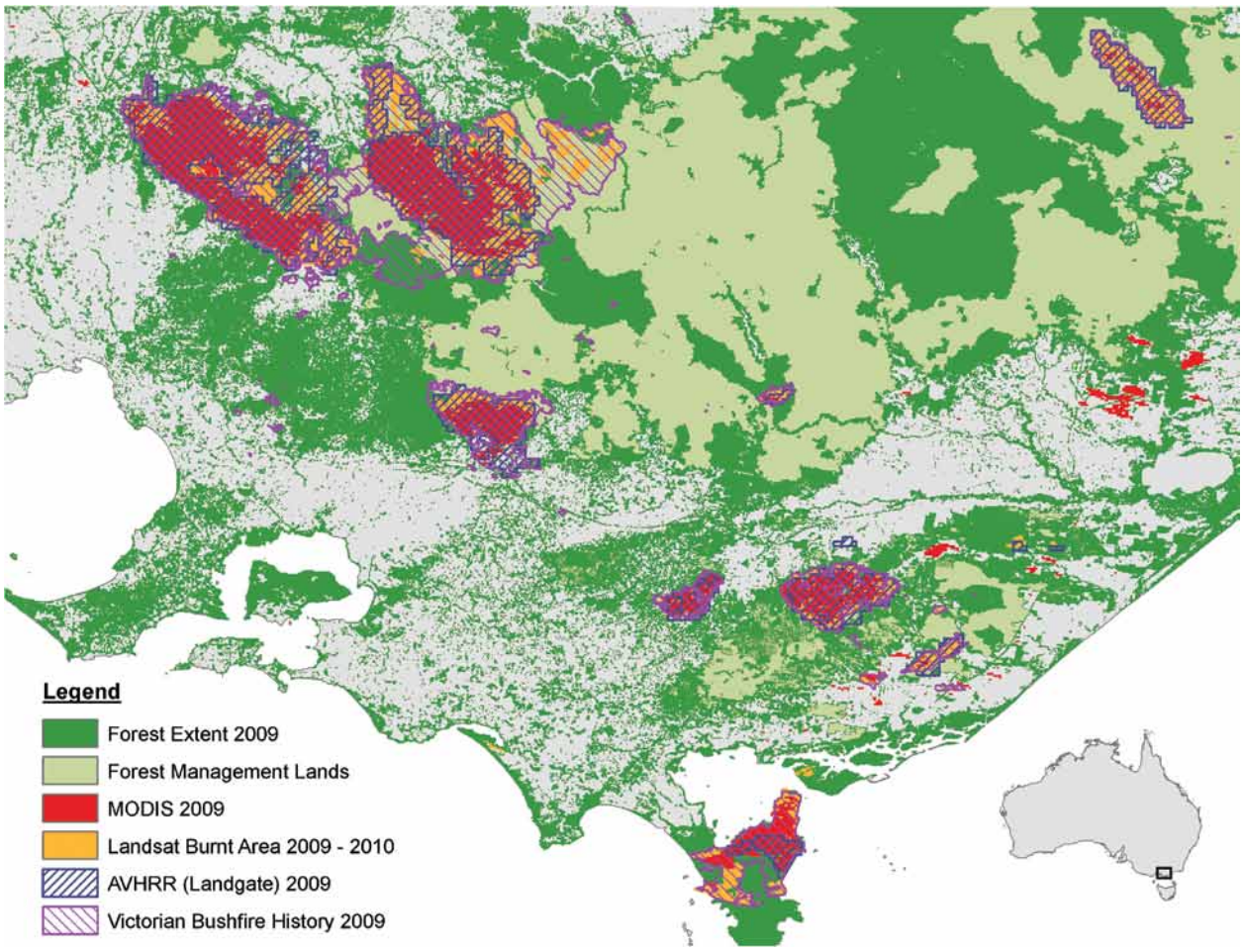
A monitoring system based on the Advanced Very High Resolution Radiometer (AVHRR) has been implemented to identify and map natural disturbance impacts due to wildfire on *forest management* lands. The new system has been designed to comply with the following safeguard mechanisms prescribed under Decision 2/CMP.7, which relate to:

- the use of geolocated time series wildfire activity data,
- coverage of all forest management lands,
- the ability to monitor if there is a permanent land use change on those lands following a wildfire event during the commitment period,
- the inclusion of emissions associated with salvage logging in the accounting,
- identification of lands where the natural disturbance is followed by another disturbance event, in order to avoid double counting, and
- when using remote sensing data, a Party needs to identify the temporal, and spatial resolutions, calibration and validation of wildfire datasets using complementary ancillary and/or ground truth data.

The AVHRR burnt area product produced by the Western Australian Land Information Authority (Landgate), is tailored to Australian conditions and based on the visual interpretation of fire areas by experienced operators. The data was assessed by the Royal Melbourne Institute of Technology (RMIT) (Lowell, 2014), and compared with a range of alternative datasets, and was found to be the most suitable and highest quality time series data available (Figure 11.3). The datasets considered by the RMIT included:

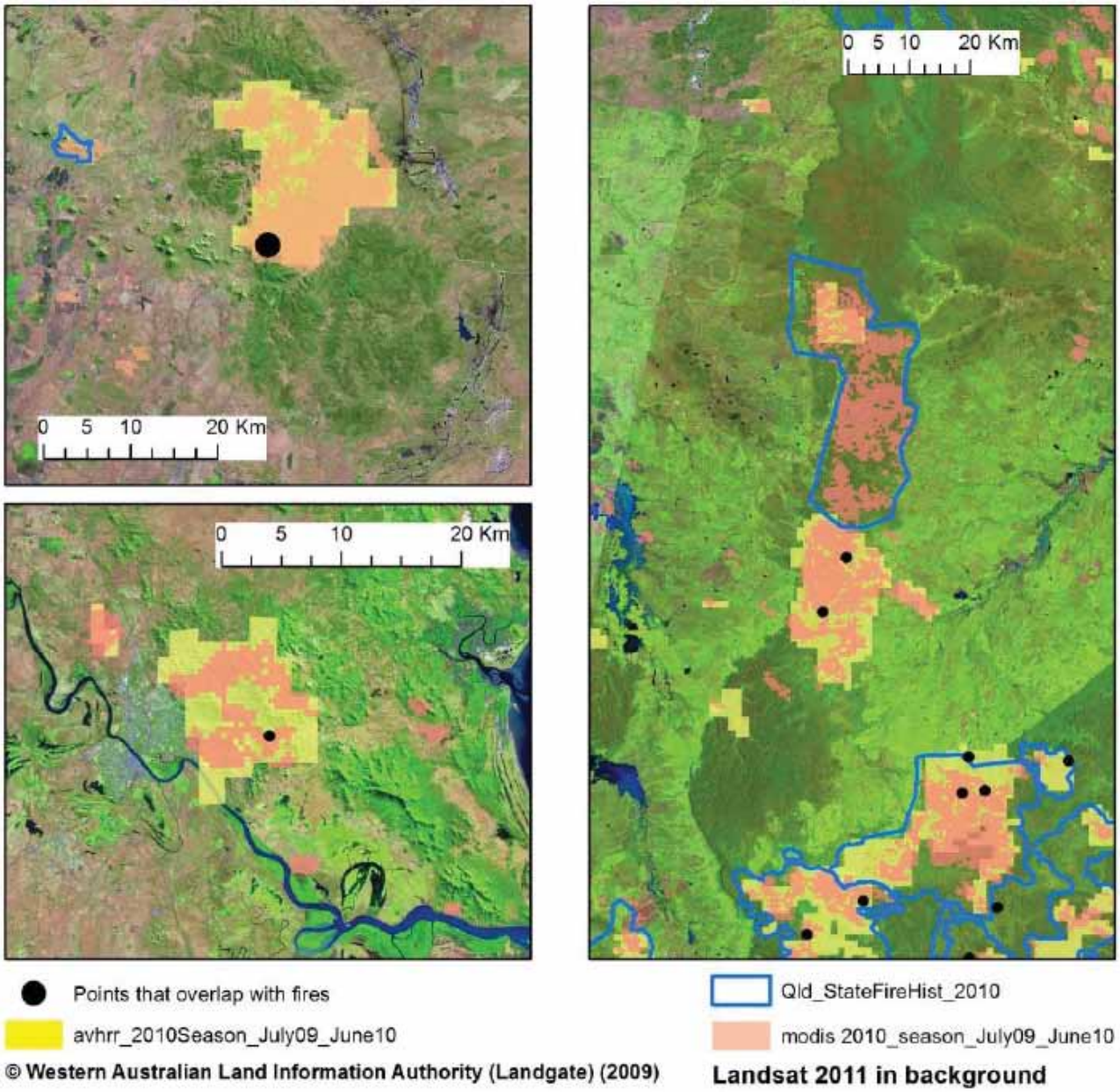
1. Monthly AVHRR burnt area products (1990 to 2014), obtained from the Western Australian Land Information Authority (Landgate);
2. Monthly MODIS burnt area 500m products (2000 to 2013), obtained from the global database maintained by the University of Maryland, USA;
3. Limited coverage of wildfire data from the Landsat series of satellites; and
4. Reference bushfire history data supplied by state agencies.

Figure 11.3 Comparison of 4 bushfire datasets over a part of Victorian multiple-use public forests



The overall quality of the post-2000 AVHRR burnt area products had a low commission error (5.4 per cent) which indicates that 94.6 per cent of the wildfire detected in the Landgate AVHRR burnt area product were correctly classified (Figure 11.4). The omission error was around 11 per cent after accounting for the undetected low-intensity prescribed burns (22 per cent) and smaller fires below the minimum mapping unit (9 per cent) which the 1km resolution AVHRR optical sensors were not expected to detect.

Figure 11.4 Validation of MODIS burnt area (orange), AVHRR burnt area (yellow) using the fire history data from Queensland (blue) derived from Landsat satellites. Black dots represent sampling points



Prescribed burns are estimated on the basis of state and territory agency reports of areas treated or from spatial data supply of treatment areas, as these fire types are hard to detect from coarser resolution satellite missions such as the AVHRR sensor. Chapter 6.4.1.5 and Appendix 6.K provide comprehensive explanations of the process for estimating emissions from prescribed burning.

In addition to the calculation of annual wildfire extent, the system has been designed to monitor post-fire regrowth to ensure that there is no permanent land use change following a fire event (see Section 11.2.3.1).

The system also monitors for incidences of multiple fires affecting the same lands within the commitment period (Figure 11.5, Figure 11.6) to avoid double-counting.

Figure 11.5 AVHRR based burnt area frequency for the period from 1988 to 2020

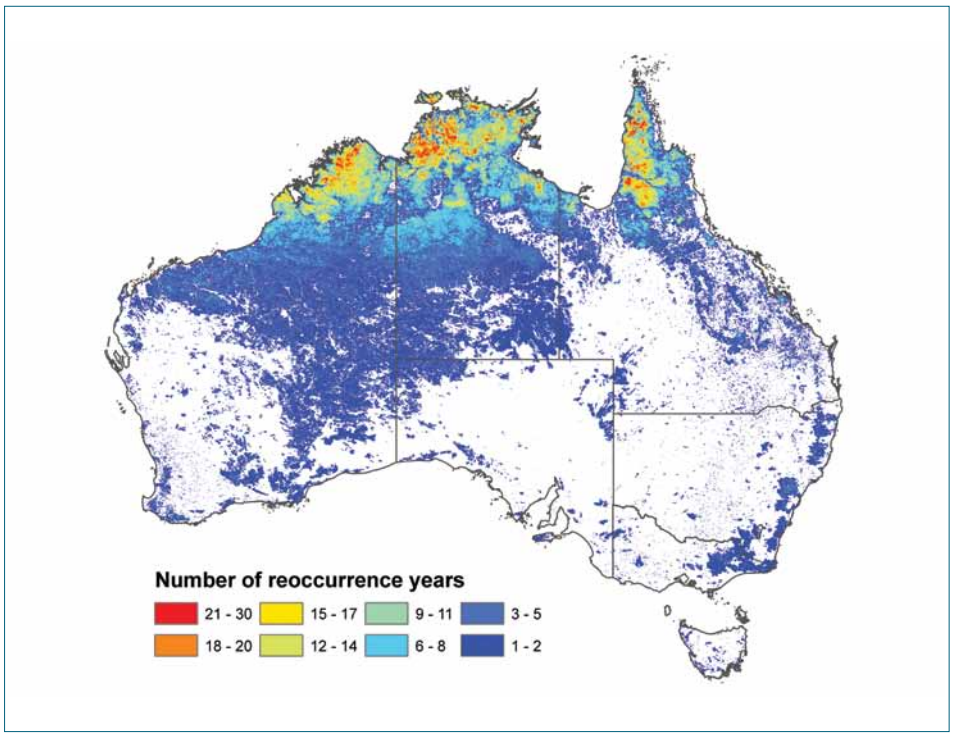
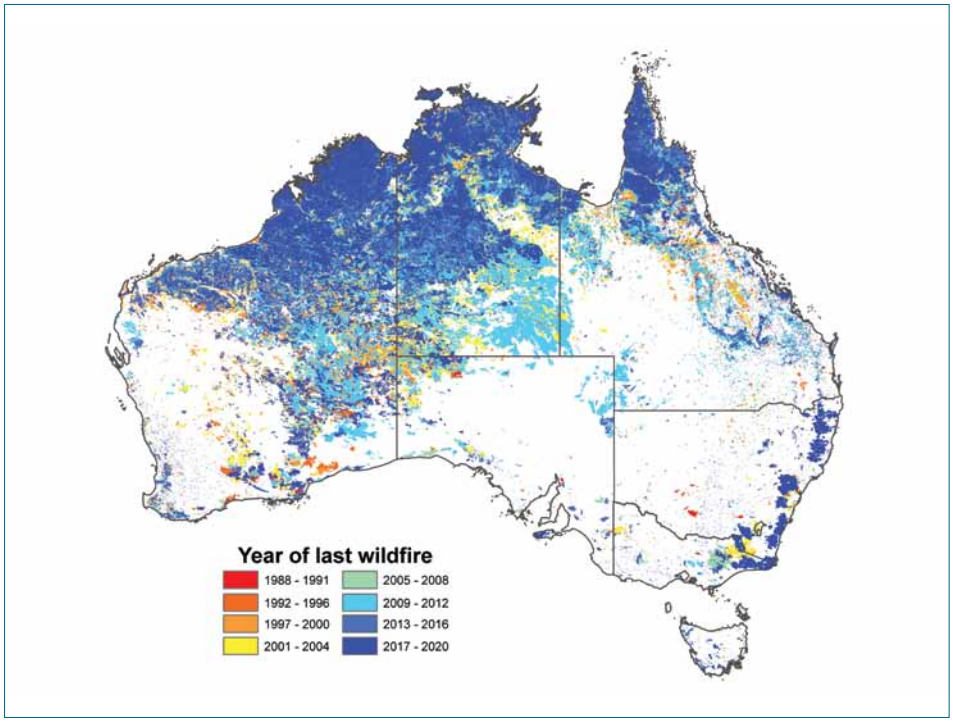


Figure 11.6 Year since last burn for the period from 1988 to 2020



The system will be subject to regular enhancements over time as remote sensing and data processing technologies evolve and as new information becomes available.

11.6.4.2 Method to estimate natural disturbance emissions and subsequent removals on *forest management* lands

The methodology used by Australia to estimate wildfire emissions and subsequent removals on *forest management* lands is consistent with the methodology applied to the *forest land remaining forest land* classification which is documented in section 6.4.3.

11.6.4.3 The Background Level and the Margin

Australia has calculated a background level and margin using the IPCC default method (see IPCC 2014, page 2.48–2.50) for the natural disturbance of wildfire. The background level and margin are presented in Table 11.18.

Table 11.18 Components of Australia's background level and margin for wildfire

Parameter	Value
Calibration period	2000–2012
Method used	IPCC default
Background level	4,622 kt CO_2-e
Margin	4,965 kt CO_2-e
Background level plus margin	9,587 kt CO_2-e
Number of excluded years	Four
Excluded years	2003, 2007, 2009, 2010

IPCC quality criteria for the construction of the background level plus margin

Four criteria for determining whether the data used to construct the background level and margin could result in an expectation of net credits or net debits are set out in Box 2.3.6 of IPCC (2014) page 2.50:

1. *Trend* – If there is a trend in natural disturbance emissions during the calibration period that is not considered in the background level estimation, or expected during the commitment period, then this could create an expectation of net debits or net credits.

2. *Balance* – The background level of emissions is equal to the average of the annual emissions from natural disturbances during the calibration period which are in the background group.

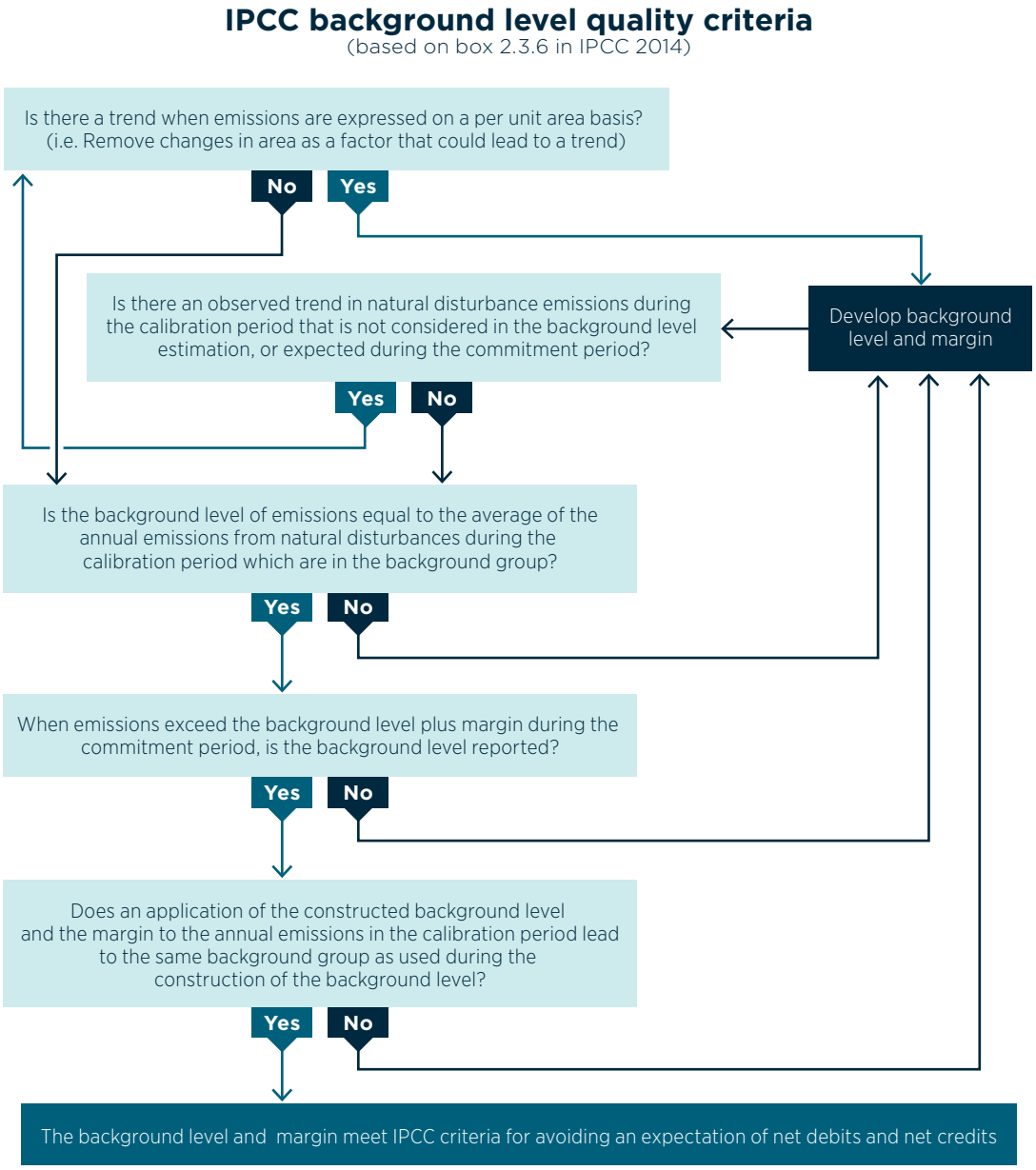
3. *Reporting the background level* – Any emission from natural disturbances during the commitment period that falls into the background group is not separately excluded from accounting. During the commitment period, emissions are only excluded from accounting when the annual emissions are greater than the background level plus the margin. When this occurs, only those emissions that are greater than the background level are excluded.

4. *Validation* – A test application of the constructed background level and the margin to the annual emissions in the calibration period leads to the same background group as used during the construction of the background level.

The procedure shown in the decision tree below (Figure 11.7) was implemented to ensure that the specified background level and margin meet these four criteria.

Reporting of natural disturbances and calculation of the background level and margin are both based on gross emissions only, instead of net emissions and removals (CO_2 removals due to post-fire regrowth are not reported). When CO_2 removals are also calculated, removals from previous year's natural disturbances can effect whether subsequent years exceed the background level and margin. Exclusion of removals therefore improves transparency in the application of the iterative process to remove outliers to establish the background group, and simplifies the application of the four IPCC criteria above.

Figure 11.7 Decision tree to support the development of a natural disturbance background level that is consistent with the IPCC background level quality criteria



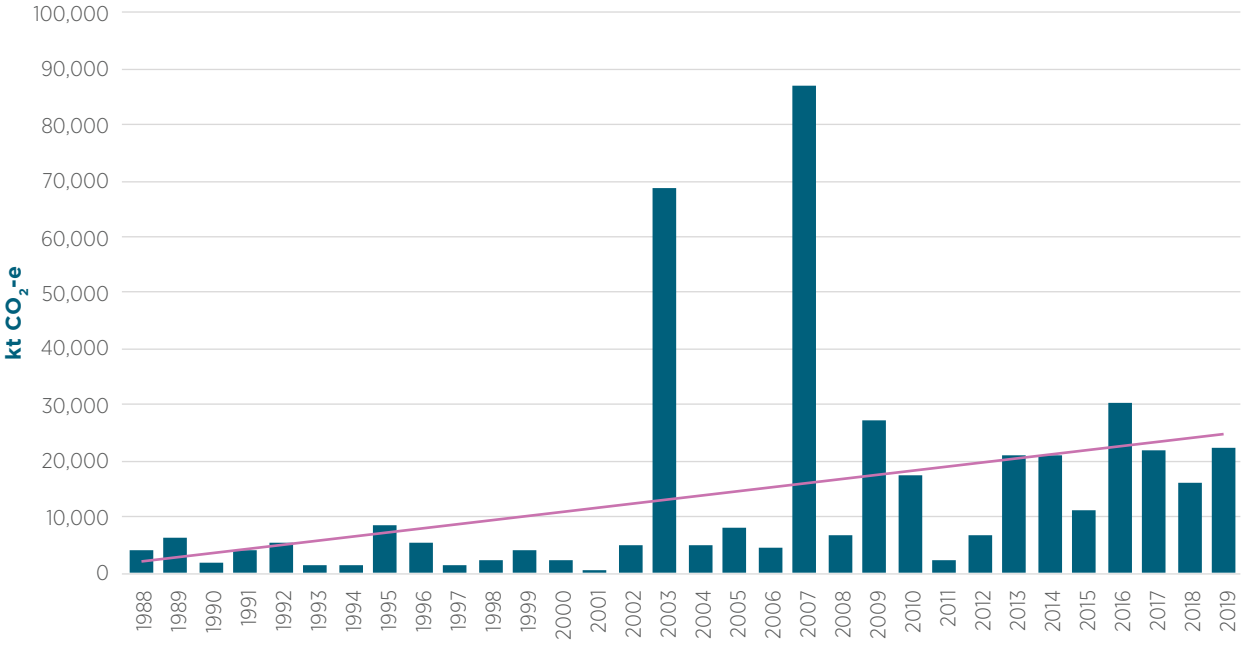
Trend criterion

Decision 2/CMP.7 indicates parties should use data from 1990–2009 – known as the calibration period – for the purpose of developing the background level and margin.

An important condition that must be satisfied is that there is no observable trend in natural disturbance emissions over the available time series. As shown in Figure 11.8, this condition is not satisfied by the full time series data on wildfire in Australia. Based on this trend assessment, the period 1988–1999 was excluded from the calibration group.

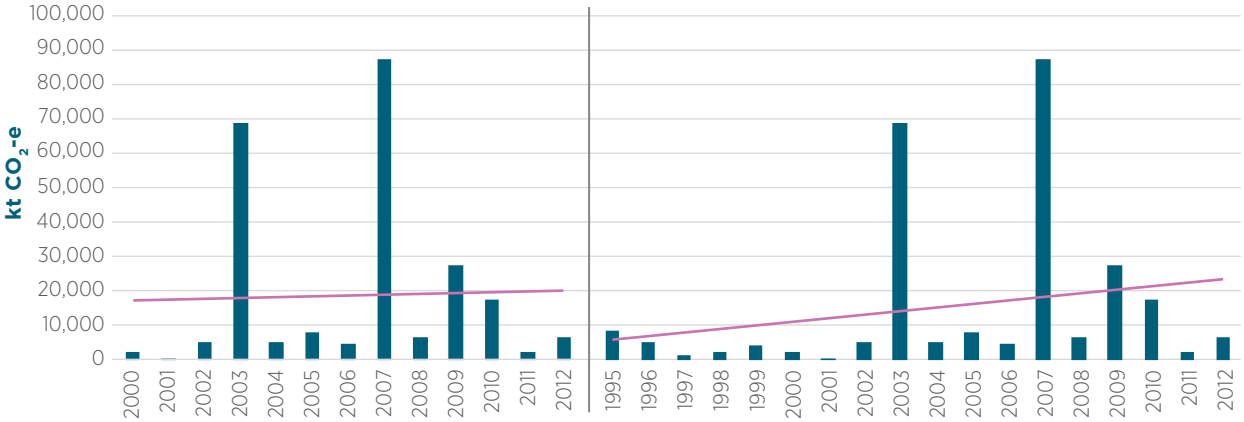
The period chosen to establish the dataset that underpins the estimation of the background level is 2000–2012. This selected calibration group was then tested against the three IPCC quality criteria.

Figure 11.8 Wildfire burnt CO_2 emissions on *forest management* land and trend line, excluding CO_2 emissions associated with salvage logging



As shown in Figure 11.9 the slope of the trend line for the selected calibration period (2000–2012) is shallower than the slope of a longer calibration period (e.g. 1995–2012) (Figure 11.9).

Figure 11.9 Comparison of emissions trend across the selected calibration period and of a longer calibration period (1995–2012)



If the trend lines in Figure 11.9 are extended over the period 2013–2020 the increase in emissions for the selected calibration period is 2,820 kt CO_2-e while with a longer calibration period, for example 1995–2012, the increase in emissions is 17,318 kt CO_2-e.

While there remains a trend in the selected calibration period, the period 2000–2012 was selected to balance the need to limit the trend in emissions against having a calibration period that was too short.

Investigations were made to consider the use of a longer time series including the period 1990–2009 and earlier. This was found not to be feasible due to the absence of readily-available, reliable and consistent source data prior to 1988. While some data on historic natural disturbances exists, it is more difficult to source data for fires other

than natural disturbances between these popularly-reported events in most Australian States, which would be essential for the derivation of a useful time series.

Balance criterion

To meet the balance criterion, the calculated background level must equal the average of the annual emissions from natural disturbances during the calibration period which are in the background group.

The performance of the calculated background level against the balance criterion is shown in Table 11.19, which shows the calculated background level meets the balance criterion.

Table 11.19 Test of the balance criterion for a background level based on the 2000–2012 calibration group

Years included in background group	Wildfire emissions kt CO_2-e
2000	2,196
2001	535
2002	5,025
2004	5,161
2005	8,156
2006	4,654
2008	6,741
2011	2,411
2012	6,716
Average of background group	4,622
Background level	4,622
Difference	-
Balance criterion met?	Yes

Reporting of the background level

Emissions should only be excluded from accounting when annual emissions are greater than the background level plus margin, and when this occurs only those emissions and removals exceeding the background level should be excluded (that is, the background level should be reported). Table 11.20 shows that only emissions exceeding the background level are excluded in years where the natural disturbances provision is applied.

Table 11.20 Reported wildfire emissions and excluded natural disturbance emissions

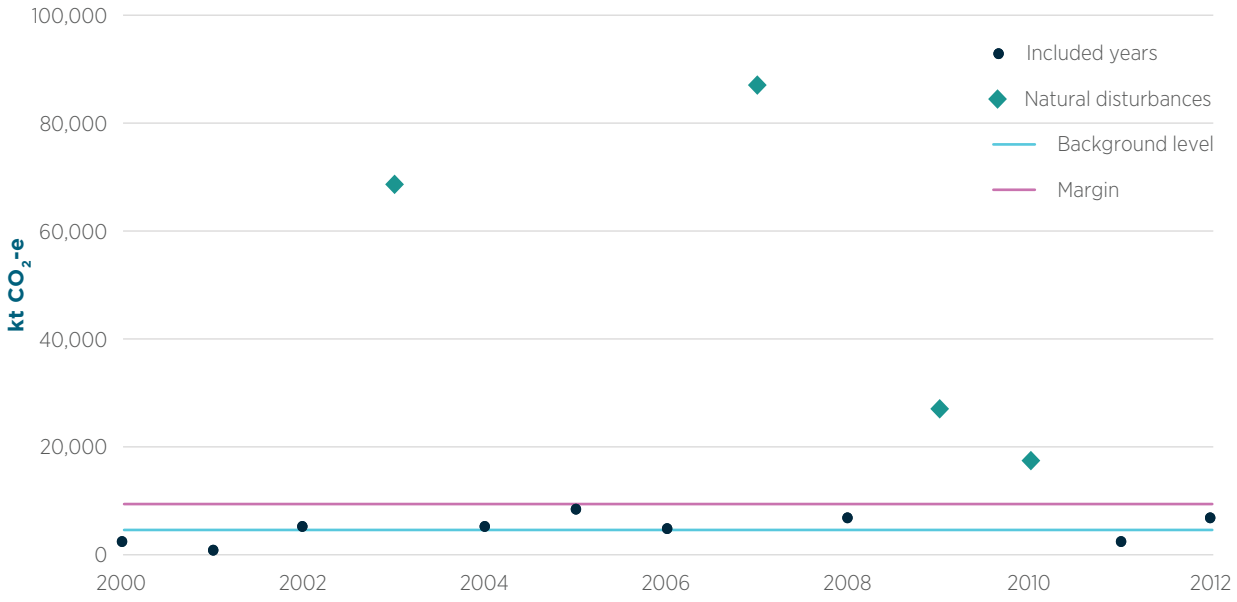
Year	Total emissions including natural disturbances	Reported emissions (after excluding natural disturbances)	Natural disturbance emissions that are excluded from reporting
		(kt CO_2-e)	
2000	2,196	2,196	0
2001	535	535	0
2002	5,025	5,025	0
2003	68,847	4,622	64,225
2004	5,161	5,161	0
2005	8,156	8,156	0
2006	4,654	4,654	0
2007	87,083	4,622	82,461

Year	Total emissions including natural disturbances	Reported emissions (after excluding natural disturbances)	Natural disturbance emissions that are excluded from reporting
		(kt CO_2-e)	
2008	6,741	6,741	0
2009	27,247	4,622	22,626
2010	17,273	4,622	12,651
2011	2,411	2,411	0
2012	6,716	6,716	0
2013	20,890	4,622	16,268
2014	21,158	4,622	16,536
2015	11,418	4,622	6,796
2016	30,430	4,622	25,808
2017	21,698	4,622	17,076
2018	16,291	4,622	11,669
2019	22,264	4,622	17,642

Validation criterion

To satisfy the validation criterion, the emissions in any of the background group years should not exceed the background level plus margin. As shown in Figure 11.10, emissions in the background group years do not exceed the background level plus margin. The validation criterion has been met.

Figure 11.10 Background level and background level plus margin based on the 2000–2012 calibration data set



11.6.4.4 Demonstration that the expectation of net credits/net debits is zero.

According to IPCC (2014) (section 2.3.9.6, step 5) it is *good practice* for parties to ensure that the method applied to the development of the background level and margin does not lead to the expectation of net credits or net debits.

The Australian Government monitors the implementation of the background level and margin to ensure that there is no expectation of net debits or net credits associated with the implementation of the natural disturbance provision. If such a situation arises a technical correction will be applied to the FMRL.

11.6.4.5 Ensuring that emissions caused by salvage logging on land subject to natural disturbance are transparently reported

Emissions from salvage logging are included in estimates for multiple-use public forests, harvested private native forests and pre-1990 plantations. Estimates of forest harvesting are based on a combination of log production information that includes the products of salvage logging, and spatial data on salvage harvesting activity in those states where tier 3 models for native forest harvesting have been implemented. Log production statistics do not differentiate between material sourced from conventional clear felling and salvaging activities following wildfire or other natural disturbances.

A review of salvage harvesting by ABARES (Finn *et al.,* 2015) identified that this is a very minor activity compared to either total harvesting activity or total areas burned. Salvage harvesting is generally opportunistic, determined as much by commercial factors as biophysical factors. However it does occur more often in forest and plantation types which are located in areas with sufficient harvesting capacity. A time series of emissions associated with salvage logging has been developed utilising industry data on the national sales of salvaged pine, and spatial logging information provided by the state government of Victoria and New South Wales, where salvage harvesting of multiple use forests is known to occur (Table 11.21). In recent years, multiple use forest salvage harvesting has predominantly occurred in ash forests where the combination of economic factors are conducive to salvage harvesting practices. For plantation pine, estimates of biomass volumes per hectare or per unit of harvested wood are based on harvesting parameters from FullCAM. Estimates of wood density and carbon content are drawn from parameters used in the modelling of *harvested wood products.* For multiple use forest salvage harvests, estimates of biomass volume and harvest-related emissions are estimated in FullCAM using spatial simulations.

Table 11.21 Estimates of salvage logging activity and emissions

Year ending 30th June	Pine plantation salvage harvests (m^3)[(a)]	Pine plantation emissions (kt CO_2-e C)[(c)]	Multiple Use Forest salvage harvests (m^3)[(b)]	Multiple Use Forest emissions (kt CO_2-e C)	Total Emissions (kt CO_2-e C)
2007	496,416	419	41,980	82	501
2008	425,350	359	211,399	663	1021
2009	389,591	329	184,638	496	825
2010	438,792	370	415,000	1,302	1672
2011	516,658	436	300,112	785	1220
2012	179,179	151	32,176	110	261
2013	111,708	94	0	0	94
2014	101,138	85	0	0	85
2015	76,187	64	2,569	9	73
2016	86,850	73	1,465	6	79
2017	106,016	89	3,228	5	94
2018	115,247	97	0	0	97
2019	95,103	80	0	0	80

(a) Based off the Australian Pine Log Price Index (stumpage), KPMG, 2019

(b) Based off spatial simulations of State harvesting data in FullCAM

(c) assumes instant oxidation of harvest area biomass for pine

11.6.4.6 Information that natural disturbance events were beyond the control of the party (IPCC 2014, page 2.36)

In Australia, wildfires threaten life and property, and are addressed in disaster response plans and management arrangements in each State and Territory. In addition to such disaster management policies, there is also a significant research effort into understanding and better managing wildfires, and following many significant fire events, inquests or enquiries are held to assess the disaster response and potential for improvement.

There are fire management policies and plans in place at the national and the state and territory level to control for the risks, events and consequence of wildfire to the extent that this is possible. These documents set out frameworks for:

- Reducing the likelihood of a wildfire occurring, for example, through the use of prescribed burning;
- Managing or controlling the disturbance during its occurrence;
- Monitoring programs and early warning systems; and
- Firefighting operations.

The implementation of plans and strategies to avoid and minimise risks to life and property from wildfires is documented in the following section.

National level

The National Bushfire Management Policy Statement for Forests and Rangelands (FFMG 2014)[4] outlines Australian, state and territory government objectives and policies for the management of landscape-level fire in Australia's forests and rangelands. The statement was developed by the Forest Fire Management Group, a national body within the Council of Australian Governments, with the role of providing information to governments on major forest fire-related issues, policies and practices affecting land management. The Australasian Fire and Emergencies Authorities Council is the national peak organisation that provides advice on a range of polices and standards. Research on bushfires is performed by a number of organisations, including:

- the Bushfire Cooperative Research Centre, which brings together experts from universities;
- the Commonwealth Scientific and Industrial Research Organisation (CSIRO);
- other Australian, state and territory government organisations, and;
- the private sector for long-term programs of collaborative research.

The national Bureau of Meteorology publishes fire weather warnings and has a role in the declaration of fire bans when weather conditions are conducive to the spread of dangerous bushfires. Warnings are generally issued within 24 hours of the potential onset of hazardous conditions. Warnings are also broadcast on radio and television.

Fire agencies determine Fire Danger Ratings. In most States and Territories, fire agencies declare fire bans based on a range of criteria including forecast weather provided by the Bureau.

The Bureau also incorporates Total Fire Ban Advices into warnings, if one is being enforced at the time of issue, and an action statement from local fire authorities detailing areas where the ban is in effect.

Fire Weather Warnings are distributed through the media, fire agencies and other key emergency service organisations. Warnings are normally issued in the afternoon for the following day so to be available for evening television and radio news broadcasts. Warnings are renewed at regular intervals and generally at the same time major forecasts are issued. However, warnings may be issued or amended and reissued at any time if

4 https://www.semc.wa.gov.au/riskmanagement/Documents/NationalBushfireManagementPolicy_2014.pdf

a need is identified. If there is a Fire Weather Warning current, the Bureau will mention this in State, Territory and District weather forecasts for that area.

In each State the issue of a Fire Weather Warning has different impacts on restrictions for lighting fires.

The Bureau of Meteorology does not have the power to declare a Total Fire Ban. This responsibility resides with designated fire agencies in each State and Territory. However, in South Australia, Northern Territory, Victoria, New South Wales and Tasmania, the Bureau does issue Total Fire Ban Advices to assist publicising and distributing the message. The Bureau also includes information about the existence of current fire bans in weather forecasts and warnings.

The areas covered by fire bans do not align with Bureau forecast districts in New South Wales, Tasmania and Northern Territory.

State and territory level

Each state and territory has published a document which sets the framework for the management of bushfires. These plans include information on the use of public information campaigns and requirements around the declaration and publication of fire bans and fire danger ratings during fire seasons. In Queensland the documents are published for a number of regions within the state, rather than at the state level.

New South Wales (NSW)

The aim of the State Bush Fire Plan is to set out the arrangements for preparedness, prevention, mitigation, response to and recovery from bush fire events by combat, participating and support agencies in NSW, including Lord Howe Island.

This plan describes the arrangements for the control and coordination by the New South Wales Rural Fire Service (NSW RFS) Commissioner for the response to Class 2 & 3 bush and grass fires, including those managed under the provisions of section 44 of the Rural Fires Act 1997, and the provisions for emergency warnings at all classes of fires.

These arrangements ensure that the two combat agencies, NSW RFS and Fire & Rescue NSW, are able to manage small scale bush and grass fires, utilising assistance from the other fire-fighting authorities being the National Park & Wildlife Service and Forestry Corporation NSW.

The current NSW State Bush Fire Plan is available at www.emergency.nsw.gov.au.

Victoria (VIC)

Victoria's State Bushfire Plan provides an overarching view of responsibilities of agencies, government and communities in bushfire management.

The first version of the State Bushfire Plan was developed in 2012 in conjunction with the Country Fire Authority, the Metropolitan Fire Brigade, the Department of Environment and Primary Industries and the Fire Services Commissioner.

The second version of the State Bushfire Plan was produced in 2014, with updates to reflect the changes in Victorian emergency management legislation and the emergency management sector.

The plan reflects an integrated approach and shared responsibility for bushfire management between government, agencies, business, communities and individuals.

Although intended as a reference document for fire and emergency management agencies, the State Bushfire Plan will be of equal interest to anyone who works or volunteers in bushfire management.

The State Bushfire Plan is a sub-plan of the State Emergency Response Plan, found in the Emergency Management Manual of Victoria, the principal document for guiding the State's emergency management arrangements.

Victoria's State Bushfire Plan is available at www.emv.vic.gov.au.

Queensland (QLD)

In Queensland, fire management policies and plans are developed at regional rather than at the state level. The Queensland government provides an overview of the approach to disaster management in the *Queensland Prevention, Preparedness, Response, and Recovery Disaster Management Guideline* for local, district, and state disaster management stakeholders with regard to their functions, obligations and legislative requirements under the *Disaster Management Act 2003*.

The aim of the Guideline is to provide flexible, good practice suggestions and advice to those responsible for implementing disaster management practices. It is augmented with other manuals, reference guides, forms, templates, maps, diagrams, handbooks and links to related publications, designed to support stakeholders to fulfil their disaster management responsibilities to the Queensland community.

The Guideline and additional items can be accessed from the Queensland Government Disaster Management website at www.disaster.qld.gov.au.

Western Australia (WA)

Western Australia has developed a series of State Hazard Plans (Westplans) through its State Emergency Management Committee. These include a hazard plan for fire which is intended to be read in conjunction with the State Emergency Management Plan.

The State Hazard Plan for Fire provides an overview of arrangements for the management of fire in WA and contains information on fire prevention, preparedness, response and initial recovery. These plans are available at semc.wa.gov.au.

South Australia (SA)

In South Australia, the State Emergency Management Committee (SEMC) is responsible for the State Emergency Management Plan (SEMP), which sets out the state's comprehensive emergency management arrangements. The South Australian Fire and Emergency Service Commission is the lead agency for disaster resilience in SA and is a member of the SEMC.

The SEMP describes SA's emergency management arrangements to support resilience, preserve and save lives, and reduce risk to the environment, property and infrastructure. It takes an 'all-hazards' approach to emergency management including bush fires as a large range of hazards can cause similar problems and similar arrangements are required to manage them.

The South Australian State Emergency Management Plan is available at www.dpc.sa.gov.au.

Tasmania (TAS)

Tasmania's State Fire Management Council (SFMC) is established under Section 14 of the *Fire Service Act 1979* (Tasmania). It is an independent body that has the responsibility of providing advice to the Minister and the State Fire Commission about the management of vegetation fire across Tasmania, particularly in the areas of prevention and mitigation of fires. It also formulates and promulgates policy in relation to vegetation fire management within Tasmania in relation to bushfire fuels and mitigation. The primary function of the SFMC is to develop a State Vegetation Fire Management Policy that is used as the basis for all fire management planning.

Fire protection plans have been prepared for each of the ten fire management areas in Tasmania to identify and prioritise bushfire risks in the landscape and strategically identify work that can be done to mitigate that risk.

The objective of the plans is to effectively manage bushfire related risk within those areas in order to protect people, assets and other things valuable to the community. The plans identify that strategic fuel management needs to occur across public and private property boundaries in order to be effective and that management of bushfire related risk is not the sole responsibility of any one land manager or agency but a shared responsibility of the whole community.

Fire protection plans for the various regions of Tasmania are maintained on the SFMC website at www.sfmc.tas.gov.au.

Northern Territory (NT)

In the Northern Territory, fire management in urban areas is the responsibility of the NT Fire and Rescue Service, and in rural areas is the responsibility of Bushfires NT.

Bushfires NT is the lead government agency for rural bushfire management in the NT and exists to help protect life, property and the environment from bushfire by providing support for mitigation, management and suppression activities, and coordinating landowner and volunteer participation in response to significant fires.

The Territory Emergency Plan has been prepared by the Northern Territory Emergency Service in accordance with the *Emergency Management Act* in order to describe NT's approach to emergency and recovery operations, the governance and coordination arrangements, and roles and responsibilities of agencies. It is supported by regional, local and hazard-specific sub plans and functional group supporting plans.

The Territory Emergency Plan and further information is available at www.pfes.nt.gov.au.

Australian Capital Territory (ACT)

The ACT Government Emergency Services Agency's Strategic Bushfire Management Plan is the overarching document that directs all levels of bushfire planning in the ACT. Its purpose is to provide a strategic framework to protect the ACT community from bushfires and reduce resulting harm to the physical, social, cultural, and economic environment of the ACT.

The plan sets objectives and actions for agency and community preparation and response for bushfires, bushfire hazard assessment and risk analysis, bushfire prevention including hazard reduction, and adaptive management to apply best practice to bushfire management and prevention practices in the ACT in a changing environment.

The latest version of the plan draws on continuing research into fire management, bushfire behaviour, the effects of climate change and seasonal weather, the important role of the community, lessons learned nationally and internationally, and feedback from the community. It is available at esa.act.gov.au.

11.6.4.7 Information to identify lands where the natural disturbance is followed by another disturbance event, in order to avoid double counting (IPCC 2014, page 2.45)

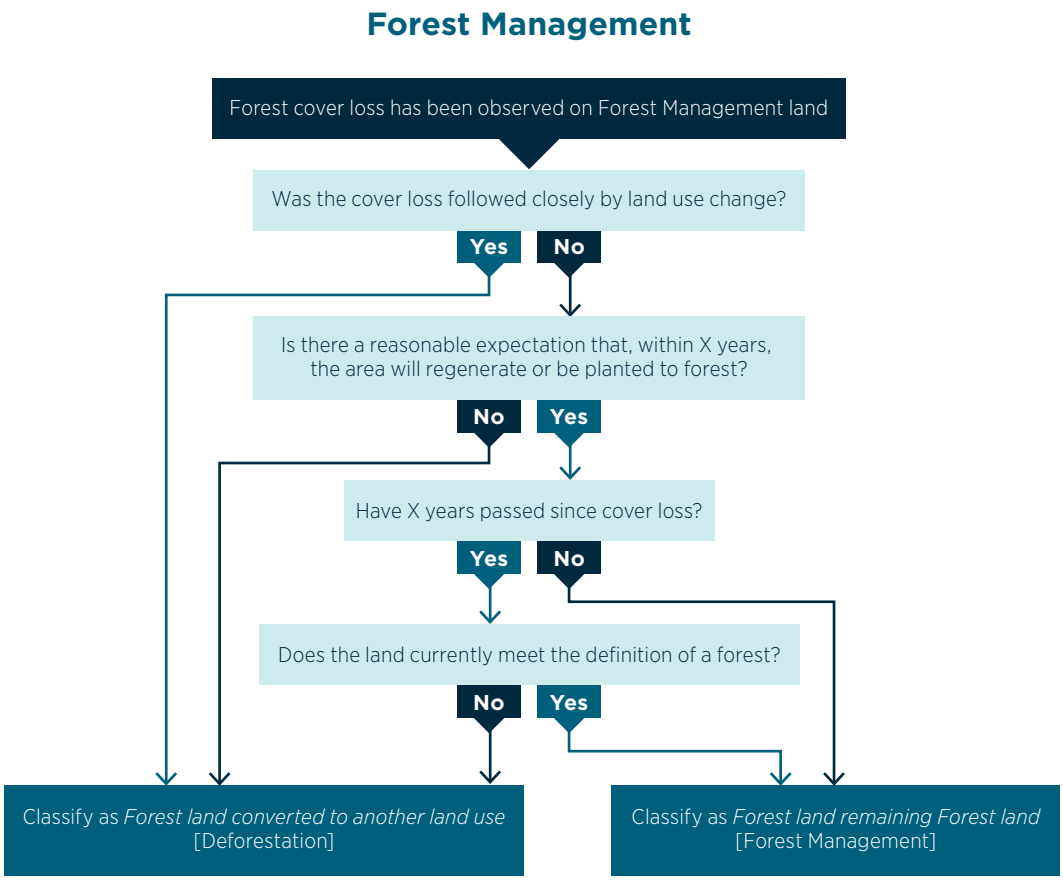
Wildfire natural disturbance events are monitored using data derived from the AVHRR sensor as described in section 11.6.4.1. The system established to monitor, track and archive the AVHRR burnt area data detects incidences of burnt areas on the same unit of land within the commitment period.

The method for estimating carbon stock changes from a natural disturbance event is documented in Volume 2, section 6.4.I.3. According to this method, the biomass consumed during a wildfire in temperate forests recovers over a number of years following the fire, modelled using Tier 3, Approach 3 spatial simulation using FullCAM. On average across Australia, fuel loads reach 95 per cent of equilibrium levels within 11 years (Roxburgh *et al.* 2015). Where repeat burning is observed before fuel loads are fully recovered, emissions from the second fire are based on the modelled fuel recovery at the time of the fire. This ensures that double-counting of emissions is avoided.

11.6.4.8 Information to identify lands where land use change has occurred after a natural disturbance (IPCC 2014, page 2.45)

All forest land is monitored for harvesting and deforestation events. *Forest management* land is monitored for 12 years following forest cover loss events (due to harvesting, fire and other disturbances) to determine if land use change has occurred (section 11.2.3.1) consistent with the requirements for determining if land is subject to *deforestation* specified in Figure 2.6.1 of IPCC (2014) (Figure 11.11).

Figure 11.11 Monitoring and classification of *forest management* land following a forest cover loss event



11.6.4.9 Information on efforts to rehabilitate the land subject to natural disturbances (IPCC 2014, page 2.53)

The need for rehabilitation of Australia's native forests following natural disturbance is dependent upon the nature of the disturbance. Australia's native forest are generally dominated by fire tolerant species. The principal fire tolerant responses in forest tree species are summarised in Table 11.22[5]. Some species however, for example Mountain Ash *(Eucalyptus regnans)* and Alpine Ash *(Eucalyptus delegatensis)* are vulnerable to frequent fires as the plants are unable to reach maturity and produce sufficient seed before the next fire.

In the case of Alpine Ash there are examples of the need for re-seeding following fire to ensure the rehabilitation of the forest.[6]

Table 11.22 Adaptation of Australia forest genera to fire

Adaptation to enable natural regeneration after fire	Forest genera
Stimulation of seed release from woody capsules by heat and desiccation	*Casuarina, Hakea, Banksia, Leptospermum and Eucalyptus.*
Stimulation of germination of soil-stored seed by fire	*Acacia*
Stimulation of bud development after fire from lignotubers	*Eucalyptus*

11.6.5 Forest management reference level technical correction

Australia's 2011 FMRL submission (DCCEE, 2011) outlines the methods used for estimating the reference level.

There have been a number of methodological refinements since this reference level was submitted, which include changes to address the subsequently agreed rules for implementing the natural disturbances provision and calculating emissions from harvested wood products (UNFCCC, 2011). There have also been refinements to other methodological elements used in the estimation of emissions from *forest management.*

Methodological consistency between the reference level and the reporting of *forest management* in the national inventory must be demonstrated, including by making technical corrections to the FMRL if necessary. If there are any recalculations of the historical data used to establish the reference level, a technical correction must be applied.

In order to maintain such methodological consistency, a technical correction has been estimated as -0.19 Mt CO_2-e. This correction incorporates corrections to the sub-categories of *forest management* reporting (Table 11.23).

5 Atwell, Kriedemann, and Turnbull (1999) Plants in Action, Macmillan Education Australia, Melbourne.

6 http://archive.premier.vic.gov.au/2014/media-centre/media-releases/7162-helicopters-sowing-alpine-ash-forest-followingharrietville-fire.html

Table 11.23 Technical correction by sub-category – summary

	Multiple-use public forests	Harvested private native forests	Pre-1990 plantations	Prescribed burning	Included natural disturbance emissions	Fuelwood combusted	Harvested wood products	N-Mineralisation	Total
FMRL 2011 Submission	-9.93	8.94	0.27	0.19	8.68	1.29	-4.74	na	**4.700**
FMRL Estimate in 2015_13	-7.81	5.70	2.63	0.10	2.63	1.60	-3.73	na	**1.117**
FMRL Estimate in 2016_14	-9.68	7.29	2.72	0.65	3.90	-0.12	-4.87	0.03	**-0.085**
FMRL Estimate in 2017_15	-10.04	7.59	3.23	0.65	3.90	-0.13	-4.87	0.03	**0.364**
FMRL Estimate in 2018_16	-10.05	7.57	3.23	0.65	3.90	-0.13	-4.57	0.03	**0.630**
FMRL Estimate in 2019_17	-10.05	7.57	4.16	0.65	3.40	-0.13	-4.47	0.03	**1.159**
FMRL Estimate in 2020_18	-10.05	7.59	2.42	0.65	5.32	-0.13	-4.48	0.03	**1.354**
$FMRL_{corr}$ in 21_19	-6.09	7.59	2.55	0.79	4.62	-0.13	-4.48	0.04	**4.885**
Technical Correction ($FMRL_{corr}$ minus FMRL 2011)	3.83	-1.35	2.28	0.59	-4.05	-1.41	0.26	0.04	**0.185**

Relevant criteria under IPCC (2014) (page 2.101) that trigger the requirement to report a technical correction include: The method used to report emissions and removals from *forest management* changed after the adoption of FMRL.

Any of the following methodological elements used to establish the FMRL (as reported in the FMRL submission) changed after the adoption of the FMRL.

- Pools and gases
- Area under forest management
- Historical inventory data Forest characteristics and related management
- Historical harvesting rates
- Climate data assumed by models for projecting FMRL
- *Harvested wood products* (including data or methods)
- Natural Disturbances.

Table 11.24 Elements of technical correction and cross-reference with IPCC good practice guidance

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Total correction	**0.19**	(sum of corrections reported in NIR 2013-2019)		
New corrections reported in NIR 2019	**3.53**			
Multiple-use public forests	3.96	Tier 3, Reporting Method 2 model developed for States of NSW and Victoria. This improves accuracy of estimates, and makes the model responsive to climate variability, especially for soil carbon.	Criteria 1. change of GHG reporting method Criteria 2.f different observed climate data to what was assumed in the FMRL	Methodological change to move to a higher tier, consistent with the inventory improvement plan (available data and new inventory methods become available; Vol 1, Ch 5.2.1).

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Pre-1990 plantations	0.12	Modelling improvements primarily affecting soil decay rates, consistent with other components of LULUCF	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement (new inventory methods have become available; Vol 1, Ch 5.2.1)
Prescribed burning	0.14	Tier 3, Reporting Method 2 model developed for States of NSW, Victoria, ACT, South Australia. This improves accuracy of estimates.	Criteria 1. change of GHG reporting method	Methodological change to move to a higher tier, consistent with the inventory improvement plan (available data have changed; Vol 1, Ch 5.2.1).
Natural Disturbances	-0.70	Modelling improvements including revised biomass recovery function	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement (new inventory methods have become available; Vol 1, Ch 5.2.1)
N-Mineralisation	0.01	Recalculation to soil C pool in Harvested private native forests, multiple-use public forests, and pre-1990 plantations (due to recalculations described above)	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
New corrections reported in NIR 2018	**0.19**			
Harvested private native forest	0.02	Correction to historical data on wood production affecting age-class structure of forests.	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, CH 5.2.1)
Multiple-use public forests	-0.01	Correction to historical data on wood production affecting age-class structure of forests.	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, CH 5.2.1)
Pre-1990 plantations	-1.74	Modelling improvements to utilise satellite detection of harvesting consistent with post-1990 plantations	Criteria 1. change of GHG reporting method	Methodological refinement to take account of new activity data source (satellite monitoring of harvesting), consistent with the inventory improvement plan (new inventory methods become available; Vol 1, Ch 5.2.1).
Natural Disturbances	1.93	Modelling improvements to include combustion of live biomass in emissions estimation	Criteria 1. change of GHG reporting method	Methodological refinement to take account of the impact of additional pools in emissions reporting (new inventory methods become available; Vol 1, Ch 5.2.1).
HWP	-0.01	Recalculation to take account of data corrections and recalculation of AD	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, CH 5.2.1)
Fuelwood & N-Mineralisation	0.00	Minor recalculations to take account of continuous improvement and refinements to input data	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, CH 5.2.1)
Total corrections reported in NIR 2017	**0.53**			

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Harvested private native forest	0.00	Correction to historical data on wood production affecting activity data in 1990 and age-class structure of forests.	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Multiple-use public forests	0.00	Correction to historical data on wood production affecting activity data in 1990 and age-class structure of forests.	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Pre-1990 plantations	0.92	Modelling improvements to utilise Tier 3, Approach 3 fully spatial capability within FullCAM, more consistent with post-1990 plantations	Criteria 1. change of GHG reporting method	Methodological change to move to a higher tier, consistent with the inventory improvement plan (new inventory methods become available; Vol 1, Ch 5.2.1).
Natural Disturbances	-0.50	Modelling improvements to utilise Tier 3, Approach 3 fully spatial capability within FullCAM, consistent with other LULUCF sectors	Criteria 1. change of GHG reporting method	Methodological change to move to a higher tier, consistent with the inventory improvement plan (new inventory methods become available; Vol 1, Ch 5.2.1).
Harvested Wood Products	0.10	Revised estimates in the Australian Forest and Wood Products Statistics, including an update to the accuracy of historical production estimates (ABARES)	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
N-Mineralisation	0.00	Recalculation to soil C pool in Harvested private native forests, multiple-use public forests, and pre-1990 plantations (due to recalculations described above)	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Total corrections reported in NIR 2016	**0.27**			
Harvested private native forest	-0.02	The age structure of the managed forest estate has been updated over the full time series to reflect data on forests harvested in 2016 (including forest type, age structure of forests at the time of harvesting)	Criteria 2.d Recalculation of historical data – age structure of forests	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Multiple-use public forests	-0.01	The age structure of the managed forest estate has been updated over the full time series to reflect data on forests harvested in 2016 (including forest type, age structure of forests at the time of harvesting)	Criteria 2.d Recalculation of historical data – age structure of forests	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Pre-1990 plantations	0.00	Availability of annual climate data	Criteria 2.f Different observed climate data as compared to what was assumed in the FMRL	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
HWP	0.30	Recalculation to take account of new source of AD regarding wood production pre-1990	Criteria 2.c Recalculated historical data from GHG inventory	Methodological refinement as part of continuous improvement when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
N-Mineralisation	0.00	Recalculation to soil C pool in Harvested private native forests, multiple-use public forests, and pre-1990 plantations	Criteria 2.c Recalculated historical data	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Total corrections reported in NIR 2015	**0.45**			
Harvested private native forest	0.30	Availability of annual climate data, Alignment with sectoral estimation periods	Criteria 2.f Different observed climate data as compared to what was assumed in the FMRL	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Multiple-use public forests	-0.35	Recalculation of harvesting attributable to deforestation, Availability of annual climate data, Alignment with sectoral estimation periods	Criteria 2.e recalculation of historical harvest rates	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Pre-1990 plantations	0.51	Availability of annual climate data	Criteria 2.f Different observed climate data as compared to what was assumed in the FMRL	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
HWP	-0.01	Corrections to AD to avoid double counting of HWP from deforestation events (already accounted for on the basis of instantaneous oxidation)	Criteria 2.g HWP – New/ recalculated data and / or methods; inclusion of provisions	Implementation of KP accounting rules (IPCC, 2014; Decision 2/ CMP.7) (consistency with IPCC guidelines; Vol 1 Ch 5.2.1)
N-Mineralisation	0.00	Implementation of new rounding policy for emission factor precision (all sectors, further detail on the 2016-17 ANAO Performance Audit can be found in section ES.4.1 of Volume 1).	Criteria 2.c Recalculated historical data for FL-FL or FM	Methodological refinement as part of continuous improvement in modelling framework following QA process (correction of errors; Vol 1, Ch 5.2.1)
Total corrections reported in NIR 2014	**-1.20**			
Harvested private native forest	1.59	Estimation and reporting of Soil Carbon pool with required model updates	Criteria 2.a inclusion of new pools or gasses	Methodological refinement to allow complete reporting of all pools and gasses required in Annex to Decision 2/CMP.7, paragraph 26 (consistency with IPCC guidelines; Vol 1 Ch 5.2.1)
Multiple-use public forests	-1.87	Estimation and reporting of Soil Carbon pool with required model updates	Criteria 2.a inclusion of new pools or gasses	Methodological refinement to allow complete reporting of all pools and gasses required in Annex to Decision 2/CMP.7, paragraph 26 (consistency with IPCC guidelines; Vol 1 Ch 5.2.1)

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Pre-1990 plantations	0.09	Revised climate, soil and clay activity data	Criteria 2.f Different observed climate data as compared to what was assumed in the FMRL	Methodological refinement as part of continuous improvement of the FullCAM modelling framework when new data becomes available (available data has changed; Vol 1, Ch 5.2.1)
Natural Disturbances	1.26	Implementation of revised model parameters from new empirical research	Criteria 2.c Recalculated historical data for FL-FL or FM	Implementation of recommendation by ERT from review of FL-FL (ARR 2015, recommendation L.27). Methodological refinement to implement new research and new empirical data, consistent with *good practice* (available data has changed; Vol 1, Ch 5.2.1)
Fuelwood	-1.71	Addressing double-counting of emissions with HWP, debris and fire	Criteria 2.c Recalculated historical data for FL-FL or FM	Avoiding double-counting of emissions (correction of error consistent with *good practice;* Vol 1, Ch 5.2.1)
HWP	-1.14	Corrections to implementation of KP accounting rules; including modelling of domestically produced wood products, disaggregation of HWP from Afforestation / Reforestation and Deforestation activities	Criteria 2.g HWP – New/ recalculated data and/ or methods; inclusion of provisions	Complete implementation of KP accounting rules (IPCC, 2014; Decision 2/CMP.7) (consistency with IPCC guidelines; Vol 1, Ch 5.2.1)
Prescribed burning	0.55	Implementation of revised model parameters from new empirical research	Criteria 2.c Recalculated historical data for FL-FL or FM	Implementation of recommendation by ERT from review of FL-FL (ARR 2015, recommendation L.27). Methodological refinement to implement new research and new empirical data, consistent with *good practice* (available data has changed; Vol 1, Ch 5.2.1)
N-Mineralisation	0.03	Reporting of Soil Carbon pool allows estimation of N Mineralisation	Criteria 2.a inclusion of new pools or gasses	Methodological refinement to allow complete reporting of all pools and gasses required in Annex to Decision 2/CMP.7, paragraph 26 (consistency with IPCC guidelines; Vol 1 Ch 5.2.1)
Technical correction reported in NIR 2013	**-3.58**	*Cumulative correction (as reported in NIR 2013)*		
Private Native Harvest				
Calendar year Reporting	-3.24	Cumulative correction Activity data converted from financial years to calendar years, consistent with broader LULUCF inventory reporting	Criteria 2.b recalculation of area under FM. and 2.e recalculation of historical harvest rates	Recalculation of activity data in order to ensure consistency with reporting of other Article 3.3 and 3.4 activities and *Forestland remaining forestland* (in accordance with *good practice:* IPCC (2014) Ch 2.7.5.1 (construction of FMRL) and Ch 2.75.2 (Methodological consistency between FMRL and reporting for FM)

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Combined	**-2.77**	*(Tasmania & other states)*		
Tasmanian harvested private native forest	-0.80	Changed time series from 1990–2020 to 1970–2020 New activity data (ABARES)	Criteria 2.b recalculation of area under FM. and 2.e recalculation of historical harvest rates	Methodological refinement to utilise new activity data (in accordance with *good practice:* CH *5.2.1 Recalculations due to methodological changes and refinements) New data ensures time series consistency by using same method and data source for all years and consistency of estimation method on a national basis including for multiple-use public forests and UNFCCC Harvested Native Forests* *Extrapolation of pre-1990 harvesting allows comparison with post-1990 emissions trend to ensure that only real changes in activity data are reflected in estimates*
Other States (NSW, Qld, WA)	-1.33	New modelling method (now FullCAM) Time series and activity data now consistent with TAS (1970–2020)	Criteria 1. change of GFIG reporting method and Criteria 2.b recalculation of area under FM, and 2.e recalculation of historical harvest rates	Methodological refinement to utilise new activity data (in accordance with *good practice:* CH *5.2.1 Recalculations due to methodological changes and refinements) New data ensures consistency of estimation method on a national basis including for multiple-use public forests and UNFCCC Harvested Native Forests and time series consistency by using same method and data source for all years*
Multiple-use public forests				
Calendar year Reporting	2.11	Cumulative correction Activity data converted from financial years to calendar years, consistent with broader LULUCF inventory reporting	Criteria 2.e recalculation of historical harvest rates	Recalculation of activity data in order to ensure consistency with reporting of other Article 3.3 and 3.4 activities and *Forestland remaining forestland* (in accordance with *good practice:* IPCC (2014) Ch 2.7.5.1 (construction of FMRL) and Ch 2.75.2 (Methodological consistency between FMRL and reporting for FM)

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Correction for observed deforestation	2.92	Cumulative correction Annual harvesting area and total forest management estate area corrected for observed deforestation Includes projected rates of deforestation during reference level period (2013–2020) (based on historical average)	Criteria 2.b recalculation of area under FM, and 2.e recalculation of historical harvest rates	Implementation of land classification system consistent with Article 3.3 and 3.4 and consistent with *good practice:* IPCC (2014) CH 1.3 and 2.7.2 Correction a result of improvements in forest monitoring capabilities enabling identification of deforestation (harvesting that was not observed to re-grow within the defined period) on FM lands Annual harvesting and lands excluded from FM are reported under deforestation
Pre-1990s average harvest rates	4.16	Cumulative correction Early '90s average used to project backwards; reflecting an assumption of harvesting occurring on lands listed as conservation reserves as at December 2009 Using new activity data from ABARES AFWPS	Criteria 2.e recalculation of historical harvest rates	Used extrapolation to estimate pre-1990 harvest and improve consistency with post-1990 harvest data (in accordance with Ch 5.3.3.4 using trend extrapolation to resolve data gaps) Ensures that modelled emissions trends reflect only real changes in activity data (post 1990), not model artefact due to technique to resolve data gap in historical activity data
Activity Data	0.09	Cumulative correction Using new activity data – Australian Forest and Wood Products Statistics by ABARES	Criteria 2.b recalculation of area under FM. and 2.e recalculation of historical harvest rates	Methodological refinement to utilise new activity data (in accordance with *good practice:* CH 5.2.1 Recalculations due to methodological changes and refinements) New data ensures consistency of estimation method on a national basis including for harvested private native forest and UNFCCC Harvested Native Forests and time series consistency by using same method and data source for all years
Time series change	0.24	Cumulative correction multiple-use public forests harvest now modelled for 1970 to 2020. (Prev 1960) Using FMRL raw harvest data	Criteria 2.e recalculation of historical harvest rates	Reduces length of time for which extrapolated activity data is used (in accordance with Ch 5.33.4 using trend extrapolation to resolve data gaps) Consistent time series with harvested private native forest and other parts of the national inventory including UNFCCC Harvested Native Forests, to more accurately reflect emissions trends across forest management reporting

Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
WA lookup	-0.04	Cumulative correction Modelling of correct subset of raw harvest data for WA Using FMRL raw harvest data	Criteria 2.e recalculation of historical harvest rates	Corrected error in activity data requiring recalculation of historical emissions trends (in accordance with good practice: Ch 5.2.1 Recalculations due to methodological changes and refinements)
NSW Allocation correction	2.00	Using additional data points to allocate harvest Using FMRL raw harvest data	Criteria 2.e recalculation of historical harvest rates	Methodological refinement to utilise new activity data (in accordance with *good practice:* CH 5.2.1 Recalculations due to methodological changes and refinements) Allocation better supported by including harvest information available after submission of FMRL
Prescribed Burning	-0.10	Updated GWPs from IPCC AR4 Updated activity data to maintain methodological consistency with time series used for reporting	Criteria 2.d recalculation of historical data on forest characteristics and related management	GWP for NO_2 and CH_4 updated in accordance with IPCC (2007) Recalculation of historical activity data (prescribed burning area) to enable reporting of time series and trends in accordance with good practice (IPCC 2006: Ch 5.2.3) Correction to maintain methodological consistency between reported time series and FMRL (IPCC 2014 Ch 2.7.5.2)
Fuelwood	0.31	New activity data based on NGERS reporting and emissions factors from the Energy sector	Criteria 2.e recalculation of historical harvest rates	Methodological refinement to utilise new activity data (in accordance with *good practice:* CH *5.2.1 Recalculations due to methodological changes and refinements) New data ensures consistency of estimation method across the inventory (including energy)*
Pre-1990 plantations	2.36	Implementation of tree yield formula to model biomass, permitting utilisation of climate data Estimation of soil carbon pool	Criteria 2.d recalculation of historical data on forest characteristics and related management	Methodological refinement to utilise new model capability (in accordance with good practice: Ch 5.2.1 Recalculations due to methodological changes and refinements) New soil carbon and tree yield formula improves consistency with other reporting categories, including afforestation/reforestation.

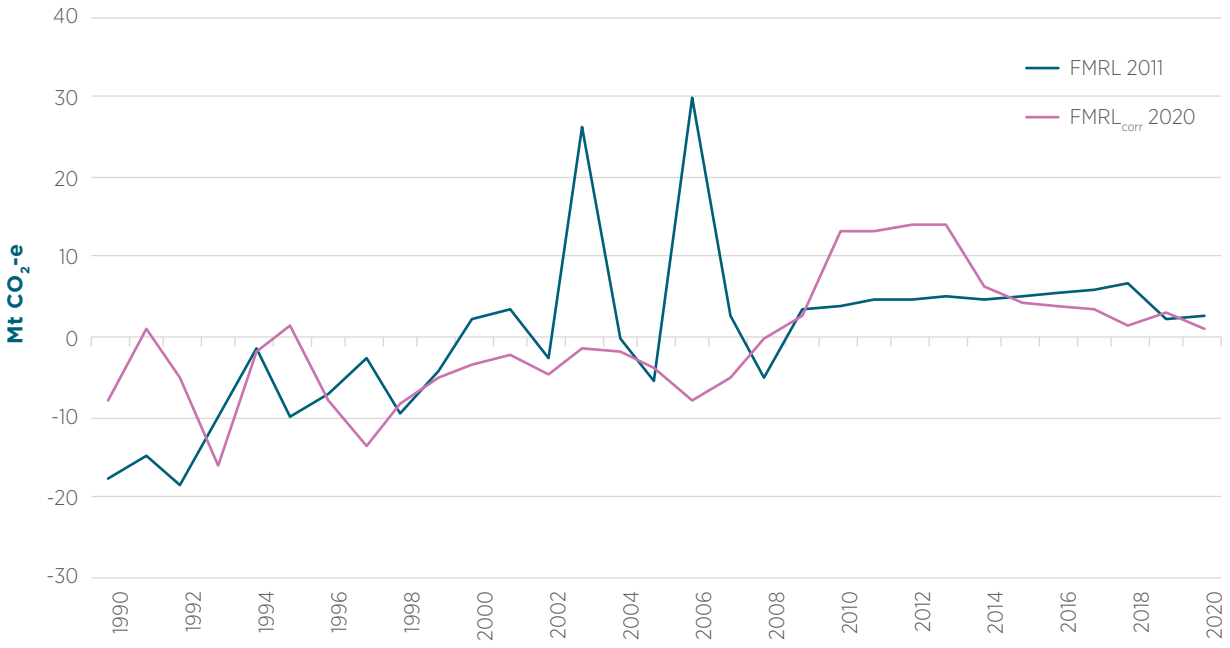
Component of *Forest Management* Correction	Technical Correction (Mt CO_2-e)	Factors leading to correction	IPCC (2013) Guidance Criteria	Reason for methodological change or methodological refinement (With reference to good practice in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 1)
Natural Disturbances	-6.04	Implementing IPCC (2014) methods and guidance, including calculation of background level and margin	Criteria 2.h new data and methods for accounting for natural disturbances	Updated supplementary methods and good practice guidance finalised after submission of the FMRL (IPCC, 2014)
Harvested Wood Products	1.01	Addressing Decision 2/CMP.7 and IPCC (2014), including by calculating emissions from the exports pool and excluding the imports pool	Criteria 2.g New/ recalculated data and methods and inclusions of provisions for Harvested Wood Products	Internationally agreed rules (Decision 2/CMP.7) on accounting for harvested wood products and Updated supplementary methods and good practice guidance (IPCC, 2014) finalised after submission of the FMRL

Table 11.25 reports the technical correction for 2018 (the accounting quantity is reported below at section 11.6.6.2), and Figure 11.12 shows a plot of the temporal dynamics of the estimates underlying the $FMRL_{corr}$ and FMRL (refer to IPCC (2014) Ch 2.7.6.2).

Table 11.25 Summary table for reporting of technical correction

Summary table for technical correction (Table 2.7.2, IPCC, 2014)		
Forest Management Reference Level recalculated for the purpose of calculating the Technical Correction ($FMRL_{corr}$)	4,885	kt CO_2-e
Forest Management Reference Level (FMRL)	4,700	kt CO_2-e
Difference in Percent	4	%
Technical Correction	185	kt CO_2-e

Figure 11.12 Comparison of recalculated reference level emissions ($FMRL_{corr}$) with previous estimates (FMRL)



* Note: the FMRL includes emissions from wildfires, consistent with the reference level inscribed in the Annex to Decision 2/CMP.7. The $FMRL_{corr}$ time series applies the natural disturbances provision as set out in the Annex to Decision 2/CMP.7 and described in IPCC 2014.

11.6.5.1 Rationale for calculating $FMRL_{corr}$

The details of the technical corrections are outlined in Table 11.24. The rationale for the changes reflected in the FMRL are outlined below only for the main changes since the 2018 submission.

Native forest harvesting from multiple use public forests and private native forest harvesting

Corrections to the historical wood harvesting data in 1990 have been made in order to maintain consistency with data and modelling of *forest land remaining forest land* – see Chapter 6.4.5 for further information.

Tier 3, Reporting method 2 model for *multiple use public forests* the states of Victoria and NSW are responsive to climate variability, particularly for soil carbon. The technical correction reflects the observed climate data during the commitment period in calculating soil carbon emissions consistent with the IPCC KP Supplement (page 2.100).

Pre-1990 Plantations

Net emissions/removals from Pre-90 Plantations were revised due to updates to FullCAM model inputs such as soil cover factor, climate data and fixes to turnover/decomposition database tables.

Natural disturbances

An additional pool has been included in the reporting of fire emissions in *forest management* and *forest land remaining forest land,* namely the combustion of live biomass. See Chapter 6.4 for further information.

Natural disturbance emissions continue to be calculated following the rules for the Kyoto Protocol, but now draw on more detailed estimates of emissions arising from fire at a detailed spatial level. The necessary quality controls to ensure there is no expectation of net debits and credits have been conducted in accordance with the methods outlined earlier in this chapter.

Harvested Wood Products

Estimates of *harvested wood products* have been revised to account for time-series revisions to the underlying source data on forestry and wood products produced by the Australian Bureau of Agricultural and Resource Economics (2018a).

11.6.6 Reporting of *forest management* in 2019

11.6.6.1 Reporting of *forest management* net emissions in 2019

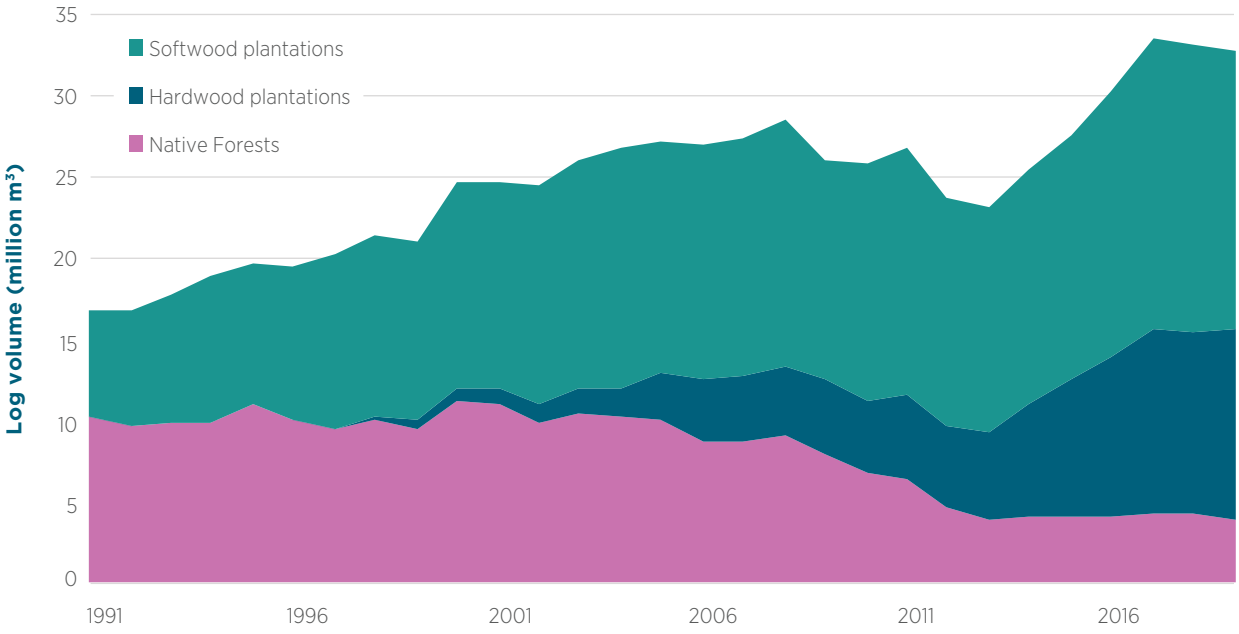
In accordance with *good practice* the emissions and removals for *forest management* are estimated using the same methodologies, models and activity data as were used in the calculation of FMRL, described above in Chapter 11.6.3.

The main factor affecting the trends in *forest management* net emissions in 2019 remains the decline in emissions from native forest harvesting from multiple-use public forests and harvested private native forests.

This corresponds to a change in activity levels that also impacts on the harvested wood products pool and related emissions. The importance of this trend in activity data to overall emissions from *forest management* is shown in the correlation in Figure 11.13.

Australian forest production statistics indicate a rapid decline in production from native forest harvesting (from multiple-use public forests and harvested private native forest) has occurred since 2008–2009 (ABARES, 2020) (Figure 11.13). This has been part of a broader structural transition in the forest production industry in Australia.

Figure 11.13 Forest production in Australia (1991–2019)



Source: ABARES (2020)

Constraints on timber supply from native forests and favourable policy and economic conditions for plantation establishment resulted in a peak in reported new plantation establishment for hardwood plantations in the decade from 2000 (ABARES 2020). Emissions and removals from these plantations are reported under *afforestation/reforestation.* Due to the standard rotation lengths for commonly used hardwood plantation species the new plantations established during these periods are now ready for harvest, causing rapid increases in hardwood plantation production rates (Figure 11.13).

This increase in the supply of plantation hardwood in Australia, in combination with broader economic factors affecting the forest industry, has led to the observed decline in harvesting from native forests in particular through the substitution of log production from native forests with production from plantations.

Currently harvesting activity levels in multiple-use public forests and harvested private native forests are below reference levels. This decline in activity levels is reflected in reported emissions from *forest management* (Table 11.26).

Table 11.26 Estimated net emissions from *forest management* (kt CO_2-e)

Year	Multiple- use public forest [(a)]	Private harvested native forests	Pre-1990 plantations	Harvested wood products	Natural disturbances	Prescribed burning	Total
2000	-3,825	9,632	-5,925	-5,289	2,196	-359	-3,570
2005	-11,375	7,857	-4,212	-4,935	8,156	517	-3,992
2010	636	3,020	-1,180	-4,182	4,622	526	3,441
2011	-2,938	2,782	218	-4,504	2,411	-539	-2,571
2012	-4,298	-640	-390	-4,043	6,716	-89	-2,743
2013	-6,059	-1,565	-159	-3,582	4,622	237	-6,506
2014	-13,811	-1,188	-442	-4,501	4,622	-1,272	-16,592
2015	-19,546	-1,445	1,571	-4,665	4,622	104	-19,360
2016	-19,870	-1,447	902	-5,251	4,622	808	-20,236
2017	-22,761	-1,405	3,156	-5,918	4,622	-290	-22,596
2018	-25,941	-1,354	4,225	-5,777	4,622	-308	-24,534
2019	-25,211	-1,601	5,573	-5,481	4,622	861	-21,237

(a) Includes carbon stock changes due to fuelwood collection and combustion

11.6.6.2 Reporting of *forest management* Accounting Quantity in 2013-19

Estimates of the accounting quantity for *forest management* – to be used to estimate the amount of RMU credits to be issued – are reported in Table 11.27. Estimates are derived by deducting the reported net emissions in the reporting year from the FMRL after technical correction up to the value of the FM cap on credits. Note that Australia has elected to account for Article 3.4 activities at the end of the commitment period, and that if this were to be accounted for now that Australia has reached its maximum credits.

Table 11.27 Estimated accounting quantity for Forest management (t CO_2-e)

Year	FMR_{corr}	Forest management	Accounting Quantity	Cumulative Accounting Quantity	Forest management cap on credits	Additional RMU Credits generated in reporting year
2013	4,885,318	-6,505,826	-11,391,144	-11,391,144		-11,391,144
2014	4,885,318	-16,592,447	-21,477,765	-32,868,909		-21,477,765
2015	4,885,318	-19,360,047	-24,245,365	-57,114,274		-24,245,365
2016	4,885,318	-20,235,914	-25,121,232	-82,235,506		-25,121,232
2017	4,885,318	-22,595,882	-27,481,200	-109,716,706		-27,481,200
2018	4,885,318	-24,534,288	-29,419,606	-139,136,313	-117,214,453	-7,497,747
2019	4,885,318	-21,236,873	-26,122,191	-165,258,504	-117,214,453	0

* Note: negative accounting quantities indicate that RMUs are to be issued.

11.6.6.3 Reporting of conversion of natural forests to planted forests (Annex to Decision 2/CMP.7, paragraph 5)

Available evidence indicates that conversion of multiple-use public forests to plantations no longer occurs in Australia as a result of state and territory regulations.

Reporting of emissions from the conversion of natural (native) forests to planted forests (plantations) is included in reported emissions under *forest management*.

11.6.7 Quality Assurance – Quality Control

11.6.7.1 Quality Control

In addition to the tests reported under section 11.6.4 (relating to the natural disturbances provision), four Quality Control tests are reported aimed at demonstrating methodological consistency and the avoidance of credits or debits between the FMRL and estimates of net emissions from *forest management* from methodological inconsistency.

(i) Comparison of the initial FMRL (DCCEE, 2011) and $FMRL_{corr}$;

(ii) Reproduction of the historical time series in the reporting of *forest management* and the forest management reference level (IPCC 2014, pages 2.100, 2.103);

(iii) A quantitative comparison of trends in native forest wood production and emissions from *forest management* from 2002 to 2013 (IPCC 2014, p2.97); and

(iv) Reconciliation of estimates used for the FMRL with estimates from *forest land remaining forest land.*

(i) Comparison of the initial FMRL (DCCEE, 2011) and $FMRL_{corr}$

Comparison of the FMRL (DCCEE, 2011) and $FMRL_{corr}$ improves transparency by highlighting the main factors generating the technical correction. There are changes in activity data and parameters for reporting on biomass burning that have been updated for the reporting of *forest management.*

However there are also methodological refinements to the subcategories of harvesting from multiple use public forests and private native forests which are the most important in terms of the trend in reported *forest management* emissions in 2019. There are changes in the pools reported to include the soil carbon pool, which is subject to annual variation in climate, and changes in activity data that affect activity levels for the reference period of 2002–2009, and changes to the area under *forest management.*

Other methodological changes include use of a Tier 3 spatially explicit method to estimate net emissions for *harvested native forests* (Chapter 6.4.1.2) on multiple-use public forests in Victoria and New South Wales. This affects activity levels, area harvested and calculated emissions. This Tier 3 model reflects the latest research and data from CSIRO, which shows that growth rates are slowing by 2020 based on current age-class assumptions.

Table 11.28 shows how these changes have affected the $FMRL_{corr}$ relative to the 2011 FMRL submission.

In multiple-use public forests, the inclusion of a sink from soil carbon pool (-2.3 Mt CO_2-e) offsets the slower modelled tree growth rates and reduced harvesting rate. Soil carbon represents a net sink for multiple-use public forests, because reference harvest rate (73,811 ha/yr) relative to the total area of multiple-use public forests (11.1 Mha) means that the area which is losing soil carbon following a harvesting event is much smaller than the area in which soil carbon stocks are increasing (recovering from historical harvesting).

The main contributor to the technical correction to harvested private native forests, is the change in area of *forest management* lands, which has been revised upwards from 0.39 Mha (as estimated in the DCCEE, 2011) to 0.93 Mha (reported in this submission). This results in a larger forest area acting as a carbon sink where CO_2 removals from biomass growth is occurring, and an overall negative technical correction (-1.5 Mt CO_2 e, Table 11.28). This increase in area of forest acting as a sink is partially offset by emissions from the inclusion of the soil carbon pool. The soil carbon pool in harvested private native forests represents a source of emissions due to a relatively higher harvesting rate in proportion to forest area.

Table 11.28 Native forest harvesting reference level and key activity data

Original FMRL submission					2021 FMRL ($FMRL_{corr}$)			
Component of FMRL Technical Correction	Technical Correction by component Mt CO_2-e	RL2011 Mt CO_2-e	Reference Harvest Rate (ha/yr)	Area under FM (M ha)	$FMRL_{corr}$ Mt CO_2-e	Included soil carbon emissions/ removals Mt CO_2-e	Reference Harvest Rate (ha/yr)	Area under FM (M ha)
Private Native forest harvesting	-1.4	8.9	16,764	0.39	7.6	1.1	16,915	0.93
Multiple-use public forests	3.8	-9.9	88,537	9.4	-6.1	-2.3	73,811	11.09

(ii) Reproduction of the time series used for the FMRL using methods used to estimate net emissions for forest management

It is *good practice* to provide information that there is no expectation of net credits or net debits linked to any methodological inconsistency between $FMRL_{corr}$ and reporting for *forest management* (IPCC, 2014, pages 2.102–2.103).

Methodological consistency and the avoidance of credits or debits can be shown by reproducing the same historical time series in the reporting of *forest management* and the forest management reference level (IPCC 2014, pages 2.100, 2.103). This historical reproduction (Table 11.29) demonstrates that the difference in estimated emissions between the FMRL and the reporting of *forest management* is linked to variations in the activity data during the period since 2009 (since 2008 for HWP). Remaining model variables have been addressed in the construction of $FMRL_{corr}$, as described in Chapter 11.6.3.

Table 11.29 Time series comparison of FMRL and reporting of forest management

Year	Historical time series used for constructing $FMRL_{corr}$	Reporting of FM
	Emissions / Removals (kt CO_2-e)	
1990	-7,745	-7,745
1991	975	975
1992	-5,099	-5,099
1993	-14,633	-14,633
1994	-1,921	-1,921
1995	1,289	1,289
1996	-7,916	-7,916
1997	-13,621	-13,621
1998	-8,435	-8,435
1999	-5,037	-5,037
2000	-3,570	-3,570
2001	-2,114	-2,114
2002	-4,587	-4,587
2003	-1,291	-1,291
2004	-1,966	-1,966
2005	-3,992	-3,992
2006	-7,863	-7,863
2007	-5,120	-5,120
2008	-128	-128
2009	na	2,733

Year	Historical time series used for constructing $FMRL_{corr}$ Emissions / Removals (kt CO_2-e)	Reporting of FM
2010	na	3,441
2011	na	-2,571
2012	na	-2,743
2013	na	-6,506
2014	na	-16,592
2015	na	-19,360
2016	na	-20,236
2017	na	-22,596
2018	na	-24,534
2019	na	-21,237
FMRL	4,885	

(iii) Quantitative comparison of trends in native forest wood production and emissions from forest management

A quantitative comparison of trends in native forest wood production and emissions from *forest management* from 2002 to 2019 is shown in Figure 11.14 (IPCC 2014, p2.97).

This comparison provides evidence that the main factor generating the accounting quantity is the decline in harvesting activity from native forests, specifically multiple-use public forests and private native harvesting relative to the activity levels assumed in the FMRL.

There are components of *forest management* estimates which introduce volatility into this relationship, in particular associated with climate impacts on soil carbon within the Tier 3 model of multiple use forests (Figure 11.14a). When climate impacts on soil are excluded from this comparison, the relationship between harvesting activity and *forest management* becomes much stronger (Figure 11.14b).

Figure 11.14a Correlation of estimated emissions from *forest management* and native forest log production (2002–2019)

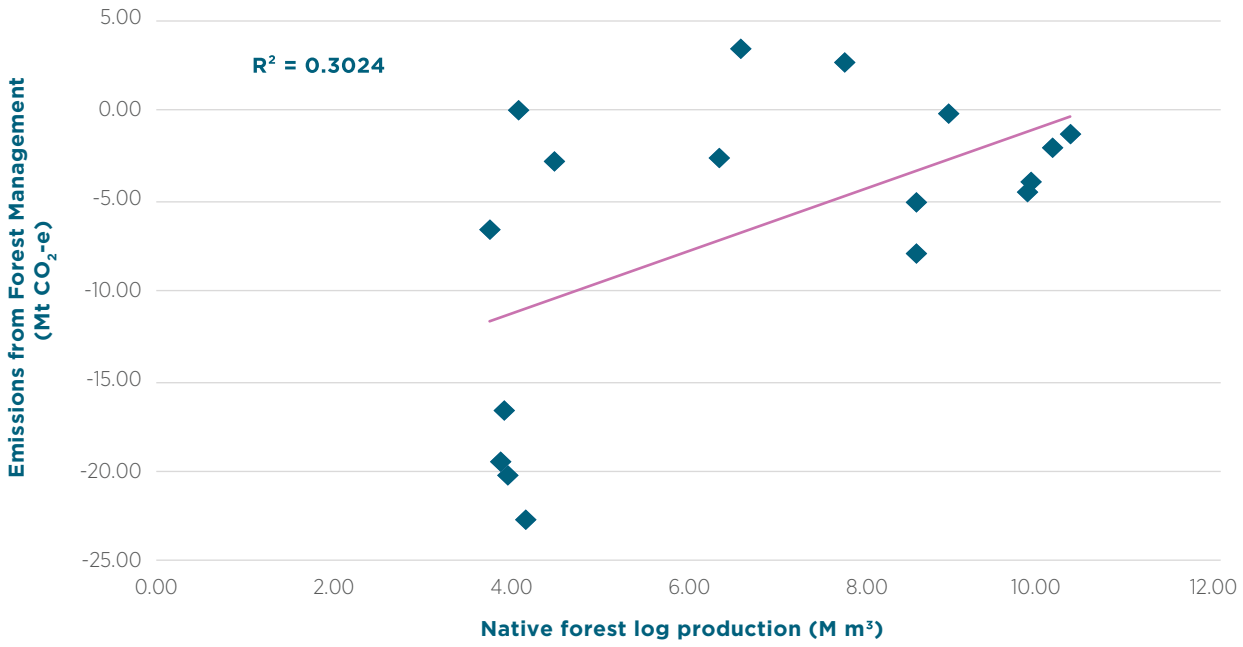
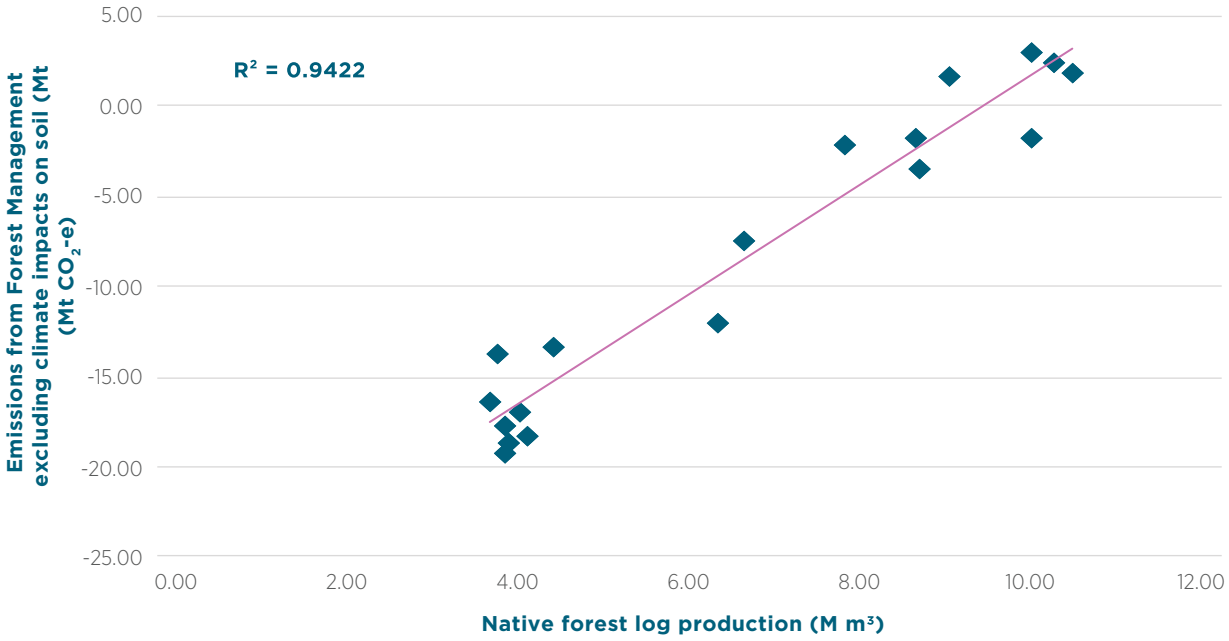


Figure 11.14b Correlation of estimated emissions from *forest management* excluding climate impacts on soil and native forest log production and native forest log production (2002–2019)



(iv) Reconciliation of forest management with forest land remaining forest land reporting

In accordance with *good practice,* the area of lands subject to *forest management* have been reconciled against the relevant categories within *forest land remaining forest land* in Table 11.30 below.

Table 11.30 Reconciliation of UNFCCC forest lands and *forest management* lands

Forest land remaining forest land category	forest management sub-classifications	Estimated area in 2018 (M ha)
Plantations	Pre-1990 plantations (commercial plantations not included under Article 3.3)	0.7
Harvested native forests	Multiple-use forests	11.1
	Private native forests (where harvest has been observed and which have been included in *forest management)*	0.9
Other native forests		121.4

Pre-1990 plantations included in *forest management* are equivalent to *plantations* reported under *forest land remaining forest land.*

The combined emissions from multiple-use public forests and private native harvesting forests are a subset of the *harvested native forest* category (Table 11.30).

Wildfire, fuelwood and prescribed burning emissions for *forest management* lands are a subset of the emissions reported for *forest land remaining forest land.* Carbon stock changes in the pool of *harvested wood products* from *forest management* lands are not reported in the corresponding categories of *forest land remaining forest land* and instead are reported in aggregate under Chapter 6.15 (Source Category 4.G) – *harvested wood products.*

Table 11.31 provides a reconciliation of emissions estimates between the reporting categories of *forest management* and *forest land remaining forest land.*

Table 11.31 Reconciliation of *forest management with forestland remaining forest land* emissions (Mt COe)

Forestland remaining forest land	Plantations		Harvested Native Forests				Reported differently for KP and UNFCCC (FM is a subset due to narrow approach to defining FM Lands; or different accounting rules)						
FM	Pre-1990 plantations	Multiple-use public forests	Private Native forest harvesting	N-mineralisation	N-leaching and runoff	*Harvested Native Forest Total*	Prescribed Burning	Fuelwood	Harvested wood products	Natural disturbances	FM total	*Other Native Forest total*	*Forest land remaining forestland total*
1990	-8,353	-5,402	6,426	43	27	-7,259	372	85	-2,734	1,818	-7,745	7,562	302
1991	-4,017	-3,412	6,108	77	53	-1,191	1,088	93	-2,813	3,851	975	5,885	4,694
1992	-7,390	-7,356	5,699	65	48	-8,934	1,486	101	-2,957	5,253	-5,099	12,369	3,435
1993	-9,619	-9,243	5,977	44	33	-12,808	-266	115	-3,222	1,580	-14,633	12,602	-206
1994	-5,969	-838	6,026	84	63	-633	1,104	110	-3,897	1,458	-1,921	8,945	8,312
1995	-9,325	-1,791	7,052	79	59	-3,926	204	95	-3,706	8,680	1,289	7,771	3,845
1996	-6,429	-9,806	6,340	27	21	-9,846	-6	88	-3,316	5,186	-7,916	9,452	-394
1997	-7,283	-11,073	5,926	25	20	-12,385	910	88	-3,624	1,410	-13,621	2,323	-10,062
1998	-7,412	-6,012	7,572	25	20	-5,806	-959	70	-4,153	2,432	-8,435	28	-5,778
1999	-4,082	-8,353	6,747	31	20	-5,637	65	56	-3,748	4,246	-5,037	933	-4,704
2000	-5,926	-3,885	9,620	26	20	-144	-359	46	-5,289	2,196	-3,570	8,938	8,794
2001	-4,004	-775	7,507	33	26	2,787	-495	24	-4,939	535	-2,114	5,975	8,761
2002	-5,807	-5,259	6,575	25	21	-4,445	-53	-186	-4,907	5,025	-4,587	6,487	2,042
2003	-3,731	-4,387	7,995	25	20	-78	-544	-15	-5,255	4,622	-1,291	9,550	9,472
2004	-3,604	-7,228	7,954	24	19	-2,835	963	-51	-5,185	5,161	-1,966	7,886	5,051
2005	-4,213	-11,305	7,843	24	20	-7,631	517	-80	-4,935	8,156	-3,992	4,130	-3,501
2006	-2,828	-9,897	5,416	28	23	-7,259	-306	-93	-4,836	4,654	-7,863	8,561	1,302
2007	-3,200	-7,965	5,655	26	21	-5,463	848	-105	-4,999	4,622	-5,120	15,919	10,455
2008	-2,079	-8,129	6,246	27	21	-3,915	1,957	-116	-4,775	6,741	-128	21,135	17,220
2009	-933	-3,253	5,129	101	57	1,102	864	-126	-3,671	4,622	2,733	18,234	19,336
2010	-1,186	597	3,003	196	112	2,722	526	-135	-4,182	4,622	3,441	14,054	16,776
2011	178	-2,945	2,766	207	116	322	-539	-144	-4,504	2,411	-2,571	18,245	18,567
2012	-402	-4,357	-658	199	120	-5,098	-89	-110	-4,043	6,716	-2,743	7,702	2,605
2013	-160	-6,134	-1,581	177	105	-7,594	237	-83	-3,582	4,622	-6,506	5,099	-2,495
2014	-446	-13,779	-1,204	67	46	-15,316	-1,272	-79	-4,501	4,622	-16,592	6,466	-8,850
2015	1,568	-19,465	-1,460	25	20	-19,313	104	-88	-4,665	4,622	-19,360	11,095	-8,218
2016	902	-19,805	-1,461	27	22	-20,316	808	-77	-5,251	4,622	-20,236	6,492	-13,825
2017	3,155	-22,701	-1,418	20	16	-20,929	-290	-65	-5,918	4,622	-22,596	5,453	-15,476
2018	4,223	-25,887	-1,367	19	14	-22,998	-308	-58	-5,777	4,622	-24,534	-2,199	-25,197
2019	5,572	-25,161	-1,613	16	13	-21,174	861	-53	-5,481	4,622	-21,237	1,639	-19,535

11.6.7.2 Quality Assurance

The methodology for the implementation of the natural disturbances provision was reviewed in S. Federici (2016).

11.6.8 Recalculations

Further descriptions of the recalculations is provided in the corresponding LULUCF category in the *forest land remaining forest land* section of Volume 2 (section 6.4.5).

Table 11.32 *Forest management*: recalculation of total CO_2-e emissions (kt), 1990–2018

	2020 submission	2021 submission	Change		Changes included in 2019 recalculation			
Year	(kt CO_2)	(kt CO_2)	(kt CO_2)	%	A. Fire emissions	B. Pre-1990 plantations	C. Method updates – native forest harvesting	D. Harvested Wood Products
1990	-12,697	-7,745	4,952	39%	-44	-891	5,887	0.0
1995	-3,854	1,289	5,143	133%	-1244	-279	6,666	0.0
2000	-9,810	-3,570	6,240	64%	-420	-179	6,839	0.0
2005	-2,402	-3,992	-1,590	-66%	-900	-121	-569	0.0
2006	-9,503	-7,863	1,640	17%	-1300	-220	3,160	0.0
2007	-9,738	-5,120	4,619	47%	-125	-406	5,150	0.0
2008	-5,326	-128	5,198	98%	923	9	4,265	0.0
2009	-10,231	2,733	12,965	127%	-295	1,039	12,221	0.0
2010	-15,515	3,441	18,956	122%	-703	473	19,186	0.0
2011	-18,416	-2,571	15,846	86%	-1464	394	16,915	0.0
2012	-21,241	-2,743	18,498	87%	-1156	59	19,594	0.0
2013	-26,186	-6,506	19,680	75%	-802	-6	20,487	0.0
2014	-27,754	-16,592	11,161	40%	-2321	-62	13,545	0.0
2015	-26,785	-19,360	7,424	28%	-788	-175	8,387	0.0
2016	-28,559	-20,236	8,323	29%	227	-188	8,284	0.0
2017	-25,825	-22,596	3,229	13%	-1110	-615	4,954	0.0
2018	-25,176	-24,534	642	3%	-1300	-220	2,161	0.6

11.7 Cropland management

Anthropogenic emissions and removals on croplands occur as a result of changes in management practices on cropping lands, from changes in crop type – particularly between herbaceous and woody crops – and from changes in land use. *Permanent* changes in management practices generate changes in the levels of soil carbon or woody biomass stocks over the longer term – and it is this process of change or transition to a higher or lower carbon stock level that generates net sequestration or net emissions of carbon dioxide that are reported in the inventory.

11.7.1 Identification of land subject to *cropland management*

Cropland management includes all land that is used for continuous cropping and those lands managed as crop-pasture (grassland) rotations as well as the land converted to cropland from grassland.

Forest land converted to cropland from 1990 to the inventory year 2019 is identified based on attribution of the Landsat time series and is included under *deforestation.* Forest land converted to cropland prior to 1990 is identified based on attribution of the Landsat time series and is included under *cropland management.*

Land converted to forest land, or land that is identified as forest land from the Landsat series, is excluded from croplands.

Perennial crops including orchards and vineyards are included under the *cropland* classification in the UNFCCC inventory and hence are included under *cropland management.* Units of land where orchards were established on land clear of forest on 31 December 1989 are included in the *cropland management* and not the *afforestation/ reforestation* classification.

Land subject to *cropland management* is identified using a reporting method 2 land identification system (IPCC, 2014, Chapter 2.2.2). The area of *cropland management* includes all land classified as cropping land in the ABARES Land Use Map Version 5 subject to a number of amendments.

FullCAM simulates on a pixel by pixel (25m x 25m) level and the carbon stock change on each pixel is tracked from the start of the simulation to the reporting year. The outputs of the simulations are stored in a datacube which can be queried using the Outputs Analysis System (OASys). OASys supports the reporting of the geographical location of the boundaries of the area that encompass land subject to *cropland management* annually, along with the total land areas subject to this activity.

11.7.2 Identification of management practices

Changes in soil carbon stocks in croplands result from changes in management practices that influence the rates of additions or losses of soil organic carbon in the system. Permanent changes in management practices generate changes in the levels of soil carbon stocks over the longer term as the system moves to new equilibrium states.

Specified management practices affecting anthropogenic emissions and removals from *cropland management* include:

- total cropping area;
- crop type and rotation (including pasture leys);
- stubble management, including burning practices;
- tillage techniques;
- fertiliser application and irrigation;
- application of green manures (particularly legume crops);
- soil ameliorants (application of manure, compost or biochar); as well as from
- changes in land use from grassland.

Carbon dioxide emissions from the application of lime are reported under *agriculture.* Nitrous oxide emissions from the application of fertiliser are also reported under *agriculture.*

11.7.3 Methods for estimating carbon stock change and emissions due to management changes over time

Emissions and removals from *cropland management* activities are estimated using methods consistent with IPCC 2006 in conjunction with techniques described in IPCC 2014.

Carbon dioxide emissions and removals from the *cropland management* soils component are estimated using the Tier 3 model FullCAM (Appendix 6.B).

The carbon dioxide emissions and removals associated with changes in the area of perennial woody crops are estimated using the Tier 2 approach outlined in Volume 2, section 6.6.

11.7.3.1 Data

Data sources for the estimation of *cropland management* are reported in Section 6.6, Volume 2. Soil carbon and clay content values are taken from the finely disaggregated soil maps (Viscarra-Rossel *et al.,* 2014, Viscarra-Rossel, 2014) – see Volume 2, Appendix 6.E – which permit organic soils to be distinguished from mineral soils. Organic soils occur only rarely in Australia.

Data on management practices are derived from ABS statistics. The climate, site and management datasets are those used in the forest land converted to cropland estimates as described in Volume 2, Appendix 6.B and 6.E.

11.7.3.2 Methods

Carbon dioxide emissions and removals from *cropland management* soils are estimated using FullCAM (Appendix 6.B).

All on-site carbon pools (living biomass, dead organic matter (DOM) and soil) are estimated. For non-woody crops in *cropland management* the changes in the soil carbon pool are reported. Carbon stock changes from living biomass and DOM of non-woody annual crops are reported to be zero, consistent with the guidance in *2006 IPCC Guidelines for National Greenhouse Gas Inventories* that indicates that the increase in biomass stocks in a single crop year may be assumed equal to biomass losses from harvest and mortality in that year – thus there is no net accumulation of biomass carbon stocks (IPCC 2006, p5.7). In general, croplands will have little or no dead wood, crop residues or litter (IPCC 2006, p5.12). Consistent with the method outlined in the *IPCC2006 Vol 4, 2.3.3.1,* a mean incremental value for the transitions between soil organic carbon near steady states is derived, in this case from the simulated monthly data.

Perennial woody crops are estimated using Tier 2 methods described in Volume 2.

Estimation of net emissions is undertaken from 1970 consistent with IPCC good practice (IPCC 2006, p2.137).

11.7.3.3 Carbon pools

FullCAM estimates emissions from soil as a result of an estimation process involving all on-site carbon pools (living biomass, dead organic matter and soil).

For non-woody crops, only the changes in the soil carbon pool are reported. Decision 2/CMP.7 specifies that a Party may choose not to account for a given pool, except for HWP, in a CP, if transparent and verifiable information is provided that the pool is not a source using reasoning based on sound knowledge of likely system responses (IPCC 2014, page 2.26). Carbon stock changes from living biomass and DOM of non-woody annual crops have been excluded. For annual crops, increases in biomass stocks in a single year may be assumed equal to biomass losses from harvest and mortality in that same year (IPCC 2006, p5.7) and croplands will have little or no dead wood, crop residues or litter (IPCC 2006, p5.12).

For perennial woody crops emission and removal estimates are reported for carbon stocks due to changes in cropping area. Net emissions from DOM or soil carbon have not been estimated.

11.7.4 Reporting of *cropland management* in 2019

11.7.4.1 Reporting of *cropland management* net emissions in 2019

Estimates of net emissions from *cropland management* are reported in Table 11.33.

Table 11.33 Estimated emissions from *cropland management* (kt CO_2-e)

Year	Annual crops	Woody crops	Forest converted to cropland prior to 1990	Nitrogen mineralisation	Wetlands converted to cropland	Total
1990	24,861	-69	14,208	26	386	39,413
1995	5,085	-100	1,623	25	386	7,019
2000	-3,140	-50	1,264	12	386	-1,528
2005	6,099	-162	927	25	386	7,276
2006	3,614	-175	1,763	7	386	5,596
2007	5,586	36	984	21	386	7,014
2008	5,232	-122	1,231	15	386	6,742
2009	7,129	-152	1,372	15	386	8,749
2010	1,225	-282	1,317	20	386	2,667
2011	1,574	-363	1,307	19	386	2,923
2012	1,782	-109	399	12	386	2,469
2013	-64	94	1,701	19	386	2,136
2014	1,137	36	1,215	14	386	2,788
2015	-2,616	-83	1,218	11	386	-1,085
2016	-6,225	-225	357	18	386	-5,689
2017	-6,484	-269	720	3	386	-5,644
2018	-4,464	-135	490	7	386	-3,716
2019	-5,698	-187	1,196	11	386	-4,292

11.7.4.2 Estimation of *cropland management* Accounting Quantity in 2019

For the Article 3.4 land activity categories credits (called RMU credits) are to be issued against the reduction in net emissions relative to a specified benchmark base year or reference level. If net emissions are higher in the reporting year than in 1990, AAUs or RMUs are to be cancelled.

For *cropland management* estimates of the accounting quantity – to be used to estimate the amount of RMU credits to be issued – are reported in Table 11.34. Estimates are derived by deducting the reported net emissions in the relevant year from the reported net emissions in 1990. Note that Australia has elected to account for Article 3.4 activities at the end of the commitment period.

Table 11.34 Estimated accounting quantity for *cropland management* (t CO_2-e)

Year	CM 1990 (a)	CM Reporting year	Estimated Accounting Quantity (RMU credits)
2013	25,178,713	2,136,056	-23,042,657
2014	25,178,713	2,788,469	-22,390,243
2015	25,178,713	-1,085,182	-26,263,895
2016	25,178,713	-5,689,011	-30,867,724

Year	CM 1990 (a)	CM Reporting year	Estimated Accounting Quantity (RMU credits)
2017	25,178,713	-5,644,195	-30,822,908
2018	25,178,713	-3,715,915	-28,894,627
2019	25,178,713	-4,292,427	-29,471,140

(a) In this report, crop land management estimates for 1990 were adjusted for the emissions reported under Forest Conversion in the UNFCCC inventory in 1990 from conversions up to 31 December 1989 and recorded in the report used to calculate the assigned amount, in order to avoid double counting.

Note: Negative values for accounting quantity indicate that RMUs are to be issued.

In order to avoid double counting of emissions from *forest converted to cropland* in 1990 which are included in the Assigned Amount, emissions and removals associated with such conversions in 1990 are not included in the base for *cropland management* for the purposes of estimating the accounting quantity.

11.7.5 Quality Assurance – Quality Control

Refer to Chapter 6 of Volume 2 (section 6.6.4)

11.7.6 Recalculations

Further descriptions of the recalculations is provided in the corresponding LULUCF category in Chapter 6, namely *cropland remaining cropland* and *land converted to cropland.* The quantification of the recalculation components is shown in Table 11.35.

Table 11.35 Cropland management: recalculation of total CO_2-e emissions (kt), 1990–2018

	2020 submission	2021 submission	Change		Reasons for recalculation		
Year	(kt CO_2)	(kt CO_2)	(kt CO_2)	%	A. Cropland remaining cropland	B. Forest land converted to cropland before 1990	C. Wetland converted to cropland
1990	32,124	39,413	7,289	22.7%	6,870.5	264.1	154.0
1995	-760	7,019	7,779	1023.8%	7,576.8	48.4	154.0
2000	-6,224	-1,528	4,696	75.4%	4,504.6	37.0	154.0
2005	3,752	7,276	3,524	93.9%	3,368.8	0.8	154.0
2006	1,782	5,596	3,814	214.1%	3,214.2	446.1	154.0
2007	4,635	7,014	2,378	51.3%	2,338.8	-114.8	154.0
2008	5,014	6,742	1,728	34.5%	1,510.8	63.7	154.0
2009	7,863	8,749	887	11.3%	621.8	110.8	154.0
2010	2,421	2,667	246	10.1%	232.6	-140.9	154.0
2011	2,934	2,923	-10	-0.4%	-617.8	453.3	154.0
2012	3,856	2,469	-1,387	-36.0%	-1,330.2	-211.2	154.0
2013	3,059	2,136	-923	-30.2%	-1,238.5	161.7	154.0
2014	3,956	2,788	-1,167	-29.5%	-1,193.8	-127.2	154.0
2015	421	-1,085	-1,507	-357.5%	-1,955.9	295.4	154.0
2016	-3,108	-5,689	-2,581	-83.1%	-2,570.8	-164.7	154.0
2017	-3,450	-5,644	-2,194	-63.6%	-2,647.4	299.2	154.0
2018	-2,650	-3,716	-1,066	-40.2%	-881.8	-338.3	154.0

11.8 Grazing land management

Grazing land management is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.

11.8.1 Identification of land subject to grazing land management

Grazing land management lands includes grasslands, grasslands with sparse woody cover, and certain specified lands with forest cover – limited to situations in which the presence of grassland has been observed from the Landsat time series and where there has been no change in land use since 1990; or where burning takes place.

Grasslands are identified using a reporting method 2 land identification system (IPCC, 2014, Chapter 2.2.2). The lands included in the *grassland* category are defined in Section 6.3.1, Volume 2.

Grassland excludes all land that is used for continuous cropping, lands managed as crop-pasture rotations and land converted to cropland from grassland at any time.

The *grassland* classification includes shrubland vegetation. Emissions and removals due to shrubland transitions are established by the methods described in Section 6.8, Volume 2 and Section 6.2, Volume 2. Activity data for shrubland transitions are based on the national mapping programme to assess both the extent, and changes in extent, of sub-forest forms of woody biomass using the Landsat TM, ETM+ and OLI data for the years from 1988 to present.

Forest land converted to grassland after 1 January 1990 is identified based on attribution of the Landsat time series and is included under *deforestation.* If the conversion occurred prior to 1990, this land is included under *grazing land management*.

Land that has been observed to be converted to *forest land* in the Landsat time series after 1 January 1990 is included under *afforestation/reforestation.*

Land that is identified as *forest land* from the Landsat series is also excluded from *grasslands* but may in certain circumstances be reported under *grazing land management.* Lands which were *grassland* in 1990, and therefore included in *grazing land management,* remain in *grazing land management* even where increases in woody cover result in the land meeting the threshold parameters for *forest* provided there is no subsequent change in land use. A change in land use occurs if the increase in woody cover occurs on lands protected as forest by national, State or Territory regulations, in which case the land would be transferred to *afforestation/reforestation.* Alternatively, if the growth occurs outside a protected forest area, no change in land use occurs and the land remains in *grazing land management.*

Land that is identified as *forest land* from the Landsat series may also be incorporated under *grazing land management* for northern and central Australia where fire management including indigenous burning takes place. The identification of fire areas in non-temperate zone forest lands and grass lands is described in Volume 2, chapter 6.8.

Forest lands are not double counted in Australia's land classification systems for KP as a 'narrow' approach to *forest management* has been applied allowing specified forests not identified as being managed for timber to be included under *grazing land management.*

FullCAM simulates on a pixel by pixel (25m x 25m) level. The outputs of the simulations are stored in a datacube which can be queried using the Outputs Analysis System (OASys). OASys supports the reporting

of the geographical location of the boundaries of the area that encompass land subject to *grazing land management* annually, along with the total land areas subject to this activity.

11.8.2 Identification of management practices

The concepts underlying carbon stock changes in biomass of *grassland* are tied to management practices (IPCC 2006, p6.6).

Specified management practices affecting anthropogenic emissions and removals from *grazing land management* include:

- the area under grasslands;
- pasture management from fertilisers, irrigation and other inputs and seed selection;
- grazing management practices;
- woody biomass management; and
- fire management.

11.8.3 Methods to estimate changes in carbon stocks and emissions due to management changes over time

11.8.3.1 Data

Data sources for the estimation of changes in carbon stocks from changes in pasture management are reported in Section 6.8, Volume 2. Soil carbon and clay content values are taken from the finely disaggregated soil maps (Viscarra-Rossel *et al.* 2014, Viscarra-Rossel, 2014) – see Volume 2, Appendix 6.E which permit organic soils to be distinguished from mineral soils. Organic soils occur only rarely in Australia.

Data on management practices are derived from ABS statistics. The climate, site and management datasets are those used in the *forest land converted to cropland* estimates as described in Volume 2, Appendix 6.B and 6.E.

11.8.3.2 Methods

Pasture Management

Areas of grassland are stratified, consistent with IPCC 2006, P2.135, step 5, by climate and pasture type to distinguish between productive pastures and rangelands.

The IPCC encourages countries to use higher tier methods to develop emissions coefficients or models to represent the effects of management practices rather than those of inter-annual variability and short term temporal dynamics (IPCC 2006, p2.149).

Changes in soil carbon stocks are estimated for productive pasture regions using FullCAM in accordance with techniques described in IPCC (2006).

For productive pastures, only the changes in the soil carbon pool are reported. Decision 2/CMP7 specifies that a Party may choose not to account for a given pool, except for HWP, in a CP, if transparent and verifiable information is provided that the pool is not a source using reasoning based on sound knowledge of likely system responses (IPCC 2014, p2.26). Carbon stock changes from living biomass have been excluded. For pastures,

increases in biomass stocks in a single year may be assumed equal to biomass losses from harvest and mortality in that same year (IPCC 2006, p5.6) and will have little or no dead wood, residues or litter (IPCC 2006, p6.11).

The effects of inter-annual variability, and how they have been addressed, have been reported in Section 6.8, Volume 2.

Changes in carbon stocks for rangeland areas are assumed to be unchanged given limited pasture management activity and an arid climate.

Grazing management practices

For grazing management practices, the international literature which underpins IPCC (2014) and IPCC (2006) suggests that the impact of grazing on emissions and removals from grazing land activities can have important impacts on carbon stocks. In this report, however, the net effects of changes in grazing pressures on carbon stocks have not been estimated.

Shrub/sparse woody biomass

The methods and data used for the estimation of net emissions from woody biomass management are described in Volume 2.

Fire management

The methods and data for estimating emissions from prescribed burning and wildfires on northern and central Australian tropical, subtropical and semi-arid forest lands and grass lands is described in Volume 2, Chapter 6.4.1.5.

11.8.3.3 Start year

For the *grazing land management* category, FullCAM simulations commence in 1970.

11.8.3.4 Carbon pools

FullCAM estimates emissions from soil as a result of an estimation process involving all on-site carbon pools (living biomass, dead organic matter and soil).

For non-woody grasses, only the changes in the soil carbon pool are reported. Decision 2/CMP.7 specifies that a Party may choose not to account for a given pool, except for HWP, in a CP, if transparent and verifiable information is provided that the pool is not a source using reasoning based on sound knowledge of likely system responses (IPCC 2014, p2.26). Carbon stock changes from living biomass and DOM of non-woody annual grasses have been excluded as they do not constitute a source based on reasoning provided by the guidance in IPCC 2014. Herbaceous grassland vegetation is assumed to cycle annually such that biomass gains equal biomass losses in a single year (IPCC 2014, p2.153).

For woody vegetation, changes in soil carbon stocks have not been estimated.

11.8.4 Reporting of *grazing land management* in 2019

11.8.4.1 Reporting of *grazing land management* net emissions in 2019

Estimates of net emissions for *grazing land management* are reported in Table 11.36.

Table 11.36 Estimated emissions from *Grazing land management* (kt CO_2-e)

Year	Grasslands	Grassland burning	Woody transitions	Forest converted to grassland prior to 1990	Wetlands converted to Grassland	Total
1990	-1,433	5,712	-3,778	91,086	456	92,043
1995	-24,158	7,391	702	6,741	456	-8,868
2000	-20,361	16,652	1,676	3,900	456	2,322
2005	3,267	7,637	3,449	4,340	456	19,150
2006	-365	11,947	3,256	2,899	456	18,193
2007	-876	12,654	2,964	4,427	456	19,625
2008	5,036	11,697	2,224	3,139	456	22,551
2009	11,128	13,139	-364	2,394	456	26,753
2010	5,795	11,995	-2,685	6,505	456	22,066
2011	5,734	11,786	-4,641	3,284	456	16,618
2012	12,031	10,299	-5,868	4,571	456	21,489
2013	4,769	10,439	-5,479	4,822	456	15,007
2014	4,556	10,901	-5,429	4,104	456	14,587
2015	6,027	9,395	-4,803	2,982	456	14,056
2016	1,184	5,573	-4,614	2,249	456	4,848
2017	-5,015	5,701	-4,647	2,432	456	-1,074
2018	1,718	3,786	-4,801	3,872	456	5,030
2019	-3,275	4,761	-4,957	670	456	-2,347

11.8.4.2 Estimation of *Grazing land management* Accounting Quantity in 2013-19

For land activity categories other than *deforestation,* credits (called RMU credits) are to be issued against the reduction in net emissions relative to a specified benchmark base year or reference level. If net emissions are higher in the reporting year than in 1990, AAUs are to be cancelled.

For *grazing land management* estimates of the accounting quantity – to be used to estimate the amount of RMU credits to be issued – are reported in Table 11.37. Estimates are derived by deducting the reported net emissions in 2016 from the reported net emissions in 1990. Note that Australia has elected to account for Article 3.4 activities at the end of the commitment period.

Table 11.37 Estimated accounting quantity for *grazing land management* (t CO_2-e)

Year	GM 1990[a]	GM Reporting years	Estimated Accounting Quantity (RMU credits)
2013	956,666	15,006,903	14,050,237
2014	956,666	14,587,303	13,630,637
2015	956,666	14,055,840	13,099,174
2016	956,666	4,847,556	3,890,889
2017	956,666	-1,073,527	-2,030,193

Year	GM 1990[a]	GM Reporting years	Estimated Accounting Quantity (RMU credits)
2018	956,666	5,030,059	4,073,393
2019	956,666	-2,346,848	-3,303,514

(a) In this report, *grazing land management* estimates in 1990 were adjusted to exclude emissions associated with *Forest Conversion* in the UNFCCC inventory in 1990 from conversions up to 31 December 1989 and that are included in assigned amount, in order to avoid double counting. See Table 11.34

Note: Negative Accounting Quantities indicate that RMUs are to be issued. Positive Accounting Quantities indicate cancellation of AAUs.

In order to avoid double counting of emissions from *forest converted to grassland* in 1990 which is included in the Assigned Amount, emissions and removals associated with such conversions in 1990 are not included in the base for *grazing land management* for the purposes of estimating the accounting quantity.

11.8.5 Quality Assurance – Quality Control

Refer to section 6.8 in Volume 2.

11.8.6 Recalculations

Further descriptions of the recalculations is provided in the corresponding LULUCF category in Chapter 6, namely *grassland remaining grassland* (section 6.8.5) and *land converted to grassland* (section 6.9.5).

The quantification of the recalculation components is shown in Table 11.38.

Table 11.38 Grazing land management: Recalculation of total CO_2-e emissions (kt), 1990–2018

Year	2019 submission	2020 submission	Change		Reasons for Recalculations				
	($kt CO_2$)	($kt CO_2$)	($kt CO_2$)	%	A. Pasture management	B. Live biomass (sparse transitions)	C. Forest land converted to grassland	D. Wetland converted to Grassland	E. Non-temperate fire management
1990	105,116	92,043	-13,073	-12%	-12,675	899	-865	-441	9
1995	3,138	-8,868	-12,007	-383%	-12,387	629	193	-441	-1
2000	13,816	2,322	-11,495	-83%	-11,534	403	110	-441	-33
2005	24,356	19,150	-5,206	-21%	-4,970	121	101	-441	-17
2006	23,372	18,193	-5,180	-22%	-4,552	123	-302	-441	-8
2007	25,047	19,625	-5,422	-22%	-5,429	94	379	-441	-26
2008	27,517	22,551	-4,966	-18%	-4,234	14	-265	-441	-40
2009	30,146	26,753	-3,393	-11%	-2,899	41	-61	-441	-33
2010	26,403	22,066	-4,337	-16%	-3,809	84	-129	-441	-41
2011	22,277	16,618	-5,659	-25%	-5,172	133	-141	-441	-39
2012	25,525	21,489	-4,035	-16%	-3,729	187	-9	-441	-44
2013	19,250	15,007	-4,243	-22%	-4,119	252	118	-441	-53
2014	19,943	14,587	-5,356	-27%	-5,170	340	-9	-441	-77
2015	16,819	14,056	-2,763	-16%	-2,774	457	89	-441	-95
2016	8,195	4,848	-3,347	-41%	-3,644	697	123	-441	-84
2017	3,779	-1,074	-4,853	-128%	-4,095	982	-289	-441	-1,011
2018	3,052	5,030	1,978	65%	2,605	967	-18	-441	-1,134

11.9 Revegetation

Revegetation is a direct human-induced activity to increase carbon stocks through establishing vegetation that does not meet the definition of forest (IPCC 2014, section 2.11.1). In Australia, this includes net emissions from changes in vegetation cover that do not constitute a forest and which occur on non-grazing or cropping lands.

11.9.1 Identification of land subject to revegetation

All forms of woody vegetation are monitored as described in section 11.2. Gains and losses in shrub or sparse woody vegetation are distinguished from *deforestation* or *afforestation/reforestation* because they fall below the definition of forest land, as identified using the comprehensive 3-class vegetation monitoring system.

Gains and losses in sparse woody vegetation on grazing lands are already included as part of *grazing land management.* Where these changes occur since 1990 on managed wetlands and settlements they are reported as part of *revegetation.*

11.9.2 Identification of management practices

The primary management practices associated with *revegetation* relate to woody vegetation management. All woody vegetation management practices on wetlands and settlements are human-induced.

In addition to reporting carbon stock changes due to establishment of woody vegetation on settlements and managed wetlands, to ensure accuracy and balanced accounting, losses of such vegetation are also included in revegetation activities.

11.9.3 Methods to estimate changes in carbon stocks and emissions due to management changes over time

11.9.3.1 Data

The remote sensing data used for the estimation of net emissions from woody biomass management are the same as those described for grass and shrub transitions in *settlements remaining settlements,* and *wetlands remaining wetlands* in NIR Sections 6.10.1 and 6.12.1, respectively.

11.9.3.2 Methods

The methods used for the estimation of net emissions from woody biomass management are the same as those described for grass and shrub transitions in *settlements remaining settlements*, and *wetlands remaining wetlands* in NIR Sections 6.10.1 and 6.12.1 respectively, except that only transitions since 1990 are taken into account.

11.9.3.3 Start year

Estimation of net emissions is undertaken from 1990 consistent with IPCC good practice (IPCC 2014, p 2.160)

11.9.3.4 Carbon pools

Currently available data only supports modelling of aggregated carbon stock changes due to *revegetation*.

These represent changes across all 5 carbon pools, however they are reported under above-ground biomass, as this reflects the most significant pool for this subcategory. Scoping work to facilitate disaggregation by carbon pool through use of Tier 3 FullCAM approaches has been completed, and the implementation of the planned improvements for this disaggregation has begun.

11.9.4 Quality Assurance – Quality Control

The QA/QC for *revegetation* estimates are the same as those described in *settlements remaining settlements*, and *wetlands remaining wetlands* in Chapters 6.10.1 and 6.12.1, respectively.

11.9.5 Reporting of revegetation in 2019

Estimates of net emissions from *revegetation* are reported in Table 11.39 and the estimated accounting quantity is reported in Table 11.40.

Table 11.39 Estimated emissions from *revegetation* (kt CO_2-e)

Year	Net Emissions (kt CO_2-e)
1990	25
1995	219
2000	175
2005	94
2006	181
2007	226
2008	255
2009	280
2010	278
2011	246
2012	81
2013	52
2014	66
2015	89
2016	83
2017	131
2018	160
2019	172

Table 11.40 Estimated accounting quantity for revegetation (t CO_2-e)

Year	RV 1990 (a)	RV Reporting year	Estimated Accounting Quantity (RMU credits)
2013	24,901	52,133	27,232
2014	24,901	66,191	41,290
2015	24,901	89,117	64,215
2016	24,901	83,377	58,476
2017	24,901	131,101	106,200
2018	24,901	160,176	135,274
2019	24,901	172,030	147,129

11.9.6 Recalculations

Further description of the recalculations is provided in the corresponding LULUCF sub-categories in Chapter 6 of Volume 2, namely sparse woody vegetation within *wetlands remaining wetlands* (section 6.10.5) and *settlements remaining settlements* (section 6.12.5).

Corrections have been made in this submission in response to ERT recommendations to ensure that only activity data since 1990 is taken into account.

Table 11.41 Revegetation: Recalculation of total CO_2-e emissions (kt), 1990–2018

	2020 submission	2021 submission	Change	
Year	(kt CO_2)	(kt CO_2)	(kt CO_2)	%
1990	323	25	-299	-92%
1995	415	219	-197	-47%
2000	310	175	-135	-44%
2005	188	94	-94	-50%
2006	274	181	-92	-34%
2007	312	226	-86	-28%
2008	329	255	-74	-23%
2009	278	280	2	1%
2010	276	278	2	1%
2011	243	246	3	1%
2012	75	81	5	7%
2013	42	52	10	23%
2014	51	66	15	29%
2015	69	89	20	28%
2016	47	83	36	78%
2017	77	131	54	69%
2018	108	160	52	49%

11.10 Other information

11.10.1 Key category analysis

The key category analysis for Article 3.3 and relevant Article 3.4 activities are reported in Annex 1 and in Table 11.42.

Table 11.42 Summary overview for key categories for land use, land use change and forestry activities under the Kyoto Protocol

Criteria used for Key Category Identification					
Key Categories of Emissions and Removals	**Gas**	**Associated category in UNFCCC inventory is key**	**Category contribution is greater than the smallest category considered key in the UNFCCC inventory (including LULUCF)**	**Other**	**Comments**
Deforestation	CO_2	forest land converted to grassland	TRUE	NA	
Deforestation	CH_4	forest land converted to grassland	FALSE	NA	
Deforestation	N_2O	forest land converted to grassland	FALSE	NA	
Forest management	CO_2	forest land remaining forest land	TRUE	NA	Australia has applied the narrow approach to forest management. As a result the forest land remaining forest land classification does not directly correspond to the forest management activity.
Afforestation/ Reforestation	CO_2	grassland converted to forest land	TRUE	NA	
Grazing land management	CO_2	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Grazing land management	CH_4	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Grazing land management	N_2O	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Cropland management	CO_2	cropland remaining cropland, land converted to cropland (conversion prior to 1990)	TRUE	NA	

11.10.2 Provision of information relating to KP-LULUCF activities under Article 3, paragraphs 3 and 4

Annex II to Decision 2/CMP.8 sets out the requirements for the reporting of Information on land use, land-use change and forestry activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol in annual greenhouse gas inventories. The following table is provided to assist the assessment of compliance with the reporting requirements set out in this decision.

Table 11.43 Australia's compliance with the requirements of 2/CMP.8.

Provision of information relating to KP-LULUCF activities under Article 3, paragraphs 3 and 4	
Information item	**Reference/additional information**
Emissions by sources and removals by sinks are clearly distinguished from emissions from categories included in Annex A to the Kyoto Protocol.	Refer to CRF tables and Volume 1 Executive Summary and Ch.11
Information on how inventory methodologies have been applied taking into account the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories and any relevant supplementary guidance recognising the principles laid out in decision 16/CMP.1.	Refer to NIR Vol.2 and Vol.3, Ch.11
Information on geographical location of the boundaries of areas that encompass:	
Units of land subject to activities under Article 3, paragraph 3.	Refer to Table 11.3, Figures 11.1 and 11.2 and Vol.2 Appendix 6.A
Units of land subject to activities under Article 3, paragraph 3, which would otherwise be included in land subject to forest management or elected activities under Article 3, paragraph 4.	Refer to CRF tables and Vol.2 Appendix 6.A
Land subject to forest management or elected activities under Article 3, paragraph 4.	Refer to Table 11.3 and Section 11.6
Information on the spatial assessment unit for determining the area of accounting for afforestation, reforestation and deforestation.	Refer to section 11.2.2
Information on GHG emissions/removals resulting from activities under Article 3, paragraph 3, and Article 3, paragraph 4, for all geographical locations reported in the current and previous years since the beginning of the commitment period or the onset of the activity, whichever comes later.	Refer to sections 11.4, 11.5, 11.6, 11.7, and 11.8
Information on carbon pools (above-ground/below-ground biomass, litter, dead wood and soil organic carbon) that are not accounted for.	All carbon pools are accounted for. Refer to CRF table NIR-1.
When a Party applies the provisions for natural disturbances, information demonstrating that these emissions in any single year exceed the background level(s), including a margin, when needed. For this purpose the Party shall include information showing:	
That all lands subject to exclusion due to natural disturbances are identified.	Refer to section 11.6.4.1
How annual emissions resulting from natural disturbances and the subsequent removals are estimated and excluded from accounting.	Refer to sections 11.6.4.2 and 11.6.4.3
That no land-use change has occurred on lands for which the provisions in decision 2/CMP.7, annex, paragraph 33, are applied.	Refer to section 11.6.4.8
That events and circumstances were beyond the control of the Party.	Refer to section 11.6.4.6
The efforts taken to rehabilitate the land for which the provisions contained in decision 2/CMP.7, annex, paragraph 33, are applied.	Refer to section 11.6.4.9
That emissions associated with salvage logging were not excluded from accounting.	Refer to section 11.6.4.5
If not accounted for by instantaneous oxidation, information on GHG emissions/removals resulting from changes in the HWP pool accounted for in accordance with decision 2/CMP.7, including:	
Activity data for the HWP categories used for estimating the pool removed from domestic forests, for domestic consumption and for export.	Refer to CRF table 4.G and NIR section 11.6.3.1.
Half-lives used in estimating emissions/removals for the HWP categories used.	Refer to CRF table 4.G and NIR section 6.15.1.
Whether emissions from HWP originating from forests prior to the start of the second commitment period have been included in the accounting, if the forest management reference level is based on a projection.	Emissions from HWP originating from forests prior to the start of the second commitment period have been included in the accounting. Refer to Sections 11.6.3 and 6.15.1.

Provision of information relating to KP-LULUCF activities under Article 3, paragraphs 3 and 4	
Information item	**Reference/additional information**
How emissions from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation have been excluded from the accounting for the second commitment period.	Australia estimates a time-series consistent with the second commitment period requirements, as per methods described in sections 11.6.3.1 and 6.15.1.
How the HWP resulting from deforestation have been accounted on the basis of instantaneous oxidation.	Refer to Section 11.4.3
How CO_2 emissions from HWP in SWDS and from wood harvested for energy purposes have been accounted on the basis of instantaneous oxidation.	Transfers from the HWP pool to the landfill pool result in a reduction in HWP carbon stock and therefore an instantaneous oxidation. For information on the CO_2 emissions associated with the combustion of fuelwood, refer to section 6.4.2.
How emissions/removals from changes in the HWP pool accounted for do not include imported harvested wood products.	Refer to section 11.6.3.1
Information on anthropogenic GHGs from LULUCF activities under Article 3, paragraph 3, and Article 3, paragraph 4, factoring out removals from:	
Elevated CO_2 concentrations above pre-industrial levels.	Refer to Section 11.3.3
Indirect nitrogen deposition.	Refer to NIR Vol 1, Ch.4, CRF tables and section 11.3.3
The dynamic effects of age structure resulting from activities prior to 1 January 1990.	Refer to Section 11.3.3
Specific information to be reported for activities under Article 3, paragraph. 3:	
Activities under Article 3, paragraph 3, that began on or after 1 January 1990 and before 31 December of the last year of the commitment period, and are directly human-induced.	Refer to Sections 11.2, 11.3, 11.4 and 11.5
How harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation.	Refer to section 11.2.3.1
Specific information to be reported for activities under Article 3, paragraph 4:	
Activities under Article 3.4 that occurred since 1 January 1990 and are human induced.	Refer to sections 11.6, 11.7 and 11.8
Cropland management, grazing land management, revegetation, wetland drainage and rewetting: emissions/ removals reported for each year of the commitment period and for the base year for each of the elected activities on the geographical locations reported.	Refer to sections 11.7, 11.8, 11.9 and CRF tables
Emissions/removals from activities under Article 3, paragraph 4, are not accounted for under activities under Article 3, paragraph 3.	Refer to Vol.2 Appendix 6.A
Information on how emissions arising from the conversion of natural forests to planted forests are accounted for.	Refer to section 11.6.6.3 and CRF table NIR 2.1
Methodological consistency between the reference level and reporting for forest management.	Refer to section 11.6.5
Technical corrections made pursuant to decision 2/CMP.7, annex, paragraph 14.	Refer to section 11.6.5
Forest management: if emissions/removals from the harvest and conversion of forest plantations to non-forest land were included, information how requirements set out in decision 2/CMP.7, annex, paragraphs 37-39 were met, including:	
The identification of all lands and associated carbon pools subject to decision 2/CMP.7, annex, paragraph 37, including the geo-referenced location and year of conversion.	Australia has not applied this provision.
A demonstration that the forest plantation was first established through direct human-induced planting and/or seeding of non-forest land before 1 January 1990, and, if the forest plantation was re-established, that this last occurred on forest land through direct human-induced planting and/ or seeding after 1 January 1960.	Australia has not applied this provision.
A demonstration that a new forest of at least equivalent area to the harvested forest plantation is established through direct human-induced planting and/or seeding of non-forested land that did not contain forest on 31 December 1989.	Australia has not applied this provision.
A demonstration that this newly established forest will reach at least the equivalent carbon stock that was contained in the harvested forest plantation at the time of harvest, within the normal harvesting cycle of the harvested forest plantation, and, if not, a debit would be generated under Article 3, paragraph 4.	Australia has not applied this provision.

12. Information on accounting of Kyoto Units

12.1 Summary of information reported in the Standard Electronic Format Tables

In accordance with decisions 1/CMP.8, 2/CMP.8 and 3/CMP.11, Annex I Parties are required to report information on KP units for the first commitment period and for the CP2 for the reported year 2020. This information has been submitted in the standard electronic format (SEF) tables (Tables 12.1 to 12.28).

12.1.1 SEF reporting for commitment period 1 (CP1)

Table 12.1 SEF Table 1, Total quantities of Kyoto Protocol units by account type at beginning of reported year 2020

	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	127,650,775	NO	NO	21,768,290	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Article 33/3.4 net source cancellation accounts	115,625,564	NO	108,941,877	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	3,149,326	367,766	NO	3,418,449	73,849	NO
Retirement account	2,711,153,478	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	**2,957,579,143**	**367,766**	**108,941,877**	**25,186,739**	**73,849**	**NO**

Table 12.2 SEF Table 2(a), Annual internal transactions for the reported year 2020

	Additions						Subtractions					
Transaction type	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
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 reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		

	Additions						Subtractions					
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
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		
Art 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired ICERs							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	10,000	NO	NO
Subtotal		**NO**	**NO**				**NO**	**NO**	**NO**	**10,000**	**NO**	**NO**

Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
Retirement	NO	NO	NO	NO	NO	NO

Table 12.3 SEF Table 2(b), Annual external transactions for the reported year 2020

	Additions						Subtractions					
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
CDM	NO	NO	NO	10,000	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	NO	NO	NO	10,000	NO	NO	NO	NO	NO	NO	NO	NO

	Additional Information											
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
Independently verified ERU								NO				

Table 12.4 SEF Table 2(c), Total annual transactions for the reported year 2020

	Additions						Subtractions					
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
Total (Sum of table 2(a) and 2(b))	NO	NO	NO	10,000	NO	NO	NO	NO	NO	10,000	NO	NO

Table 12.5 SEF Table 3, Expiry, cancellation and replacement for the reported year 2020

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

Table 12.6 SEF Table 4, Total quantities of Kyoto Protocol units by account type at end of reported year 2020

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	127,650,775	NO	NO	21,768,290	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Article 33/3.4 net source cancellation accounts	115,625,564	NO	108,941,877	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	3,149,326	367,766	NO	3,428,449	73,849	NO
Retirement account	2,711,153,478	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	**2,957,579,143**	**367,766**	**108,941,877**	**25,196,739**	**73,849**	**NO**

Table 12.7 SEF Table 5(a), Summary information on additions and subtractions for the reported year 2020

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Starting values												
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	23,262,032	102,714	NO	NO	44,164,557	NO	NO	123,712	NO	NO
Year 6 (2013)	NO	150,000	23,834,852	530,972	NO	NO	11,894,403	150,000	46,294,933	515,872	NO	NO
Year 7 (2014)	NO	100,000	25,907,257	713,954	NO	NO	NO	100,000	38,543,673	530,098	NO	NO
Year 8 (2015)	NO	118,935	12,904,835	28,124,304	NO	NO	13,065,399	118,935	24,103,271	6,584,972	NO	NO
Year 9 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 10(2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 11 (2018)	NO	NO	NO	490	10	NO	NO	NO	NO	490	10	NO
Year 12(2019)	NO	NO	NO	42,344	73,839	NO	NO	NO	NO	42,344	73,839	NO
Year 13 (2020)	NO	NO	NO	10,000	NO	NO	NO	NO	NO	10,000	NO	NO
Year 14(2021)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 15 (2022)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 16(2023)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	**NO**	**368,935**	**108,941,877**	**29,651,630**	**73,849**	**NO**	**118,774,890**	**368,935**	**108,941,877**	**7,883,340**	**73,849**	**NO**
Total	**2,957,579,143**	**368,935**	**108,941,877**	**29,651,630**	**73,849**	**NO**	**118,774,890**	**368,935**	**108,941,877**	**7,883,340**	**73,849**	**NO**

Table 12.8 SEF Table 5(b), Summary information on replacement for the reported year 2020

Expiry, cancellation and requirement to replace			Replacement					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
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
Year 9 (2016)	NO	NO	NO	NO	NO	NO	NO	NO
Year 10(2017)	NO	NO	NO	NO	NO	NO	NO	NO
Year 11 (2018)	NO	NO	NO	NO	NO	NO	NO	NO
Year 12(2019)	NO	NO	NO	NO	NO	NO	NO	NO
Year 13 (2020)	NO	NO	NO	NO	NO	NO	NO	NO
Year 14(2021)	NO	NO	NO	NO	NO	NO	NO	NO
Year 15 (2022)	NO	NO	NO	NO	NO	NO	NO	NO
Year 16(2023)	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 for the reported year 2020

Year	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
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)	2,711,153,478	NO	NO	NO	NO	NO
Year 9 (2016)	NO	NO	NO	NO	NO	NO
Year 10 (2017)	NO	NO	NO	NO	NO	NO
Year 11 (2018)	NO	NO	NO	NO	NO	NO
Year 12 (2019)	NO	NO	NO	NO	NO	NO
Year 13 (2020)	NO	NO	NO	NO	NO	NO
Year 14 (2021)	NO	NO	NO	NO	NO	NO
Year 15 (2022)	NO	NO	NO	NO	NO	NO
Year 16 (2023)	NO	NO	NO	NO	NO	NO
Total	**2,711,153,478**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.10 SEF Table 6(a), Memo item: Corrective transactions relating to additions and subtractions for the reported year 2020

Additions						Subtractions					
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 for the reported year 2020

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

Table 12.12 SEF Table 6(c), Memo item: Corrective transactions relating to retirement for the reported year 2020

Retirement					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.1.2 SEF reporting for commitment period 2 for the reported year 2020

Table 12.13 SEF Table 1, Total quantities of Kyoto Protocol units by account type at beginning of reported year 2020

	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	9,388,078	NO	16,617,550	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	6,598,076	22,822	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	**NO**	**9,388,078**	**NO**	**23,215,626**	**22,822**	**NO**

Table 12.14 Table 12.14 SEF Table 2(a), Annual internal transactions for the reported year 2019

	Additions						Subtractions					
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
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			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	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		
3.4 Wetlands drainage and rewetting			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired ICERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Cancellation for reversal of storage												NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Cancellation for non-submission of certification report												NO
Other cancellation												
Voluntary cancellation							NO	NO	NO	5,753,251	NO	NO
Article 3.1 ter and quater ambition increase cancellation							NO					
Subtotal	**NO**		**NO**				**NO**	**NO**	**NO**	**5,753,251**	**NO**	**NO**

	Retirement Unit type					
Transaction type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
Retirement	NO	NO	NO	NO	NO	NO
Retirement from PPSR	NO					
Total	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.15 SEF Table 2(b), Annual external transactions for the reported year 2020

Total transfers and acquisitions	Additions Unit Type						Subtractions Unit Type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
CDM	NO	NO	NO	6,207,842	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	NO	NO	581,724	NO	NO	NO	NO	NO	1,230,817	NO	NO
DE	NO	NO	NO	1,126,643	NO	NO	NO	NO	NO	10,000	NO	NO
EU	NO	NO	NO	2,503,778	NO	NO	NO	NO	NO	3,415,163	NO	NO
GB	NO	NO	NO	578,179	NO	NO	NO	9,388,078	NO	2,547,654	NO	NO
NL	NO	NO	NO	378,086	NO	NO	NO	NO	NO	57,524	NO	NO
SE	NO	NO	NO	NO	NO	NO	NO	NO	NO	62,551	NO	NO
CDM	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
GB	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	**NO**	**NO**	**NO**	**11,376,252**	**NO**	**NO**	**NO**	**9,388,078**	**NO**	**7,323,709**	**NO**	**NO**

Table 12.16 SEF Table 2(c), Annual transactions between PPSR accounts for the reported year 2020

Transfers and acquisitions between PPSR accounts	Additions Unit Type						Subtractions Unit Type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO						NO					

Table 12.17 SEF Table 2 (d) Share of proceeds transactions under decision 1/CMP.8, paragraph 21 – Adaptation Fund – for the reported year 2020

	Amount transferred or converted						Amount contributed as SoP to the adaptation fund					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
First international transfers of AAUs	NO						NO					
Issuance of ERU from Party-verified projects		NO						NO				
Issuance of independently verified ERUs		NO						NO				

Table 12.18 SEF Table 2(e),Total annual transactions for the reported year 2020

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Total (Sum of sub-totals in table 2a and table 2b)	NO	NO	NO	11,376,252	NO	NO	NO	9,388,078	NO	13,076,960	NO	NO

Table 12.19 SEF Table 3, Expiry, cancellation and replacement for the reported year 2020

Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
	Unit type			Unit type						Unit type					
	tCERs	ICERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Temporary CERs															
Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
Expired in holding accounts	NO													NO	
Long-term CERs															
Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
Expired in holding accounts		NO													NO
Subject to reversal of storage		NO		NO	NO	NO	NO		NO						NO
Subject to non-submission of certification Report		NO		NO	NO	NO	NO		NO						NO
Carbon Capture and Storage CERs															
Subject to net reversal of storage			NO							NO	NO	NO	NO		
Subject to non-submission of certification report			NO							NO	NO	NO	NO		
Total	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.20 SEF Table 4, Total quantities of Kyoto Protocol units by account type at end of reported year 2020

	Unit type					
Account type	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	NO	NO	NO	14,916,842	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	12,351,327	22,822	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
ICER cancellation account for expiry						NO
ICER cancellation account for reversal of storage						NO
ICER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	**NO**	**NO**	**NO**	**27,268,169**	**22,822**	**NO**

Table 12.21 SEF Table 5(a), Summary information on additions and subtractions for the reported year 2020

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Assigned amount units issued	NO											
Article 3 paragraph 7 ter cancellations							NO					
Cancellation following increase in ambition							NO					
Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over		NO		NO				NO		NO		
Carry-over to PPSR	NO						NO					
Total	**NO**	**NO**		**NO**			**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.22 SEF Table 5(b), Summary information on annual transactions for the reported year 2020

	Additions Unit Type						Subtractions Unit Type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	130,870	NO	NO	NO	NO	NO	130,870	NO	NO
Year 3 (2015)	NO	NO	NO	3,605,224	NO	NO	NO	NO	NO	2,163,128	NO	NO
Year 4 (2016)	NO	NO	NO	7,239,334	NO	NO	NO	NO	NO	646,428	NO	NO
Year 5 (2017)	NO	NO	NO	6,492,374	NO	NO	NO	NO	NO	2,602,357	NO	NO
Year 6 (2018)	NO	NO	NO	4,906,968	NO	NO	NO	NO	NO	3,274,970	NO	NO
Year 7 (2019)	NO	9,388,078	NO	9,609,556	22,822	NO	NO	NO	NO	6,549,023	22,822	NO
Year 8 (2020)	NO	NO	NO	11,376,252	NO	NO	NO	9,388,078	NO	13,076,960	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	**NO**	**9,388,078**	**NO**	**43,360,578**	**22,822**	**NO**	**NO**	**9,388,078**	**NO**	**28,443,736**	**22,822**	**NO**

Table 12.23 SEF Table 5(c), Summary information on annual transactions between PPSR accounts for the reported year 2020

	Additions Unit Type						Subtractions Unit Type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO						NO					
Year 2 (2014)	NO						NO					
Year 3 (2015)	NO						NO					
Year 4 (2016)	NO						NO					
Year 5 (2017)	NO						NO					
Year 6 (2018)	NO						NO					
Year 7 (2019)	NO						NO					
Year 8 (2020)	NO						NO					
Year 2021	NO						NO					
Year 2022	NO						NO					
Year 2023	NO						NO					
Total	**NO**						**NO**					

Table 12.24 SEF Table 5(d), Summary information on expiry, cancellation and replacement for the reported year 2020

	Requirement to replace or cancel Unit type			Replacement Unit type					Cancellation Unit type						
	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.25 SEF Table 5(e), Summary information on retirement for the reported year 2020

	Retirement Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO
Total	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Table 12.26 SEF Table 6(a), Memo item: Corrective transactions relating to additions and subtractions for the reported year 2020

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

Table 12.27 SEF Table 6 (b), Memo item: corrective transactions relating to replacement for the reported year 2020

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

Table 12.28 SEF Table 6(c), Memo item: Corrective transactions relating to retirement for the reported year 2020

Retirement Unit type					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.2 Discrepancies and notifications

Decision 15/CMP.1 annex I.E paragraphs 12–17, decision 2/CMP.8 and decision 3/CMP.11, require Annex I Parties to report on various possible discrepancies and notifications. Australia's discrepancies and notifications are summarised in Table 12.29 for the reported year 2020.

Table 12.29 Accounting of Kyoto Protocol Units

Annual Submission Item	Report
Decision 15/CMP.1 annex I.E paragraph 11 and 19 as updated by decision 3/CMP.11: Standard electronic format (SEF)	See section 12.1. The SEF tables have been submitted to the UNFCCC.
Decision 15/CMP.1 annex I.E paragraph 12: List of discrepant transaction	Australia had no transaction with discrepancies for the reporting period.
Decision 15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	Australia did not receive any CDM notifications.
Decision 15/CMP.1 annex I.E paragraph 15: List of non-replacements	Australia had no non-replacements.
Decision 15/CMP.1 annex I.E paragraph 16: List of invalid units	Australia had no invalid units.
Decision 15/CMP.1 annex I.E paragraph 17: Actions and changes to address discrepancies	None required.
Decision 15/CMP.1 annex I.E paragraph 18: Commitment period reserve calculation	See section 12.4

12.3 Publicly accessible information

In accordance with decision 13/CMP.1 paragraph 44, as amended by decision 3/CMP.11, and Regulation 66 of the *Australian National Registry of Emissions Units Regulations 2011,* non-confidential information is publicly available at https://nationalregistry.cleanenergyregulator.gov.au/report/listPublicReports under the Public Reports facility. A full description of the information that is available is in Annex 7.

12.4 Calculation of the Commitment Period Reserve

For CP2, Australia's commitment period reserve (CPR) is 4,060,457,844 tonnes CO_2 equivalent, calculated as 90 per cent of its assigned amount in accordance with decisions 11/CMP.1, 1 and 2/CMP8 and 2/CMP11.

12.5 KP-LULUCF Accounting

Australia has elected to account for the KP Article 3.3 LULUCF activities on an annual basis and to account for the Article 3.4 activities at the end of the CP2 as set out in Table 12.30 below.

Table 12.30 Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol

Greenhouse gas source and sink activities	Base Year[2]	Net emissions/removals								Accounting parameters		Accounting quantity[4]
		2013	2014	2015	2016	2017	2018	2019	Total[3]	Calibration period (2000–2012)	FMRL	
		(kt CO_2-e)										
A. Article 3.3 activities												
A.1. Afforestation/reforestation		-30,110.44	-30,671.82	-29,188.05	-31,830.41	-32,895.53	-23,556.05	-17,659.66	-195,911.96			-195,911.96
Excluded emissions from natural disturbances[6]		NA	NA	NA	NA	NA	NA	NA	NA			NA
Excluded subsequent removals from land subject to natural disturbances[6]		NA	NA	NA	NA	NA	NA	NA	NA			NA
A.2. Deforestation		35,988.98	38,262.44	30,082.56	27,656.72	26,917.12	29,336.92	22,283.63	210,528.38			210,528.38
B. Article 3.4 activities												
B.I. Forest management									-131,061.28			NA[12]
Net emissions/removals excluding emissions from natural disturbances		-6,505.83	-16,592.45	-19,360.05	-20,235.91	-22,595.88	-24,534.29	-21,236.87	-131,061.28			NA[12]
Note: Emissions from anthropogenic wildfire in reporting period		4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	32,352.16			NA[12]
Emissions from anthropogenic wildfire in FMRL[5][13] (2013–2019: Annual average over calibration period)		4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	4,621.74	32,352.16	55,460.88		
Note 2: Emissions from natural disturbances in reporting period [5] [13]		20,889.66	21,154.29	11,418.07	30,429.61	21,697.58	16,290.75	22,263.02	144,142.98			

Greenhouse gas source and sink activities	Base Year[2]	Net emissions/removals								Accounting parameters		
		2013	2014	2015	2016	2017	2018	2019	Total[3]	Calibration period (2000–2012)	FMRL	Accounting quantity[4]
		(kt CO_2-e)										
Emissions from natural disturbances in FMRL[5][13] (2013–2018: Annual average over calibration period)		20,169.92	20,169.92	20,169.92	20,169.92	20,169.92	20,169.92	20,169.92	141,189.43	242,039.03		
Note 3: Subsequent removals natural disturbances in reporting period[6][13]		NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]			
Subsequent removals from natural disturbances in FMRL[6][13] (2013–2018: Annual average over calibration period)		NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]		
Any debits from newly established forest (CEF-ne) [7][8]		NA	NA	NA	NA	NA	NA	NA	NA			NA
Forest management reference level (FMRL)[9]											4,700.00	
Technical corrections to FMRL[10]											-185.32	
Forest management cap[11]											117,214.45	NA[12]
B.2. Cropland management (if elected)	25,178.71	2,136.06	2,788.47	-1,085.18	-5,689.01	-5.644.19	-3,715.91	-4,292.43	-15,502.20			NA[12]
B.3. Grazing land management (if elected)	956.67	15,006.90	14,587.30	14,055.84	4,847.56	-1,073.53	5,030.06	-2,346.85	50,107.29			NA[12]
B.4. Revegetation (if elected)	24.90	52.13	66.19	89.12	83.38	131.10	160.18	172.03	754.13			NA[12]
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA			NA

(1) All values are reported in table 4(KP) and tables 4(KP-I).A.1.1,4(KP-I).B.1.1,4(KP-I).B.1.2 and 4(KP-I).B.1.3 of the CRF for the relevant inventory year as reported in the current submission and are automatically entered in this table.

(2) Net emissions and removals from cropland management, grazing land management, revegetation and/or wetland drainage and rewetting, if elected, in the Party's base year, as established by decision 9/CP.2.

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

(4) 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.

(5) A Party that has indicated their intent to apply the natural disturbance provisions may choose to exclude emissions from natural disturbances either annually or at the end of the commitment period.

(6) All subsequent CO_2 removals from post-wildfire recovery (including in years where the natural disturbances provision applies) are excluded from the calculation of FMRL (that is, the removals are excluded from the calculation of the background level and margin), and from reporting of forest management emissions during the commitment period, as outlined in the NIR Volume 3, Section 11.6.4.3 (consistent with guidance on exclusion of removals where projected reference levels are used – IPCC 2014, page 2.53; and ensuring consistency between the FMRL and the reporting of forest management – IPCC 2014, chapter 27.5.2). Because estimated natural disturbance emissions exceeded the background level plus margin in CP2 years, emissions from natural disturbances that exceed the background level in these years are excluded ('excluded natural disturbances emissions'). Therefore the accounting of natural disturbances in these years are equal to the background level of natural disturbance emissions (the same value as is in the FMRL) ensuring that the exclusion of natural disturbance emissions in these years generates zero net credits (in accordance with avoiding the expectation of net credits or net debits – IPCC 2014, pages 2.49-2.50). More information on the application of the natural disturbances provision is included in Chapter 11.6.4 of the NIR.

(7) A debit is generated in case the newly established forest does not reach at least the expected carbon stock at the end of the normal harvesting period. Total debits from carbon equivalent forests are subtracted from the accounting quantity forest management.

(8) In case of a projected forest management reference level, Parties should not fill in this row.

(9) Forest management reference level as inscribed in the appendix of the annex to decision 2/CMP.7, in kt CO_2eq per year.

(10) Technical corrections in accordance with paragraphs 14 and 15 of the annex to decision 2/CMP.7 and reported in table 4(KP-I)B.1.1 in kt CO_2eq per year.

(11) For the second commitment period, additions to the assigned amount of a Party resulting from forest management shall, in accordance with paragraph 13 of the annex to decision 2/CMP.7, not exceed 3.5 per cent of the national total emissions excluding LULUCF in the base year times eight.

(12) Australia has opted for end of commitment period reporting for Article 3.4 activities.

(13) In accordance with footnote (5) in CRF table 4(KP) 'accounting' Australia has chosen to exclude emissions from natural disturbances annually, rather than at the end of the commitment period. To ensure that this is correctly reflected in the CRF table (does not allow annual exclusions) excluded emissions from natural disturbances are included in the reporting of net emissions/removals from forest management in 4(KP)B.1. More information on the application of the natural disturbances provision is included in Chapter 11.6.4 of the NIR.

13. Changes to the National System

Under the KP, decision 15/CMP1 annex I.F paragraph 21, as amended by decisions 3/CMP11, requires Parties to include in the Report information on any changes that have occurred in its national system compared with its last submission.

Changes in Australia's national systems implemented since the last submission are set out in Table 13.1.

Table 13.1 Change to the national system

Reporting Item	Annual Report
Decision 15/CMP.1 annex II.D paragraph 30 (a) Change of name or contact information	No change in this submission.
Decision 15/CMP1 annex II.D paragraph 30 (b) Change of roles and responsibilities as well as change of the institutional, legal and procedural arrangements	No change in this submission
Decision 15/CMP1 annex II.D paragraph 30 (c) Changes in the process of inventory compilation	Section ES.4 summarises major inventory developments, with further detail in the relevant chapters of the Report.
Decision 15/CMP1 annex II.E paragraph 30 (d) Change of process for key category identification and archiving	No change in this submission.
Decision 15/CMP1 annex II.D paragraph 30 (e) Change of process for recalculations	No change in this submission.
Decision 15/CMP1 annex II.D paragraph 30 (f) Changes with regard to QA/QC plan, QA/QC activities and procedures	Additional QA/QC activities and procedures have been implemented as identified in Chapter 1 and the relevant chapters of the Report.
Decision 15/CMP1 annex II.D paragraph 30 (g) Change of procedures for the official consideration and approval of the inventory	No change since last submission.

14. Changes to the National Registry

Under the KP, 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 7. 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, as amended by decisions 3/CMP.11, requires Parties to include in the Report information on any changes that have occurred in its national registry compared with its last submission. Changes to Australia's National Registry since its last submission are included in Table 14.1 below.

Table 14.1 Change to the national registry – 2020

Reporting Item	Annual Report
Decision 15/CMP.1 annex II.E, paragraph 32 Change of name or contact	No change in this submission
Decision 15/CMP.1 annex II.E, subparagraph 32 (b) Change of cooperation arrangement	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (c) Change to database or the capacity of National Registry	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (d) Change of conformance to technical standards	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (e) Change of discrepancies procedures	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (f) Change of Security	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (g) Change of list of publicly available information	• 'Representative Identifier' is made publicly available at Public Reports > Account Information Report, with Unit Block Holdings, as required under Decision 13/CMP.1 Annex II.E, subparagraph 45 (d), as amended by Decision 3/CMP.11. • Representative name and contact information, including full name, mailing address, telephone number, facsimile number and email address is not published as Decision 13/CMP.1 Annex II.E, subparagraph 45 (e), as amended by Decision 3/CMP.11, no longer applies, • The information required under Decision 13/CMP.1 Annex II.E, subparagraph 47 (a) bis, as amended by Decision 3/CMP.11, is available under Public Reports > Account Information Report, with Unit Block Holdings. • The information required under Decision 13/CMP.1 Annex II.E, subparagraphs 47 (b) to (k), as amended by Decision 3/CMP.11, is made publicly available at Public Reports > Annual Transaction Summary Report. • The information required under Decision 13/CMP.1 Annex II.E, subparagraph 47 (l) is available at Public Reports > Account Information Report, with Unit Block Holdings
Decision 15/CMP.1 annex II.E, subparagraph 32 (h) Change of Internet address	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (i) Change of data integrity measure	No change in this submission.
Decision 15/CMP.1 annex II.E, subparagraph 32 (j) Change of test results	No change in this submission.
Response to previous Annual Review recommendations	Nil recommendations.

15. Minimisation of adverse impacts in accordance with Article 3.14

Australia is pleased to provide an update on how it is striving, under Article 3, paragraph 14, of the KP, to implement its greenhouse gas emission limitation and reduction commitments in such a way as to minimise adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the UNFCCC.

Australia recognises that the economic cost of reducing emissions is lower than the cost of inaction on climate change (Stern 2006; Garnaut 2008 and 2011). Curbing emissions in support of the global temperature goal will reduce the economic, social and environmental impacts of climate change, particularly for developing countries that are most vulnerable. This is why Australia is committed to reducing emissions and supporting other countries' efforts to mitigate and adapt to climate change.

Australia also recognises that measures to address climate change can have social, environmental and economic impacts. In developing its climate change response measures, Australia seeks to identify possible impacts and minimise those that are negative.

How Australia addresses domestic impacts of response measures

Australia is playing its role in global efforts to reduce emissions, while maintaining a strong economy and realising the benefits of the transition to a lower-emissions future. Central to this are the consultation processes that typically accompany policy development in Australia and that enable those potentially affected to raise concerns and present ideas.

For example, in May 2020, the Australian Government released a discussion paper on a Technology Investment Roadmap – an enduring strategy to accelerate the development and commercialisation of new and emerging low emissions technologies. Approximately 500 written submissions from industry, researchers and the community were received in response to the discussion paper. In addition, around 150 people attended targeted workshops and more than 400 people attended a webinar hosted by Australia's former Chief Scientist, Dr Alan Finkel AO, on the Roadmap. (New information since last submission).

In conducting the 2017 review of Australia's climate change policies, officials from the former Department of Environment and Energy (new text for clarity since last submission) consulted widely with businesses across all sectors of the economy and with the community. This included the release of a discussion paper which generated over 350 public submissions. The Department also met with more than 270 stakeholders and the then Minister for the Environment and Energy hosted two roundtables attended by 42 business, community, environmental and Indigenous stakeholders.

Impact assessment is an integral part of Australia's policy development process. Any legislation introduced to the Australian parliament must be accompanied by a Regulatory Impact Statement that assesses the economic and social impacts of a measure.

The Australian Government aims to meet its international climate change obligations while protecting the livelihoods and employment of Australian workers. It sees the development and use of technological solutions as key to achieving emissions reductions while maintaining social and economic gains. In support of this approach, in September 2020 the Australian Government released the Technology Investment Roadmap's first Low Emissions Technology Statement which articulates five priority technologies and accompanying stretch goals to bring priority low emissions technologies to economic parity with existing mature technologies. (New information since last submission). The technology priorities will be developed in partnership with industry to address the challenges of energy transition.

How Australia addresses the international impacts of response measures

Australia's bilateral consultations with other countries and engagement in international platforms such as the UNFCCC Forum on the Impact of the Implementation of Response Measures helps build understanding of positive and negative impacts and allows countries to raise concerns and suggest ways to minimise adverse impacts. Australia participates actively in the UNFCCC Response Measures Forum and is committed to maximising its effectiveness. Australia is also a supporter of the Katowice Committee of Experts on the Impacts of the Implementation of Response Measures.

Australia helps minimise the economic and social impacts of response measures on developing countries by supporting their economic diversification and transition towards lower emissions forms of energy and other technologies, (new information since last submission) while strengthening employment and economic growth. Sustainable economic growth, poverty reduction and the promotion of prosperity are at the heart of Australia's development cooperation (new text since last submission) program and the Australian Government is committed to integrating climate action throughout the program. For example, this means anticipating what future jobs might look like in a low emissions global economy when supporting education, livelihood and governance (new text since last submission) programs.

In November 2019, Australia released its Climate Change Action Strategy which guides climate action through the development cooperation program over 2020–25. The Strategy sets three key objectives to make the best use of our development assistance: supporting partner countries to adapt to climate change, and to plan, prepare for and respond to climate related impacts; promoting the shift to lower-emissions development in the Indo-Pacific region; and supporting innovative solutions to climate change, including those that engage private sector investment. Australia also has a complementary private sector development strategy to support the growth and inclusiveness of the private sector in developing countries. The Climate Change Action Strategy (new text since last submission for clarity) underpins our climate investments and help us meet Australia's commitments, building on our $1 billion climate development assistance from 2015–2020 and our new $1.5 billion commitment over 2020–25. (new information since last submission)

Mandatory safeguard requirements on all Australian aid investments, including our bilateral climate finance programs, ensure potential adverse social and environmental impacts are identified and adequately addressed. In May 2020, the Australian Government released its new overarching development policy, Partnerships for Recovery — Australia's COVID-19 Development Response, which outlines Australia's approach to tackling the impacts of COVID-19 in our region. The policy details how Australia is pivoting its development program to focus on health security, stability and economic recovery. The Government has also released COVID-19 Development Response Plans – brief, two-year development plans outlining Australia's COVID-19 response at the country, regional and global level. (new information since last submission).

Going forward, Australia will look at opportunities to continue (new text since last submission) working through the development cooperation program to help developing county partners reduce emissions and build resilience to the effects of climate change, while demonstrating the co-benefits of these activities in responding to the COVID-19 health and economic crisis.

Australia provides a range of assistance to support the development and deployment of low emissions technologies in developing countries and to build countries' capacities to implement low emissions development strategies.

For example, Australia is supporting:

- The Climate Technology Initiative Private Finance Advisory Network, which provides project development and investment advice, and facilitates the financing of clean energy projects;
- The Regional Pacific NDC Hub, which provides a technical support unit and coordination to assist Pacific countries develop and implement their adaptation and mitigation plans;
- ARENA's International Engagement Program (IEP) which provides funding to 12 projects to take part in the International Energy Agency Technology Collaboration Programmes (IEA TCP) and the Mission Innovation Challenges (MICs). These projects primarily facilitate knowledge and information exchange on research activities for renewable energy technologies
- Multilateral Funds including the Global Environment Facility, World Bank, Montreal Protocol Multilateral Fund and Asian Development Bank;
- The Sustainable Development Investment Portfolio which takes an integrated approach to water, energy and food management in three major Himalayan river basins, with a focus on climate change risks
- Bilateral initiatives to deploy low carbon technologies and expertise in developing countries, such as micro-grids in the Pacific and support for the solarisation of health centres in the Pacific through the International Solar Alliance (new information since last submission); and
- The Global Green Growth Institute, which supports developing countries with green growth planning and implementation.

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 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). This approach identifies sources that contribute to 95 per cent of the total emissions or 95 per cent of the trend of the inventory in absolute terms.

When the LULUCF sector is included in the analysis, Australia has identified *public electricity (solid fuel), road transportation (liquid fuels) and enteric fermentation (cattle)* as the most significant of the key categories (i.e. contributing more than 10 per cent of the level or trend) in 2019. The full results for the 2019 key source analysis are reported in Tables A.1.1 to A.1.3.

When the LULUCF sector is excluded from the analysis the most significant key categories in 2019 are *public electricity (solid fuel), road transportation (liquid fuels) and enteric fermentation (cattle).* The results of this latter analysis are presented in Tables A.1.4 to A.1.6. Table A.1.7 summarises the results of the key category analysis for LULUCF categories under KP accounting.

The Australian analysis has been undertaken using a relatively high degree of disaggregation of sources, as recommended in table 4.1 of the 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006).

This 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; however there are some cases where categories not identified as a key category in the key category analysis within the Common Reporting Format (CRF) tables have been identified as a key category in the Australian analysis. This is a consequence of the higher level of disaggregation.

In the trend key category analysis some categories that have been identified as trend key categories in the key category analysis within the CRF tables are not identified as trend key categories in the Australian analysis. This is because when the categories are disaggregated to a higher degree – more sectors are identified as key categories and this can move some categories further down the list where they do not make the 95 per cent cumulative total cut off.

Table A1.1 Key categories for Australia's 2019 inventory-level assessment including LULUCF

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
1.A.1.A	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	145,743	0.22	0.22
1.A.3.B	Road Transportation \ Liquid Fuels	CO_2	52,645	83,362	0.12	0.34
3.A.1	Enteric Fermentation \ Cattle	CH_4	34,106	36,258	0.05	0.40
4.C.2	Land converted to Grassland	CO_2	144,460	30,031	0.04	0.44
4.A.2	Land converted to Forest Land	CO_2	4,630	29,400	0.04	0.48
1.A.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,281	28,921	0.04	0.53
4.A.1	Forest Land remaining Forest Land	CO_2	5,953	25,250	0.04	0.56

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,577	20,597	0.03	0.59
1.B.1.a.i	Mining Activities	CH_4	16,605	13,863	0.02	0.62
3.A.2	Enteric Fermentation \ Sheep	CH_4	30,128	11,645	0.02	0.63
4.C.1	Grassland remaining Grassland	CO_2	6,945	10,989	0.02	0.65
2.F.1	Refrigeration and air-conditioning	HFC	-	9,826	0.01	0.66
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	968	9,572	0.01	0.68
1.B.2.c1	Venting	CO_2	1,967	9,519	0.01	0.69
5.A	Solid Waste Disposal	CH_4	15,240	9,154	0.01	0.71
1.A.4.B	Residential \ Gaseous Fuels	CO_2	4,646	8,677	0.01	0.72
1.A.3.A	Domestic Aviation	CO_2	2,615	8,453	0.01	0.73
1.A.2.F	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,759	8,361	0.01	0.74
1.B.2.c2.ii	Flaring - Gas	CO_2	2,426	8,011	0.01	0.76
2.C	Metal Industry	CO_2	9,203	7,532	0.01	0.77
1.B.1.a.ii	Mining Activities	CH_4	3,351	6,692	0.01	0.78
1.A.4.C	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,406	6,533	0.01	0.79
1.A.2.B	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,170	6,339	0.01	0.80
4.B.1	Cropland remaining Cropland	CO_2	24,793	5,885	0.01	0.80
1.A.2.B	Non-Ferrous Metals \ Solid Fuels	CO_2	4,132	4,826	0.01	0.81
4.G	Harvested Wood Products	CO_2	7,417	4,815	0.01	0.82
4.A.1	Forest Land remaining Forest Land	CH_4	5,230	4,813	0.01	0.83
4.C.1	Grassland remaining Grassland	CH_4	3,930	4,166	0.01	0.83
1.A.2.C	Chemicals \ Liquid Fuels	CO_2	3,297	4,081	0.01	0.84
3.B.1	Manure Management \ Cattle	CH_4	2,971	3,733	0.01	0.84
1.A.3.C	Railways \ Liquid Fuels	CO_2	1,734	3,638	0.01	0.85
1.A.1.A	Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,907	3,593	0.01	0.85
3.D.a.4	Agricultural Soil \ Direct Soil Emissions \ Crop Residue	N_2O	2,753	3,536	0.01	0.86
4.D.1	Wetland remaining Wetland	CH_4	4,056	3,147	0.00	0.86
1.A.4.A	Commercial/Institutional \ Gaseous Fuels	CO_2	1,824	3,098	0.00	0.87
2.A.1	Cement Industry	CO_2	3,463	3,040	0.00	0.87
3.D.a.3	Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	4,278	2,895	0.00	0.88
1.A.4.A	Commercial/Institutional \ Liquid Fuels	CO_2	1,246	2,763	0.00	0.88
1.A.2.C	Chemicals \ Gaseous Fuels	CO_2	1,452	2,714	0.00	0.89
1.A.1.B	Petroleum Refining \ Liquid Fuels	CO_2	4,931	2,712	0.00	0.89
4.B.2	Land converted to Cropland	CO_2	18,414	2,689	0.00	0.89
1.A.2.F	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,972	2,638	0.00	0.90
5.D	Wastewater treatment and discharge	CH_4	4,389	2,488	0.00	0.90
3.D.b.2	Agricultural Soils \ Indirect Soil Emissions \ Nitrogen Leaching and Run-Off	N_2O	2,337	2,347	0.00	0.91
2.C	Metal Industry	CO_2	2,058	2,296	0.00	0.91
2.B.2	Nitric Acid Production	N_2O	995	2,228	0.00	0.91

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
3.D.a.1	Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	1,351	2,218	0.00	0.92
1.A.3.D	domestic navigation \ Liquid Fuels	CO_2	2,208	2,193	0.00	0.92
1.B.2.c1	Venting	CH_4	2,114	2,027	0.00	0.92
2.B.1	Ammonia Production	CO_2	544	1,953	0.00	0.92
1.B.2.B.4	Distribution, Transmission and Storage	CH_4	4,316	1,800	0.00	0.93
1.A.2.F	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,212	1,739	0.00	0.93
1.A.2.E	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,255	1,687	0.00	0.93
4.C.1	Grassland remaining Grassland	N_2O	1,541	1,593	0.00	0.94
2.A	Mineral Industry	CO_2	1,251	1,524	0.00	0.94
1.B.2.b.3	Natural Gas Processing	CH_4	225	1,448	0.00	0.94
1.A.2.F	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,838	1,439	0.00	0.94
3.B.3	Manure Management \ Swine	CH_4	1,546	1,360	0.00	0.94
3.H	Urea Application	CO_2	367	1,347	0.00	0.95
3.G	Liming	CO_2	215	1,318	0.00	0.95
1.B.1.a.i	Mining Activities	CO_2	1,122	1,237	0.00	0.95

Table A1.2 Key categories for Australia's 2019 inventory–trend assessment including LULUCF

B IPCC Source Category	C Direct Greenhouse Gas	D Base Year Estimate	E Current Year Estimate	F Trend Assessment	% Contribution to Trend	G Cumulative Total
Land converted to Grassland	CO_2	144,460	30,031	0.14	0.20	0.20
Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	145,743	0.07	0.10	0.30
Road Transportation \ Liquid Fuels	CO_2	52,645	83,362	0.06	0.08	0.39
Cropland remaining Cropland	CO_2	24,793	5,885	0.04	0.06	0.44
Land converted to Forest Land	CO_2	4,630	29,400	0.04	0.05	0.50
Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,281	28,921	0.03	0.05	0.54
Forest Land remaining Forest Land	CO_2	5,953	25,250	0.03	0.04	0.58
Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,577	20,597	0.03	0.04	0.62
Enteric Fermentation \ Sheep	CH_4	30,128	11,645	0.02	0.03	0.65
Land converted to Cropland	CO_2	18,414	2,689	0.02	0.03	0.68
Refrigeration and air-conditioning	HFC	-	9,826	0.01	0.02	0.70
Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	968	9,572	0.01	0.02	0.72
Venting	CO_2	1,967	9,519	0.01	0.02	0.74
Enteric Fermentation \ Cattle	CH_4	34,106	36,258	0.01	0.02	0.75
Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,759	8,361	0.01	0.01	0.77
domestic Aviation	CO_2	2,615	8,453	0.01	0.01	0.78
Flaring - Gas	CO_2	2,426	8,011	0.01	0.01	0.79
Residential \ Gaseous Fuels	CO_2	4,646	8,677	0.01	0.01	0.80

B IPCC Source Category	C Direct Greenhouse Gas	D Base Year Estimate	E Current Year Estimate	F Trend Assessment	% Contribution to Trend	G Cumulative Total
Mining Activities	CH_4	3,351	6,692	0.01	0.01	0.81
Harvested Wood Products	CO_2	7,417	4,815	0.01	0.01	0.82
Solid Waste Disposal	CH_4	15,240	9,154	0.01	0.01	0.83
Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,406	6,533	0.01	0.01	0.84
Land converted to Grassland	CH_4	5,185	950	0.01	0.01	0.84
Land converted to Settlements	CO_2	4,770	817	0.00	0.01	0.85
Aluminium Production	CF_4	3,794	182	0.00	0.01	0.86
Grassland remaining Grassland	CO_2	6,945	10,989	0.00	0.01	0.86
Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,170	6,339	0.00	0.01	0.87
Railways \ Liquid Fuels	CO_2	1,734	3,638	0.00	0.00	0.87
Non-Ferrous Metals \ Liquid Fuels	CO_2	2,849	424	0.00	0.00	0.88
Distribution, Transmission and Storage	CH_4	4,316	1,800	0.00	0.00	0.88
Commercial/Institutional \ Liquid Fuels	CO_2	1,246	2,763	0.00	0.00	0.89
Commercial/Institutional \ Gaseous Fuels	CO_2	1,824	3,098	0.00	0.00	0.89
Ammonia Production	CO_2	544	1,953	0.00	0.00	0.89
Chemicals \ Gaseous Fuels	CO_2	1,452	2,714	0.00	0.00	0.90
Petroleum Refining \ Liquid Fuels	CO_2	4,931	2,712	0.00	0.00	0.90
Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,397	603	0.00	0.00	0.90
Chemical Industry	N_2O	995	2,228	0.00	0.00	0.91
Non-Ferrous Metals \ Solid Fuels	CO_2	4,132	4,826	0.00	0.00	0.91
Chemicals \ Liquid Fuels	CO_2	3,297	4,081	0.00	0.00	0.91
Natural Gas Processing	CH_4	225	1,448	0.00	0.00	0.91
Manure Management \ Cattle	CH_4	2,971	3,733	0.00	0.00	0.92
Agricultural Soil \ Direct Soil Emissions \ Crop Residue	N_2O	2,753	3,536	0.00	0.00	0.92
Wastewater treatment and discharge	CH_4	4,389	2,488	0.00	0.00	0.92
Chemical Industry \ Fluorochemical production	HFC-23	1,425	-	0.00	0.00	0.93
Residential \ Biomass	CH_4	2,403	848	0.00	0.00	0.93
Public Electricity and Heat Production \ Liquid Fuels	CO_2	2,907	3,593	0.00	0.00	0.93
Liming	CO_2	215	1,318	0.00	0.00	0.93
Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	1,351	2,218	0.00	0.00	0.93
Urea Application	CO_2	367	1,347	0.00	0.00	0.94
Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,838	1,439	0.00	0.00	0.94
Gas Production	CH_4	124	1,028	0.00	0.00	0.94
Grassland remaining Grassland	CH_4	3,930	4,166	0.00	0.00	0.94
Land converted to Grassland	N_2O	1,304	322	0.00	0.00	0.94
Manure Management \ Sheep	CH_4	1,553	591	0.00	0.00	0.95
Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	4,278	2,895	0.00	0.00	0.95
Other	CO_2	0	681	0.00	0.00	0.95

Table A1.3 Key categories for Australia's 2019 inventory–summary including LULUCF

A IPCC Source Categories		B Direct Greenhouse Gas	C Key Source Category Flag	D 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.3.B	Road Transportation \ Liquid Fuels	CO_2	Yes	Level, Trend
3.A.1	Enteric Fermentation \ Cattle	CH_4	Yes	Level, Trend
4.C.2	Land converted to Grassland	CO_2	Yes	Level, Trend
4.A.2	Land converted to Forest Land	CO_2	Yes	Level, Trend
1.A.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	Yes	Level, Trend
4.A.1	Forest Land remaining Forest Land	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.B.1.a.i	Mining Activities	CH_4	Yes	Level
3.A.2	Enteric Fermentation \ Sheep	CH_4	Yes	Level, Trend
4.C.1	Grassland remaining Grassland	CO_2	Yes	Level, Trend
2.F.1	Refrigeration and air-conditioning	HFC	Yes	Level, Trend
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	Yes	Level, Trend
1.B.2.c1	Venting	CO_2	Yes	Level, Trend
5.A	Solid Waste Disposal	CH_4	Yes	Level, Trend
1.A.4.B	Residential \ Gaseous Fuels	CO_2	Yes	Level, Trend
1.A.3.A	domestic Aviation	CO_2	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mining \ Liquid Fuels	CO_2	Yes	Level, Trend
1.B.2.c2.ii	Flaring - Gas	CO_2	Yes	Level, Trend
2.C	Metal Industry	CO_2	Yes	Level
1.A.4.C	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.2.B	Non-Ferrous Metals \ Gaseous Fuels	CO_2	Yes	Level, Trend
4.B.1	Cropland remaining Cropland	CO_2	Yes	Level, Trend
1.A.2.B	Non-Ferrous Metals \ Solid Fuels	CO_2	Yes	Level, Trend
4.G	Harvested Wood Products	CO_2	Yes	Level, Trend
1.A.2.C	Chemicals \ Liquid Fuels	CO_2	Yes	Level, Trend
3.B.1	Manure Management \ Cattle	CH_4	Yes	Level, Trend
1.A.3.C	Railways \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.1.A	Public Electricity and Heat Production \ Liquid Fuels	CO_2	Yes	Level, Trend
3.D.a.4	Agricultural Soil \ Direct Soil Emissions \ Crop Residue	N_2O	Yes	Level, Trend
4.D.1	Wetland remaining Wetland	CH_4	Yes	Level
1.A.4.A	Commercial/Institutional \ Gaseous Fuels	CO_2	Yes	Level, Trend
2.A.1	Cement Industry	CO_2	Yes	Level
3.D.a.3	Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	Yes	Level, Trend
1.A.4.A	Commercial/Institutional \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.2.C	Chemicals \ Gaseous Fuels	CO_2	Yes	Level, Trend
1.A.1.B	Petroleum Refining \ Liquid Fuels	CO_2	Yes	Level, Trend
4.B.2	Land converted to Cropland	CO_2	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	Yes	Level, Trend
5.D	Wastewater treatment and discharge	CH_4	Yes	Level, Trend

A IPCC Source Categories		B Direct Greenhouse Gas	C Key Source Category Flag	D If Column C is Yes, Criteria for Identification
3.D.b.2	Agricultural Soils \ Indirect Soil Emissions \ Nitrogen Leaching and Run-Off	N_2O	Yes	Level
2.B	Chemical Industry	CO_2	Yes	Level, Trend
2.B.2	Nitric Acid Production	N_2O	Yes	Level
3.D.a.1	Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	Yes	Level, Trend
1.A.3.D	domestic navigation \ Liquid Fuels	CO_2	Yes	Level
2.B.1	Ammonia Production	CO_2	Yes	Level, Trend
1.B.2.B.4	Distribution, Transmission and Storage	CH_4	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	Yes	Level, Trend
1.A.2.E	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	Yes	Level
2.A	Mineral Industry	CO_2	Yes	Level
1.B.2.b.3	Natural Gas Processing	CH_4	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Construction \ Liquid Fuels	CO_2	Yes	Level, Trend
3.B.3	Manure Management \ Swine	CH_4	Yes	Level
3.H	Urea Application	CO_2	Yes	Level, Trend
3.G	Liming	CO_2	Yes	Level, Trend
4.E.2	Land converted to Settlements	CO_2	Yes	Trend
2.C.3	Aluminium Production	CF_4	Yes	Trend
1.A.2.B	Non-Ferrous Metals \ 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
2.B.9	Chemical Industry \ Fluorochemical production	HFC-23	Yes	Trend
1.A.4.B	Residential \ Biomass	CH_4	Yes	Level, Trend
1.B.2.B.2	Gas Production	CH_4	Yes	Trend
3.B.2	Manure Management \ Sheep	CH_4	Yes	Trend
1.B.1.c	Other	CO_2	Yes	Trend

Table A1.4 Key categories for Australia's 2019 inventory-level assessment excluding LULUCF

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
1.A.1.A	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	145,743	0.27	0.27
1.A.3.B	Road Transportation \ Liquid Fuels	CO_2	52,645	83,362	0.15	0.42
3.A.1	Enteric Fermentation \ Cattle	CH_4	34,106	36,258	0.07	0.49
1.A.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,281	28,921	0.05	0.54
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,577	20,597	0.04	0.58
1.B.1.a.i	Mining Activities	CH_4	16,605	13,863	0.03	0.60
3.A.2	Enteric Fermentation \ Sheep	CH_4	30,128	11,645	0.02	0.62
2.F.1	Refrigeration and air-conditioning	HFC	-	9,826	0.02	0.64
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	968	9,572	0.02	0.66
1.B.2.c1	Venting	CO_2	1,967	9,519	0.02	0.68

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
5.A	Solid Waste Disposal	CH_4	15,240	9,154	0.02	0.69
1.A.4.B	Residential \ Gaseous Fuels	CO_2	4,646	8,677	0.02	0.71
1.A.3.A	domestic Aviation	CO_2	2,615	8,453	0.02	0.73
1.A.2.F	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,759	8,361	0.02	0.74
1.B.2.c2.ii	Flaring - Gas	CO_2	2,426	8,011	0.01	0.76
2.C	Metal Industry	CO_2	9,203	7,532	0.01	0.77
1.B.1.a.ii	Mining Activities	CH_4	3,351	6,692	0.01	0.78
1.A.4.C	Agriculture/Forestry/Fisheries \ Liquid Fuels	CO_2	3,406	6,533	0.01	0.79
1.A.2.B	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,170	6,339	0.01	0.81
1.A.2.B	Non-Ferrous Metals \ Solid Fuels	CO_2	4,132	4,826	0.01	0.81
1.A.2.C	Chemicals \ Liquid Fuels	CO_2	3,297	4,081	0.01	0.82
3.B.1	Manure Management \ Cattle	CH_4	2,971	3,733	0.01	0.83
1.A.3.C	Railways \ Liquid Fuels	CO_2	1,734	3,638	0.01	0.84
1.A.1.A	Public Electricity and Heat Production \ Liquid≈Fuels	CO_2	2,907	3,593	0.01	0.84
3.D.a.4	Agricultural Soil \ Direct Soil Emissions \ Crop Residue	N_2O	2,753	3,536	0.01	0.85
1.A.4.A	Commercial/Institutional \ Gaseous Fuels	CO_2	1,824	3,098	0.01	0.85
2.A.1	Cement Industry	CO_2	3,463	3,040	0.01	0.86
3.D.a.3	Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	4,278	2,895	0.01	0.86
1.A.4.A	Commercial/Institutional \ Liquid Fuels	CO_2	1,246	2,763	0.01	0.87
1.A.2.C	Chemicals \ Gaseous Fuels	CO_2	1,452	2,714	0.00	0.87
1.A.1.B	Petroleum Refining \ Liquid Fuels	CO_2	4,931	2,712	0.00	0.88
1.A.2.F	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,972	2,638	0.00	0.88
5.D	Wastewater treatment and discharge	CH_4	4,389	2,488	0.00	0.89
3.D.b.2	Agricultural Soils \ Indirect Soil Emissions \ Nitrogen Leaching and Run-Off	N_2O	2,337	2,347	0.00	0.89
2.C	Metal Industry	CO_2	2,058	2,296	0.00	0.90
2.B	Chemical Industry	N_2O	995	2,228	0.00	0.90
3.D.a.1	Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	1,351	2,218	0.00	0.91
1.A.3.D	domestic navigation \ Liquid Fuels	CO_2	2,208	2,193	0.00	0.91
1.B.2.c1	Venting	CH_4	2,114	2,027	0.00	0.91
2.B.1	Ammonia Production	CO_2	544	1,953	0.00	0.92
1.B.2.B.4	Transmission and Storage	CH_4	4,316	1,800	0.00	0.92
1.A.2.F	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,212	1,739	0.00	0.92
1.A.2.E	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	1,255	1,687	0.00	0.93
2.A	Mineral Industry	CO_2	1,251	1,524	0.00	0.93
1.B.2.b.3	Natural Gas Processing	CH_4	225	1,448	0.00	0.93
1.A.2.F	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,838	1,439	0.00	0.93

A IPCC Source Abbreviation	B IPCC Source Category	C Direct G'house Gas	D Base Year Estimate	E Current Year Estimate	F Level Assessment	G Cumulative Total
3.B.3	Manure Management \ Swine	CH_4	1,546	1,360	0.00	0.94
3.H	Urea Application	CO_2	367	1,347	0.00	0.94
3.G	Liming	CO_2	215	1,318	0.00	0.94
1.B.1.a.i	Mining Activities	CO_2	1,122	1,237	0.00	0.94
1.A.4.B	Residential \ Liquid Fuels	CO_2	1,320	1,220	0.00	0.95
1.B.2.B.2	Gas Production	CH_4	124	1,028	0.00	0.95

Table A1.5 Key categories for Australia's 2019 inventory–trend assessment excluding LULUCF

A IPCC Source Abbreviation	B IPCC Source Category	C Direct Greenhouse Gas	D Base Year Estimate	E Current Year Estimate	F Trend Assessment	% Contribution to Trend	G Cumulative Total
3.A.2	Enteric Fermentation \ Sheep	CH_4	30,128	11,645	0.06	0.12	0.12
1.A.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CO_2	8,281	28,921	0.04	0.08	0.19
1.A.3.B	Road Transportation \ Liquid Fuels	CO_2	52,645	83,362	0.04	0.07	0.26
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Gaseous Fuels	CO_2	4,577	20,597	0.03	0.06	0.32
5.A	Solid Waste Disposal	CH_4	15,240	9,154	0.02	0.04	0.37
2.F.1	Refrigeration and air-conditioning	HFC	-	9,826	0.02	0.04	0.41
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	968	9,572	0.02	0.04	0.45
3.A.1	Enteric Fermentation \ Cattle	CH_4	34,106	36,258	0.02	0.03	0.48
1.B.1.a.i	Mining Activities	CH_4	16,605	13,863	0.02	0.03	0.51
1.B.2.c1	Venting	CO_2	1,967	9,519	0.02	0.03	0.54
1.A.2.F	Other (please specify) \ Mining \ Liquid Fuels	CO_2	1,759	8,361	0.01	0.03	0.57
1.A.1.A	Public Electricity and Heat Production \ Solid Fuels	CO_2	117,909	145,743	0.01	0.03	0.59
1.A.3.A	domestic Aviation	CO_2	2,615	8,453	0.01	0.02	0.62
1.B.2.c2.ii	Flaring - Gas	CO_2	2,426	8,011	0.01	0.02	0.64
2.C	Metal Industry	CF_4	3,794	182	0.01	0.02	0.66
2.C	Metal Industry	CO_2	9,203	7,532	0.01	0.02	0.67
1.B.2.B.4	Distribution, Transmission and Storage	CH_4	4,316	1,800	0.01	0.02	0.69
1.A.1.B	Petroleum Refining \ Liquid Fuels	CO_2	4,931	2,712	0.01	0.02	0.71
1.A.2.B	Non-Ferrous Metals \ Liquid Fuels	CO_2	2,849	424	0.01	0.01	0.72
5.D	Wastewater treatment and discharge	CH_4	4,389	2,488	0.01	0.01	0.73
1.A.4.B	Residential \ Gaseous Fuels	CO_2	4,646	8,677	0.01	0.01	0.75

A IPCC Source Abbreviation	B IPCC Source Category	C Direct Greenhouse Gas	D Base Year Estimate	E Current Year Estimate	F Trend Assessment	% Contribution to Trend	G Cumulative Total
3.D.a.3	Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	4,278	2,895	0.01	0.01	0.76
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Solid Fuels	CO_2	2,397	603	0.01	0.01	0.77
1.B.1.a.ii	Mining Activities	CH_4	3,351	6,692	0.01	0.01	0.78
1.A.4.B	Residential \ Biomass	CH_4	2,403	848	0.01	0.01	0.79
1.A.2.F	Other (please specify) \ Construction \ Liquid Fuels	CO_2	2,838	1,439	0.01	0.01	0.80
1.A.4.C	Agriculture/Forestry/ Fisheries \ Liquid Fuels	CO_2	3,406	6,533	0.01	0.01	0.81
2.B.9	Chemical Industry \ Fluorochemical production	HFC-23	1,425	-	0.00	0.01	0.81
2.A.1	Cement Industry	CO_2	3,463	3,040	0.00	0.01	0.82
3.B.2	Manure Management \ Sheep	CH_4	1,553	591	0.00	0.01	0.83
1.A.3.C	Railways \ Liquid Fuels	CO_2	1,734	3,638	0.00	0.01	0.83
2.B.1	Ammonia Production	CO_2	544	1,953	0.00	0.01	0.84
1.A.2.F	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	2,972	2,638	0.00	0.01	0.84
1.A.4.A	Commercial/Institutional \ Liquid Fuels	CO_2	1,246	2,763	0.00	0.00	0.85
1.B.2.b.3	Natural Gas Processing	CH_4	225	1,448	0.00	0.00	0.85
1.A.2.F	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	2,212	1,739	0.00	0.00	0.86
1.B.2.c2.i	Oil	CO_2	1,217	474	0.00	0.00	0.86
1.A.2.A	Iron and Steel \ Gaseous Fuels	CO_2	1,393	710	0.00	0.00	0.87
3.G	Liming	CO_2	215	1,318	0.00	0.00	0.87
1.A.2.B	Non-Ferrous Metals \ Gaseous Fuels	CO_2	4,170	6,339	0.00	0.00	0.88
2.B	Chemical Industry	N_2O	995	2,228	0.00	0.00	0.88
1.A.2.E	Food Processing, Beverages and Tobacco \ Solid Fuels	CO_2	1,214	621	0.00	0.00	0.88
2.C.3	Aluminium Production	C_2F_6	813	121	0.00	0.00	0.89
1.A.2.A	Iron and Steel \ Solid Fuels	CO_2	1,206	652	0.00	0.00	0.89
3.H	Urea Application	CO_2	367	1,347	0.00	0.00	0.89
1.B.2.B.2	Gas Production	CH_4	124	1,028	0.00	0.00	0.90
1.A.2.C	Chemicals \ Gaseous Fuels	CO_2	1,452	2,714	0.00	0.00	0.90
1.A.4.A	Commercial/Institutional \ Gaseous Fuels	CO_2	1,824	3,098	0.00	0.00	0.91
3.D.a.5	Mineralisation due to loss of soil carbon	N_2O	635	73	0.00	0.00	0.91

A IPCC Source Abbreviation	B IPCC Source Category	C Direct Greenhouse Gas	D Base Year Estimate	E Current Year Estimate	F Trend Assessment	% Contribution to Trend	G Cumulative Total
1.B.2.c1	Venting	CH_4	2,114	2,027	0.00	0.00	0.91
1.B.1.c	Other	CO_2	0	681	0.00	0.00	0.91
3.D.b.2	Agricultural Soils \ Indirect Soil Emissions \ Nitrogen Leaching and Run-Off	N_2O	2,337	2,347	0.00	0.00	0.92
1.A.3.D	domestic navigation \ Liquid Fuels	CO_2	2,208	2,193	0.00	0.00	0.92
1.A.4.A	Commercial/Institutional \ Solid Fuels	CO_2	523	43	0.00	0.00	0.92
3.B.3	Manure Management \ Swine	CH_4	1,546	1,360	0.00	0.00	0.93
3.C	Rice Cultivation	CH_4	476	32	0.00	0.00	0.93
1.A.3.E	Other Transportation (please specify) \ pipeline transport \ Gaseous Fuels	CO_2	262	894	0.00	0.00	0.93
1.A.3.B	Road Transportation \ Liquid Fuels	CH_4	560	191	0.00	0.00	0.93
1.A.2.g.i	Other (please specify) \ Manufacturing of Machinery	CO_2	422	29	0.00	0.00	0.93
1.A.2.B	Non-Ferrous Metals \ Solid Fuels	CO_2	4,132	4,826	0.00	0.00	0.94
3.D.a.1	Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	1,351	2,218	0.00	0.00	0.94
1.A.4.B	Residential \ Liquid Fuels	CO_2	1,320	1,220	0.00	0.00	0.94
1.A.1.B	Petroleum Refining \ Gaseous Fuels	CO_2	581	290	0.00	0.00	0.94
1.A.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CH_4	7	448	0.00	0.00	0.94
2.F.4	Aerosols	HFC	-	429	0.00	0.00	0.95
1.A.3.D	Domestic navigation \ Solid Fuels	CO_2	313	-	0.00	0.00	0.95
1.B.2.a.4	Oil Refining / Storage	CO_2	392	109	0.00	0.00	0.95

Table A1.6 Key categories for Australia's 2019 inventory–summary excluding LULUCF

A IPCC Source Categories		B Gas	C Key Source Category Flag	D 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.3.B	Road Transportation \ Liquid Fuels	CO_2	Yes	Level, Trend
3.A.1	Enteric Fermentation \ Cattle	CH_4	Yes	Level, Trend
1.A.1.A	Public Electricity and Heat Production \ Gaseous 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.B.1.a.i	Mining Activities	CH_4	Yes	Level, Trend
3.A.2	Enteric Fermentation \ Sheep	CH_4	Yes	Level, Trend
2.F.1	Refrigeration and air-conditioning	HFC	Yes	Level, Trend

A IPCC Source Categories		B Gas	C Key Source Category Flag	D If Colum C is Yes, Criteria for Identification
1.A.1.C	Manufacture of Solid Fuels and Other Energy Industries \ Liquid Fuels	CO_2	Yes	Level, Trend
1.B.2.c1	Venting	CO_2	Yes	Level, Trend
5.A	Solid Waste Disposal	CH_4	Yes	Level, Trend
1.A.4.B	Residential \ Gaseous Fuels	CO_2	Yes	Level, Trend
1.A.3.A	Domestic Aviation	CO_2	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mining \ Liquid Fuels	CO_2	Yes	Level, Trend
1.B.2.c2.ii	Flaring - Gas	CO_2	Yes	Level, Trend
2.C	Metal Industry	CO_2	Yes	Level, Trend
1.A.4.C	Agriculture/Forestry/Fisheries \ Liquid 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.C	Chemicals \ Liquid Fuels	CO_2	Yes	Level, Trend
3.B.1	Manure Management \ Cattle	CH_4	Yes	Level
1.A.3.C	Railways \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.1.A	Public Electricity and Heat Production \ Liquid Fuels	CO_2	Yes	Level, Trend
3.D.a.4	Agricultural Soil \ Direct Soil Emissions \ Crop Residue	N_2O	Yes	Level
1.A.4.A	Commercial/Institutional \ Gaseous Fuels	CO_2	Yes	Level, Trend
2.A.1	Cement Industry	CO_2	Yes	Level, Trend
3.D.a.3	Agricultural Soils \ Direct Soil Emissions \ Urine and Dung Deposited by Grazing Animals	N_2O	Yes	Level, Trend
1.A.4.A	Commercial/Institutional \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.2.C	Chemicals \ Gaseous Fuels	CO_2	Yes	Level, Trend
1.A.1.B	Petroleum Refining \ Liquid Fuels	CO_2	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mineral industry \ Gaseous Fuels	CO_2	Yes	Level, Trend
5.D	Wastewater treatment and discharge	CH_4	Yes	Level, Trend
3.D.b.2	Agricultural Soils \ Indirect Soil Emissions \ Nitrogen Leaching and Run-Off	N_2O	Yes	Level, Trend
2.B	Chemical Industry	N_2O	Yes	Level, Trend
3.D.a.1	Agricultural Soils \ Direct Soil Emissions \ Inorganic Fertilisers	N_2O	Yes	Level, Trend
1.A.3.D	Domestic navigation \ Liquid Fuels	CO_2	Yes	Level, Trend
2.B.1	Ammonia Production	CO_2	Yes	Level, Trend
1.B.2.B.4	Distribution, Transmission and Storage	CH_4	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Mineral industry \ Solid Fuels	CO_2	Yes	Level, Trend
1.A.2.E	Food Processing, Beverages and Tobacco \ Gaseous Fuels	CO_2	Yes	Level, Trend
2.A	Mineral Industry	CO_2	Yes	Level
1.B.2.b.3	Natural Gas Processing	CH_4	Yes	Level, Trend
1.A.2.F	Other (please specify) \ Construction \ Liquid Fuels	CO_2	Yes	Level, Trend
3.B.3	Manure Management \ Swine	CH_4	Yes	Level, Trend
3.H	Urea Application	CO_2	Yes	Level, Trend
3.G	Liming	CO_2	Yes	Level, Trend
1.A.4.B	Residential \ Liquid Fuels	CO_2	Yes	Level, Trend
1.B.2.B.2	Production	CH_4	Yes	Level, Trend
3.C	Rice Cultivation	CH_4	Yes	Trend

A IPCC Source Categories		B Gas	C Key Source Category Flag	D If Colum C is Yes, Criteria for Identification
1.A.3.E	Other Transportation (please specify) \ pipeline transport \ Gaseous Fuels	CO_2	Yes	Trend
1.A.2.g.i	Other (please specify) \ Manufacturing of Machinery	CO_2	Yes	Trend
2.F.4	Aerosols	HFC	Yes	Trend
1.B.2.a.4	Refining / Storage	CO_2	Yes	Trend
1.A.2.B	Non-Ferrous Metals \ 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.4.B	Residential \ Biomass	CH_4	Yes	Level, Trend
1.A.2.A	Iron and Steel \ Solid Fuels	CO_2	Yes	Trend
1.A.4.A	Commercial/Institutional \ Solid Fuels	CO_2	Yes	Level, Trend
1.A.1.B	Petroleum Refining \ Gaseous Fuels	CO_2	Yes	Level, Trend
1.A.3.D	Domestic navigation \ Solid Fuels	CO_2	Yes	Level, Trend
2.B.9	Chemical Industry \ Fluorochemical production	HFC-23	Yes	Trend
3.B.2	Manure Management \ Sheep	CH_4	Yes	Trend
1.B.2.c2.i	Oil	CO_2	Yes	Trend
1.A.2.A	Iron and Steel \ Gaseous Fuels	CO_2	Yes	Trend
1.A.2.E	Food Processing, Beverages and Tobacco \ Solid Fuels	CO_2	Yes	Level, Trend
3.D.a.5	Mineralisation due to loss of soil carbon	N_2O	Yes	Trend
1.B.1.c	Other	CO_2	Yes	Trend

A1.2 Kyoto Protocol LULUCF Activities

The KP-LULUCF key categories have been identified using the method documented in section 2.3.6 of IPCC 2018. The results are presented in Table A1.7.

Table A1.7 Summary overview for key categories for Land use, Land-use Change and Forestry activities under the Kyoto Protocol – 2019

		Criteria used for Key Category Identification			
Key Categories of Emissions and Removals	Gas	Associated category in UNFCCC inventory is key	Category contribution is greater than the smallest category considered key in the UNFCCC inventory (including LULUCF)	Other	Comments
Deforestation	CO_2	forest land converted to grassland	TRUE	NA	
Deforestation	CH_4	forest land converted to grassland	FALSE	NA	
Deforestation	N_2O	forest land converted to grassland	FALSE	NA	
Forest management	CO_2	forest land remaining forest land	TRUE	NA	Australia has applied the narrow approach to forest management. As a result the forest land remaining forest land classification does not directly correspond to the forest management activity.

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	grassland converted to forest land	TRUE	NA	
Grazing land management	CO_2	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Grazing land management	CH_4	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Grazing land management	N_2O	grassland remaining grassland, land converted to grassland (conversion prior to 1990)	TRUE	NA	
Cropland management	CO_2	cropland remaining cropland, land converted to cropland (conversion prior to 1990)	TRUE	NA	

ANNEX 2: 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 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 2006 *Guidelines for National Greenhouse Gas Inventories.* Monte Carlo and Latin Hypercube approaches were used to estimate emission uncertainty in some sectors, which is equivalent to the IPCC tier 2 methodology. Companies with large single sources of emissions must annually report through NGERS on the level of uncertainty associated with these emissions. Statistical uncertainty must be estimated and reported by NGER reporters with emissions of more than 25 $GgCO_2$-e from the combustion of a fuel type, or an IPPU, fugitive or waste source other than fuel combustion. NGER reporters must follow the methods for assessing uncertainty published in the NGER (Measurement) Determination and report a combined estimate for activity data and emission factor uncertainty. Uncertainty estimates associated with single sources of emissions first became available under NGER in 2014.

NGER uncertainty estimates have been incorporated into the national uncertainty assessment in sectors where there are a limited number of large facilities such as electricity generation, cement production, aluminium production, petroleum refining and coal mining. Estimates for other sectors have been prepared using the judgement of the sectoral expert consultants. These estimates of uncertainty were 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 ± 1–5 per cent. 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 IPCC 2006.

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. 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 Tables A2.1 to A2.4.

As indicated in IPCC 2006, 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 DISER 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.

In this inventory submission, DISER has included the base year uncertainty assessment as well as the latest inventory year. The base year is 1990 and the latest inventory year is 2019.

The tier 1 results presented in Table A.2.1 show the estimated uncertainty surrounding the aggregate inventory estimate for base year 1990 to be ± 7.5 per cent. The reported estimated uncertainty for the trend in emissions is ± 4.4 per cent. 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.

A significant part of the uncertainty for the UNFCCC inventory in 1990 derives from the LULUCF sector. The uncertainty for the aggregate inventory excluding LULUCF is estimated at ± 4.8 per cent and the uncertainty in the trend is estimated ± 2.8 per cent (Table A2.2).

The tier 1 results presented in Table A.2.3 show the estimated uncertainty surrounding the aggregate inventory estimate for 2019 to be ± 4.2 per cent. The reported estimated uncertainty for the trend in emissions is ± 4.7 per cent. 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.

The uncertainty for the aggregate inventory excluding LULUCF in 2019 is estimated at ± 3.1 per cent and the uncertainty in the trend is estimated ± 4.7 per cent (Table A2.4).

The 2019 uncertainty result of 4.2 per cent is an improvement on the 2018 result of 4.7 per cent for the whole of inventory, a large amount of which came from improvements in LULUCF uncertainty, as the improvement for the inventory excluding LULUCF improved from 3.3 per cent in 2018 to 3.1 per cent in 2019. The uncertainty in the total trend remained stable at 4.7 per cent, but the uncertainty in the trend excluding LULUCF increased, likely impacted by a new gas facility that reported over 100 per cent uncertainty in their 2019 NGER reporting. In addition, the estimated uncertainty in harvested wood products CO_2 emissions in Table A2.10 was amended from 100 per cent to 22.4 per cent, to match the value calculated from reported uncertainty data.

Table A2.1 General reporting table for uncertainty including LULUCF for base year 1990

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.a Electricity generation – black coal	CO_2	72,725.26	72,725.26	1.60	1.60	2.26	0.27	-	0.12	-	0.26	0.26	1
I.A.I.a Electricity generation – black coal	CH_4	13.54	13.54	1.60	50.00	50.03	0.00	-	0.00	-	0.00	0.00	1
I.A.I.a Electricity generation – black coal	N_2O	189.54	189.54	1.60	50.00	50.03	0.02	-	0.00	-	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.a Electricity generation – brown coal	CO_2	45,184.71	45,184.71	0.51	0.51	0.73	0.05	-	0.07	-	0.05	0.05	1
I.A.I.a Electricity generation – brown coal	CH_4	7.46	7.46	0.51	50.00	50.00	0.00	-	0.00	-	0.00	0.00	1
I.A.I.a Electricity generation – brown coal	N_2O	188.58	188.58	0.51	50.00	50.00	0.02	-	0.00	-	0.00	0.00	1
I.A.I.a Electricity generation – natural gas	CO_2	8,280.60	8,280.60	1.99	1.99	2.81	0.04	-	0.01	-	0.04	0.04	1
I.A.I.a Electricity generation – natural gas	CH_4	7.20	7.20	1.99	50.00	50.04	0.00	-	0.00	-	0.00	0.00	1
I.A.I.a Electricity generation – natural gas	N_2O	43.68	43.68	1.99	50.00	50.04	0.00	-	0.00	-	0.00	0.00	1
I.A.I.a Electricity generation – liquid fuels	CO_2	2,907.27	2,907.27	2.83	2.83	4.00	0.02	-	0.00	-	0.02	0.02	2
I.A.I.a Electricity generation – liquid fuels	CH_4	2.71	2.71	35.36	35.36	50.00	0.00	-	0.00	-	0.00	0.00	2
I.A.I.a Electricity generation – liquid fuels	N_2O	4.13	4.13	35.36	35.36	50.00	0.00	-	0.00	-	0.00	0.00	2
I.A.I.b Petroleum refining – liquid fuels	CO_2	4,931.12	4,931.12	15.56	15.56	22.00	0.18	-	0.01	-	0.17	0.17	1
I.A.I.b Petroleum refining – liquid fuels	CH_4	1.26	1.26	15.56	50.00	52.36	0.00	-	0.00	-	0.00	0.00	1
I.A.I.b Petroleum refining – liquid fuels	N_2O	12.10	12.10	15.56	50.00	52.36	0.00	-	0.00	-	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	CO_2	580.95	580.95	17.00	17.00	24.04	0.02	-	0.00	-	0.02	0.02	1
I.A.I.b Petroleum refining – gaseous fuels	CH_4	0.29	0.29	17.00	50.00	52.81	0.00	-	0.00	-	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	N_2O	1.43	1.43	17.00	50.00	52.81	0.00	-	0.00	-	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CO_2	7,942.01	7,942.01	3.62	3.62	5.12	0.07	-	0.01	-	0.07	0.07	1
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CH_4	117.50	117.50	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	N_2O	43.68	43.68	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CO_2	11,375.13	11,375.13	2.83	2.83	4.00	0.07	-	0.02	-	0.07	0.07	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CH_4	3.40	3.40	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	N_2O	29.30	29.30	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CO_2	19,643.69	19,643.69	2.83	2.83	4.00	0.13	-	0.03	-	0.13	0.13	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CH_4	9.00	9.00	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	N_2O	74.21	74.21	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CO_2	18,285.08	18,285.08	2.83	2.83	4.00	0.12	-	0.03	-	0.12	0.12	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CH_4	43.07	43.07	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	N_2O	178.50	178.50	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.3 Transport fossil fuels	CO_2	59,821.60	59,821.60	2.83	2.83	4.00	0.39	-	0.10	-	0.38	0.38	3
1.A.3 Transport fossil fuels	CH_4	658.63	658.63	16.97	16.97	24.00	0.03	-	0.00	-	0.03	0.03	3
1.A.3 Transport fossil fuels	N_2O	914.33	914.33	29.70	29.70	42.00	0.06	-	0.00	-	0.05	0.05	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A. Biomass fuels	CH_4	2,427.13	2,427.13	-	20.00	20.00	0.08	-	0.00	-	-	-	2
I.A. Biomass fuels	N_2O	240.60	240.60	-	50.00	50.00	0.02	-	0.00	-	-	-	2
I.B.I.a.i Solid Fuels – Underground Mines	CO_2	1,121.82	1,121.82	2.00	10.00	10.20	0.02	-	0.00	-	0.01	0.01	1
I.B.I.a.i Solid Fuels – Underground Mines	CH_4	17,640.76	17,640.76	2.00	10.00	10.20	0.29	-	0.03	-	0.09	0.09	1
I.B.I.a.i Solid Fuels – Underground Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	
I.B.I.a.ii Solid Fuels – Open Cut Mines	CO_2	61.78	61.78	6.30	30.89	31.52	0.00	-	0.00	-	0.00	0.00	1
I.B.I.a.ii Solid Fuels – Open Cut Mines	CH_4	3,350.71	3,350.71	6.30	30.89	31.52	0.17	-	0.01	-	0.05	0.05	1
I.B.I.a.ii Solid Fuels – Open Cut Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	
I.B.I.c Solid Fuels – Other	CO_2	0.28	0.28	5.00	20.00	20.62	0.00	-	0.00	-	0.00	0.00	3
I.B.I.c Solid Fuels – Other	CH_4	0.02	0.02	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	3
I.B.I.c Solid Fuels – Other	N_2O	0.00	0.00	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	3
1.B.2.a Oil and Natural Gas – Oil	CO_2	393.90	393.90	5.00	5.00	7.07	0.00	-	0.00	-	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	CO_2	84.42	84.42	10.00	3.00	10.44	0.00	-	0.00	-	0.00	0.00	3
1.B.2.C Oil and Natural Gas – Venting and Flaring	CO_2	5,610.40	5,610.40	5.00	5.00	7.07	0.06	-	0.01	-	0.06	0.06	3
1.B.2.a Oil and Natural Gas – Oil	CH_4	77.77	77.77	9.86	48.30	49.30	0.01	-	0.00	-	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	CH_4	5,031.34	5,031.34	12.04	58.97	60.18	0.49	-	0.01	-	0.15	0.15	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.B.2.C Oil and Natural Gas – Venting and Flaring	CH_4	2,588.52	2,588.52	8.00	39.18	39.99	0.17	-	0.00	-	0.05	0.05	3
1.B.2.a Oil and Natural Gas – Oil	N_2O	3.55	3.55	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	N_2O	0.65	0.65	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
1.B.2 Oil and Natural Gas – Venting and Flaring	N_2O	36.04	36.04	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
2.A.1 Cement Production	CO_2	3,462.87	3,462.87	3.43	3.43	4.85	0.03	-	0.01	-	0.03	0.03	1
2.A.2 Lime Production	CO_2	775.37	775.37	3.43	3.43	4.85	0.01	-	0.00	-	0.01	0.01	1
2.A.4 Other Process Uses of Carbonates	CO_2	1,251.34	1,251.34	4.00	2.50	4.72	0.01	-	0.00	-	0.01	0.01	4
2.B Chemicals	CO_2	1,054.69	1,054.69	2.58	2.58	3.64	0.01	-	0.00	-	0.01	0.01	1
2.B Chemicals	CH_4	10.94	10.94	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	4
2.B Chemicals	N_2O	995.04	995.04	4.10	4.10	5.80	0.01	-	0.00	-	0.01	0.01	1
2.B Chemicals	FIFOs	1,424.68	1,424.68	-	27.00	27.00	0.06	-	0.00	-	-	-	4
2.C.1 Iron and Steel Production	CO_2	9,203.23	9,203.23	1.61	1.61	2.28	0.03	-	0.01	-	0.03	0.03	1
2.C.1 Iron and Steel Production	CH_4	70.55	70.55	2.00	50.00	50.04	0.01	-	0.00	-	0.00	0.00	4
2.C.1 Iron and Steel Production	N_2O	21.48	21.48	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	4
2.C.3 Aluminium Production	CO_2	2,058.10	2,058.10	3.21	3.21	4.54	0.02	-	0.00	-	0.01	0.01	1
2.C.3 Aluminium Production	PFCs	4,607.01	4,607.01	-	27.00	27.00	0.20	-	0.01	-	-	-	4
2.C.2 Ferroalloys Production	CO_2	232.62	232.62	6.45	6.45	9.12	0.00	-	0.00	-	0.00	0.00	1
2.C.2 Ferroalloys Production	CH_4	0.05	0.05	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.2 Ferroalloys Production	N_2O	0.48	0.48	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	CO_2	150.52	150.52	6.45	6.45	9.12	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	CH_4	0.07	0.07	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	N_2O	0.32	0.32	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
2.D Non-energy Products from Fuels and Solvent Use	CO_2	279.93	279.93	2.00	3.00	3.61	0.00	-	0.00	-	0.00	0.00	1
2.H.2 Food and Beverages Industry	CO_2	82.57	82.57	2.58	2.58	3.64	0.00	-	0.00	-	0.00	0.00	1
2.F Product Uses as Substitutes for Ozone Depleting Substances	HFCs	-	-	-	27.00	27.00	-	-	-	-	-	-	4
2.G Other Product Manufacture and Use	SF_6	220.56	220.56	-	27.00	27.00	0.01	-	0.00	-	-	-	4
3.A Enteric Fermentation	CH_4	64,632.91	64,632.91	10.00	22.43	24.56	2.58	-	0.12	-	1.64	1.64	6
3.B Manure Management	CH_4	6,150.90	6,150.90	22.36	50.00	54.77	0.55	-	0.01	-	0.35	0.35	6
3.B Manure Management	N_2O	238.31	238.31	22.36	50.00	54.77	0.02	-	0.00	-	0.01	0.01	7
3.C Rice Cultivation	CH_4	475.62	475.62	5.00	50.00	50.25	0.04	-	0.00	-	0.01	0.01	7
3.D Agricultural Soils	N_2O	12,342.53	12,342.53	25.00	50.00	55.90	1.12	-	0.02	-	0.62	0.62	7
3.F Agricultural Residue Burning	CH_4	291.96	291.96	32.40	50.00	59.58	0.03	-	0.00	-	0.02	0.02	7
3.F Agricultural Residue Burning	N_2O	138.90	138.90	32.40	50.00	59.58	0.01	-	0.00	-	0.01	0.01	7
3.G Liming	CO_2	215.35	215.35	20.00	50.00	53.85	0.02	-	0.00	-	0.01	0.01	7
3.H Urea application	CO_2	366.67	366.67	10.00	50.00	50.99	0.03	-	0.00	-	0.01	0.01	7
4.A.1 Forest Land remaining Forest Land	CO_2	-5,953.19	-5,953.19	15.00	30.00	33.54	0.32	-	0.01	-	0.20	0.20	3
4.A.1 Forest Land remaining Forest Land	CH_4	5,230.50	5,230.50	15.00	50.00	52.20	0.44	-	0.01	-	0.20	0.20	3
4.A.1 Forest Land remaining Forest Land	N_2O	1,024.89	1,024.89	15.00	50.00	52.20	0.09	-	0.00	-	0.03	0.03	3
4.A.2 Land converted to Forest Land	CO_2	-4,629.84	-4,629.84	12.23	11.50	16.79	0.13	-	0.01	-	0.13	0.13	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
4.A.2 Land converted to Forest Land	CH_4	22.83	22.83	11.00	50.00	51.20	0.00	-	0.00	-	0.00	0.00	3
4.A.2 Land converted to Forest Land	N_2O	112.57	112.57	11.00	50.00	51.20	0.01	-	0.00	-	0.00	0.00	3
4.B.1 Cropland remaining Cropland	CO_2	24,792.60	24,792.60	25.00	20.00	32.02	1.29	-	0.04	-	1.40	1.40	3
4.B.2 Land converted to Cropland	CO_2	18,414.42	18,414.42	11.20	25.50	27.85	0.83	-	0.03	-	0.47	0.47	3
4.B.2 Land converted to Cropland	CH_4	580.19	580.19	11.00	50.00	51.20	0.05	-	0.00	-	0.02	0.02	3
4.B.2 Land converted to Cropland	N_2O	165.79	165.79	11.00	50.00	51.20	0.01	-	0.00	-	0.00	0.00	3
4.C.1 Grassland remaining Grassland	CO_2	-6,944.65	-6,944.65	25.00	20.00	32.02	0.36	-	0.01	-	0.39	0.39	3
4.C.1 Grassland remaining Grassland	CH_4	3,930.38	3,930.38	25.00	50.00	55.90	0.36	-	0.01	-	0.25	0.25	3
4.C.1 Grassland remaining Grassland	N_2O	1,541.01	1,541.01	25.00	50.00	55.90	0.14	-	0.00	-	0.08	0.08	3
4.C.2 Land converted to Grassland	CO_2	144,459.56	144,459.56	11.00	25.00	27.31	6.41	-	0.23	-	3.60	3.60	3
4.C.2 Land converted to Grassland	CH_4	5,184.76	5,184.76	11.00	50.00	51.20	0.43	-	0.01	-	0.14	0.14	3
4.C.2 Land converted to Grassland	N_2O	1,304.02	1,304.02	11.00	50.00	51.20	0.11	-	0.00	-	0.03	0.03	3
4.D.1 Wetlands remaining Wetlands	CO_2	228.97	228.97	11.00	20.00	22.83	0.01	-	0.00	-	0.01	0.01	3
4.D.1 Wetlands remaining Wetlands	N_2O	4,105.97	4,105.97	10.00	100.00	100.50	0.67	-	0.00	-	0.00	0.00	3
4.D.2 Land converted to Wetland	CO_2	707.62	707.62	11.00	25.00	27.31	0.03	-	0.00	-	0.02	0.02	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
4.E.1 Settlements remaining Settlements	CO_2	-33.48	-33.48	11.00	20.00	22.83	0.00	-	0.00	-	0.00	0.00	3
4.E.2 Land converted to Settlements	CO_2	4,769.67	4,769.67	11.50	26.00	28.43	0.22	-	0.01	-	0.12	0.12	3
4.E.2 Land converted to Settlements	CH_4	164.88	164.88	11.50	50.00	51.31	0.01	-	0.00	-	0.00	0.00	3
4.E.2 Land converted to Settlements	N_2O	43.21	43.21	11.50	50.00	51.31	0.00	-	0.00	-	0.00	0.00	3
4.G Harvested Wood Products	CO_2	-7,416.93	-7,416.93	10.00	20.00	22.36	0.27	-	0.01	-	0.17	0.17	3
5.A Solid Waste Disposal	CH_4	15,239.94	15,239.94	10.80	52.91	54.00	1.34	-	0.03	-	0.42	0.42	8
5.D Wastewater Treatment and Discharge	CH_4	4,389.40	4,389.40	10.00	48.99	50.00	0.36	-	0.01	-	0.11	0.11	9
5.D Wastewater Treatment and Discharge	N_2O	287.56	287.56	10.00	48.99	50.00	0.02	-	0.00	-	0.01	0.01	9
5.C Incineration and Open Burning of Waste	CO_2	73.36	73.36	8.00	39.19	40.00	0.00	-	0.00	-	0.00	0.00	9
5.C Incineration and Open Burning of Waste	CH_4	2.32	2.32	10.00	48.99	50.00	0.00	-	0.00	-	0.00	0.00	9
5.C Incineration and Open Burning of Waste	N_2O	11.32	11.32	10.00	48.99	50.00	0.00	-	0.00	-	0.00	0.00	9
5.B Biological treatment of solid waste	CH_4	8.76	8.76	20.00	97.98	100.00	0.00	-	0.00	-	0.00	0.00	9
5.B Biological treatment of solid waste	N_2O	13.36	13.36	20.00	97.98	100.00	0.00	-	0.00	-	0.00	0.00	9
Total Emissions		**615,477.99**	**615,477.99**										
Total Uncertainties							**7.5**					**4.4**	

Table A2.2 General reporting table for uncertainty excluding LULUCF for base year 1990

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.A.1.a Electricity generation - black coal	CO_2	72,725.26	72,725.26	1.60	1.60	2.26	0.39	-	0.17	-	0.38	0.38	1
1.A.1.a Electricity generation - black coal	CH_4	13.54	13.54	1.60	50.00	50.03	0.00	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - black coal	N_2O	189.54	189.54	1.60	50.00	50.03	0.02	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - brown coal	CO_2	45,184.71	45,184.71	0.51	0.51	0.73	0.08	-	0.10	-	0.07	0.07	1
1.A.1.a Electricity generation - brown coal	CH_4	7.46	7.46	0.51	50.00	50.00	0.00	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - brown coal	N_2O	188.58	188.58	0.51	50.00	50.00	0.02	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - natural gas	CO_2	8,280.60	8,280.60	1.99	1.99	2.81	0.05	-	0.02	-	0.05	0.05	1
1.A.1.a Electricity generation - natural gas	CH_4	7.20	7.20	1.99	50.00	50.04	0.00	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - natural gas	N_2O	43.68	43.68	1.99	50.00	50.04	0.01	-	0.00	-	0.00	0.00	1
1.A.1.a Electricity generation - liquid fuels	CO_2	2,907.27	2,907.27	2.83	2.83	4.00	0.03	-	0.01	-	0.03	0.03	2
1.A.1.a Electricity generation - liquid fuels	CH_4	2.71	2.71	35.36	35.36	50.00	0.00	-	0.00	-	0.00	0.00	2
1.A.1.a Electricity generation - liquid fuels	N_2O	4.13	4.13	35.36	35.36	50.00	0.00	-	0.00	-	0.00	0.00	2
1.A.1.b Petroleum refining - liquid fuels	CO_2	4,931.12	4,931.12	15.56	15.56	22.00	0.26	-	0.01	-	0.25	0.25	1
1.A.1.b Petroleum refining - liquid fuels	CH_4	1.26	1.26	15.56	50.00	52.36	0.00	-	0.00	-	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.A.1.b Petroleum refining - liquid fuels	N_2O	12.10	12.10	15.56	50.00	52.36	0.00	-	0.00	-	0.00	0.00	1
1.A.1.b Petroleum refining - gaseous fuels	CO_2	580.95	580.95	17.00	17.00	24.04	0.03	-	0.00	-	0.03	0.03	1
1.A.1.b Petroleum refining - gaseous fuels	CH_4	0.29	0.29	17.00	50.00	52.81	0.00	-	0.00	-	0.00	0.00	1
1.A.1.b Petroleum refining - gaseous fuels	N_2O	1.43	1.43	17.00	50.00	52.81	0.00	-	0.00	-	0.00	0.00	1
1.A.1.c Manufacture of solid fuels and other energy industries - fossil fuels	CO_2	7,942.01	7,942.01	3.62	3.62	5.12	0.10	-	0.02	-	0.09	0.09	1
1.A.1.c Manufacture of solid fuels and other energy industries - fossil fuels	CH_4	117.50	117.50	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.1.c Manufacture of solid fuels and other energy industries - fossil fuels	N_2O	43.68	43.68	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2, 1.A.4, 1.A.5 Solid fossil fuels	CO_2	11,375.13	11,375.13	2.83	2.83	4.00	0.11	-	0.03	-	0.10	0.10	2
1.A.2, 1.A.4, 1.A.5 Solid fossil fuels	CH_4	3.40	3.40	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2, 1.A.4, 1.A.5 Solid fossil fuels	N_2O	29.30	29.30	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2, 1.A.4, 1.A.5 Gaseous fossil fuels	CO_2	19,643.69	19,643.69	2.83	2.83	4.00	0.19	-	0.05	-	0.18	0.18	2
1.A.2, 1.A.4, 1.A.5 Gaseous fossil fuels	CH_4	9.00	9.00	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.A.2, 1.A.4, 1.A.5 Gaseous fossil fuels	N_2O	74.21	74.21	8.49	8.49	12.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2, 1.A.4, 1.A.5 Liquid fossil fuels	CO_2	18,285.08	18,285.08	2.83	2.83	4.00	0.17	-	0.04	-	0.17	0.17	2
1.A.2, 1.A.4, 1.A.5 Liquid fossil fuels	CH_4	43.07	43.07	6.36	6.36	9.00	0.00	-	0.00	-	0.00	0.00	2
1.A.2, 1.A.4, 1.A.5 Liquid fossil fuels	N_2O	178.50	178.50	8.49	8.49	12.00	0.01	-	0.00	-	0.00	0.00	2
1.A.3 Transport fossil fuels	CH_4	59,821.60	59,821.60	2.83	2.83	4.00	0.56	-	0.14	-	0.55	0.55	3
1.A.3 Transport fossil fuels	N_2O	658.63	658.63	16.97	16.97	24.00	0.04	-	0.00	-	0.04	0.04	3
1.A.3 Transport fossil fuels	CO_2	914.33	914.33	29.70	29.70	42.00	0.09	-	0.00	-	0.08	0.08	3
1.A. Biomass fuels	CH_4	2,427.13	2,427.13	-	20.00	20.00	0.11	-	0.01	-	-	-	2
1.A. Biomass fuels	N_2O	240.60	240.60	-	50.00	50.00	0.03	-	0.00	-	-	-	2
1.B.1.a.i Solid Fuels - Underground Mines	CO_2	1,121.82	1,121.82	2.00	10.00	10.20	0.03	-	0.00	-	0.01	0.01	1
1.B.1.a.i Solid Fuels - Underground Mines	CH_4	17,640.76	17,640.76	2.00	10.00	10.20	0.42	-	0.05	-	0.13	0.13	1
1.B.1.a.i Solid Fuels - Underground Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	0
1.B.1.a.ii Solid Fuels - Open Cut Mines	CO_2	61.78	61.78	6.30	30.89	31.52	0.00	-	0.00	-	0.00	0.00	1
1.B.1.a.ii Solid Fuels - Open Cut Mines	CH_4	3,350.71	3,350.71	6.30	30.89	31.52	0.25	-	0.01	-	0.08	0.08	1
1.B.1.a.ii Solid Fuels - Open Cut Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	0
1.B.1.c Solid Fuels - Other	CO_2	0.28	0.28	5.00	20.00	20.62	0.00	-	0.00	-	0.00	0.00	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.B.1.c Solid Fuels - Other	CO_2	0.02	0.02	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	3
1.B.1.c Solid Fuels - Other	CO_2	0.00	0.00	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	3
1.B.2.a Oil and Natural Gas - Oil	CO_2	393.90	393.90	5.00	5.00	7.07	0.01	-	0.00	-	0.01	0.01	3
1.B.2.b Oil and Natural Gas - Natural Gas	CO_2	84.42	84.42	10.00	3.00	10.44	0.00	-	0.00	-	0.00	0.00	3
1.B.2.c Oil and Natural Gas - Venting and Flaring	CO_2	5,610.40	5,610.40	5.00	5.00	7.07	0.09	-	0.01	-	0.09	0.09	3
1.B.2.a Oil and Natural Gas - Oil	CH_4	77.77	77.77	9.86	48.30	49.30	0.01	-	0.00	-	0.00	0.00	3
1.B.2.b Oil and Natural Gas - Natural Gas	CH_4	5,031.34	5,031.34	12.04	58.97	60.18	0.71	-	0.01	-	0.22	0.22	3
1.B.2.c Oil and Natural Gas - Venting and Flaring	CH_4	2,588.52	2,588.52	8.00	39.18	39.99	0.24	-	0.01	-	0.08	0.08	3
1.B.2.a Oil and Natural Gas - Oil	N_2O	3.55	3.55	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
1.B.2.b Oil and Natural Gas - Natural Gas	N_2O	0.65	0.65	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
1.B.2 Oil and Natural Gas - Venting and Flaring	N_2O	36.04	36.04	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	3
2.A.1 Cement Production	CO_2	3,462.87	3,462.87	3.43	3.43	4.85	0.04	-	0.01	-	0.04	0.04	1
2.A.2 Lime Production	CH_4	775.37	775.37	3.43	3.43	4.85	0.01	-	0.00	-	0.01	0.01	1
2.A.4 Other Process Uses of Carbonates	N_2O	1,251.34	1,251.34	4.00	2.50	4.72	0.01	-	0.00	-	0.02	0.02	4
2.B Chemicals	HFCs	1,054.69	1,054.69	2.58	2.58	3.64	0.01	-	0.00	-	0.01	0.01	1
2.B Chemicals	CO_2	10.94	10.94	5.00	50.00	50.25	0.00	-	0.00	-	0.00	0.00	4
2.B Chemicals	CH_4	995.04	995.04	4.10	4.10	5.80	0.01	-	0.00	-	0.01	0.01	1
2.B Chemicals	N_2O	1,424.68	1,424.68	-	27.00	27.00	0.09	-	0.00	-	-	-	4
2.C.1 Iron and Steel Production	CO_2	9,203.23	9,203.23	1.61	1.61	2.28	0.05	-	0.02	-	0.05	0.05	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
2.C.1 Iron and Steel Production	PFCs	70.55	70.55	2.00	50.00	50.04	0.01	-	0.00	-	0.00	0.00	4
2.C.1 Iron and Steel Production	CO_2	21.48	21.48	2.00	50.00	50.04	0.00	-	0.00	-	0.00	0.00	4
2.C.3 Aluminium Production	CH_4	2,058.10	2,058.10	3.21	3.21	4.54	0.02	-	0.00	-	0.02	0.02	1
2.C.3 Aluminium Production	N_2O	4,607.01	4,607.01	-	27.00	27.00	0.29	-	0.01	-	-	-	4
2.C.2 Ferroalloys Production	CO_2	232.62	232.62	6.45	6.45	9.12	0.01	-	0.00	-	0.00	0.00	1
2.C.2 Ferroalloys Production	CH_4	0.05	0.05	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.2 Ferroalloys Production	N_2O	0.48	0.48	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	CO_2	150.52	150.52	6.45	6.45	9.12	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	CO_2	0.07	0.07	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.C.7 Other	FIFOs	0.32	0.32	6.45	50.00	50.41	0.00	-	0.00	-	0.00	0.00	1
2.D Non-energy Products from Fuels and Solvent Use	sf_6	279.93	279.93	2.00	3.00	3.61	0.00	-	0.00	-	0.00	0.00	1
2.H.2 Food and Beverages Industry	CH_4	82.57	82.57	2.58	2.58	3.64	0.00	-	0.00	-	0.00	0.00	1
2.F Product Uses as Substitutes for Ozone Depleting Substances	CH_4	-	-	-	27.00	27.00	-	-	-	-	-	-	4
2.G Other Product Manufacture and Use	N_2O	220.56	220.56	-	27.00	27.00	0.01	-	0.00	-	-	-	4
3.A Enteric Fermentation	CH_4	64,632.91	64,632.91	10.00	22.43	24.56	3.75	-	0.17	-	2.35	2.35	6
3.B Manure Management	CH_4	6,150.90	6,150.90	22.36	50.00	54.77	0.80	-	0.02	-	0.50	0.50	6
3.B Manure Management	N_2O	238.31	238.31	22.36	50.00	54.77	0.03	-	0.00	-	0.02	0.02	7
3.C Rice Cultivation	CH_4	475.62	475.62	5.00	50.00	50.25	0.06	-	0.00	-	0.01	0.01	7
3.D Agricultural Soils	N_2O	12,342.53	12,342.53	25.00	50.00	55.90	1.63	-	0.03	-	0.89	0.89	7

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 1990 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
3.F Agricultural Residue Burning	CH_4	291.96	291.96	32.40	50.00	59.58	0.04	-	0.00	-	0.03	0.03	7
3.F Agricultural Residue Burning	N_2O	138.90	138.90	32.40	50.00	59.58	0.02	-	0.00	-	0.01	0.01	7
3.G Liming	CO_2	215.35	215.35	20.00	50.00	53.85	0.03	-	0.00	-	0.01	0.01	7
3.H Urea application	CO_2	366.67	366.67	10.00	50.00	50.99	0.04	-	0.00	-	0.01	0.01	7
5.A Solid Waste Disposal	CO_2	15,239.94	15,239.94	10.80	52.91	54.00	1.94	-	0.04	-	0.60	0.60	9
5.D Wastewater Treatment and Discharge	CH_4	4,389.40	4,389.40	10.00	48.99	50.00	0.52	-	0.01	-	0.16	0.16	9
5.D Wastewater Treatment and Discharge	N_2O	287.56	287.56	10.00	48.99	50.00	0.03	-	0.00	-	0.01	0.01	9
5.C Incineration and Open Burning of Waste	CH_4	73.36	73.36	8.00	39.19	40.00	0.01	-	0.00	-	0.00	0.00	9
5.C Incineration and Open Burning of Waste	N_2O	2.32	2.32	10.00	48.99	50.00	0.00	-	0.00	-	0.00	0.00	9
5.C Incineration and Open Burning of Waste		11.32	11.32	10.00	48.99	50.00	0.00	-	0.00	-	0.00	0.00	9
5.B Biological treatment of solid waste		8.76	8.76	20.00	97.98	100.00	0.00	-	0.00	-	0.00	0.00	9
5.B Biological treatment of solid waste		13.36	13.36	20.00	97.98	100.00	0.00	-	0.00	-	0.00	0.00	9
Total Emissions		**423,672.22**	**423,672.22**										
Total Uncertainties							**4.8**					**2.8**	

Table A2.3 General reporting table for uncertainty including LULUCF for latest inventory year 2019

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 2019 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.a Electricity generation – black coal	CO_2	72,725.26	104,635.05	1.65	1.65	2.33	0.47	0.07	0.17	0.12	0.40	0.41	1
I.A.I.a Electricity generation – black coal	CH_4	13.54	19.88	1.65	50.00	50.03	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.a Electricity generation – black coal	N_2O	189.54	224.28	1.65	50.00	50.03	0.02	0.00	0.00	0.01	0.00	0.01	1
I.A.I.a Electricity generation – brown coal	CO_2	45,184.71	41,108.14	0.71	0.71	1.01	0.08	0.00	0.07	0.00	0.07	0.07	1
I.A.I.a Electricity generation – brown coal	CH_4	7.46	7.37	0.71	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.a Electricity generation – brown coal	N_2O	188.58	201.70	0.71	50.00	50.01	0.02	0.00	0.00	0.00	0.00	0.00	1
I.A.I.a Electricity generation – natural gas	CO_2	8,280.60	28,920.72	1.79	1.79	2.53	0.14	0.04	0.05	0.06	0.12	0.13	1
I.A.I.a Electricity generation – natural gas	CH_4	7.20	447.53	1.79	50.00	50.03	0.04	0.00	0.00	0.04	0.00	0.04	1
I.A.I.a Electricity generation – natural gas	N_2O	43.68	188.00	1.79	50.00	50.03	0.02	0.00	0.00	0.01	0.00	0.01	1
I.A.I.a Electricity generation – liquid fuels	CO_2	2,907.27	3,593.40	2.83	2.83	4.00	0.03	0.00	0.01	0.01	0.02	0.02	2
I.A.I.a Electricity generation – liquid fuels	CH_4	2.71	4.42	35.36	35.36	50.00	0.00	0.00	0.00	0.00	0.00	0.00	2
I.A.I.a Electricity generation – liquid fuels	N_2O	4.13	5.33	35.36	35.36	50.00	0.00	0.00	0.00	0.00	0.00	0.00	2
I.A.I.b Petroleum refining – liquid fuels	CO_2	4,931.12	2,711.57	15.54	15.54	21.98	0.11	0.00	0.00	0.04	0.10	0.10	1
I.A.I.b Petroleum refining – liquid fuels	CH_4	1.26	1.05	15.54	50.00	52.36	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – liquid fuels	N_2O	12.10	1.29	15.54	50.00	52.36	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	CO_2	580.95	290.47	15.82	15.82	22.38	0.01	0.00	0.00	0.01	0.01	0.01	1
I.A.I.b Petroleum refining – gaseous fuels	CH_4	0.29	0.15	15.82	50.00	52.44	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	N_2O	1.43	0.73	15.82	50.00	52.44	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CO_2	7,942.01	30,771.70	3.75	3.75	5.31	0.31	0.04	0.05	0.15	0.27	0.30	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2e	Year t emissions 2019 Gg CO_2e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CH_4	117.50	334.70	6.36	6.36	9.00	0.01	0.00	0.00	0.00	0.00	0.01	2
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	N_2O	43.68	251.60	8.49	8.49	12.00	0.01	0.00	0.00	0.00	0.00	0.01	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CO_2	11,375.13	9,446.80	2.83	2.83	4.00	0.07	0.00	0.02	0.00	0.06	0.06	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CH_4	3.40	2.71	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	N_2O	29.30	23.80	8.49	8.49	12.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CO_2	19,643.69	30,556.39	2.83	2.83	4.00	0.24	0.02	0.05	0.06	0.20	0.21	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CH_4	9.00	12.62	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	N_2O	74.21	111.76	8.49	8.49	12.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CO_2	18,285.08	26,625.55	2.83	2.83	4.00	0.21	0.02	0.04	0.05	0.17	0.18	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CH_4	43.07	59.43	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	N_2O	178.50	300.66	8.49	8.49	12.00	0.01	0.00	0.00	0.00	0.01	0.01	2
1.A.3 Transport fossil fuels	CO_2	59,821.60	98,769.99	2.83	2.83	4.00	0.76	0.08	0.16	0.22	0.64	0.68	3
1.A.3 Transport fossil fuels	CH_4	658.63	322.72	16.97	16.97	24.00	0.01	0.00	0.00	0.01	0.01	0.01	3
1.A.3 Transport fossil fuels	N_2O	914.33	1,365.78	29.70	29.70	42.00	0.11	0.00	0.00	0.03	0.09	0.10	3
I.A. Biomass fuels	CH_4	2,427.13	946.04	-	20.00	20.00	0.04	0.00	0.00	0.04	-	0.04	2
I.A. Biomass fuels	N_2O	240.60	239.43	-	50.00	50.00	0.02	0.00	0.00	0.00	-	0.00	2
I.B.I.a.i Solid Fuels – Underground Mines	CO_2	1,121.82	1,237.10	2.00	10.00	10.20	0.02	0.00	0.00	0.00	0.01	0.01	1
I.B.I.a.i Solid Fuels – Underground Mines	CH_4	17,640.76	15,762.33	2.00	10.00	10.20	0.31	0.00	0.03	0.01	0.07	0.07	1
I.B.I.a.i Solid Fuels – Underground Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	
I.B.I.a.i! Solid Fuels – Open Cut Mines	CO_2	61.78	143.85	6.49	31.80	32.46	0.01	0.00	0.00	0.00	0.00	0.01	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 2019 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.B.I.a.i! Solid Fuels – Open Cut Mines	CH_4	3,350.71	6,692.45	6.49	31.80	32.46	0.42	0.01	0.01	0.20	0.10	0.22	1
I.B.I.a.i! Solid Fuels – Open Cut Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	
I.B.I.c Solid Fuels – Other	CO_2	0.28	681.39	5.00	20.00	20.62	0.03	0.00	0.00	0.02	0.01	0.02	3
I.B.I.c Solid Fuels – Other	CH_4	0.02	56.24	5.00	50.00	50.25	0.01	0.00	0.00	0.00	0.00	0.00	3
I.B.I.c Solid Fuels – Other	N_2O	0.00	0.40	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.a Oil and Natural	CO,	393.90	108.70	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	CO_2	84.42	26.66	10.00	3.00	10.44	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.C Oil and Natural Gas – Venting and Flaring	CO_2	5,610.40	18,003.56	5.00	5.00	7.07	0.25	0.02	0.03	0.11	0.21	0.23	3
1.B.2.a Oil and Natural Gas – Oil	CH_4	77.77	62.19	9.09	44.53	45.44	0.01	0.00	0.00	0.00	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	CH_4	5,031.34	5,647.56	14.34	70.27	71.72	0.78	0.00	0.01	0.16	0.19	0.25	3
1.B.2.C Oil and Natural Gas – Venting and Flaring	CH_4	2,588.52	2,521.65	8.42	41.25	42.10	0.20	0.00	0.00	0.02	0.05	0.05	3
1.B.2.a Oil and Natural Gas – Oil	N_2O	3.55	1.01	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	N_2O	0.65	0.08	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2 Oil and Natural Gas – Venting and Flaring	N_2O	36.04	89.32	2.00	50.00	50.04	0.01	0.00	0.00	0.00	0.00	0.00	3
2.A.1 Cement Production	CO_2	3,462.87	3,039.55	3.67	3.67	5.20	0.03	0.00	0.00	0.00	0.03	0.03	1
2.A.2 Lime Production	CO_2	775.37	1,025.26	3.67	3.67	5.20	0.01	0.00	0.00	0.00	0.01	0.01	1
2.A.4 Other Process Uses of Carbonates	CO_2	1,251.34	1,524.43	4.00	2.50	4.72	0.01	0.00	0.00	0.00	0.01	0.01	4
2.B Chemicals	CO_2	1,054.69	2,820.77	3.07	3.07	4.34	0.02	0.00	0.00	0.01	0.02	0.02	1
2.B Chemicals	CH_4	10.94	10.84	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	4
2.B Chemicals	N_2O	995.04	2,227.56	6.55	6.55	9.26	0.04	0.00	0.00	0.01	0.03	0.04	1
2.B Chemicals	HFCs	1,424.68	-	-	27.00	27.00	-	0.00	-	0.05	-	0.05	4
2.C.1 Iron and Steel Production	CO_2	9,203.23	7,531.57	1.57	1.57	2.22	0.03	0.00	0.01	0.00	0.03	0.03	1
2.C.1 Iron and Steel Production	CH_4	70.55	61.00	2.00	50.00	50.04	0.01	0.00	0.00	0.00	0.00	0.00	4

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2e	Year t emissions 2019 Gg CO_2e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
2.C.1 Iron and Steel Production	N_2O	21.48	15.26	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	4
2.C.3 Aluminium Production	CO_2	2,058.10	2,296.38	2.85	2.85	4.03	0.02	0.00	0.00	0.00	0.02	0.02	1
2.C.3 Aluminium Production	PFCs	4,607.01	303.14	-	27.00	27.00	0.02	0.01	0.00	0.16	-	0.16	4
2.C.2 Ferroalloys Production	CO_2	232.62	453.23	7.07	7.07	10.00	0.01	0.00	0.00	0.00	0.01	0.01	1
2.C.2 Ferroalloys Production	CH_4	0.05	0.10	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.2 Ferroalloys Production	N_2O	0.48	0.89	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.7 Other	CO_2	150.52	277.39	7.07	7.07	10.00	0.01	0.00	0.00	0.00	0.00	0.00	1
2.C.7 Other	CH_4	0.07	0.09	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.7 Other	N_2O	0.32	0.57	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.D Non-energy Products from Fuels and Solvent Use	CO_2	279.93	180.05	2.00	3.00	3.61	0.00	0.00	0.00	0.00	0.00	0.00	1
2.FI.2 Food and Beverages Industry	CO_2	82.57	218.99	3.07	3.07	4.34	0.00	0.00	0.00	0.00	0.00	0.00	1
2.F Product Uses as Substitutes for Ozone Depleting Substances	FIFOs	-	10,444.59	-	27.00	27.00	0.54	0.02	0.02	0.46	-	0.46	4
2.G Other Product Manufacture and Use	sf_6	220.56	136.86	-	27.00	27.00	0.01	0.00	0.00	0.00	-	0.00	4
3.A Enteric Fermentation	CH_4	64,632.91	48,209.36	10.00	22.43	24.56	2.28	0.01	0.08	0.23	1.11	1.13	6
3.B Manure Management	CH_4	6,150.90	5,801.89	22.36	50.00	54.77	0.61	0.00	0.01	0.05	0.30	0.30	6
3.B Manure Management	N_2O	238.31	630.65	22.36	50.00	54.77	0.07	0.00	0.00	0.03	0.03	0.05	7
3.C Rice Cultivation	CH_4	475.62	31.52	5.00	50.00	50.25	0.00	0.00	0.00	0.03	0.00	0.03	7
3.D Agricultural Soils	N_2O	12,342.53	12,209.79	25.00	50.00	55.90	1.32	0.00	0.02	0.15	0.70	0.72	7
3.F Agricultural Residue Burning	CH_4	291.96	136.45	32.40	50.00	59.58	0.02	0.00	0.00	0.01	0.01	0.01	7
3.F Agricultural Residue Burning	N_2O	138.90	67.67	32.40	50.00	59.58	0.01	0.00	0.00	0.00	0.01	0.01	7
3.G Liming	CO_2	215.35	1,318.39	20.00	50.00	53.85	0.14	0.00	0.00	0.09	0.06	0.11	7
3.H Urea application	CO_2	366.67	1,347.00	10.00	50.00	50.99	0.13	0.00	0.00	0.08	0.03	0.09	7
4.A.1 Forest Land remaining Forest Land	CO_2	-5,953.19	-25,250.39	15.00	30.00	33.54	1.63	0.03	0.04	0.99	0.87	1.32	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 2019 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
4.A.1 Forest Land remaining Forest Land	CH_4	5,230.50	4,812.60	15.00	50.00	52.20	0.48	0.00	0.01	0.03	0.17	0.17	3
4.A.1 Forest Land remaining Forest Land	N_2O	1,024.89	903.01	15.00	50.00	52.20	0.09	0.00	0.00	0.00	0.03	0.03	3
4.A.2 Land converted to Forest Land	CO_2	-4,629.84	-29,400.40	12.23	11.50	16.79	0.95	0.04	0.05	0.48	0.83	0.95	3
4.A.2 Land converted to Forest Land	CH_4	22.83	67.42	11.00	50.00	51.20	0.01	0.00	0.00	0.00	0.00	0.00	3
4.A.2 Land converted to Forest Land	N_2O	112.57	257.50	11.00	50.00	51.20	0.03	0.00	0.00	0.01	0.01	0.01	3
4.B.1 Cropland remaining Cropland	CO_2	24,792.60	-5,885.22	25.00	20.00	32.02	0.36	0.04	0.01	0.87	0.34	0.93	3
4.B.2 Land converted to Cropland	CO_2	18,414.42	2,689.37	11.20	25.50	27.85	0.14	0.02	0.00	0.53	0.07	0.54	3
4.B.2 Land converted to Cropland	CH_4	580.19	16.50	11.00	50.00	51.20	0.00	0.00	0.00	0.04	0.00	0.04	3
4.B.2 Land converted to Cropland	N_2O	165.79	26.12	11.00	50.00	51.20	0.00	0.00	0.00	0.01	0.00	0.01	3
4.C.1 Grassland remaining Grassland	CO_2	-6,944.65	-10,989.47	25.00	20.00	32.02	0.68	0.01	0.02	0.17	0.63	0.65	3
4.C.1 Grassland remaining Grassland	CH_4	3,930.38	4,165.66	25.00	50.00	55.90	0.45	0.00	0.01	0.07	0.24	0.25	3
4.C.1 Grassland remaining Grassland	N_2O	1,541.01	1,592.68	25.00	50.00	55.90	0.17	0.00	0.00	0.02	0.09	0.09	3
4.C.2 Land converted to Grassland	CO_2	144,459.56	30,030.82	11.00	25.00	27.31	1.58	0.15	0.05	3.72	0.76	3.79	3
4.C.2 Land converted to Grassland	CH_4	5,184.76	950.27	11.00	50.00	51.20	0.09	0.01	0.00	0.28	0.02	0.28	3
4.C.2 Land converted to Grassland	N_2O	1,304.02	322.33	11.00	50.00	51.20	0.03	0.00	0.00	0.06	0.01	0.06	3
4.D.1 Wetlands remaining Wetlands	CO_2	228.97	186.55	11.00	20.00	22.83	0.01	0.00	0.00	0.00	0.00	0.00	3
4.D.1 Wetlands remaining Wetlands	N_2O	4,105.97	119.41	10.00	100.00	100.50	0.02	0.01	0.00	0.54	0.00	0.54	3
4.D.2 Land converted to Wetland	CO_2	707.62	2.83	11.00	25.00	27.31	0.00	0.00	0.00	0.02	0.00	0.02	3
4.E.1 Settlements remaining Settlements	CO_2	-33.48	-76.99	11.00	20.00	22.83	0.00	0.00	0.00	0.00	0.00	0.00	3
4.E.2 Land converted to Settlements	CO_2	4,769.67	817.31	11.50	26.00	28.43	0.04	0.01	0.00	0.14	0.02	0.14	3
4.E.2 Land converted to Settlements	CH_4	164.88	16.46	11.50	50.00	51.31	0.00	0.00	0.00	0.01	0.00	0.01	3

A IPCC Source category	B Gas	C Base year emissions 1990 Gg CO_2 e	D Year t emissions 2019 Gg CO_2 e	E Activity data Uncert'y %	F Emission factor uncert'y %	G Combined uncert'y %	H Uncert'y in total inventory %	I Type A Sensit'y %	J Type B Sensit'y %	K Uncert'y in trend of ef %	L Uncert'y in activity data %	M Uncert'y in trend of total emissions %	Q footnote ref no.
4.E.2 Land converted to Settlements	N_2O	43.21	9.27	11.50	50.00	51.31	0.00	0.00	0.00	0.00	0.00	0.00	3
4.G Harvested Wood Products	CO_2	-7,416.93	-4,815.26	10.00	20.00	22.36	0.21	0.00	0.01	0.05	0.11	0.12	3
5.A Solid Waste Disposal	CH_4	15,239.94	9,153.75	10.80	52.91	54.00	0.95	0.01	0.01	0.32	0.23	0.39	8
5.D Wastewater Treatment and Discharge	CH_4	4,389.40	2,488.07	10.00	48.99	50.00	0.24	0.00	0.00	0.10	0.06	0.11	9
5.D Wastewater Treatment and Discharge	N_2O	287.56	482.64	10.00	48.99	50.00	0.05	0.00	0.00	0.02	0.01	0.02	9
5.C Incineration and Open Burning of Waste	CO_2	73.36	30.68	8.00	39.19	40.00	0.00	0.00	0.00	0.00	0.00	0.00	9
5.C Incineration and Open Burning of Waste	CH_4	2.32	-	10.00	48.99	50.00	-	0.00	-	0.00	-	0.00	9
5.C Incineration and Open Burning of Waste	N_2O	11.32	-	10.00	48.99	50.00	-	0.00	-	0.00	-	0.00	9
5.B Biological treatment of solid waste	CH_4	8.76	112.25	20.00	97.98	100.00	0.02	0.00	0.00	0.02	0.01	0.02	9
5.B Biological treatment of solid waste	N_2O	13.36	171.26	20.00	97.98	100.00	0.03	0.00	0.00	0.03	0.01	0.03	9
Total Emissions		**615,477.99**	**518,865.54**										
Total Uncertainties							**4.2**					**4.7**	

Table A2.4 General reporting table for uncertainty excluding LULUCF for latest inventory year 2019

A IPCC Source category	B Gas	C Base year emissions 1990 Gg CO_2 e	D Year t emissions 2019 Gg CO_2 e	E Activity data Uncert'y %	F Emission factor uncert'y %	G Combined uncert'y %	H Uncert'y in total inventory %	I Type A Sensit'y %	J Type B Sensit'y %	K Uncert'y in trend of ef %	L Uncert'y in activity data %	M Uncert'y in trend of total emissions %	Q footnote ref no.
I.A.I.a Electricity generation – black coal	CO_2	72,725.26	104,635.05	1.65	1.65	2.33	0.45	0.02	0.25	0.04	0.58	0.58	1
I.A.I.a Electricity generation – black coal	CH_4	13.54	19.88	1.65	50.00	50.03	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.a Electricity generation – black coal	N_2O	189.54	224.28	1.65	50.00	50.03	0.02	0.00	0.00	0.00	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2e	Year t emissions 2019 Gg CO_2e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
I.A.I.a Electricity generation – brown coal	CO_2	45,184.71	41,108.14	0.71	0.71	1.01	0.08	0.04	0.10	0.03	0.10	0.10	1
I.A.I.a Electricity generation – brown coal	CH_4	7.46	7.37	0.71	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.a Electricity generation – brown coal	N_2O	188.58	201.70	0.71	50.00	50.01	0.02	0.00	0.00	0.00	0.00	0.01	1
I.A.I.a Electricity generation – natural gas	CO_2	8,280.60	28,920.72	1.79	1.79	2.53	0.13	0.04	0.07	0.08	0.17	0.19	1
I.A.I.a Electricity generation – natural gas	CH_4	7.20	447.53	1.79	50.00	50.03	0.04	0.00	0.00	0.05	0.00	0.05	1
I.A.I.a Electricity generation – natural gas	N_2O	43.68	188.00	1.79	50.00	50.03	0.02	0.00	0.00	0.02	0.00	0.02	1
I.A.I.a Electricity generation – liquid fuels	CO_2	2,907.27	3,593.40	2.83	2.83	4.00	0.03	0.00	0.01	0.00	0.03	0.03	2
I.A.I.a Electricity generation – liquid fuels	CH_4	2.71	4.42	35.36	35.36	50.00	0.00	0.00	0.00	0.00	0.00	0.00	2
I.A.I.a Electricity generation – liquid fuels	N_2O	4.13	5.33	35.36	35.36	50.00	0.00	0.00	0.00	0.00	0.00	0.00	2
I.A.I.b Petroleum refining – liquid fuels	CO_2	4,931.12	2,711.57	15.54	15.54	21.98	0.11	0.01	0.01	0.13	0.14	0.19	1
I.A.I.b Petroleum refining – liquid fuels	CH_4	1.26	1.05	15.54	50.00	52.36	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – liquid fuels	N_2O	12.10	1.29	15.54	50.00	52.36	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	CO_2	580.95	290.47	15.82	15.82	22.38	0.01	0.00	0.00	0.02	0.02	0.02	1
I.A.I.b Petroleum refining – gaseous fuels	CH_4	0.29	0.15	15.82	50.00	52.44	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.b Petroleum refining – gaseous fuels	N_2O	1.43	0.73	15.82	50.00	52.44	0.00	0.00	0.00	0.00	0.00	0.00	1
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CO_2	7,942.01	30,771.70	3.75	3.75	5.31	0.30	0.05	0.07	0.18	0.39	0.43	1
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	CH_4	117.50	334.70	6.36	6.36	9.00	0.01	0.00	0.00	0.00	0.01	0.01	2
I.A.I.c Manufacture of solid fuels and other energy industries – fossil fuels	N_2O	43.68	251.60	8.49	8.49	12.00	0.01	0.00	0.00	0.00	0.01	0.01	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CO_2	11,375.13	9,446.80	2.83	2.83	4.00	0.07	0.01	0.02	0.04	0.09	0.10	2

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2e	Year t emissions 2019 Gg CO_2e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.A.2,1.A.4,1.A.5 Solid fossil fuels	CH_4	3.40	2.71	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Solid fossil fuels	N_2O	29.30	23.80	8.49	8.49	12.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CO_2	19,643.69	30,556.39	2.83	2.83	4.00	0.22	0.01	0.07	0.03	0.29	0.29	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	CH_4	9.00	12.62	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Gaseous fossil fuels	N_2O	74.21	111.76	8.49	8.49	12.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CO_2	18,285.08	26,625.55	2.83	2.83	4.00	0.19	0.01	0.06	0.02	0.25	0.25	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	CH_4	43.07	59.43	6.36	6.36	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2
1.A.2,1.A.4,1.A.5 Liquid fossil fuels	N_2O	178.50	300.66	8.49	8.49	12.00	0.01	0.00	0.00	0.00	0.01	0.01	2
1.A.3 Transport fossil fuels	CO_2	59,821.60	98,769.99	2.83	2.83	4.00	0.72	0.05	0.23	0.14	0.93	0.94	3
1.A.3 Transport fossil fuels	CH_4	658.63	322.72	16.97	16.97	24.00	0.01	0.00	0.00	0.02	0.02	0.03	3
1.A.3 Transport fossil fuels	N_2O	914.33	1,365.78	29.70	29.70	42.00	0.10	0.00	0.00	0.01	0.14	0.14	3
I.A. Biomass fuels	CH_4	2,427.13	946.04	-	20.00	20.00	0.03	0.01	0.00	0.10	-	0.10	2
I.A. Biomass fuels	N_2O	240.60	239.43	-	50.00	50.00	0.02	0.00	0.00	0.01	-	0.01	2
I.B.I.a.i Solid Fuels – Underground Mines	CO_2	1,121.82	1,237.10	2.00	10.00	10.20	0.02	0.00	0.00	0.01	0.01	0.01	1
I.B.I.a.i Solid Fuels – Underground Mines	CH_4	17,640.76	15,762.33	2.00	10.00	10.20	0.29	0.02	0.04	0.17	0.11	0.20	1
I.B.I.a.i Solid Fuels – Underground Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	0
I.B.I.a.i! Solid Fuels – Open Cut Mines	CO_2	61.78	143.85	6.49	31.80	32.46	0.01	0.00	0.00	0.00	0.00	0.01	1
I.B.I.a.i! Solid Fuels – Open Cut Mines	CH_4	3,350.71	6,692.45	6.49	31.80	32.46	0.40	0.01	0.02	0.18	0.15	0.23	1
I.B.I.a.i! Solid Fuels – Open Cut Mines	N_2O	-	-	-	-	-	-	-	-	-	-	-	0
I.B.I.c Solid Fuels – Other	CO_2	0.28	681.39	5.00	20.00	20.62	0.03	0.00	0.00	0.03	0.01	0.03	3
I.B.I.c Solid Fuels – Other	CH_4	0.02	56.24	5.00	50.00	50.25	0.01	0.00	0.00	0.01	0.00	0.01	3
I.B.I.c Solid Fuels – Other	N_2O	0.00	0.40	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.a Oil and Natural - Oil	CO,	393.90	108.70	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.01	3
1.B.2.b Oil and Natural Gas – Natural Gas	CO_2	84.42	26.66	10.00	3.00	10.44	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.C Oil and Natural Gas – Venting and Flaring	CO_2	5,610.40	18,003.56	5.00	5.00	7.07	0.23	0.03	0.04	0.13	0.30	0.33	3

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2 e	Year t emissions 2019 Gg CO_2 e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
1.B.2.a Oil and Natural Gas – Oil	CH_4	77.77	62.19	9.09	44.53	45.44	0.01	0.00	0.00	0.00	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	CH_4	5,031.34	5,647.56	14.34	70.27	71.72	0.74	0.00	0.01	0.14	0.27	0.31	3
1.B.2.C Oil and Natural Gas – Venting and Flaring	CH_4	2,588.52	2,521.65	8.42	41.25	42.10	0.19	0.00	0.01	0.08	0.07	0.11	3
1.B.2.a Oil and Natural Gas – Oil	N_2O	3.55	1.01	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2.b Oil and Natural Gas – Natural Gas	N_2O	0.65	0.08	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	3
1.B.2 Oil and Natural Gas – Venting and Flaring	N_2O	36.04	89.32	2.00	50.00	50.04	0.01	0.00	0.00	0.01	0.00	0.01	3
2.A.1 Cement Production	CO_2	3,462.87	3,039.55	3.67	3.67	5.20	0.03	0.00	0.01	0.01	0.04	0.04	1
2.A.2 Lime Production	CO_2	775.37	1,025.26	3.67	3.67	5.20	0.01	0.00	0.00	0.00	0.01	0.01	1
2.A.4 Other Process Uses of Carbonates	CO_2	1,251.34	1,524.43	4.00	2.50	4.72	0.01	0.00	0.00	0.00	0.02	0.02	4
2.B Chemicals	CO_2	1,054.69	2,820.77	3.07	3.07	4.34	0.02	0.00	0.01	0.01	0.03	0.03	1
2.B Chemicals	CH_4	10.94	10.84	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	4
2.B Chemicals	N_2O	995.04	2,227.56	6.55	6.55	9.26	0.04	0.00	0.01	0.01	0.05	0.05	1
2.B Chemicals	HFCs	1,424.68	-	-	27.00	27.00	-	0.00	-	0.12	-	0.12	4
2.C.1 Iron and Steel Production	CO_2	9,203.23	7,531.57	1.57	1.57	2.22	0.03	0.01	0.02	0.02	0.04	0.04	1
2.C.1 Iron and Steel Production	CH_4	70.55	61.00	2.00	50.00	50.04	0.01	0.00	0.00	0.00	0.00	0.00	4
2.C.1 Iron and Steel Production	N_2O	21.48	15.26	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	4
2.C.3 Aluminium Production	CO_2	2,058.10	2,296.38	2.85	2.85	4.03	0.02	0.00	0.01	0.00	0.02	0.02	1
2.C.3 Aluminium Production	PFCs	4,607.01	303.14	-	27.00	27.00	0.01	0.01	0.00	0.36	-	0.36	4
2.C.2 Ferroalloys Production	CO_2	232.62	453.23	7.07	7.07	10.00	0.01	0.00	0.00	0.00	0.01	0.01	1
2.C.2 Ferroalloys Production	CH_4	0.05	0.10	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.2 Ferroalloys Production	N_2O	0.48	0.89	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.7 Other	CO_2	150.52	277.39	7.07	7.07	10.00	0.01	0.00	0.00	0.00	0.01	0.01	1
2.C.7 Other	CH_4	0.07	0.09	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1
2.C.7 Other	N_2O	0.32	0.57	7.07	50.00	50.50	0.00	0.00	0.00	0.00	0.00	0.00	1

A	B	C	D	E	F	G	H	I	J	K	L	M	Q
IPCC Source category	Gas	Base year emissions 1990 Gg CO_2e	Year t emissions 2019 Gg CO_2e	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 activity data %	Uncert'y in trend of total emissions %	footnote ref no.
2.D Non-energy Products from Fuels and Solvent Use	CO_2	279.93	180.05	2.00	3.00	3.61	0.00	0.00	0.00	0.00	0.00	0.00	1
2.FI.2 Food and Beverages Industry	CO_2	82.57	218.99	3.07	3.07	4.34	0.00	0.00	0.00	0.00	0.00	0.00	1
2.F Product Uses as Substitutes for Ozone Depleting Substances	FIFOs	-	10,444.59	-	27.00	27.00	0.51	0.02	0.02	0.67	-	0.67	5
2.G Other Product Manufacture and Use	sf_6	220.56	136.86	-	27.00	27.00	0.01	0.00	0.00	0.01	-	0.01	5
3.A Enteric Fermentation	CH_4	64,632.91	48,209.36	10.00	22.43	24.56	2.16	0.08	0.11	1.87	1.61	2.47	6
3.B Manure Management	CH_4	6,150.90	5,801.89	22.36	50.00	54.77	0.58	0.01	0.01	0.25	0.43	0.50	6
3.B Manure Management	N_2O	238.31	630.65	22.36	50.00	54.77	0.06	0.00	0.00	0.04	0.05	0.06	7
3.C Rice Cultivation	CH_4	475.62	31.52	5.00	50.00	50.25	0.00	0.00	0.00	0.07	0.00	0.07	7
3.D Agricultural Soils	N_2O	12,342.53	12,209.79	25.00	50.00	55.90	1.24	0.01	0.03	0.44	1.02	1.11	7
3.F Agricultural Residue Burning	CH_4	291.96	136.45	32.40	50.00	59.58	0.01	0.00	0.00	0.03	0.01	0.03	7
3.F Agricultural Residue Burning	N_2O	138.90	67.67	32.40	50.00	59.58	0.01	0.00	0.00	0.01	0.01	0.02	7
3.G Liming	CO_2	215.35	1,318.39	20.00	50.00	53.85	0.13	0.00	0.00	0.12	0.09	0.15	7
3.H Urea application	CO_2	366.67	1,347.00	10.00	50.00	50.99	0.13	0.00	0.00	0.10	0.04	0.11	7
5.A Solid Waste Disposal	CH_4	15,239.94	9,153.75	10.80	52.91	54.00	0.90	0.02	0.02	1.32	0.33	1.36	9
5.D Wastewater Treatment and Discharge	CH_4	4,389.40	2,488.07	10.00	48.99	50.00	0.23	0.01	0.01	0.37	0.08	0.38	9
5.D Wastewater Treatment and Discharge	N_2O	287.56	482.64	10.00	48.99	50.00	0.04	0.00	0.00	0.01	0.02	0.02	9
5.C Incineration and Open Burning of Waste	CO_2	73.36	30.68	8.00	39.19	40.00	0.00	0.00	0.00	0.01	0.00	0.01	9
5.C Incineration and Open Burning of Waste	CH_4	2.32	-	10.00	48.99	50.00	-	0.00	-	0.00	-	0.00	9
5.C Incineration and Open Burning of Waste	N_2O	11.32	-	10.00	48.99	50.00	-	0.00	-	0.00	-	0.00	9
5.B Biological treatment of solid waste	CH_4	8.76	112.25	20.00	97.98	100.00	0.02	0.00	0.00	0.02	0.01	0.02	9
5.B Biological treatment of solid waste	N_2O	13.36	171.26	20.00	97.98	100.00	0.03	0.00	0.00	0.04	0.01	0.04	9
Total Emissions		**423,672.22**	**548,297.17**										
Total Uncertainties							**3.1**					**3.5**	

1. NGER, 2. Energy Strategies 2003,3. DISER/expert judgement, 4. Burnbank Consulting 2006,5. IPCC 2006,6. Dr Mark Howden, CSIRO, 7. Dr Carl Meyer, CSIRO, 8. Dr Gary Richards, Department of Climate Change and Energy Efficiency, 9. Blue Environment 2016

A2.1 Energy

A2.1.1 Stationary energy

Uncertainty analyses were conducted for emissions from three sectors: 1.A.1.a. *Electricity,* 1.A.1.b. *Petroleum refining* and 1.A.1.c. *Manufacture of solid fuels and other energy industries* (Table A2.5).

In the electricity generation sector (black coal, brown coal, natural gas and liquid fuels) and petroleum refining sector (liquid fuels and gaseous fuels) the uncertainty associated with most of Australia's emissions in these sectors are reported under NGERS as source specific uncertainty estimates. The reported CO_2-e uncertainties for NGER facilities were combined to derive an overall estimate that has been applied against the sector and fuel.

In the electricity generation sector, CO_2 emissions from the combustion of coal or gas for electricity generation must be estimated using facility specific measurements. The use of facility specific measurements based on sampling and analysis of fuels results in relatively low uncertainty estimates as published in Table A2.5.

Table A2.5 Quantified uncertainty values for key stationary energy subcategories

Greenhouse gas source and sink category	Uncertainty (%)[a]			
	CO_2	CH_4	N_2O	Total CO_2-e
I.A.I.a Electricity				
Black coal [b]	±2.3	±50	±50	±2.3
Brown coal [b]	±0.7	±50	±50	±0.7
Petroleum	±4.0	±50	±50	±4.0
Natural gas [b]	±2.8	±50	±50	±2.8
I.A.I.b Petroleum refining				
Petroleum [b]	±22.0	±52.4	±52.4	±22.0
Gas [b]	±24.0	±52.8	±52.8	±24.0
1.A.1.c Manufacture of solid fuels and other energy industries				
Fossil Fuels	±5.1	±9	±12	±5.1

(a) Uncertainty reported at 95 per cent confidence limits estimated using Latin Hypercube (a type of Monte Carlo) analysis and preliminary estimates for electricity incorporating NGER uncertainty estimates.

(b) Derived from NGER

In the fuel combustion sector the uncertainty associated with emissions of N_2O and CH_4 has negligible impact on overall uncertainty.

A2.1.2 Transport

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

The total estimated uncertainties in the *transport* subsector were ±4 per cent for CO_2, ±24 per cent for CH_4, and ±42 per cent for N_2O. Uncertainties in the emissions from individual source categories ranged from ±4 per cent to ±24 per cent for CO_2, ±24 per cent to ±59 per cent for CH_4, and ±32 per cent to ±63 per cent 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 A2.6 Emissions and quantified uncertainty values for key transport subcategories

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

(a) Uncertainty reported at 95 per cent confidence limits.

A2.1.3 Fugitives

In the coal fugitives sector uncertainty associated with most of Australia's emissions in this sector are reported under NGERS. The reported CO_2-e uncertainties for each large underground and open cut coal mine have been combined to derive a sector estimate which is reported in Table A2.7.

In the coal fugitives sector underground coal mines must directly monitor their CH_4 emissions while open cut coal mines either undertake analysis and measurements or use state based default emission factors. The uncertainty estimates reported in Table A2.7 reflect the uncertainty associated with these measurement approaches.

Table A2.7 Quantified uncertainty values for key fugitive emissions subcategories

Greenhouse gas source and sink category	Uncertainty (%)[a]		
	CO_2	CH_4	N_2O
1.B.1. Solid fuels			
1B1a.i. Underground mines	±10.2	±10.4	
1.B.1.a.ii. Surface mining	±31.5	±31.5	
1.B.2.a. Oil	±7.1	±49.3	±50.0
1.B.2.b. Natural gas	±10.4	±60.4	±50.0
1.B.2.c. Venting and flaring	±40.0	±50.3	±50.0

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

A2.2 Industrial Processes and Product Use

An analysis of uncertainty was conducted using the methods and random sampling techniques described in IPCC 2006. Uncertainty estimates from CO_2 emissions from cement production and CO_2 from aluminum production are derived from NGER. Uncertainty estimates of the other sectors (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 uncertainty in the *industrial processes* subsectors ranged from ±2.3 per cent to ±50.4 per cent.

Table A2.8 Quantified uncertainty values for key industrial processes subsectors using different techniques

Greenhouse gas source and sink category	Uncertainty (%)[a,b]					
	CO_2	CH_4	N_2O	HFC	PFC	SF_6
2.A.1 Cement Production	± 4.85					
2.A.2 Lime Production	± 4.85					
2.A.4 Other Process Uses of Carbonates	± 4.72					
2.B Chemicals	± 3.64	± 50.25	± 5.80	± 27.00		
2.C.1 Iron and Steel Production	± 2.28	± 50.04	± 50.04			
2.C.3 Aluminium Production	± 4.54				± 27.00	
2.C.2 Ferroalloys Production	± 9.12	± 50.41	± 50.41			
2.C.7 Other	± 9.12	± 50.41	± 50.41			
2.D Non-energy Products from Fuels and Solvent Use	± 3.61					
2.H.2 Food and Beverages Industry	± 3.64					
2.F Product Uses as Substitutes for Ozone Depleting Substances				± 27.00		
2.G Other Product Manufacture and Use						± 27.00

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

(b) Uncertainty derived from NGER data. Source: NGER, Burnbank Consulting 2007, IPCC 2006.

A2.3 Agriculture

An uncertainty analysis was undertaken for the *agriculture* subsectors using the approach 1 propagation of error method. The uncertainties applied to activity data and emission factors were based on IPCC (2006) uncertainty estimates and expert judgement (see Table A2.9). It is planned in the future to develop approach 2 uncertainty estimates to better reflect data correlations and the complex tier 2 functions used to estimate emissions.

Table A.2.9 Uncertainty in emission estimates for agriculture sectors

Greenhouse gas source and sink categories	Uncertainty (%)		
	CH_4	N_2O	CO_2
A. Enteric fermentation	±25		
B. Manure management	±55	±55	
C. Rice cultivation	±50		
D. Agricultural soils		±56	
E. Agricultural residue burning	±60	±60	
F. Liming			±54
G. Urea application			±51

A2.4 Land Use, Land Use Change and Forestry

Uncertainty analysis for the LULUCF sector was undertaken using the IPCC Approach 1, propagation of error method as described in IPCC 2006.

Forest land

In the sub-sector *forest land remaining forest land* activity data is derived from national statistics of forest harvesting (ABARES 2020). The uncertainty of these activity data has not been published and so is estimated to be +/-15 per cent. The uncertainties regarding the emission factor used are also unpublished and are estimated to be +/-30 per cent. For Victoria and New South Wales a spatially explicit Tier 3 model is used, with far lower uncertainty surrounding activity data (location and type of harvest), but similar uncertainty over the emission factor.

The sub-sector *land converted to forest land* includes *grassland converted to forest* and *wetlands converted to forest.* The uncertainty associated with the detection of forest cover gains is reported to be +/3.5 per cent (see Appendix 6.A). Field sampling results presented by Paul *et al.* 2014 indicate an uncertainty of +/-11.5 per cent for the estimation of standing biomass. As explained in Volume 2, Section 6.5.3, the higher uncertainty around *wetland converted to forest land* contributes only a small increment to the overall uncertainty for the sub-sector.

Cropland

Cropland remaining cropland activity data are derived from ABS reporting of agricultural management practices as a regional level. The uncertainty associated with these reported activity data is estimated to be +/-25 per cent and the uncertainty associated with model results is estimated to be +/-20 per cent.

The sub-sector *land converted to cropland* includes *forest land converted to cropland* and *wetlands converted to cropland.* For *forest land converted to cropland,* remote sensing-based data are used and the uncertainty in these data is reported to be +/-3.5 per cent. The key input variable to the estimation of biomass at the time of forest conversion to other land uses is the initial assumed above ground biomass. Based on data presented by Richards and Brack (2004) uncertainty in this parameter is estimated to be +/-25 per cent.

For *wetlands converted to cropland,* as explained in Volume 2, Section 6.7.3, the higher uncertainty around *wetlands converted cropland* contributes only a small increment to the overall uncertainty for the sub-sector.

Grassland

Grassland remaining grassland activity data are derived from ABS reporting of agricultural management practices as a regional level, and from remote-sensed area changes in sparse woody vegetation. The uncertainty associated with these reported activity data is estimated to be +/-25 per cent and the uncertainty associated with model results is estimated to be +/-20 per cent.

The sub-sector *land converted to grassland* includes *forest land converted to grassland* and *wetlands converted to grassland.* The remote-sensing-based activity data and FullCAM modelling of carbon stock changes for *forest converted to grassland* are similar to *forest converted to cropland,* and the activity data and estimation method for *wetlands converted to grassland* is similar to that for *wetlands converted to cropland*. As such, overall uncertainty is also similar to *land converted to cropland*.

Wetlands

Wetlands remaining wetlands data includes sparse woody vegetation cover changes based on satellite imagery and ABARES aquaculture production statistics with similar levels of uncertainty. Estimation of net emissions from sparse woody vegetation is via a Tier 2 spreadsheet model. The higher overall uncertainty around aquaculture emissions (Table A2.10 below) is driven by that of the simple Tier 1 model used to estimate N_2O emissions from aquaculture.

The sub-sector *land converted to wetlands* comprises forest land converted to flooded land (e.g. reservoirs). Activity data collection and emissions estimates, and thus uncertainty, are similar to that for *forest converted to grassland*.

Settlements

Settlements remaining settlements data comprises sparse woody vegetation cover changes based on satellite imagery with net emissions estimated via a Tier 2 spreadsheet model. As such, the level of uncertainty is similar to the CO_2 component of *wetlands remaining wetlands* (Table A2.10 below).

The sub-sector land *converted to settlements* includes *forest land* (both terrestrial and coastal mangrove) *converted to settlements* and *wetlands converted to settlements*. Terrestrial forest conversions exert the dominant influence on overall uncertainty. As such, although the uncertainties around emissions from mangrove forest and tidal marsh conversions are greater than for terrestrial forest conversions, their impact is relatively small.

Harvested wood products

The harvested wood products model uses the same source of activity data as the *forest land remaining forest land* model. Uncertainties associated with these activity data are estimated to be +/-10 per cent. Estimated uncertainty associated with the harvested wood products carbon stock change were derived as reduced form outputs of monte carlo analyses (see chapter 6.13) providing an uncertainty of +/-20 per cent.

Table A2.10 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	±33.5	±52.2	±52.2
A.2 Land converted to forest land	±17.3	±51.2	±51.2
B.1 Cropland remaining	±32.0		
C.1 Grassland remaining	±32.0	±56.0	±56.0

Greenhouse gas source and sink categories	Uncertainty (%)		
	CO_2	CH_4	N_2O
B.2 Forest land converted to Cropland	±27.9	±51.2	±51.2
C.2 Forest land converted to Grassland	±27.3	±51.2	±51.2
D.1 Wetlands remaining Wetlands	±22.8	±100.5	±100.5
D.2 Land converted to Wetlands	±27.3		
E.1 Settlements remaining Settlements	±22.8		
E.2 Land converted to Settlements	±28.4	±51.3	±51.3
G Harvested wood products	±22.4		

A2.5 Waste

Estimates for uncertainty for emissions from solid waste disposal and wastewater treatment were estimated by Blue Environment. Estimates of uncertainty for biological treatment and incineration are based on expert judgement.

Table A2.11 Relative uncertainty in emission estimates for key waste subsectors

Greenhouse gas source and sink categories	Uncertainty (%)		
	CO_2	CH_4	N_2O
Waste			
A. Solid waste disposal on land(a)	NA	±54	NA
B. Biological treatment of solid waste	NA	±100	±100
C. Incineration and open burning of waste	±40	±50	±50
D. Wastewater treatment and discharge(a)	NA	±50	±50

(a) Source Blue Environment 2016

ANNEX 3: Other Detailed Methodological Descriptions

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

A3.1 Australia's emissions estimates: Paris Agreement GWP values

The estimates in Table A3.1 are compiled using the 100-year time GWP values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), consistent with rules adopted under the UN Framework Convention on Climate Change (UNFCCC) Paris Agreement (Decision 18/CMA.1 Annex 2.D Paragraph 37). This approach will also be used to track Australia's progress towards its Paris Agreement Nationally Determined Contribution of 26-28 per cent below 2005 levels by 2030, on an emissions budget basis.

Table A3.1 Australia's emissions estimates using AR5 GWPs

UNFCCC classification sector and subsector	Emissions Mt CO_2-e							Per cent change
	1990	2005	2010	2015	2018	2019	2020 (preliminary)	2005–2019
1 Energy (combustion + fugitive)	296.5	401.7	420.7	420.8	434.4	434.0	420.8	8.0
Stationary energy	195.7	278.9	288.2	278.8	281.1	278.9	274.5	0.0
Transport	61.4	82.0	88.7	95.3	100.0	100.3	93.7	22.3
Fugitive emissions from fuel	39.4	40.8	43.8	46.8	53.4	54.7	52.7	34.1
2 Industrial processes and product use	25.1	31.1	32.9	29.7	30.7	31.8	30.5	2.3
3 Agriculture	92.0	86.0	75.1	78.9	80.6	74.8	71.2	-13.0
4 Land use, land use change	193.6	89.4	66.3	2.0	- 21.2	- 25.1	-24.6	-128.1
6 Waste	22.3	16.0	16.9	13.4	13.9	13.8	13.3	-13.8
Total net emissions	**629.6**	**624.2**	**611.9**	**544.8**	**538.4**	**529.3**	**511.2**	**-15.2**

A3.2 Sector-specific Black Carbon Emissions

Black carbon (BC) is a short-lived, small aerosol (or airborne) particle linked to both climate warming and adverse health effects. Black carbon emissions have recently become a focus of attention because their effects on the near-term warming of the atmosphere and on human health. Reducing black carbon emissions is of particular interest in Polar Regions, such as the Arctic, which are especially sensitive to the effects of black carbon. (Canada BC 2018)

Black carbon particles are emitted from combustion processes. Black carbon is not emitted on its own, but as a component of particulate matter (PM) less than or equal to 2.5 micrometres in diameter (PM2.5), along with other components, such as organic carbon (OC) and inorganic compounds such as sulphates.

Two important assumptions underlie the methodologies used to develop the BC inventory:

1. Black carbon, in the form of PM2.5, is primarily the result of combustion. Therefore, the basis for the black carbon inventory is the PM2.5 emitted from combustion processes, multiplied by black carbon ratios specific to each type of inventory sector and fuel source.

2. Although important in some cases, PM2.5 emissions from non-combustion sources, such as dust raised by traffic on paved and unpaved roads or by wind and machinery on open fields or mine sites, are not considered sources of black carbon in this inventory.

The dataset that breaks down the PM2.5 emitted from a particular source (e.g. diesel engine emissions) into its different components, including black carbon and organic carbon, is known as a speciation profile. Most speciation profiles contain a fraction for elemental carbon; these fractions are commonly used as a surrogate to quantify black carbon emissions. The current inventory primarily relies on the United States Environmental Protection Agency's (U.S. EPA) SPECIATE 4.5 database (EPA 2014a) for speciation factors to calculate black carbon emissions from compiled combustion-related PM2.5 emissions. Several BC/PM2.5 ratios are specific to the combustion processes or technologies (e.g. appliance types for residential wood combustion), to the fuel type (e.g. diesel, gasoline, natural gas) or to the application (e.g. natural gas use for electrical power generation).

Industrial PM2.5 emissions originate from both combustion and non-combustion sources; however, only PM2.5 emissions resulting from combustion contain significant amounts of black carbon. Where readily available, the PM2.5 emissions data from combustion were used in conjunction with BC/ PM2.5 fractions to estimate black carbon emissions.

Separating combustion from non-combustion sources of PM2.5 remains a challenge in some cases due to a lack of data on activities (i.e. quantity of fuel burned) and on non-combustion sources (e.g. rock dust at a mine). In those cases, combustion and non-combustion PM2.5 are separated based on the judgement of experts with knowledge of industrial processes. (Canada BC 2018)

Generally, black carbon emissions are calculated using PM2.5 emissions from combustion processes and the fraction of black carbon in the PM2.5. For example, diesel engines have relatively high emission rates of PM2.5 per unit energy, and the fraction of black carbon in these PM2.5 emissions is also relatively high.

Other combustion sources with high PM2.5 emissions include solid fuel combustion units, such as coal- and wood-fired boilers. Industrial sources are generally equipped with highly effective PM2.5 controls on boiler emissions, with PM-control efficiencies often in the 90 per cent range. This is reflected in the lower PM2.5 emissions compared to other sources.

However, the smaller and distinctly different equipment used for residential wood combustion (fireplaces, wood stoves or furnaces) have poorer PM2.5 control efficiencies than larger units, despite the different types of fuel and firing practices used for burning firewood. Due to the lower efficiency combined with the limited treatment of stack gases for many existing residential wood-burning devices, they are the largest source of combustion-related PM2.5 emissions. Black carbon emissions from residential wood burning are only one third that of mobile sources due to a lower BC/PM2.5 fraction for wood devices than for diesel engines. (Canada BC 2018)

A3.2.1 Scope

This Report provides estimates of black carbon emissions for energy, IPPU, waste, transport, residential burning and biomass burning for 2008-09 and 2018–19. Australia's BC Inventory uses data from the National Pollutant Inventory (NPI) to complement the activity data found in the annual inventory. The PM2.5 emissions data from the NPI have been measured and therefore used in a Tier 3 methodology, covering a range of inventory sectors. Sectors that are not covered by the NPI dataset have used activity data calculated in the inventory analysis as the input to the Tier 2 methodology. These methodologies are explained in detail below.

A3.2.2 Tier Framework and Limitations

Understanding Limitations in Black Carbon Emissions Estimations

There are several limitations in estimating BC emissions for the BC inventory. A foremost limitation is that air pollutant inventories are focused on mass emissions, while BC is defined based on optical properties, and measurements that form the basis of underlying emissions, and speciation factors do not provide a complete accounting for these optical properties. Another limitation is that post-hoc speciation factors do not match the level of detail of PM emission factors in many sectors, introducing additional error to the process. These issues are discussed in the following sections.

A3.2.3 Sector-specific Black Carbon Emission Estimation Methods

Black carbon definition

What is referred to as "black carbon" varies in the literature, and in measurement practice; the definition also depends on whether a BC analysis is focused on climate-forcing or health-based outcomes. From a climate-forcing perspective, the term black carbon may be used for the broader metric of "light absorbing carbon" (LAC), comprising both light-absorbing elemental carbon (EC) and light-absorbing organic carbon (OC) (i.e., brown carbon). From a health perspective, BC has typically been defined only as the mass of EC (i.e., the graphitic component of PM). So, BC may refer to the mass of EC only, or to the broader, optically-defined LAC.

Black carbon emissions can be calculated using either a Tier 3 or Tier 2 method.

Tier 3 Method

For the Tier 3 method, NPI PM2.5 emissions data is used to calculate Black Carbon (BC) emissions.

This method involves multiplying the PM2.5 emissions with a speciation factor (BC fraction) that converts PM2.5 to BC emissions. Because the NPI PM2.5 emissions are considered measured, this is Tier 3.

PM2.5 emissions x Speciation Factor = BC emissions

The Speciation Factors are specified by sector and by fuel type. The fractions are sourced from US EPA Speciate 4.5 database. The PM2.5 emissions are from the NPI database.

The NPI emissions are broken down into fuel types with a breakdown of tonnes of fuel used by fuel type and using this information, a calculation is done to breakdown the total emissions by facility into each fuel type.

Black carbon emissions are calculated by inventory sector, by State and aggregated to the National level. The NPI datasets includes data for Energy, Industrial Processes and Waste.

Tier 2 method

For the Tier 2 method, inventory analysis data is used to calculate BC emissions. In this method, the amount of fuel combusted is used and multiplied by a PM2.5 emission factor (by fuel type) and a speciation factor.

Quantity of fuel combusted x PM2.5 emission factor x BC Fractions = BC emissions by sector

For sectors that are not covered by the NPI, the Tier 2 method is used.

Energy, Industrial Processes and Waste

For these sectors, Tier 3 method was used with PM2.5 emissions from the NPI dataset and Speciation Factors.

Transport

For the Transport sector, the methods are sub-sector specific using the Tier 2 approach.

On-road Sources

Tier 2 for On-road sources

Total Black Carbon emissions from on-road vehicles (EBC)

i	Type of fuel
j	vehicle class
Qi,j	quantity of fuel type i for vehicle class j
EFi,j,EC	fuel based EC (elemental carbon) emission factor for fuel type i and vehicle class j
Eni	energy content of fuel type i

EBC = Si,j (Qi,j * EFi,j,EC * 1/Eni)

Non-road Sources

Total Black Carbon emissions from non-road vehicles (EBC)

c	equipment use category
i	fuel type
t	technology level (year it was made)
Qc,i,t	fuel consumption for a given equipment use category c, fuel type i, and technology level t
EFc,i,t,PM2.5	PM2.5 emission factor for a given equipment use category c, fuel type i, and technology level t
SFi,t,BC/PM2.5	speciation factor to convert PM2.5 to black carbon for fuel type i, and technology level t (if available)

EBC = Sc,i,t (Qc,i,t * EFc,i,t,PM2.5 * SFi,t,BC/PM2.5)

Railway

Total Black Carbon emissions from locomotives (EBC)

i	rail operation type
Qi	amount of locomotive fuel combusted, by rail operation type i
EFi,PM2.5	PM2.5 emission factor for rail operation type i
SFBC/PM2.5	speciation factor to convert PM2.5 to black carbon for locomotives

EBC = Si (Qi * EFi,PM2.5) * SFBC/PM2.5)

Marine

Tier 1 Method for Marine Sources

Total Black Carbon emissions from marine sources (EBC)

i	fuel type
Qi	fuel consumption for a given equipment use category c, fuel type i, and technology level t
EFi,PM2.5	PM2.5 emission factor for a given equipment use category c, fuel type i, and technology level t
SFi,BC/PM2.5	speciation factor to convert PM2.5 to black carbon for fuel type i, and technology level t (if available)

EBC = Si (Qi * EFi,PM2.5 * SFi,BC/PM2.5)

Aviation

Method for Aviation: Tier 2 – Tier 1 = cruising emissions

Tier 2: Total Black Carbon emissions from aviation sources (EBC)

LTOi,j	activity annual airport LTOs for aircraft type i using fuel type j (land and takeoff cycles)
i	aircraft type (i.e. commercial air carriers, air taxis, general aviation, military)
j	aircraft fuel type (i.e. aviation gasoline, or jet fuel)
EFi,j,PM2.5	PM2.5 emission factor for aircraft type i and fuel type j
SFi,j,BC/PM2.5	speciation factor to convert PM2.5 to black carbon for fuel type j

EBC = Si,j (LTOi,j * EFi,j,PM2.5 * SFi,j,BC/PM2.5)

Tier 1: Total Black Carbon emissions from aviation sources (EBC)

i	type of fuel (i.e. aviation gasoline or jet fuel). Note that piston engines associated with smaller i aircraft and helicopters use aviation gasoline while jet fuel is used by larger helicopters and aircraft equipped with turboprops, turbofans and jets
Qi	quantity of aviation fuel used by fuel type, i
EFi,PM2.5	PM2.5 emission factor for aircraft type i and fuel type i
SFi,BC/PM2.5	speciation factor to convert PM2.5 to black carbon for fuel type i

EBC = Si,j (Qi * EFi,PM2.5 * SFi,BC/PM2.5)

Residential Combustion

For this sector, the Tier 2 method was used for wood heaters.

Other Sources

Biomass Burning

Open Burning

A Tier 3 FullCAM method was used for Biomass Burning.

Variable	Description
0.45	Fraction of carbon in fuel
Ak	area burned of biome'k'
Bk	fuel load (mass of fuel per area for biome'k')
ak	Fraction of above-ground biomass for biome'k'
bk	Combustion efficiency (fraction of fuel burned for biome'k')
EFk,PM2.5	PM2.5 emission factor for biome'k' (i.e. emissions per mass of C in the fuel [kg/kg-C in fuel])
SFk,BC/PM2.5	speciation factor to convert PM2.5 to black carbon for biome'k'

EBC,k = (0.45 * Ak * Bk * ak * bk) * EFk,PM2.5 * SFk,BC/PM2.5)

Agricultural Burning

For this sector, the Tier 2 method is used.

A3.2.4 Black Carbon Emissions by Sector

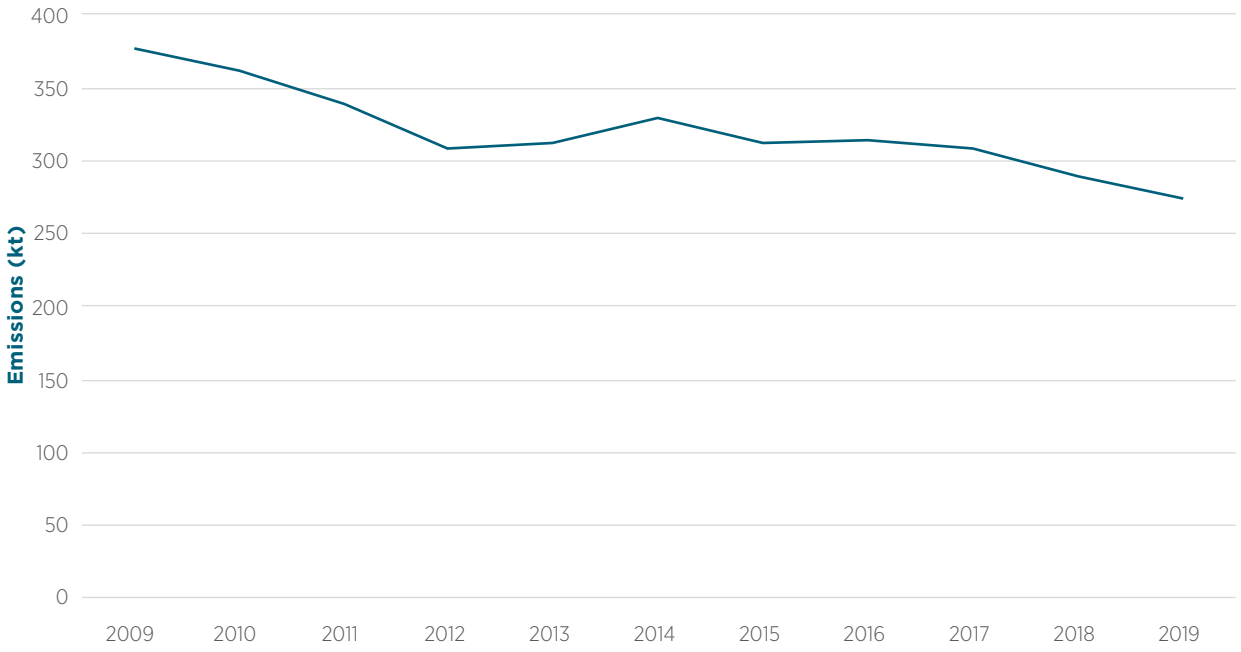
The black carbon emissions by sector from 2008–09 to 2018–19 are displayed below. There is a downward trend of black carbon emissions across all sectors in this period.

Table A3.2 Black carbon emissions including Land Use, Land-Use Change and Forestry (LULUCF)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1 Energy	**45.3**	**49.1**	**52.1**	**56.5**	**58.3**	**60.2**	**61.0**	**63.2**	**62.7**	**66.2**	**66.0**
Fuel Combustion	45.3	49.1	52.1	56.5	58.3	60.2	61.0	63.2	62.7	66.2	66.0
Energy Industries	5.2	5.3	5.1	7.0	6.9	7.4	6.9	7.1	5.0	5.5	5.7
Manufacture of Solid Fuels and Other Energy Industries	4.4	4.6	4.4	6.3	6.2	6.7	6.2	6.5	4.5	5.1	5.2
Petroleum Refining	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.1
Public Electricity and Heat Production	0.7	0.4	0.5	0.5	0.3	0.4	0.4	0.4	0.3	0.3	0.3
Manufacturing Industries and Construction	6.3	6.0	6.1	7.2	7.5	7.6	7.4	7.4	7.7	7.4	7.5
Other (not elsewhere classified)	0.2	0.3	0.4	0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.3
Other Sectors	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3
Transport	33.3	37.5	40.3	41.7	43.3	44.6	46.2	48.0	49.3	52.6	52.2
2 Industrial Processes	**0.4**	**0.3**	**0.4**	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.3**
3 Agriculture	**4.1**	**3.6**	**5.2**	**5.2**	**4.9**	**4.6**	**4.4**	**4.0**	**6.5**	**4.5**	**2.9**

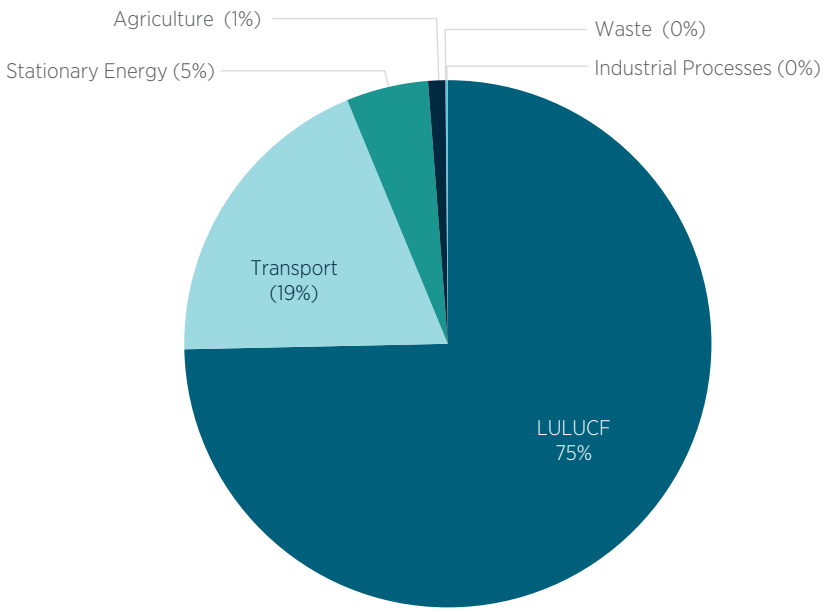
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
4 Land Use, Land Use Change and Forestry UNFCCC	**327.8**	**308.4**	**280.7**	**246.2**	**249.2**	**263.4**	**245.4**	**246.9**	**237.3**	**218.0**	**204.2**
5 Waste	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.8**	**0.1**	**0.1**
Memo Items (including International Bunkers – Marine and Aviation)	18.2	23.4	22.7	24.0	24.7	26.8	26.2	27.5	30.0	31.8	34.2
Total	**377.7**	**361.5**	**338.4**	**308.3**	**312.6**	**328.5**	**311.2**	**314.6**	**307.6**	**289.1**	**273.4**

Figure A3.1 Black carbon emissions including Land Use, Land-Use Change and Forestry (LULUCF)



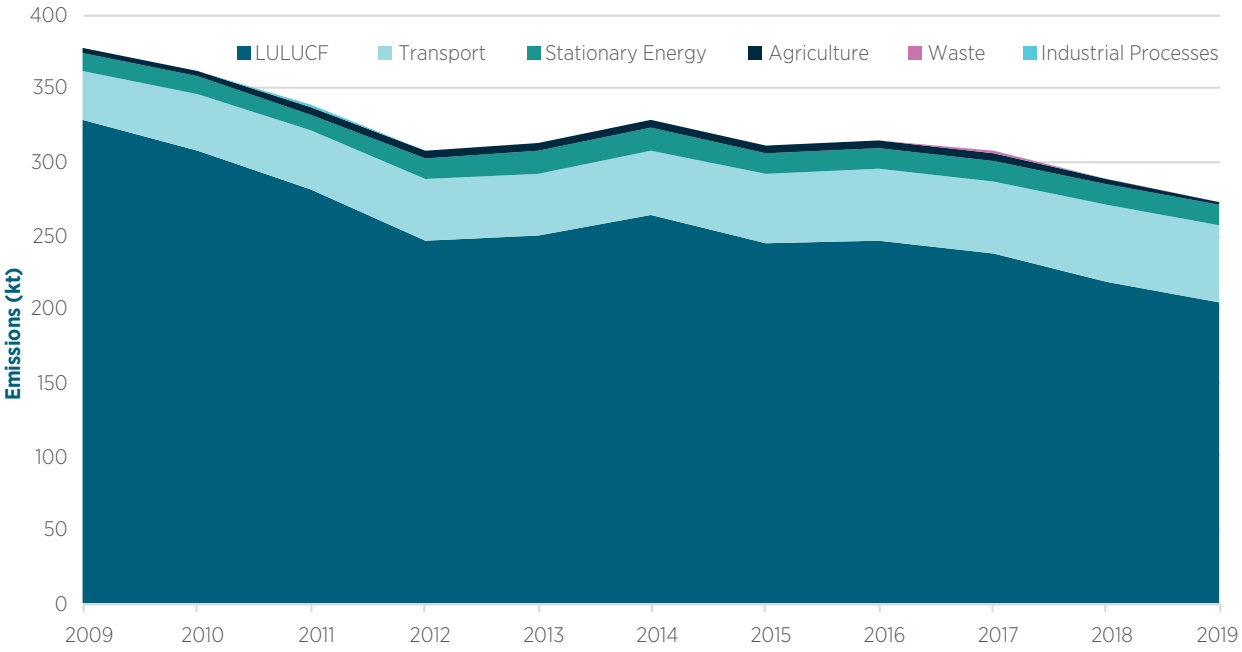
The distribution of black carbon by sector for year 2019 is displayed below. LULUCF sector (including biomass burning) is the highest emitter of black carbon followed by Transport sector (including diesel consumption in heavy vehicle and Kerosene consumption in aviation).

Figure A3.2 Black Carbon distribution by sector for year 2019



The figure below displays the trend of black carbon distribution by sector. Over this time period, LULUCF and Transport sectors were the largest emitters.

Figure A3.3 Black carbon distribution by sector, trend



Measured data from the NPI for the aerosol particulate matter with an aerodynamic diameter less than 10 pm (PM10) and the precursor SO_2, since 2008-09 for energy, waste and industrial processes has also been published in this Report.

Table A3.3 National pollutant Inventory measured PM10 data from combustion processes, 2008-09 to 2018-19 kt

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1 Energy	**518.7**	**521.6**	**623.3**	**724.8**	**812.0**	**892.6**	**930.8**	**944.0**	**899.0**	**826.0**	**885.6**
Fuel Combustion	518.7	521.6	623.3	724.8	812.0	892.6	930.8	944.0	899.0	826.0	885.6
Energy Industries	245.9	244.1	320.1	354.4	408.7	450.8	432.9	429.7	394.7	356.5	365.8
Manufacture of Solid Fuels and Other Energy Industries	212.2	219.8	293.0	328.9	386.4	427.7	407.0	405.2	371.3	334.4	343.7
Petroleum Refining	1.2	1.1	0.8	0.8	1.1	1.0	0.8	0.6	0.6	0.5	0.6
Public Electricity and Heat Production	32.5	23.2	26.3	24.7	21.2	22.1	25.1	23.8	22.8	21.7	21.5
Manufacturing Industries and Construction	264.4	264.5	293.7	360.1	394.7	432.4	487.9	501.4	492.2	457.6	506.9
Other Sectors	8.3	13.1	9.5	10.3	8.5	9.4	10.0	13.0	12.1	11.9	13.0
2 Industrial Processes	**11.3**	**11.7**	**12.0**	**11.2**	**12.0**	**13.7**	**12.8**	**13.4**	**13.3**	**13.5**	**15.3**
5 Waste	**0.3**	**0.5**	**0.2**	**0.2**	**0.2**	**0.4**	**1.4**	**1.3**	**4.3**	**2.1**	**2.7**
Total	**530.3**	**533.8**	**635.6**	**736.2**	**824.2**	**906.8**	**945.0**	**958.7**	**916.6**	**841.5**	**903.6**

Table A3.4 National pollutant Inventory measured SO_2 data from combustion processes, 2008-09 to 2018-19 kt

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1 Energy	**777.8**	**759.4**	**733.1**	**726.8**	**700.8**	**680.4**	**661.2**	**644.6**	**637.7**	**637.7**	**585.5**
Fuel Combustion	777.8	759.4	733.1	726.8	700.8	680.4	661.2	644.6	637.7	637.7	585.4
Energy Industries	651.6	632.9	608.6	604.2	577.0	560.4	560.6	546.8	543.6	543.1	487.2
Manufacture of Solid Fuels and Other Energy Industries	11.4	13.8	11.8	14.7	14.3	13.1	11.3	11.5	13.0	11.4	11.7
Petroleum Refining	8.7	9.1	9.8	7.4	7.7	7.2	6.4	5.6	5.4	5.7	21.6
Public Electricity and Heat Production	631.4	610.1	587.0	582.1	554.9	540.1	542.8	529.7	525.3	525.9	453.9
Manufacturing Industries and Construction	90.7	90.8	89.2	88.2	92.8	88.0	67.9	64.3	60.6	60.3	59.8
Other (not elsewhere classified)	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.3
Other Sectors	7.4	7.5	7.4	7.8	7.9	8.1	8.4	8.8	9.2	9.4	8.3
Transport	28.0	27.9	27.5	26.2	22.8	23.5	24.1	24.4	24.0	24.7	30.0
2 Industrial Processes	**1,820.2**	**1,618.8**	**1,774.0**	**1,791.4**	**1,713.5**	**1,819.4**	**1,723.3**	**1,820.7**	**1,647.7**	**1,441.6**	**1568.4**
Total	**2,598.0**	**2,378.2**	**2,507.1**	**2,518.2**	**2,414.3**	**2,500.0**	**2,384.5**	**2,465.3**	**2,285.4**	**2,079.3**	**2,154.0**

A3.3 Consumption-based Inventory

In this submission, Australia has generated a consumption-based national greenhouse gas inventory. This new account estimates the impacts on emissions in Australia and in other countries due to Australian consumption. The Australian methodology for the estimation of this consumption-based inventory is documented in the *Quarterly Update of Australia's National Greenhouse Gas Inventory, June 2019.*

ANNEX 4: Carbon dioxide reference approach for the energy sector

A4.1 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 Australia's energy balance statistics for production, imports, exports and stock change. Data are obtained from the *Australian Energy Statistics* published by the Department of Industry, Science, Energy and Resources with supplementary sectoral-specific data where available. The *Australian Petroleum Statistics* are used as a basis for the liquid fossil fuel data.

A4.2 Comparison of Australian methodology with IPCC reference approach

For 2019, the total CO_2 emissions estimated using Australia's sectoral approach methodology are 373.5 Mt. Total CO_2 emissions estimated using the reference approach are 379.4 Mt – this is a 1.6 per cent difference between the two methods.

The reference approach has also been recalculated for 2018 due to revised data in the AES. The recalculations are presented in Table A4.1.

Table A4.1 Reference approach and sectoral approach comparison for 1990 to 2019

Year	IPCC Reference (CO_2 Mt)	Sectoral (CO_2 Mt)	Difference in %
1990	254	252	1.12 %
1991	258	254	1.46 %
1992	259	258	0.19 %
1993	266	262	1.32 %
1994	269	265	1.3 %
1995	277	276	0.33 %
1996	287	283	1.47 %
1997	291	291	0.03 %
1998	306	304	0.53 %
1999	314	313	0.29 %
2000	319	318	0.27 %
2001	324	326	-0.57 %
2002	331	330	0.06 %
2003	337	337	-0.18 %
2004	349	350	-0.2 %
2005	356	355	0.34 %
2006	355	360	-1.34 %
2007	365	366	-0.18 %
2008	370	371	-0.22 %
2009	380	376	1.13 %
2010	374	371	0.76 %
2011	373	370	0.86 %
2012	381	374	1.69 %
2013	370	367	0.71 %
2014	361	363	-0.58 %
2015	368	369	-0.15 %
2016	373	377	-0.95 %
2017	375	377	-0.63 %
2018	371	376	-1.27 %
2019	379	374	1.59 %

The overall difference between the reference approach and the sectoral approach is within 2 per cent for all years. The differences between the reference approach and the sectoral approach for specific fuel types exceeds 2 per cent for some years. The main reason for the differences in petroleum fuels relates to the sensitivity of final apparent consumption and emissions to the average density and energy content values used to convert production, exports, imports and stock changes from volume/mass units into energy units. Other minor differences can be attributed to the derived implied emission factors used by the reference approach and the different reporting techniques and categories used by the publications.

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.

A5.1 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.

This submission includes Abandoned Oil Wells, Abandoned Gas Wells, and Gas Post-meter emissions from all sub-segments as defined by the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (first included in Australia's National Inventory Report 2018 submitted in 2020) and estimates for certain activities under the voluntary reporting category of Wetlands. These sources are voluntarily reported to improve the completeness of Australia's inventory. This submission captures carbon stock change data for the following activities relating to coastal wetlands; mangrove forests (reported under forests), tidal marsh habitats, and the impacts of capital dredging on seagrass meadows. Nitrous oxide emissions are also estimated for *aquaculture use* in coastal wetlands. Methane emissions are estimated for *Reservoirs,* and *Other constructed waterbodies* (freshwater ponds), as defined in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* and the seasonal flooding of 'ponded pastures' in certain parts of Australia.

Further additional estimates are to be included in future submissions, as per planned improvements described in Chapter 6.

In *LULUCF,* Australia uses a combination of Approach 3 (for conversions to and from forest land) and Approach 1 (for other land uses) for land representation, as described by the *IPCC2006 Guidelines* Vol. 4, chapter 3. As such, some conversion categories cannot be separately reported, but in accordance with the *IPCC2006 Guidelines,* this does not represent a lack of completeness. Some conversions to croplands, grasslands, wetlands or settlements are included in lands remaining in that category. For conversions where separate estimates and activity data are not provided, table A.5.1 identifies where these conversion categories are included elsewhere. Planned improvements are underway to develop a fully spatially explicit time series of land-use maps to apply Approach 3, land representation, to all land-uses. Such improvements will enable reporting of separate activity data and emissions estimates for all conversion categories.

Table A5.1 *LULUCF* reporting matrix

Final land use: to \ Initial land-use: from	Forest land [a]	Cropland [a]	Grassland [a]	Wetlands [a]	Settlements [a]	Other land
Forest land [a]	R	R	R	R	R	NO
Cropland [a]	R	R	Included in *Cropland remaining Cropland* (crop-pasture rotations)	R	NO	NO
Grassland [a]	R	Included in *Cropland remaining Cropland* (crop-pasture rotations)	R	R	NO	NO
Wetlands [a]	R	Included in Wetlands remaining wetlands [b]	Included in Wetlands remaining wetlands [b]	R	NO	NO
Settlements [a]	R	Included in Settlements remaining settlements [b]	Included in Settlements remaining settlements [b]	R	R	NO
Other land	NO	NO	NO	NO	NO	R

(a) Australia considers all land to be managed, except for *other land,* therefore there is no land in unmanaged land sub-categories and there are no transitions from managed to unmanaged land or vice-versa.

(b) Australia applies Approach 3 spatially explicit tracking of annual conversions to and from forest lands and Approach 1 for areas under grasslands, wetlands and settlements. As a result, only total areas are known for the areas under the latter conversion categories, not the prior land-use. In accordance with the *2006 IPCC Guidelines,* emissions and removals are estimated using the methods for land remaining in a land category where the prior land-use is not known.

A5.2 Omitted emissions 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 (1.B.1). 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. The *2006 IPCC Guidelines* do not include a default methodology that could be applied in the absence of information on this source.

The UNFCCC reporting guidelines (FCCC/CP/2013/10/Add.3) also allow minor emission sources to be reported as "not estimated" where a disproportionate amount of effort would be required to collect data for a category that would be insignificant in terms of the overall level and trend in national emissions (i.e. <0.05 per cent of national emissions excluding *LULUCF* and not exceeding 500 kt CO_2-e). In summary, the total national aggregate of estimated emissions for all gases and categories reported as "not estimated" are below 0.1 per cent of Australia's total GHG emissions, as reported in the CRF tables (Table A5.2). Sources reported as "not estimated" under this provision include: *2.G.3 NO from product uses (imports), 3.D.1.d other organic fertilisers,* and *5.C.1 Incineration and open burning of waste – clinical waste* (CH_4 and N_2O).

The organic fertilisers used in Australia are principally derived from animal wastes (3.D.1.d). Emissions from this organic N source are covered elsewhere. Data on the application of other organic N fertiliser is not available through either ABS or industry data collections, nor is a comprehensive list of organic fertiliser producers available. To assess the significance of the category, data was sourced from one of the largest commercial producers. They reported production of meat and fish meal containing 117.8 tonnes of Nitrogen. Applying the IPCC default EF of 1 per cent this equates to 0.55 kt CO_2-e of emissions. Even allowing for the complete estimate to be over 900 times greater, this category can be considered insignificant (<500 kt CO_2-e.) and as such, emissions are "not estimated".

The use of urea based additives (diesel emissions fluid DEF) in catalytic converters occurs in Australia. A certain proportion of heavy vehicles and passenger vehicles designed to meet Euro 5 emission standards are equipped with engine emission control systems using selective catalyst reduction (SCR) technology. The vast majority of DEF consumption will be in the heavy vehicle fleet. In Australia, around 4 million kL of diesel fuel is consumed by heavy vehicles. Manufacturers of heavy diesel engines cite around 2 per cent consumption of DEF to diesel. Assuming every Euro 5 compliant heavy vehicle used SCR technology, this consumption equates to around 3000 tonnes of CO_2 attributed to urea based catalysts. Therefore, this category can be considered insignificant (<500 kt CO_2-e.) and as such, emissions are "not estimated".

For the incineration of clinical waste and solvents (5.C.1), the *2006 IPCC guidelines* do not provide default CH_4 and N_2O emission factors. Furthermore, when the highest 2006 IPCC default EFs for CH_4 and N_2O listed for municipal solid and general industrial waste incineration are applied to the AD for clinical waste and solvents incineration, emissions estimates contribute around 0.0001 per cent (0.7 Gg CO_2-e) of total emissions from all sectors. Accordingly, emissions of CH_4 and N_2O from this source can be considered insignificant (<500 kt CO_2-e.) and as such, emissions are "not estimated".

Table A5.2 Omitted emissions sources

Source of Emissions	Estimated Emissions (ktCO_2-e)
Other organic fertilisers	0.55
Urea based additives in catalytic converters	3.00
Incineration of clinical waste	0.70
Total omitted sources estimate	*4.25*
Total National Emissions (UNFCCC)	518,865.54
Proportion of omitted sources	0.0008%

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 Department of Industry, Science, Energy and Resources (DISER) 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 DISER 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, synthetic gases and wastewater consumption have been constructed and the results presented as Australia's National Carbon Balance in Table A6.2.

In response to a recommendation by the previous UNFCCC ERT reports, models have been developed to demonstrate the flows of fugitive methane and carbon dioxide associated with underground and surface coal mines. The underground coal mine model shown in Figure A6.2 also demonstrates the effectiveness of methane capture for electricity generation and flaring in reducing the net fugitive emissions – capturing 40 per cent 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 and 2016–17. In addition, each year the inventory is reviewed by international experts organised as part of the UNFCCC expert review team process. In Tables A6.6a to A6.6e,

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.

Table A6.1 Summary of principal mitigation strategies and quality control measures

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006IPCC Guidelines Vol 1 cross reference
1.A.1 (i)	Accuracy, completeness and time series consistency	Facility-level data for Energy, IP and Waste subject to national measurement system and Australian regulations and international standards as specified in the NGER Measurement Determination 2008	Compliance	Department of Industry, Science, Energy and Resources	6.7.2.2, page 6.16
1.A.1 (ii)	Accuracy, completeness and time series consistency	Agriculture and transport data subject to measurement standards of the Australian Bureau of Statistics (ABS)	Compliance	Monitoring through evaluation of NGER (Measurement) Determination 2008	6.7.2.2, page 6.16
1.A.1 (iii)	Accuracy, completeness and time series consistency	Geospatial data	<10% of SLATS forest clearing.	Department of Industry, Science, Energy and Resources	6.7.2.2, page 6.16
1.A.1 (iv)	Accuracy, completeness and time series consistency	Climate data received by the Department subjected to rigorous visual and quantitative checks based on ensuring 1) no null values 2) coverage of entirety of Australia 3) free of errors while ingesting into FullCAM	Compliance	Department of Industry, Science, Energy and Resources	6.7.2.2, page 6.16
1.A.2	Accuracy	Data submitted under NGERs subject to Clean Energy Regulator Scheme Audit and Assurance unit	Compliance	Clean Energy Regulator Scheme Audit and Assurance unit	6.7.2.2, page 6.16
1.B.1	Comparability	Integration of national and facility estimation method within National Greenhouse Accounts Framework	Compliance	National Inventory Team	6.7.1.2 page 6.12
1.D.1	Transparency	Company level data published by the Clean Energy Regulator under the NGER Act 2007	Compliance	Company level data published by the Clean Energy Regulator under the NGER Act 2007	6.5, page 6.8
2.A.1	Accuracy	Comparison of energy data with independent sources of activity data	Reconciliation within <2%	Excel spreadsheet comparison using dataset from AES, NEM review, Coal Services Pty Ltd, Queensland Department of Mines and Energy	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 Board	6.4, page 6.16
2.B.1	Completeness	Application of standardised rules for use of facility level data in national inventory	Compliance	See Chapter 1 of the National Inventory Report (NIR)	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	2006IPCC Guidelines Vol 1 cross reference
2.B.2 (i)	Completeness	Reconciliation of estimates of energy in fuel supplies to the Australian economy and energy contained in data inputs used in the estimation of carbon in emissions; or stored in products; or non-oxidised; or in permanent storage	Compliance with target objective of <0.1%	AGEIS Automated Report	Table 6.1, page 6.11; section 6.7.2.1, page 6.15
2.B.2 (ii)	Completeness	Reconciliation of estimates of carbonate supplies to the Australian economy and estimates of carbonates in data inputs used in estimation of emissions; or stored in products; or waste residues or in permanent storage	Compliance with target objective of <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 data inputs used for estimation of emissions or stored in products or waste residues or in permanent storage	Compliance with target objective of <1%	Excel spreadsheet using data from ABARES forestry publication	Table 6.1, page 6.11; section 6.7.2.1, page 6.15
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	Compliance with target objective of <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	Compliance with target objective of <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	Compliance with target objective of <0.1%	AGEIS Automated Report	Table 6.1, page 6.11; section 6.7.2.1, page 6.15
2.B.2 (vii)	Completeness	Reconciliation of estimates of natural gas consumption in the Australian economy as reported by various data sources	Compliance with target objective of <3%	NGER data	Table 6.1, page 6.11; section 6.7.2.1, page 6.15
2.B.2 (viii)	Completeness	Reconciliation of estimates of land allocated to land use and land use change classifications and aggregated total land supply	Compliance with target objective of <0.1%	National Inventory Report	Table 6.1, page 6.11; section 6.7.2.1, page 6.15
3.A.1 (i)	Accuracy	Selection of emission estimation methodologies should be consistent with IPCC Good Practice and comparable with international practice	Compliance	NGGI Committee	IPCC Good Practice Guidance
3.A.1 (ii)	Accuracy	Tier 2 (3) model parameters should not be significantly different to the mean of NGER facility-specific data	Compliance	National Inventory Team	6.7.1.2, page 6.13
3.A.1 (iii)	Accuracy	Tier 2 (3) model parameters should not be significantly different to results from the public empirical research program that meet specified conditions for quality	Compliance	National Inventory Team	6.7.1.2, page 6.13
3.A.1 (iv)	Accuracy	Tier 2 (3) model parameters should not be significantly different to results from privately measured datasets that meet specified conditions for quality	Compliance	National Inventory Team	6.7.1.2, page 6.13
3.A.2 (i)	Accuracy	AGEIS development in accordance with COBIT	Compliance	AGEIS and FullCAM Advisory Board	AGEIS Strategic Plan
3.A.2 (ii)	Accuracy	AGEIS operation in accordance with COBIT	Compliance	AGEIS and FullCAM Advisory Board	AGEIS Strategic Plan

Measure No.	Quality objective	Mitigation strategy or control measure	Target	Monitoring mechanism	2006IPCC Guidelines Vol 1 cross reference
3.A.2 (iii)	Accuracy	Allocation of separate staff roles and responsibilities	Compliance	AGEIS and FullCAM Advisory Board	6.4, page 6.7
3.A.2 (iv)	Accuracy	FullCAM development in accordance with COBIT	Compliance	AGEIS and FullCAM Advisory Board	FullCAM Strategic Plan
3.A.2 (v)	Accuracy	FullCAM operation in accordance with COBIT	Compliance	AGEIS and FullCAM Advisory Board	FullCAM Strategic Plan
3.A.3	Accuracy	Verification of selected AGEIS estimates by sectoral experts	Difference between AGEIS inventory estimates and verification estimates should be less than 0.1%	Data comparison with sector-specific calculation sheets using Excel spreadsheet	6.7.3, page 6.16
3.A.4	Accuracy	The estimated uncertainty of the overall inventory should decline over time	Compliance	Annex 2 of the NIR 2016	6.9, page 6.18
3.A.5	Accuracy	Number of significant accuracy issues raised by the UNFCCC ERT, and agreed by the Department, should reduce over time	Compliance	UNFCCC Expert Review Team Report	6.8, 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	Compliance with target objective of <0.01%	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	Compliance with target objective of <0.01%	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	Compliance with target objective of <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 wastewater data submitted into the AGEIS and carbon contained in emissions or stored in products or waste residues or in permanent storage	Compliance with target objective of <0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3, page 6.16
3.B.1 (v)	Completeness	Reconciliation of nitrogen in wastewater data submitted into the AGEIS and nitrogen contained in emissions or stored in products or waste residues or in permanent storage	Compliance with target objective of <0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3, page 6.16
3.B.1 (vi)	Completeness	Reconciliation of HFCs in data submitted into the AGEIS and carbon contained in emissions or stored in products or waste residues or in permanent storage	Compliance with target objective of <0.001%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3, page 6.16
3.B.1 (vii)	Completeness	Reconciliation of CO_2 emissions in the LULUCF sector with the results of carbon stock accounting models	Compliance with target objective of <0.001%	ABARES Australia's State of Forests 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	2006IPCC Guidelines Vol 1 cross reference
3.B.1 (viii)	Completeness	Reconciliation of carbon in fossil fuels, carbonates, biomass, synthetic gases and wastewater in data submitted into the AGEIS and carbon contained in emissions or stored in products or destroyed	Compliance with target objective of <0.01%	AGEIS Automated Report	Table 6.1, page 6.10; 6.7.3, page 6.16
3.B.2 (i)	Completeness	Reconciliation of National Inventory with aggregate of State and Territory inventories	Compliance with target objective of <0.1%	AGEIS Automated Report	6.7.2.1, page 6.14
3.B.2 (ii)	Completeness	Reconciliation of the National Greenhouse Gas Inventory with the National Inventory by Economic Sector	Compliance with target objective of <0.1%	AGEIS Automated Report	6.7.2.1, page 6.14
3.B.2 (iii)	Completeness	Reconciliation of the National Greenhouse Gas Inventory with OLAP output from the Australian Greenhouse Emissions Information System	Compliance with target objective of <0.1%	AGEIS Automated Report	6.7.2.1, page 6.14
3.B.3	Completeness	Number of emission sources not estimated, for which IPCC methods exist, comparable with international practice	Consistent with international practice	UNFCCC Expert Review Team Report	6.8, page 6.18
3.B.4	Completeness	Number of significant completeness issues raised by the UNFCCC ERT, and agreed by the Department, should reduce over time	Compliance	UNFCCC Expert Review Team 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	6.7.1.2, page 6.13
3.C.2	Comparability	Number of significant comparability issues raised by the UNFCCC ERT, and agreed by the Department, should reduce over time	Compliance	UNFCCC Expert Review Team 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	UNFCCC National Inventory submissions	6.8, page 6.18
3.D.1	Time series	Analysis by category for time series consistency	Compliance	UNFCCC Expert Review Team Report	Table 6.1, page 6.11
3.D.2	Time series	Number of significant time series consistency issues raised by the UNFCCC ERT, and agreed by the Department, should reduce over time	Compliance	UNFCCC Expert Review Team 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 Report 2019	6.5, page 6.8
3.E.2	Transparency	Publication of the AGEIS emissions database on the Department website and related products	Compliance	http://ageis.climatechange.gov.au/	6.5, page 6.
3.E.3	Transparency	Number of significant transparency issues raised by the UNFCCC ERT, and agreed by the Department, should reduce over time	Compliance	UNFCCC Expert Review Team Report	6.5, page 6.

A6.2 Australia's National Carbon Balance

Table A6.2 Australia's National Carbon Balance 2019

Supply	kt C	Uses	kt C
Fossil fuels for consumption* [a]	111,739	*Emissions*	
Carbonate for consumption [a]	1,896	1.A Combustion emissions (fossil fuels)	102,081
Hydrofluorocarbon for consumption [d]	4,182	1.B Fugitive emissions	31
		2.A Industrial process fossil fuel emissions	3,890
		Memo: International bunker fuels	4,833
		2.A Mineral product carbonate emissions	1,879
Biomass products produced		2.F Hydrofluorocarbon emissions [d]	2,729
Wood and paper products [a]	6,346	Memo: Combustion emissions (wood products and waste)	391
Bagasse, ethanol, biogas [b]	2,398	Memo: Combustion emissions (bagasse, ethanol, biogas)	2,397
Firewood collected [b]	1,010	Memo: Combustion emissions (all wood)	1,761
Other wood [b]	791	5.A Landfill emissions from HWP	278
		5.A Landfill emissions from non-HWP	782
Waste disposal (food, garden, textiles, rubber – landfill) [c]	1,434	Aerobic treatment processes (paper, wood and wood waste)	1,052
		Increment to product stocks	
		Petrochemical and steel products	92
		Carbonate products	2
		Hydrofluorocarbon products [d]	1,214
		Increment to HWP stocks	2,831
		Biomass fibre recycled	1,563
		Increment to waste stocks and residues	
		Carbon dioxide captured for permanent storage	
		Non-oxidised carbon *	813
		Carbonate wastes	14
		Increment to HWP waste in landfill	265
		Increment to non-HWP waste in landfill	651
		Miscellaneous	
		Hydrofluorocarbons destroyed	220
		Residual	29
Total supply	**129,796**	**Total uses**	**129,796**

Notes: (a) Entering the domestic economy. (b) Final domestic consumption. (c) Entering waste stream; (d) based on carbon dioxide equivalents. * Coal fuelled electricity generation assumes the NGERS oxidation factor of less than 100 per cent oxidation.

Australia's National Carbon Balance records the supply of carbon entering the domestic economy through the most important channels and tracks the uses or fates of that carbon allocated amongst greenhouse gas emissions, increments to the stock of carbon in products and increments to the stock of carbon in waste residues. Of the 129,796 kt C of carbon entering the domestic economy, 122,104 kt C is estimated to result in greenhouse gas emissions; 5,701 kt C is estimated to result in increments of the carbon stock in products and 1,742 kt C is estimated to result in increments to carbon stored in waste product and residues.

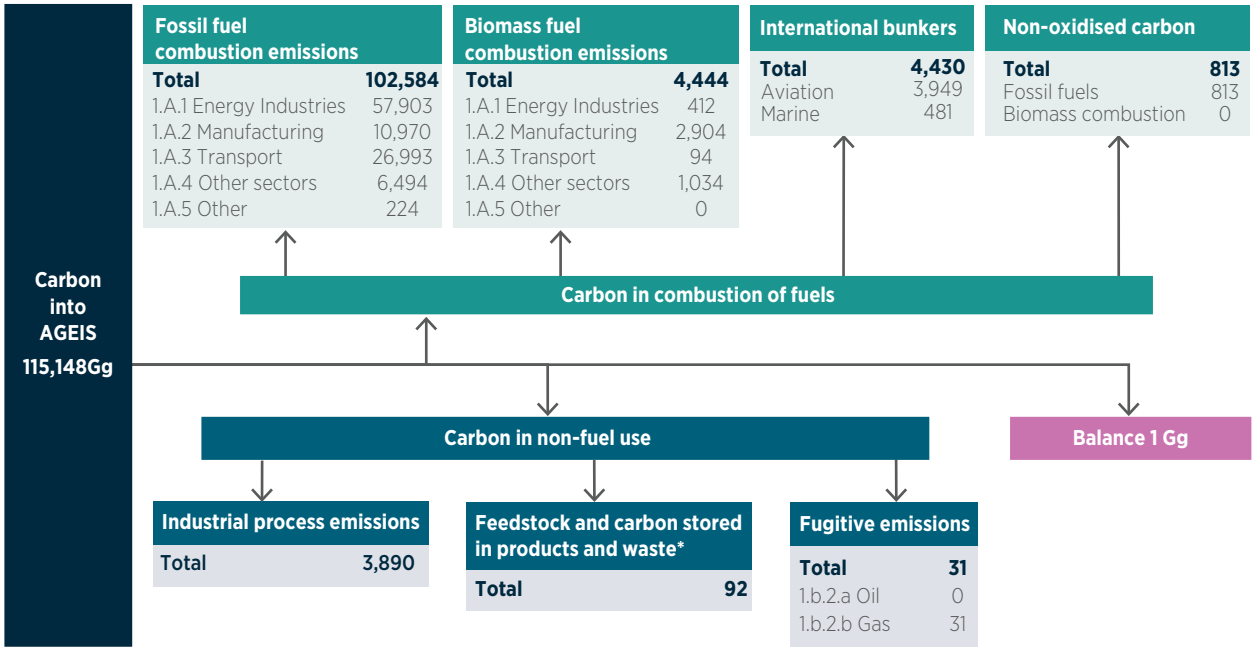
Assessments of the total amount of carbon in stock are more difficult to assess and depend critically on starting assumptions. It is estimated that there is approximately 2,831 kt of carbon stored in harvested wood products in Australia and about 265 kt of carbon stored in landfills. The latter estimate 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. No provision is currently made in this balance for the estimation of carbon stored in geological strata or in forest growing stock. It is assumed that any fossil fuels, carbonates and hydrofluorocarbons consumed were mined, manufactured or imported in the same year as their consumption in the domestic economy. This simplifies the balance assessment by avoiding a need to consider the changes in reserves and storage.

The department also produces a set of spatially-explicit carbon stock accounts which will extend the National Carbon Balance to a time-series analysis of biocarbon stocks associated with activity in Land Use, Land Use Change and Forestry. These are described below.

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 2019 is at Figure A6.1.

For 2019, all carbon was within 0.01 per cent, which is the tolerance level prescribed in the Quality Assurance-Quality Control Plan. The carbonate balance is one of the components that make up the overall carbon balance. Assumptions on the molecular weight of the mix of 'other' carbonates, which contents are unknown causes a difference of 0.06 per cent. Due to this, the carbonate balance is accounted for at an acceptable level.

Figure A6.1 Balance flow chart showing carbon inputs and distribution of outputs for 2019



* Includes carbon captured for temporary storage and transfer offsite

Figure A6.2 Fugitive gas balance flow chart for underground mines, 2019

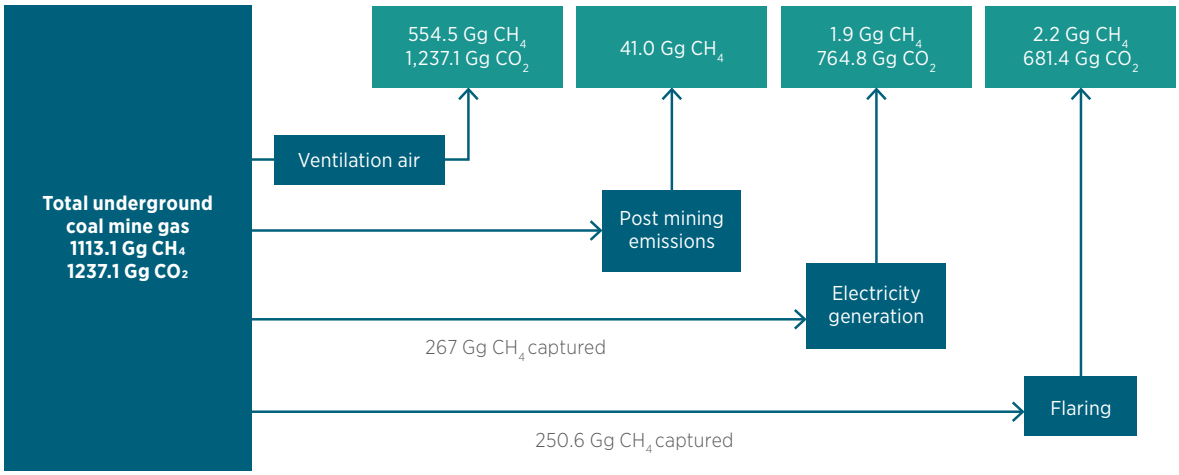


Figure A6.3 Fugitive gas balance flow chart for open cut mines, 2019

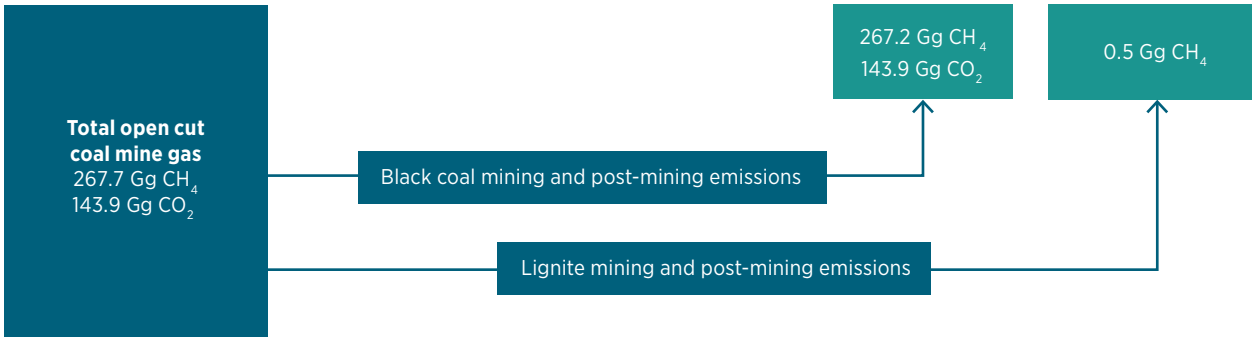


Table A6.3 Underground mining raw coal production, by coal field

	Coal Production by Basin (tonnes of production)							
Year	Hunter	Southern	Western	Newcastle	Bowen Northern	Bowen Southern	Bowen Central	Qld Southern
1990	4,344,800	17,771,200	8,685,300	18,971,900	684,542	5,173,984	591,808	523,410
1991	4,848,129	18,134,150	9,433,269	18,435,910	659,348	6,549,461	635,513	779,744
1992	5,197,075	18,071,525	7,806,943	18,423,863	508,221	8,175,110	548,438	595,156
1993	4,622,113	17,566,298	9,947,807	17,705,992	589,456	8,782,642	632,108	692,298
1994	3,371,283	16,217,123	10,377,687	16,824,755	1,159,564	10,711,371	629,277	618,883
1995	6,364,090	14,663,729	11,613,380	16,061,104	2,564,908	13,172,078		687,236
1996	9,192,400	15,314,900	13,002,300	16,804,600	1,612,780	10,992,009		597,411
1997	10,813,245	15,784,757	12,697,898	15,346,470	3,846,835	13,756,322		558,769
1998	14,144,563	15,360,353	12,010,638	16,783,447	4,543,003	19,158,765		
1999	13,680,481	13,112,341	10,860,591	13,664,985	7,398,073	20,290,940		
2000	15,252,463	11,805,638	10,447,917	15,257,326	13,169,231	25,006,028		
2001	14,589,035	12,602,477	12,775,399	13,751,733	11,214,891	27,105,717		
2002	13,081,548	12,693,281	12,984,571	13,831,303	12,196,246	26,580,624		
2003	12,257,057	11,174,159	12,683,711	10,842,531	11,661,140	23,111,145		
2004	16,582,600	10,434,890	10,924,964	11,412,069	9,618,348	22,058,438		
2005	15,207,383	12,142,786	13,655,101	10,901,574	11,953,481	22,731,234		
2006	15,674,644	13,340,369	12,676,749	10,540,319	11,754,358	22,534,011		
2007	16,875,285	13,412,166	12,929,478	14,023,563	14,351,067	21,268,729		
2008	17,311,462	11,507,490	12,741,554	13,917,235	16,842,856	25,972,448		
2009	19,245,169	12,707,969	16,562,805	14,552,747	16,778,503	24,262,219		
2010	19,580,571	12,985,314	15,082,379	15,156,042	21,775,029	30,182,038		
2011	16,028,421	14,261,975	16,146,188	15,697,532	17,056,976	28,099,846		
2012	11,579,449	16,559,350	16,262,355	16,060,680	10,634,861	24,734,441		
2013	18,719,469	16,059,422	17,306,310	16,907,142	19,811,148	26,869,534		
2014	21,502,396	15,008,927	21,269,733	16,311,233	18,420,997	28,550,873		
2015	15,011,591	17,257,917	28,540,355	16,935,960	22,856,422	30,662,361		
2016	13,349,675	15,094,766	25,236,372	11,778,374	22,564,967	32,219,885		
2017	12,390,066	12,825,284	27,860,425	11,228,860	24,624,784	26,738,958		
2018	11,206,770	10,034,679	25,742,925	13,699,914	26,814,898	24,718,536		
2019	7,353,809	12,831,190	22,375,124	13,286,499	22,127,302	25,311,030		

Source: NGERS 2020, Queensland Department of Natural Resources and Mines, Coal Services Pty Ltd

Table A6.4 Australian Petroleum Refining fuel consumption data

Year	Fuel type (PJ)		
	Solid	Liquid	Gas
1990	-	76.0	11.3
2000	-	80.1	18.6
2001	-	80.6	20.0
2002	-	78.9	20.7
2003	-	75.4	22.3
2004	-	67.0	22.7
2005	-	65.1	24.1
2006	-	56.1	24.6
2007	-	63.3	23.6
2008	-	60.7	22.8
2009	-	68.2	14.1
2010	-	72.4	12.5
2011	-	75.6	14.5
2012	-	69.5	17.6
2013	-	69.2	14.1
2014	-	66.1	10.9
2015	-	55.6	10.3
2016	-	44.2	4.2
2017	-	45.0	7.8
2018	-	45.5	6.4
2019	-	43.7	5.8

Source: NGERS

A6.3 Time-series Stock Accounting for Biocarbon

In addition to producing emissions estimates for LULUCF, the spatially explicit Tier 3 modelling in FullCAM also tracks carbon stock levels across Australia over time. The presentation of carbon stock data provides an alternative assessment of the observed trends in the inventory and therefore facilitates ongoing quality assurance.

High-resolution maps of carbon stock levels and carbon stock changes on the Australian continent were produced using the FullCAM modelling system in 2017. These FullCAM outputs were supplemented with information from those elements of the land sector that were not calculated in the FullCAM architecture to produce consistent carbon stock accounts for Australia under the System of Environmental-Economic Accounting (UN, 2014a) and its supplement on Experimental Ecosystem Accounting (UN, 2014b). Further information on the construction of these accounts is described in Appendix 6.M of Volume 2. This accounting structure was used as the basis for information published in the State of the Forests Report, indicator 5.1, by the Australian Bureau of Agriculture and Resource Economics and Sciences in February 2019. An aggregated account of carbon stocks in Australia was presented in the 2016 Inventory and is included in tables A6.5a to A6.5c below.

Figure A6.4a presents carbon stocks on the Australian continent as a carbon density measure in tonnes per hectare as calculated for 2016 Inventory. Figure A6.4b shows these carbon stocks for the South East Queensland region. These include all living biomass, deadwood, litter and soil carbon as assessed by FullCAM spatial simulations. Carbon density is highest in areas of forest, especially the native forests of South-Eastern Australia, South-Western Australia and the tropical rainforests of northern Queensland, where these have been undisturbed since at least 1972.

Figures A6.5a and A6.5b present the total changes, nationally and for South East Queensland, in carbon stock associated with lands converted to or from forest for the period of 1990–2005. Figures A6.6a and A6.6b present this for the period of 2005–2016. The transient impacts of wildfire are excluded from this analysis, but the continuing impacts of clearing and regrowth events observed before 1990 are included. Particularly prominent are the widespread losses in the moderately carbon-dense regions of Southern Queensland, and the gains from planting activity around the Green Triangle of south-western Victoria and south-eastern South Australia.

Table A6.5a Australian biocarbon stocks, 1990-2016, Mt C

Carbon Stocks (Mt C)	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Forests & wood products															
Native non-production forests	18,466	18,299	18,187	18,002	17,967	17,927	17,921	17,921	17,913	17,924	17,941	17,948	17,959	17,984	18,004
Native production forests	2,937	2,944	2,952	2,955	2,957	2,960	2,961	2,964	2,968	2,973	2,980	2,988	2,995	3,003	3,012
Mangroves	658	659	659	659	659	659	659	659	659	659	659	659	659	659	659
Native environmental plantings	0	3	6	8	9	9	9	10	11	12	13	13	14	15	15
Plantations - Softwood	113	133	146	152	152	152	152	151	151	151	151	150	149	148	147
Plantations - Hardwood	14	21	36	66	70	75	81	88	94	101	107	111	113	113	111
Post-1940 wood products	97	107	117	127	129	131	133	135	136	138	139	140	142	143	144
Total forests & products	**22,286**	**22,167**	**22,102**	**21,970**	**21,943**	**21,912**	**21,916**	**21,928**	**21,933**	**21,958**	**21,989**	**22,010**	**22,031**	**22,065**	**22,093**
Non-forests															
Tidal Marsh	840	839	839	839	839	839	839	839	839	839	839	839	839	839	839
Cropland	1,196	1,198	1,201	1,220	1,221	1,223	1,225	1,226	1,227	1,228	1,228	1,229	1,230	1,231	1,232
Grassland	15,467	15,494	15,515	15,537	15,548	15,553	15,544	15,529	15,517	15,499	15,478	15,462	15,440	15,421	15,405
Total non-forests	**17,503**	**17,531**	**17,555**	**17,596**	**17,609**	**17,615**	**17,608**	**17,594**	**17,583**	**17,566**	**17,545**	**17,530**	**17,509**	**17,491**	**17,476**
Grand Total	**39,789**	**39,698**	**39,657**	**39,565**	**39,552**	**39,527**	**39,524**	**39,521**	**39,516**	**39,524**	**39,534**	**39,539**	**39,540**	**39,556**	**39,569**

*data is presented on the basis of the 2016 inventory

Table A6.5b Changes in biocarbon stocks, 1989-2016, Mt C

Carbon Stocks (Mt C)	1989-1994	1994-1999	1999-2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Forests															
Opening stocks	22,243	22,072	22,005	21,870	21,842	21,813	21,781	21,783	21,793	21,797	21,820	21,850	21,869	21,890	21,922
Net growth and decay	66	78	78	16	16	17	18	17	20	22	23	24	25	25	28
Fire and regrowth from fire	-8	7	-24	7	4	-10	5	4	-7	4	4	-3	-7	6	1
Transfers to wood products	-24	-27	-33	-7	-7	-7	-8	-7	-7	-7	-6	-6	-7	-7	-8
Reclassifications	-206	-125	-155	-44	-42	-32	-13	-4	-3	4	10	4	9	7	6
Closing stocks	**22,072**	**22,005**	**21,870**	**21,842**	**21,813**	**21,781**	**21,783**	**21,793**	**21,797**	**21,820**	**21,850**	**21,869**	**21,890**	**21,922**	**21,949**
→ Living biomass	8,380	8,346	8,285	8,268	8,254	8,243	8,238	8,236	8,240	8,249	8,258	8,267	8,276	8,284	8,292
→ Deadwood and litter	2,208	2,221	2,201	2,207	2,210	2,200	2,205	2,210	2,203	2,208	2,213	2,210	2,204	2,210	2,211
→ Soil carbon	11,484	11,438	11,384	11,367	11,349	11,338	11,339	11,347	11,353	11,363	11,379	11,392	11,410	11,428	11,445

Carbon Stocks (Mt C)	1989-1994	1994-1999	1999-2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Non-forests															
Opening stocks	17,488	17,528	17,547	17,581	17,596	17,609	17,615	17,608	17,594	17,583	17,566	17,545	17,530	17,509	17,491
Net growth and decay	-169	-103	-120	-29	-28	-25	-20	-18	-14	-14	-12	-12	-12	-11	-10
Fire and regrowth from fire	3	-2	-1	0	-1	-1	0	0	0	1	1	1	0	1	0
Reclassifications	206	125	155	44	42	32	13	4	3	-4	-10	-4	-9	-7	-6
Closing stocks	**17,528**	**17,547**	**17,581**	**17,596**	**17,609**	**17,615**	**17,608**	**17,594**	**17,583**	**17,566**	**17,545**	**17,530**	**17,509**	**17,491**	**17,476**
→ Living biomass	699	701	696	695	694	695	695	694	698	700	699	698	700	700	703
→ Deadwood and litter	82	78	78	80	80	76	75	73	71	72	72	72	72	74	75
→ Soil carbon	16,747	16,768	16,806	16,820	16,835	16,843	16,837	16,826	16,814	16,794	16,774	16,759	16,738	16,717	16,697
Post-1940 wood products															
Opening stocks	95	105	114	125	127	129	131	133	135	136	138	139	140	142	143
Net accumulation	10	10	11	2	2	2	2	2	1	2	1	1	1	1	1
Closing stocks	**105**	**114**	**125**	**127**	**129**	**131**	**133**	**135**	**136**	**138**	**139**	**140**	**142**	**143**	**144**
All Lands															
Opening stocks	39,825	39,704	39,667	39,577	39,565	39,552	39,527	39,524	39,521	39,516	39,524	39,534	39,539	39,540	39,556
Net growth and decay	-93	-15	-31	-11	-10	-7	-1	1	8	10	12	13	14	16	19
Fire and regrowth from fire	-5	5	-26	7	4	-11	5	4	-7	5	5	-2	-7	7	2
Transfers to wood products	-24	-27	-33	-7	-7	-7	-8	-7	-7	-7	-6	-6	-7	-7	-8
Reclassifications	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Closing stocks	**39,704**	**39,667**	**39,577**	**39,565**	**39,552**	**39,527**	**39,524**	**39,521**	**39,516**	**39,524**	**39,534**	**39,539**	**39,540**	**39,556**	**39,569**

*data is presented on the basis of the 2016 inventory

Table A6.5c Carbon stocks by land cover and carbon pool, 2016, Mt C

Carbon Stocks (Mt C)	Above-ground living biomass	Below-ground living biomass	Litter	Deadwood	Soil	Wood Products	Total
Forests & wood products							
Native non-production forests	4,046	2,230	523	1,165	10,040	0	**18,004**
Native production forests	1,344	324	49	428	866	0	**3,012**
Mangroves	158	87	1	2	412	0	**659**
Native environmental plantings	3	2	0	1	10	0	**15**
Plantations – Softwood	41	9	14	15	67	0	**147**
Plantations – Hardwood	35	13	6	6	52	0	**111**
Post-1940 wood products	0	0	0	0	0	144	**144**
Total forests & wood products	**5,627**	**2,665**	**593**	**1,618**	**11,445**	**144**	**22,093**
Non-forests							
Tidal marsh	6	16	0	0	817	0	**839**
Cropland	17	7	2	0	1,206	0	**1,232**
Grassland	293	366	60	12	14,674	0	**15,405**
Total non-forests	**315**	**388**	**62**	**13**	**16,697**	**0**	**17,476**
Grand Total	**5,942**	**3,053**	**656**	**1,631**	**28,143**	**144**	**39,569**

*data is presented on the basis of the 2016 inventory

Figure A6.4a Carbon Stocks on the Australian Continent, 2016, t/ha

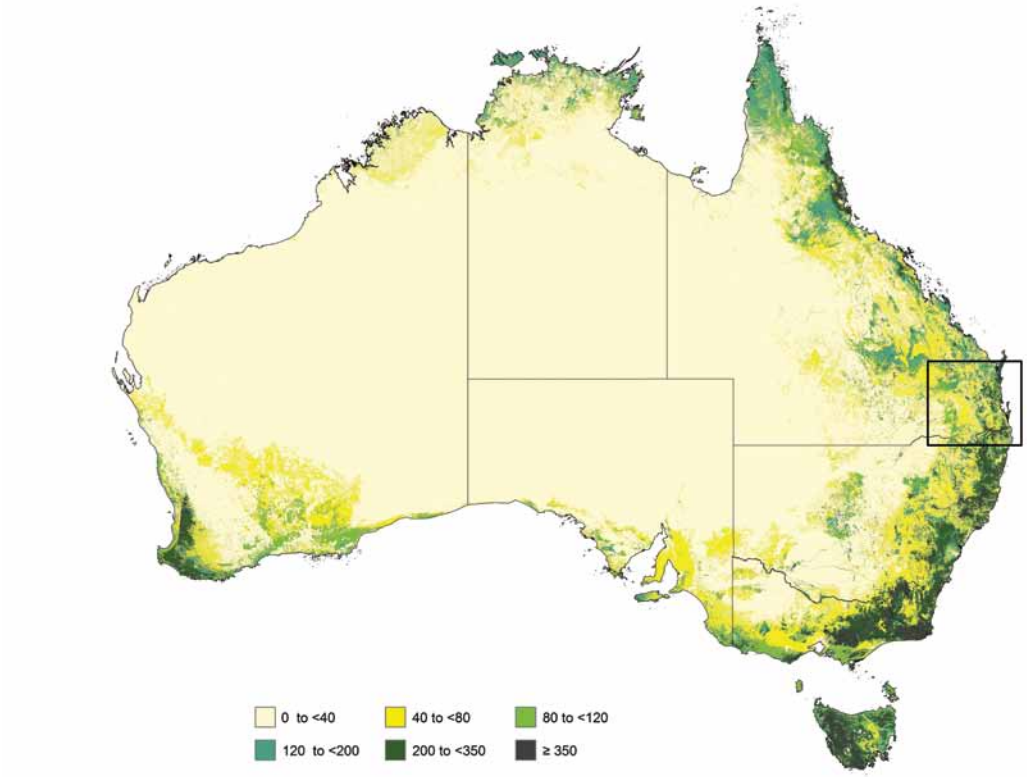


Figure A6.4b Carbon Stocks in South-East Queensland, 2016, t/ha

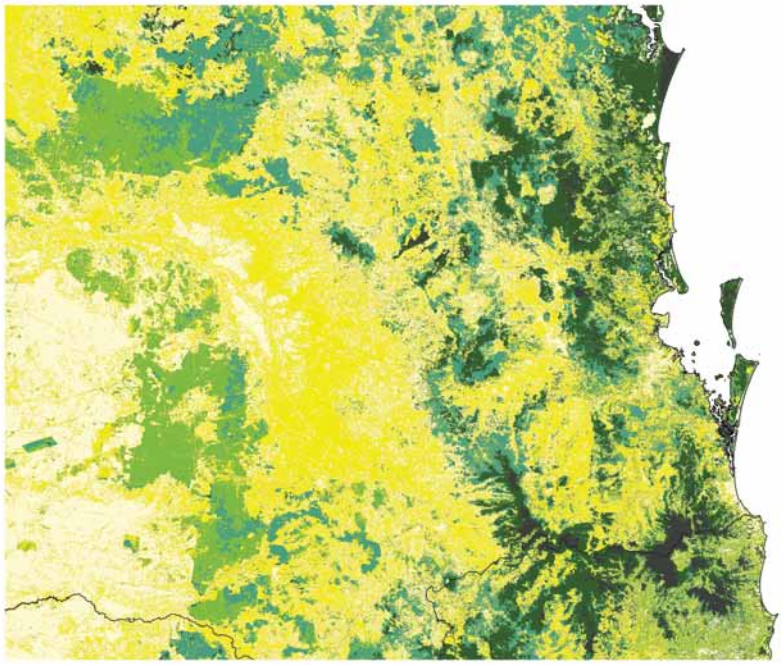


Figure A6.5a Carbon stock changes in Australia due to forest gains and losses 1990–2005, t/ha

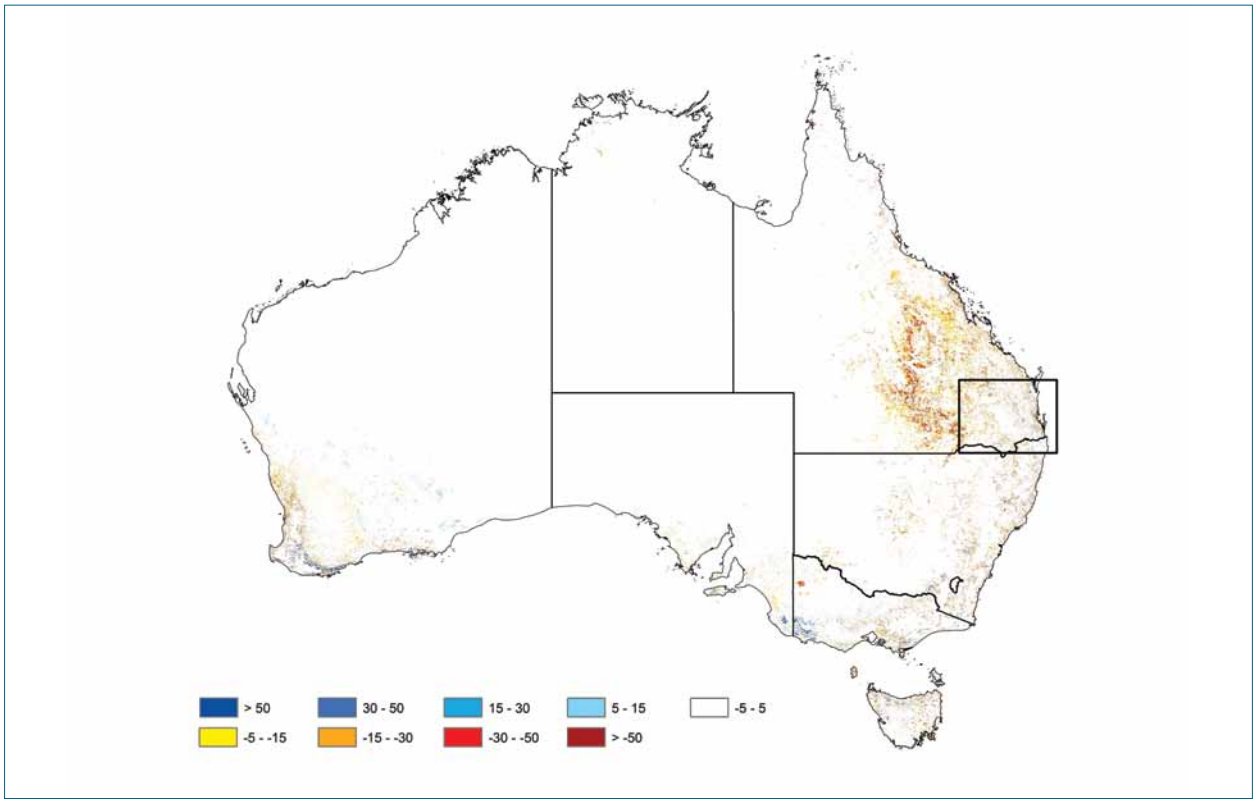


Figure A6.5b Carbon stock changes in South-East Queensland due to forest gains and losses 1990–2005, t/ha

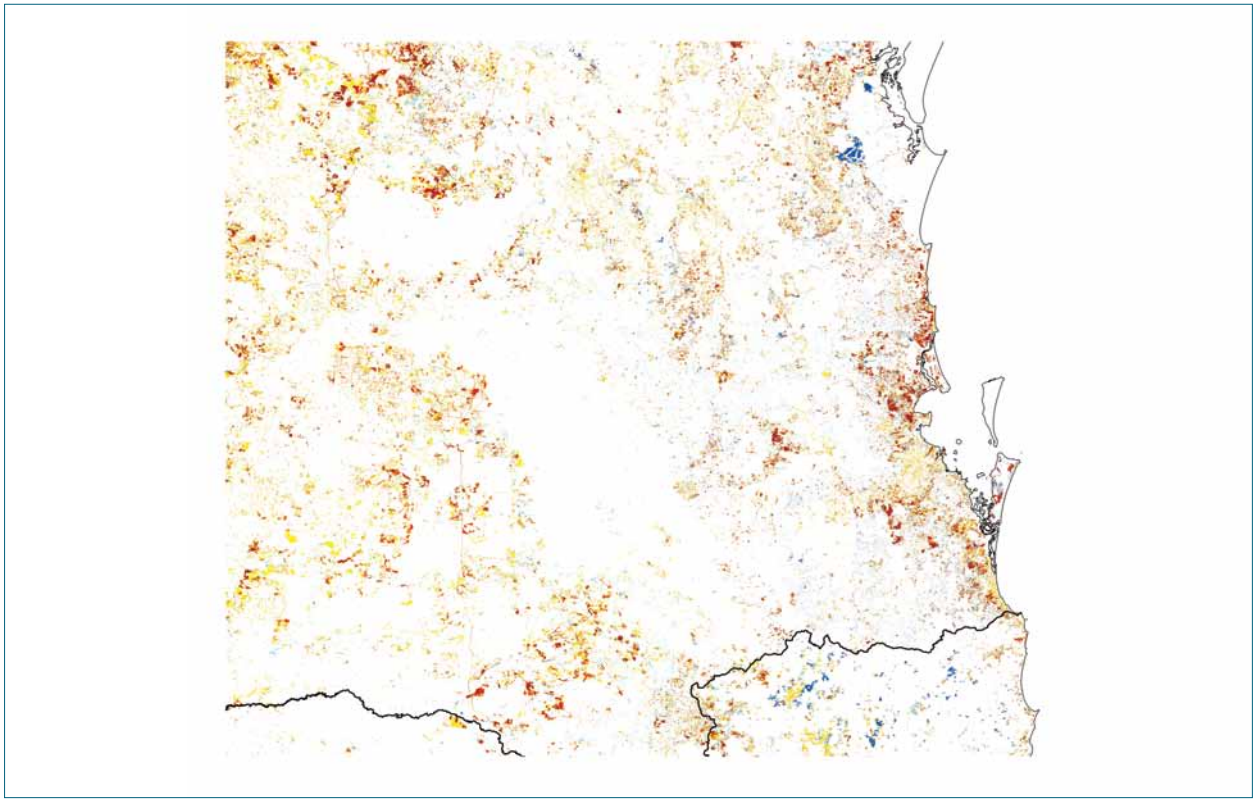


Figure A6.6a Carbon stock changes in Australia due to forest gains and losses 2005–2016, t/ha

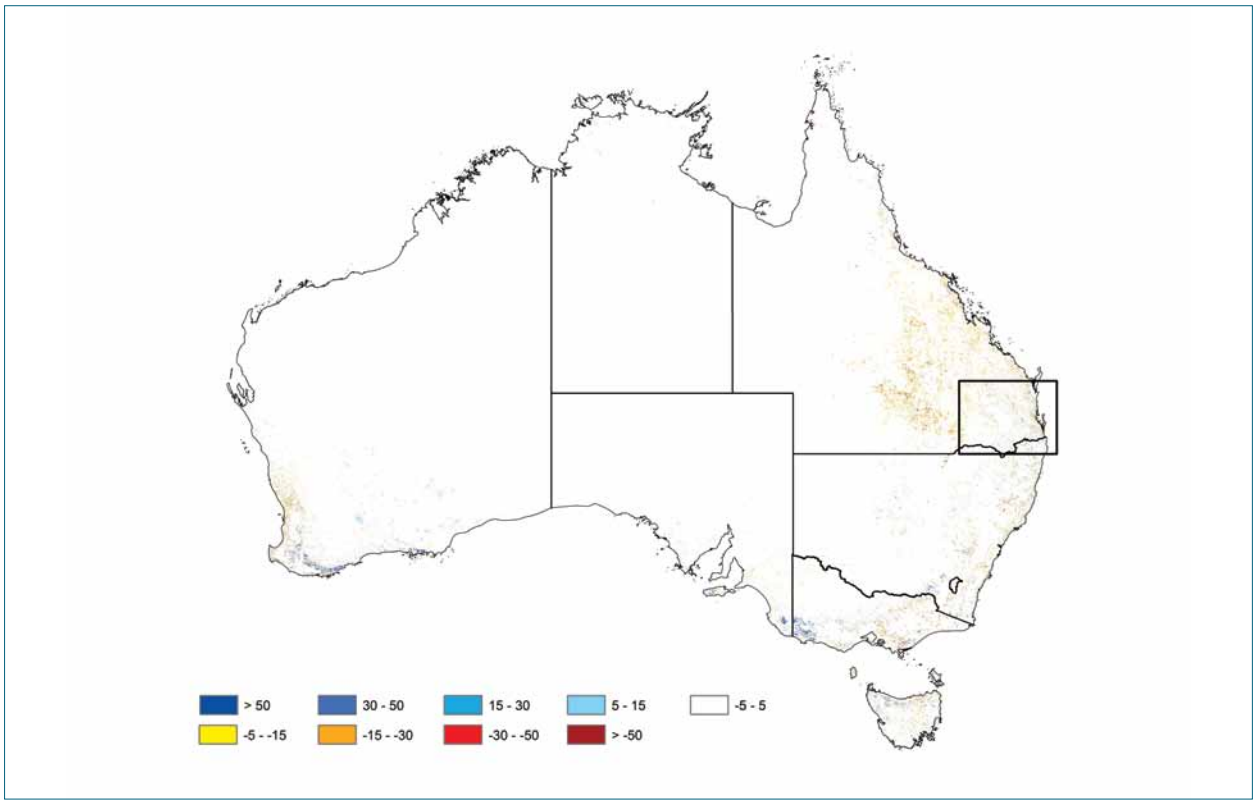
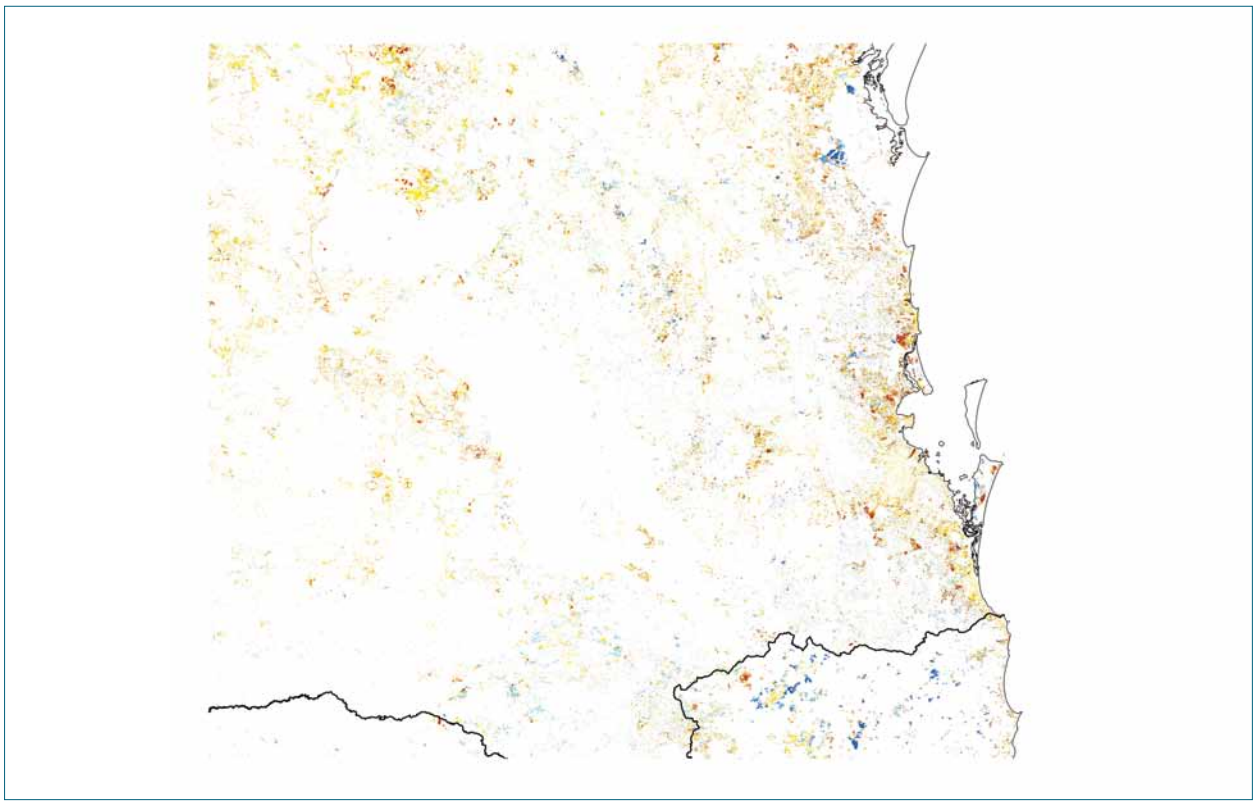


Figure A6.6b Carbon stock changes in South-East Queensland due to forest gains and losses 2005–2016, t/ha



A6.4 Summary of Responses to UNFCCC ERT Recommendations and Comments

The recommendations contained in this section are included in the draft review report of Australia's National Inventory Report 2018.

Table A6.6a Status of Issues raised in the previous report

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
G.1	Notation keys (G.7, 2019) Transparency	Provide information stating that the total national aggregate estimated emissions for all gases and categories reported as "NE" remain below 0.1 per cent of the national total GHG emissions in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines	Australia provided information in annex 5 to the NIR (vol. 3, pp.167–168) regarding the total aggregate emissions and removals for all gases and categories reported as "NE", reporting that total emissions excluded remain below 0.1 per cent of the national total GHG emissions.	Additional information confirming NE categories are below 0.1 per cent of total emissions is at Table A5.2.
E1	International bunkers and multilateral operations – liquid fuels – all gases (E.2, 2019) Convention reporting adherence	Correct the AD on international bunkers to avoid discrepancies between CRF tables 1.D and 1.A(b).	The discrepancies in AD for international marine bunkers identified for 2017 and reported in CRF tables 1.D and 1.A(b) have been corrected in the 2020 annual submission. The values reported for 2018 in CRF tables 1.D and 1.A(b) are also consistent. However, the errors identified for jet kerosene used in international aviation have not been corrected for 2011, 2016 and 2017, and the errors identified for gas/diesel oil and residual fuel oil used in international marine bunkers for 2014 and 2016 have not been corrected.	International bunkers activity data has been corrected to avoid discrepancies between CRF tables 1.D and 1.A(b).
I.5	2.D.1 Lubricant use – CO_2 (I.21, 2019) Comparability	Report emissions from lubricant use in two-stroke engines separately under category 1.A.3.b (road transportation) under the energy sector.	Australia reported that, since it did not have any AD for lubricant use in two-stroke engines, it could not disaggregate and reallocate lubricant use in two-stroke engines to the energy sector. Therefore, all emissions were reported in category 2.D.1. Australia added information in its NIR to explain this allocation (vol. 1, pp.233 and 235) and indicated its intent to keep it under review.	Addressing. All activity data, methodologies and EFs are kept under review. Particular focus will be on the investigation of AD to enable the re-allocation of emission from lubricant use in 2-stroke engines to the Energy sector.

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
L.5	4.B Cropland – CO_2 (L.9, 2019) Accuracy	Stratify cropland areas on organic soils by natural zone and calculate the CO_2 emissions by applying corresponding EFs, for example from the 2006 IPCC Guidelines (vol. 4, chap. 5, table 5.6).	Australia reported in its NIR (vol. 2, pp.85–86) all CO_2 emissions from drained organic soils in wetlands converted to cropland using the EF for the cool temperate zone (5t carbon/ha/year as provided in vol. 4, chap. 5, table 5.6 of the 2006 IPCC Guidelines) on the basis of expert understanding of wetland ecosystems in areas where such conversions occur. During the review, Australia clarified that organic soils are mostly located in Tasmania, which has a cool temperate climate, but noted that this area is not actually subject to cultivation and that cultivated organic soils in cropland are mostly used for sugar cane production (reported under the agriculture sector, category 3.D.a.6 (N_2O emissions from cultivation of organic soils), and amounting to an area of 4,000 ha). Australia also explained that organic soils in cropland accounted for a very small area, with no significant variation in landscape characteristics.	Resolved in the current submission. See methodology description in Chapter 6.7.1.2.
W.1	5.A Solid waste disposal on land – CH_4 (W.10, 2019) Transparency	Explain how data from background studies conducted in 2008 were used to estimate the waste composition for the most recent years of the time series.	Australia reported in the NIR (vol. 2, p.306) that data from the 2008 studies (conducted by the GHD and Hyder Consulting companies), which were not considered NGER data, accounted for approximately 30 per cent of landfilled waste in 2018 and that the base waste mix percentages are derived as a simple average of waste mixes presented in these studies. Australia also stated that waste mix percentages changed over time in line with the varying quantities of wood waste and paper entering landfill, for which a separate reference was provided in the NIR (table 7.8).	Revised text is included in section 7.3.3.2
W.2	5.B Biological treatment of solid waste – CH_4 (W.11 2019) Transparency	Explain in the NIR the method used for calculating the CH_4 emissions and its adherence to the IPCC tier 1 method and revise the reference to the method in the NIR and CRF table summary 3, as needed.	Australia transparently reported its country-specific methodology and choice of EFs for estimating emissions from composting in its NIR (vol. 2, pp.315–316).	Additional text is included in section 7.4.
KL.4	RV – CO_2 (KL.7, 2019) Comparability	Report the carbon stock changes for different carbon pools separately and eliminate the error in the reporting of the notation key in CRF table 4(KP-I)B.4	Australia reported all carbon pools together under above-ground biomass but eliminated the error in the reporting of the notation key for litter, deadwood, mineral soils and organic soils, reporting them as "IE" instead of "NA" for the entire time series in CRF table 4(KP-I)B.4. During the review, the Party clarified that it was working on incorporating sparse woody vegetation into its Full Carbon Accounting Model, and that field work was under way across all significant bioregions in Australia to better characterize biomass in subforest woody vegetation.	Addressing. The department is developing a new model which we hope will enable the estimates to be included for all pools in the next submissions.

Table A6.6b Issues and/or problems identified in three or more successive reviews and not addressed by Australia

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
I.2	2.C Metal industry – CO_2 (I.8, 2019) (I.7, 2017) (I.11, 2016) (I.34, 2015) Consistency	Investigate whether other drivers could be applied to estimate emissions from lead production, zinc production and other (metal production) for 1990–2008, such as production volumes.	Australia still assumed constant AD for lead, zinc and other metals (except silver and nickel) for years prior to 2009, as reported in the NIR (vol. 1, pp.229–230). During the review, Australia explained that it has identified an alternative data set for estimating CO_2 emissions for 1990–2008 and is in the process of incorporating it into the time series, but that further analysis is required to verify the suitability of the data set for deriving production AD.	Australia has obtained activity data for lead, zinc and other metals (including magnesium production), and inferred the consumption of fossil fuels from production rates and consumption at the facility level in years where consumption data is available. These estimates have been included in the 2021 submission, with an explanation included in section 4.5.2.
I.6	2.G.3 N_2O from product uses – N_2O (I.15, 2019) (I.18, 2017) Accuracy	Explain the methodology used for estimating N_2O imports using the per capita usage factor, verify that no under- or overestimation of emissions occurs and report the results in the NIR.	Australia did not explain the methodology used for estimating N_2O imports using the per capita usage factor, or verify that no under- or overestimation of emissions occurs. During the review, Australia indicated that it did not have access to any data on industrial gas production and importation since 2008.	Addressing. Australia is continuing to investigate sources of new import and production data in Australia to refine the approach to emissions estimation in this category.
L.2	4. General (LULUCF) – CO_2, CH_4 and N_2O (L.3, 2019) (L.4, 2017) (L.29, 2016) Comparability	Provide separate AD and estimates for the following categories and pools currently reported as "IE": cropland, wetlands and settlements converted to forest land (all pools except organic soils); cropland converted to grassland (all pools); and cropland and grassland converted to settlements (all pools). Until this is done, provide in the NIR an update of the status of efforts to provide estimates for these pools.	The Party reported AD and carbon stock changes for all carbon pools for cropland, wetlands and settlements converted to forest land separately in CRF table 4.A. During the review, the Party clarified that a project to identify cropland and grassland converted to settlements was ongoing and related information was included in its NIR (vol. 2, p.134).	Addressing. The department has a project underway to develop new spatial data that will identify conversion of croplands and grasslands to settlements.
KL.5	HWP – CO_2 (KL.4, 2019) (KL.7, 2017) (KL.8, 2016) Transparency	Document the process for deriving the country-specific half-lives for HWP and provide information to justify that the methodologies used are at least as detailed or accurate as those prescribed in decision 2/CMP.7, annex, paragraph 29.	The Party has yet to report the required information in its NIR. During the review, the Party provided details on the method used to calculate the implied half-lives reported in CRF table 4.Gs2, including on the application of a formula and the consideration of country-specific stratified data on HWP pools. In addition, the Party clarified that it was continuing to undertake analyses, including a comparison of its tier 3 method and the default method based on the first-order decay function contained in equation 12.1 from the 2006 IPCC Guidelines (vol. 4, chap. 12, p.11) with default half-lives. According to the Party, an improved explanation of its methodology is being prepared for inclusion in a future submission.	Addressing. The department has a project underway to develop a Tier 2 model using default half-lives for comparison with Australia's Tier 3 model. We hope this work will be available for the next NIR submission.

Table A6.6c General

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
G.2	Key category analysis	Australia did not complete CRF table NIR-3 with information on key categories for KP-LULUCF. In response to a question raised during the review, Australia stated that it had never been able to complete table NIR-3 using CRF Reporter, and that the information on the key category analysis for Article 3, paragraph 3, and relevant activities under Article 3, paragraph 4, was reported in table 11.42 of the NIR (vol. 3, p.73). The ERT encourages Australia to address this matter with the UNFCCC secretariat CRF Reporter help desk and to complete CRF table NIR-3.	Accept	NIR-3 is competed for this submission.
G.4	Recalculations	The ERT recommends that Australia correct the error in NIR table 10.1 regarding recalculations for category 3.E, and encourages the Party to outline in chapter 10 and the relevant sectoral chapters of the NIR the quantitative impact of recalculations by gas on the sectoral and national totals, including and excluding LULUCF.	Accept	Table 10.1 has been corrected for this submission. Additional information on the impacts of recalculations has been included in section 10.1
G.5	Uncertainty analysis	The ERT recommends that Australia elaborate, in annex 2 to the NIR and the appropriate sectoral chapters, on any changes to the category-specific uncertainty estimates as well as to the overall uncertainty analysis affecting the uncertainties estimated for the level of and trend in emissions (including and excluding LULUCF) with respect to the uncertainty assessment conducted for the previous annual submission.	Accept	Annex 2 has additional information covering the change in uncertainty between 2018 and 2019.

Table A6.6d Energy

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
E.5	1.A Fuel combustion – sectoral approach –biomass – CH_4 and N_2O	The ERT recommends that the Party either report the correct notation key ("NE") from biomass for categories 1.A.3.d (domestic navigation), 1.A.3.e.ii (other (other transportation)) and 1.A.4.b.ii (off-road and other machinery (residential)) and justify why the emissions were not estimated if below the significance threshold in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines and in line with the information provided to the ERT during the review, or estimate and report CH_4 and N_2O emissions from these categories.	Accept	Notation keys have been updated to estimate N_2O and CH_4 emissions from biomass in categories 1.A.3.d (domestic navigation), 1.A.3.e.ii (other (other transportation)), and 1.A.4.b.ii (off road and other machinery (residential)). Non-CO_2 emissions from the combustion of ethanol (E10 gasoline is used in some parts of Australia) in gasoline in these minor uses are considered negligible and are not estimated. In addition, emission factors for CH_4 and N_2O are not available for ethanol in these technology types.

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
E.6	1.A.1.b Petroleum refining – gaseous fuels – CO_2	The ERT recommends that the Party allocate any known refinery gas used in petroleum refining to liquid fuels, or if the volumes and types of "other" gaseous fossil fuels are not known with sufficient certainty, allocate them to other fossil fuels under CRF category 1.A.1.b and only report natural gas under gaseous fuels. If Australia is unable to reallocate these other gaseous fossil fuels, the ERT recommends that the Party explain in the NIR why the CO_2 IEF for gaseous fuels consumed in petroleum refining is comparatively low by including the (non-confidential) information provided to the ERT during the review (e.g. that a large share of the volume reported under gaseous fuels corresponds to the "other" gaseous fossil fuels reported by a single refinery).	Accept	Further discussion text regarding the makeup of the petroleum refining EFs has been added to the NIR (see Vol 1, section 1.3.2 Energy industries methodology discussion). A feasibility study will be conducted on changing the allocation of "gaseous fossil fuels" for the petroleum refining sector for the next NIR.
E.7	1.A.2 Manufacturing industries and construction – all fuels – CO_2, CH_4, N_2O	The ERT recommends that Australia improve the transparency of explanations related to any recalculations under manufacturing industries and construction by providing more specific reasons for the recalculations, for example by providing any relevant explanations provided by Australian Energy Statistics, together with a link to the annual guide in which such revisions are explained and updated.	Accept	Recalculation explanations for fuel combustion have been expanded to specify the sub-sector and fuel recalculated as a result of AES revisions. In addition, the AES discussion text has been adjusted to provide more transparency on the AES annual revision process. See Vol 1, section 1.2.4 Activity data.
E.8	1.B.2 Oil, natural gas and other emissions from energy production liquid and gaseous fuels – CH_4	The ERT recommends that Australia include a table categorizing abandoned wells by plugging status (plugged, unplugged, unknown), production type (oil, gas) and location (onshore, offshore) in its NIR.	Accept	Table 3.43, reporting abandoned wells categories, is included in this submission.
E.9	1.B.2 Oil, natural gas and other emissions from energy production gaseous fuels – CH_4	The ERT recommends that Australia provide a rationale in its NIR for its choice of country-specific EFs for post-meter emissions, explaining why the factors chosen are representative of Australia's circumstances. The ERT also recommends that Australia include a table in its NIR distinguishing between CH_4 emissions from abandoned gas wells and post-meter CH_4 emissions.	Accept	Additional information on the selection of country specific emissions factors for post meter gas is included in section 1.9.2. An additional table 3.49a is included, reporting CH_4 emissions from abandoned gas wells and post-meter emissions.
E.10	1.B.2.c Venting and flaring – liquid and gaseous fuels – CO_2, CH_4 and N_2O	The ERT recommends that the Party more comprehensively explain the reasons for any recalculations in its NIR, for example by providing information on the specific drivers for the recalculations or the process by which such errors were identified (e.g. QC activities). In addition, the ERT encourages the Party to continue improving the QC of data of individual facilities to ensure that no double counting or omission of emissions occurs and that emissions are correctly allocated across the relevant CRF categories.	Accept	An expanded explanation of Fugitive emission recalculations, detailing the reasons, drivers and quantity by subsector has been included in Vol 1 section 1.9.5 – Recalculations.

Table A6.6e Industrial processes and product use

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
I.7	2.B.1 Ammonia production – CO_2	The ERT recommends that Australia provide an explanation for the large inter-annual fluctuations in the CO_2 IEF for 2013 onwards, for example by describing the fluctuations in the underlying fuel requirement per unit of ammonia production reported by plants, and correct the data entry error relating to AD for 2014.	Accept	Natural gas consumption data entry error for 2014 is corrected. Australia has identified that one facility had reported production combined with imports for the years 2014 – 2017, rendering actual production data for the facility uncertain. Australia will continue to source accurate data, however in the meantime Australia has indexed production data for these years based accurate production and IEF for 2018, providing a more accurate estimate of total ammonia production in Australia. This has corrected the IEFs for the time series, with the IEF between 2013 and 2014 increasing by 1.9%. This explanation is provided in section 4.4.1 Ammonia production.
I.8	2.B.8 Petrochemical and carbon black production – CO_2	The ERT recommends that the Party estimate CO_2 emissions from methanol production for all years of the time series by conducting a literature review of the leading concept methanol process with a view to identifying the most relevant tier 1 EF, or alternatively apply a mass balance equation (equation 3.17 in vol. 3, chap. 3, of the 2006 IPCC Guidelines).	Accept	Australia was not able to identify a CO_2 EF unique to the technology type previously used in Australia, and does not have feedstock consumption data available to support a mass balance equation. As an alternative, it was identified the CH_4 IEF for Methanol production in the USA is similar to Australia (2.3 vs 2.0 for Australia) – as this implies a comparable production technology in used, Australia has derived CO_2 emissions using the USA CO_2 IEF of 670 kg/t. Australia has also corrected reported CH_4 emissions for 2017 onwards noting that methanol production has ceased.
I.9	2.B.8 Petrochemical and carbon black production – CO_2	The ERT recommends that Australia report CO_2 emissions from ethylene oxide separately in category 2.B.8, or, if this is not possible, report them as "IE" and indicate in CRF table 9 where the emissions are reported. The ERT also recommends that the Party provide a description, in the relevant section of the NIR, of the method used for estimating CO_2 emissions for this category.	Accept	Notation key for 2.B.8 Petrochemical and carbon black production has been changed to IE. For Petrochemical and carbon black production (2.B.8) Australia was not able to identify a Methanol production CO_2 EF unique to the technology type previously used in Australia, and does not have feedstock consumption data available to support a mass balance equation. As an alternative, it was identified the CH_4 IEF for Methanol production in the USA is similar to Australia (2.3 vs 2.0 for Australia) – as this implies a comparable production technology in used, Australia has can derive CO_2 emissions using the USA CO_2 IEF of 670 kg/t. This will be included in the next submission.
I.10	2.C.1 Iron and steel production – CO_2	The ERT recommends that Australia estimate and report CO_2 emissions from steel production separately under category 2.C.1.a, or, if this is not possible, report the emissions as "IE" under category 2.C.1.a and indicate in CRF table 9 and in the NIR where these emissions are reported.		Fugitive emissions of CO_2 from blast furnace gas and other process gases are included in totals reported in the energy sector, with fugitive emissions reported for Iron and Steel production being from the distribution of natural gas within facilities containing no CO_2.

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
I.11	2.F.1 Refrigeration and air conditioning – HFCs	The ERT recommends that Australia clarify how its HFC allocation model does or does not explain any large inter-annual percentage changes observed in the volumes of HFCs filled into new manufactured products.	Accept	Relevant text has been added to section 4.8.2.
I.12	2.F.1 Refrigeration and air conditioning –HFCs	The ERT recommends that Australia provide an explanation of the model used for estimating the volumes of HFCs filled into new manufactured products, and describe the inter-annual changes resulting from use of that model in its NIR.	Accept	Relevant text has been added to section 4.8.2.
I.13	2.F Product uses as substitutes for ozone-depleting substances – HFCs	The ERT recommends that Australia explain in the NIR that when imports exceed the increase in new vehicle stocks it is assumed that no domestic filling of new manufactured products occurs.	Accept	Relevant text has been added to section 4.8.2.

Table A6.6f Agriculture

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
A.4	3. General (agriculture) – CH_4 and N_2O	The ERT encourages the Party to provide more detailed information in its NIR on the impact of individual recalculations so that their impact on emission totals can be assessed.	Accept	Additional information is included at table 5.34, which itemises the impact of three different recalculations within the Agricultural Soils subsector
A.5	3. General (agriculture) – CH_4, N_2O	The ERT encourages the Party to discuss comparisons between the data provided to the UNFCCC and other international organizations in the appropriate subchapters of the NIR on category-specific QA/QC (e.g. vol. 1, chaps. 5.3.7, 5.4.10 and 5.6.12) and issues related to time-series consistency of animal populations in the subchapters of the NIR on uncertainties and time-series consistency (e.g. vol. 1, chaps. 5.3.6, 5.4.9 and 5.6.11), or to include references in those subchapters to the appropriate paragraphs of the NIR (vol. 1, chap. 5.2.1).	Accept	Additional text is included in sections 5.3.6, 5.4.9 and 5.6.11.
A.6	3. General (agriculture) – CH_4, N_2O	The ERT recommends that the Party transparently report data sources for the calculation parameters included in appendices 5.A, 5.B, 5.D, 5.E, 5.F and 5.I of the NIR and indicate where calculation parameters were estimated on the basis of expert judgment.	Accept	Appendices 5.A–5.J have been amended to provide references for calculation parameters.
A.7	3. General (agriculture) – CH_4, N_2O	The ERT recommends that the Party provide a clear justification in its NIR for the use of the following country-specific parameters and EFs from the 2019 IPCC Refinement: CH_4 EF for enteric fermentation for buffalos, VS excretion rate per animal mass per day for other cattle, MCF values for uncovered anaerobic lagoons and the baseline CH_4 EF for rice cultivation and the appropriate scaling factors for a continuously flooded water regime and a non-flooded pre-season.	Accept	Additional information is included in the following sections: CH_4 EF buffalo – 5.3.5 VS excretion other cattle – 5.4.1.1 Rice CH_4 EF – 5.5.1 MCF values – tables 5.A.7, 5.C.5, 5.E.6 – all IPCC 2006
A.8	3. General (agriculture) – N_2O	The ERT recommends that the Party revise the estimation of N losses from manure management by updating FracLEACH-MS to an appropriately justified value within the range of the 2006 IPCC Guidelines (vol. 4, chap.10, equation 10.28) (i.e. 0.01–0.20), or provide a justification for the country-specific value currently used in the calculation model, including any value adopted from the 2019 IPCC Refinement.	Accept	Additional justification for the use of the country-specific value is included in sections 5.4.1.2 (N_2O MMS emissions) and 5.4.12 (planned improvements)
A.9	3.B Manure management – CH_4	The ERT encourages the Party to revise the MCFs in CRF table 3.B(a)s2 and to report values as percentages..	Accept	CRF table 3.B(a)s2 has been corrected for this submission
A.10	3.B Manure management – CH_4	The ERT recommends that the Party provide a more transparent description and justification in the NIR of the approach used for estimating CH_4 emissions from livestock manure deposited onto pasture, range and paddock, and report all data sources for all calculation parameters (CH_4 EFs by animal category (g CH_4/kg VS), typical animal mass (kg), VS excretion rate (g/kg animal mass/day), EFW and EFT (kg CH_4/kg dry matter), weighting proportions (per cent), and any other parameter as appropriate, clearly delineating the calculation procedure.	Accept	Section 5.4.1.1 is amended to clarify methods, and table 5.16 reports factors used to calculate CH_4 emissions from pasture-based livestock

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
A.11	3.B Manure management – CH_4, N_2O	The ERT encourages the Party to revise the reporting of emissions from manure management in the CRF tables so that the total shares of manure allocated across the MMS do not exceed 100 per cent, and adjust the MCFs and EFs as necessary.		As noted by the ERT, Australia resolved the transparency issue in the previous review report in NIR 2018 Section 5.4.1.1. The current method may be reviewed in future to move towards total shares of manure allocations not exceeding 100% for swine and poultry.
A.12	3.B.1 Cattle – CH_4	The ERT recommends that the Party correct the data entry error in CRF table 3.B(a)s2 and ensure that the cell for temperate climate for beef cattle – feedlot is completed.	Accept	CRF table 3.B(a)s2 has been corrected and completed for this submission.
A.13	3.B.3 Swine – N_2O	The ERT recommends that the Party provide an explanation in the NIR for the trend in the N_2O IEF from manure management of swine.	Accept	Additional information is provided in section 5.4.6.2.
A.14	3.B.4 Other livestock – CH_4	The ERT recommends that the Party report correct and consistent data for allocation of manure by climate region for buffalo and deer in CRF tables 3.B(a)s1 and 3.B(a)s2.	Accept	CRF tables 3.B(a)s1 and 3.B(a)s2 have been corrected for this submission.
A.15	3.D.a.1 Inorganic N fertilizers – N_2O	The ERT recommends that the Party provide transparent information in the NIR on how the different EFs in the study by Sherbak and Grace (2014) are weighted by crop type, climate region, management system (e.g. irrigation) and fertilizer type (particularly relevant for non-urea fertilizers).	Accept	Additional information is included in sections 5.6.7 and 5.6.9 This work has been identified as requiring a review of methods – see "Source specific planned improvements" for Agricultural soils in section 5.6.13
A.16	3.D.a.1 Inorganic N fertilizers – N_2O	The ERT recommends that the Party provide detailed evidence in the NIR to support the country-specific N_2O EF for the application of inorganic N fertilizers, including a justification for the application of the EFs in the study by Scherbak and Grace (2014) to non-urea fertilizers.	Accept	This work has been identified as requiring a review of methods – see "Source specific planned improvements" for Agricultural soils NIR 2019 vol 1 Section 5.6.13
A.17	3.D.a.1 Inorganic N fertilizers – N_2O	The ERT recommends that the Party provide in the NIR a more detailed causal justification for the use of country-specific EFs for categories 3.D.a.5 (mineralization/immobilization associated with loss/gain of soil organic matter) and 3.D.b.1 (atmospheric deposition), for example by referring to measurements, published scientific findings, causal biochemical explanations, and country-specific soil and/or climate conditions.	Accept	Additional information is included in sections 5.6.7 and 5.6.9
A.18	3.D.a.2.a Animal manure applied to soils – N_2O	The ERT recommends that the Party transparently explain in the NIR the estimation of the N_2O EF for animal manure applied to soils.	Accept	Additional information is included in section 5.6.3
A.19	3.D.a.2.b Sewage sludge applied to soils – N_2O	The ERT recommends that the Party provide the data source for the amount of sewage sludge applied to soils in the agriculture chapter of the NIR.	Accept	Data source is included in section 5.6.4.

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
A.20	3.D.a.5 Mineralization/ immobilization associated with loss/gain of soil organic matter – N_2O	The ERT recommends that the Party report the correct AD for category 3.D.a.5 and ensure consistency between the values reported in the NIR and CRF table 3.D.	Accept	CRF table 3.D.1.5 has been amended to 2.00 kg N_2O-N/kg N (converted from 0.002 Gg N_2O-N/ Gg N) in this submission.
A.21	3.D.a.6 Cultivation of organic soils (i.e. histosols) – N_2O	The ERT recommends that the Party clearly describe the data source for the area of cultivated organic soils reported in the agriculture chapter of the NIR, and explain in the NIR any differences between this reported area and the areas reported in CRF tables 4.B and 4.C.	Accept	Cultivation area data has been aligned. Additional information is included in section 6.7.1.2 (croplands converted to wetlands) and section 5.6.8 (data sources).
A.22	3.D.a.6 Cultivation of organic soils (i.e. histosols) – N_2O	The ERT recommends that Australia report N_2O emissions from the area of cultivated organic soils under category 3.D.a.6 using the appropriate N_2O EFs considering all relevant climate zones.	Accept	N_2O emissions are reported in section 5.6.8.
A.23	3.D.b.1 Atmospheric deposition – N_2O	The ERT recommends that the Party report correct and consistent values for FracGASM in CRF table 3.D and in the NIR and provide clear evidence in the NIR to support the use of the 2019 IPCC Refinement value of FracGASM as more representative for Australia's circumstances than the default values given in the 2006 IPCC Guidelines (vol. 4, table 11.3).	Accept	Additional information is included section 5.6.9. CRF table 3.D has been corrected and completed for this submission.
A.24	3.D.b.1 Atmospheric deposition – N_2O	The ERT recommends that the Party report accurate AD and corresponding N_2O IEF for atmospheric deposition in CRF table 3.D and explain significant trends in the time series in the NIR.	Accept	CRF table 3.D has been corrected and completed for this submission. Once IEF was corrected, there was no significant trend.
A.25	3.D.b.2 N leaching and run-off – N_2O	The ERT recommends that the Party report the correct value of FracLEACH-(H) in CRF table 3.D and provide clear evidence to support the use of a country-specific FracLEACH-(H) of 0.24 kg N/kg N additions or deposition by grazing animals and a country-specific EF5 of 0.011 kg N_2O–N/kg N leaching/runoff as a more accurate representation of Australia's circumstances than the default values given in the 2006 IPCC Guidelines (vol. 4, table 11.3).	Accept	Additional information is included in section 5.6.10 CRF table 3.D has been corrected and completed for this submission.

Table A6.6g Land Use, Land Use Change and Forestry

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
L.8	4.A.2.3 Wetlands converted to forest land – CO_2	The ERT recommends that the Party include in its NIR the reason for using organic soils for reporting carbon stock changes for establishment or reforestation of mangrove forest on degraded coastal (tidal) wetlands, and the scientific basis for the relatively significant carbon gain in organic soils.	Accept	Relevant information has been included in Chapter 6.5.1.3
L.9	4.B.2.3 Wetlands converted to cropland – CO_2	The ERT recommends that the Party calculate CO_2 emissions for organic soils on wetlands converted to cropland using a consistent cultivated area to that used under category 3.D.a.6, and reconsider the assumption that all wetlands converted to cropland contain organic soil.	Accept	Estimates for CO_2 emissions from organic soils have been updated, using consistent cultivated area to the reporting in the Agriculture sector. See Chapter 6.7.1.2 and 6.7.5.2.
L.10	4.C.2.3 Wetlands converted to grassland – CO_2	To ensure consistent reporting of organic soils areas between the agriculture and LULUCF sectors, the ERT recommends that the Party (1) explain the relationship between the areas reported under the agriculture sector and the LULUCF sector (specifically categories 4.B and 4.C); (2) assess whether using the EF for cropland is appropriate for cultivated grassland organic soils in Australia; and (3) assess and report appropriate areas of drained or cultivated organic soil grassland as AD for GHG estimation and undrained or uncultivated organic soil on grassland. The ERT further recommends that the Party recalculate the emissions for the entire time series and describe the impact of the recalculation in the NIR.	Accept	Estimates for CO_2 emissions from organic soils have been updated, using consistent cultivated area to the reporting in the Agriculture sector. See Chapter 6.9.1.2 and 6.9.5.2.
L.11	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – CO_2 and N_2O	The ERT recommends that the Party report N_2O emissions from drained forest organic soils, using the same AD that were used to estimate CO_2 emissions from drained forest organic soils, to enhance completeness. The ERT further recommends that the Party complete the cells for CO_2 emissions from drained organic soils in forest land, cropland and grassland in CRF table 4(II) consistently with the reporting of carbon stock changes in organic soils in background CRF tables 4.A–4.C to enhance comparability.	Accept	Emissions already reported from drained organic soils in croplands and grasslands are now reported under CRF Table 4(II). Notation keys have been corrected for the other land uses to reflect that drained organic soils in these areas are not occurring in Australia.
L.12	4.H Other (LULUCF) – N_2O	The ERT recommends that the Party accurately report N_2O emissions from aquaculture production by expressing the emissions in CRF table 4 as N_2O instead of N_2O-N and also include the AD for aquaculture production in the same table, showing the estimated emissions, in the NIR (vol. 2, table 6.56).	Accept	A recalculation has been included for N_2O emissions from aquaculture production in the current submission.

Table A6.6h Waste

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
W.6	5.B.2 Anaerobic digestion at biogas facilities – CH_4	The ERT recommends that the Party provide a rationale for reporting CH_4 emissions from anaerobic digestion as "NE" in CRF table 9.	Accept	Rationale has been provided in CRF Table 9.
W.7	5.C.1 Waste incineration – CO_2	The ERT recommends that the Party correct the missing information for 2018 and include AD for clinical waste incineration in CRF table 5.C.	Accept	This error has been corrected and AD for clinical waste has been included for this submission.

Table A6.6i KP-LULUCF Activities

Sector	Report and Sector paragraph reference	ERT Recommendation	Response	Implementation
KL.6	General (KP-LULUCF) – CO_2, CH_4 and N_2O	The ERT recommends that the Party consistently and accurately report areas of AR, deforestation and RV in background CRF tables 4(KP-I)A.1, 4(KP-I)A.2 and 4(KP-I)B.4, respectively, and CRF table NIR-2 (KP-LULUCF land matrix).	Accept	Corrected data has been applied in the NIR and sectoral tables for the current submission, consistent with that provided to the ERT during the review.
KL.7	CM – CO_2	The ERT recommends that the Party report the correct area used for estimation of CO_2 emissions from drainage of organic soils under CM, ensuring consistency with the area reported for the LULUCF sector, as appropriate.	Accept	CM emissions have been recalculated, consistent with the LULUCF sector.
KL.8	GM – CO_2	The ERT recommends that the Party report the correct area used for estimation of CO_2 emissions from drainage of organic soils under GM, ensuring consistency with the area reported for the LULUCF sector, as appropriate.	Accept	GM emissions have been recalculated, consistent with the LULUCF sector.
KL.9	RV – CO_2, CH_4 and N_2O	The ERT recommends that the Party report and account for only net emissions and removals from human-induced RV activities that have occurred since 1990 in the next annual submission.	Accept	Emissions have been recalculated to account for only net emissions and removals from human-induced RV activities that have occurred since 1990.

ANNEX 7: Description of Australia's National Registry

The description of Australia's national registry follows the reporting guidance set down in decision 15/CMP.1, Annex II (Reporting of supplementary information under Article 7, paragraph 1, E. National registries), as amended by decision 3/CMP.11, under the KP.

A7.1 Name and contact information of the registry administrator designated by the Party to maintain the national registry

Steven Stolk
Registry System Administrator
Clean Energy Regulator
GPO Box 621
CANBERRA ACT 2601
AUSTRALIA

Tel: +61 2 6159 3593
Email: steven.stolk@cleanenergyregulator.gov.au

A7.2 Names of any other Party with which the Party cooperates by maintaining their respective registries in a consolidated system

The Australian National Registry of Emission Units (ANREU) is not operated in a consolidated system with any other Party's registry.

A7.3 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 8 (IIS) for its front-end web servers. 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 International Transactions Log (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 IIS web 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 9.0. 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 externalised 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

The Clean Energy Regulator undertook a migration of all systems to the Azure cloud environment. As of March 2020, the database is a Microsoft Azure SQL Managed Instance.

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 Axisl (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 changes 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.

A7.4 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 mechanism registry and the 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 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 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 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 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 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 ANREU and the ITL are via web-services using XML messages – as specified in the DES. These web services, XML message format and the processing sequence are checked by the registry to ensure the compliance with the DES;
- The ANREU validates data entries against the formats of information as specified in Annex F of the DES;
- The ANREU 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 ANREU; 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 ANREU and the ITL;
- Finally, if an unforeseen failure were to occur, the data discrepancies between the ANREU 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 ANREU and the ITL. If a discrepancy reoccurs in the ANREU, the following measures will be applied:
  - Identification, and registration of the discrepancy;
  - Identification of the source of the discrepancy (DES, ANREU 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 minimise operator error

Below is a brief description of security measures implemented by the ANREU. For more detailed information, please refer to the formal readiness documentation which has been submitted as required to the ITL.

A7.5 Identification and Authentication

All applicants looking to open an account in the ANREU are required to provide specified proof of identity documentation, along with completing a "fit and proper" person test. These identity requirements are defined in the *Australian National Registry of Emissions Unit Act 2011* and the *Australian National Registry of Emissions Unit Regulations 2011.*

Access to the ANREU is allowed via an email address and password. Passwords have an expiry date and any reset requires revalidation of the user's identity. Password configuration is as per Australian Government guidelines.

A7.6 Access control

Users of the ANREU are divided into seven 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 ANREU supports the following user groups.

System Administrator

The System Administrator group has global authority throughout the ANREU. 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. The System Administrator is only available to personnel employed by the Clean Energy Regulator and is IP restricted.

IT Administrator

The IT Administrator group has authority to update system settings. These users are responsible for the day to day operation of the ANREU. An IT Administrator is unable to perform any transaction or administer accounts.

Business Administrator

The Business Administrator group is limited to users within the Clean Energy Regulator and possesses all the abilities of the account administrator, but also has the ability to initiate issuance transactions (domestic Australian units) and to approve issuance transactions initiated by a separate individual. In certain restricted instances, Business Administrators may initiate transfer transactions on behalf of the Clean Energy Regulator.

Account Administrator

The Account Administrator group is limited to selected users within the Clean Energy Regulator and allows access to account administration functions within the ANREU (creation/editing/deletion of account holders, accounts and users). An Account Administrator is unable to perform any transactions (e.g. unit transfers) in the ANREU.

Approval Officer

The Approval Officer group is limited to users within the Clean Energy Regulatorand has permissions to view all data related to accounts, account holders (organisations), and registered users (people). The Approval Officer user group may not alter any data related to accounts, account holders (organisations), and registered users (people), with the exception of their own personal data. The Approval Officer user group is permitted to approve (but not initiate) issuance transactions. They may not edit or delete any other transactional data.

System Auditor

The System Auditor group has read only access to ANREU account and transaction information. A System Auditor is unable to update any information on an account, nor able to perform any transactions. System Auditor access is only available to personnel employed by the Clean Energy Regulator.

Industry User

The Industry User group is assigned to external persons who require access to specific accounts within the ANREU. Industry Users are established when an ANREU account is initially created. All Industry Users must pass required Proof of Identity and Fit and Proper person validations prior to being associated with an account. Additional security permissions are maintained for each Industry User associated with each account e.g. the ability to initiate or approve transactions for that account. These permissions are set by the Clean Energy Regulator upon advice from the account holder.

A7.7 Access protection

In order to prevent operator errors, the ANREU incorporates validations on all user inputs to ensure that only valid details are submitted for processing; The ANREU displays confirmation of user input to help the user to spot any errors that had been made and implements an internal approval process (input of relevant password details) for secondary approval for relevant operations before submitting the details to the ITL for processing.

Additional Security measures

In addition to the above, the ANREU incorporates an initiator / approver design to assist in mitigating the risks associated with high risk unit transfer functions. The initiator / approver function requires a transaction to be initiated by one identity (authorised representative) and be approved by another (authorised representative).

The approval step includes validating the transaction by entering a single use PIN issued to the approver when the "initiate" transaction component is completed.

This measure supports the recommendations as outlined by the ITL Change Advisory Board.

A7.8 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 Decision 13/CMP.1, Annex II.E, as amended by Decision 3/CMP.11, on the National Registry website under the Public Reports menu: https://nationalregistry.cleanenergyregulator.gov.au/report/listPublicReports

Up to date information on accounts as required by paragraph 45 of Decision 13/CMP.1, as amended by Decision 3/CMP.11, has been included under Public Reports > Account Information Report, with Unit Block Holdings. 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.
- Representative identifier;

Information relating to projects as required by paragraph 46 of Decision 13/CMP.1, as amended by Decision 3/CMP.11, has been included under Public Reports > Joint Implementation Project Information Report.

Holding and transaction information as required by paragraph 47 of Decision 13/CMP.1, as amended by Decision 3/CMP.11, 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.

   (a) bis. The total quantity of AAUs in the previous period surplus reserve account at the beginning of the year is available under Public Reports > Account Information Report, with Unit Block Holdings.

b. The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 bis, 8 and 8 bis is available at Public Reports > Annual Transaction Summary Report.

c. The total quantity of ERUs issued on the basis of Article 6 projects is available at Public Reports > Annual 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 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 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 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 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 Transaction Summary Report.

(h) bis. The total quantity of AAUs cancelled under Article 3, paragraphs 1 ter and 1 quater is available at Public Reports > Annual Transaction Summary Report.

(h) ter. The total quantity of AAUs cancelled under Article 3, paragraph 7 ter is available at Public Reports > Annual Transaction Summary Report.

i. The total quantity of other ERUs, CERs, AAUs and RMUs cancelled is available at Public Reports > Annual Transaction Summary Report.

j. The total quantity of ERUs, CERs, AAUs and RMUs retired is available at Public Reports > Annual 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 Transaction Summary Report.

l. Current holdings of ERUs, CERs, AAUs and RMUs in each account is available at Public Reports > Account Information Report, with Unit Block Holdings.

A7.9 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 http://nationalregistry.cleanenergyregulator.gov.au/

A7.10 Measures to safeguard, maintain and recover data in the event of a disaster

The servers (main and backup sites) that host the ANREU and databases have been hosted in Microsoft Azure datacenters since March 2020. These are physically secure datacentres fitted with secure access control systems. All datacentres 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. Following the migration of servers and databases to the Microsoft Azure datacentres, the same data integrity measures are still active and fit for purpose.

A full backup of each database and an hourly transaction log backup during business hours take place every day with the back-up media being held at an offsite third party secure storage facility. The database content will also be replicated at a minimum of 30 minute intervals to a secondary data centre location when the clustering environment is implemented. This will serve as the hosting platform for Disaster Recovery.

In the event of a disaster a decision will be taken (between the Clean Energy Regulator and the IT contract supplier) to invoke Disaster Recovery (DR). 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 Clean Energy Regulator operators within 8 hours of the decision being made.

A7.11 Results of previous test procedures

Comprehensive testing information has been submitted as part of the ITL readiness documentation in December 2013. Please refer to this documentation for details.

Australia's independent assessment reports are available from the UNFCCC website https://unfccc.int/process/the-kyoto-protocol/registry-systems/independent-assessment-reports

ANNEX 8: General notes, glossary and abbreviations

A8.1 General notes

Units

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

kilo $_{(k)}$ = 10^3 (thousand)

mega $_{(M)}$ = 10^6 (million)

giga $_{(G)}$ = 10^9

tera $_{(T)}$ = 10^{12}

peta $_{(P)}$ = 10^{15}

Emissions are generally expressed in gigagrams (Gg) in the inventory tables, as called for under international guidelines, and in megatonnes (Mt) in the text of the inventory report: gigagram (Gg) = 1,000 tonnes = 1 kilotonne (kt) megatonne (Mt) = 1,000,000 tonnes = 1,000 Gg

Gases

CF_4	perfluoromethane (a perfluorocarbon)
C_2F_6	perfluoroethane (a perfluorocarbon)
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
HFCs	hydrofluorocarbons
NF_3	nitrogen trifluoride
N_2O	nitrous oxide
NMVOC	non-methane volatile organic compounds
NO_x	oxides of nitrogen
PFCs	perfluorocarbons
SF_6	sulphur hexafluoride
SO_2	sulphur dioxide

Global warming potentials

CO_2 = 1	HFC-23 = 14,800
CH_4 = 25	HFC-125 = 3,500
N_2O = 298	HFC-134a = 1,430
CF_4 = 7,390	HFC-143a = 4,470
C_2F_2 = 12,200	SF_6 = 17,700

Conversion factors

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

A8.1.1 Indicators

In the tables, the following standard indicators are used:

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

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

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

IE (included elsewhere) where emissions or removals are estimated but included elsewhere in the inventory

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

A8.2 Glossary

Term	Description
Accounting quantity	The accounting quantity for the Kyoto Protocol *land use, land use change and forestry* activities represents RMU credits issued or assigned amount units (AAUs) cancelled for a given year of the commitment period. A net removal will result in the issuance of RMU credits while a net source will result in the deletion of AAUs.
Activity	A process that generates greenhouse gas emissions or uptake. In some sectors it refers to the level of production or manufacture for a given process or category.
Automotive Diesel Oil (ADO)	A middle distillate petroleum product used as a fuel in high-speed diesel engines. It is mostly consumed in the road and rail transport sectors and agriculture, mining and construction sectors.
Anaerobic	A process relying on bacteria that can live without oxygen.
Anthropogenic	Resulting from human activities. In the inventory, anthropogenic emissions are distinguished from natural emissions.
Bagasse	The fibrous residue of the sugar cane milling process which is used as a fuel in sugar mills.
Briquettes	A composition fuel manufactured from brown coal, which is crushed, dried and moulded under high pressure without the addition of binders.
Bushfire	A term used in Australia to describe wildfire in native vegetation.
Calibration	Model calibration is the estimation and adjustment of model parameters and constants to improve the agreement between model outputs and a data set. Calibration requires high quality data that represent the range of conditions under which the model is required to perform so as to avoid possible bias in emission estimates.
Clinker	An intermediate product from which cement is made.
Coke	The solid product obtained from the carbonisation of suitable types of coal at high temperature. It is low in moisture and volatile matter and is mainly used in the iron and steel industry as an energy source and chemical agent. Semi-coke or coke obtained by carbonisation at low temperatures is included in this category.
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.

Term	Description
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 and/or oil at a crude oil or gas production site, a gas processing plant or an oil refinery.
Forest	Parties are required to select single minimum values for land area, tree crown cover and tree height. Australia uses a criteria of 20% tree crown cover, 2 metre minimum tree height, and a minimum of 0.2 hectares in land area for inclusion. These minimum criteria are within the ranges outlined in the Marrakech Accords.
Fuel Oil	Covers all residual (heavy) fuel oils including those obtained by blending.
Fugitive Emissions	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), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). 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).
Initial Assigned Amount	Represents Australia's emissions target for the first commitment period of the Kyoto Protocol. The initial assigned amount for the first commitment period was 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. At such time as the government ratifies the Doha Amendment to the KP, Australia's assigned amount for the second commitment period will be calculated based on its target of 99.5% of base year emissions.
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. The first commitment period of the KP ran from 2008–2012. In 2012 Parties to the KP agreed to the Doha Amendment, establishing a second commitment period (CP2) to run from 2013–2020. The CP_2 is yet to enter into force.
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.

Term	Description
Natural Disturbances	In accordance with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, natural disturbances include some wildfire events which are non-anthropogenic and are beyond the control of, and not materially influenced by, Australian authorities and occur despite costly and ongoing efforts across regional and national government agencies and emergency services organisations to prevent, manage and control them.
Natural Gas	Consists primarily of methane (around 90%, 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' or 'hazard 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).
Sink	Any process, mechanism, or activity that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.
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)	An international environmental treaty which entered into force in 1994. Parties to the convention have agreed to work towards achieving the ultimate aim of stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.
Validation	Model validation is a demonstration that a model, within its domain of applicability, possesses a satisfactory range of accuracy consistent with the intended application of the model. Validation compares simulated system output with real system observations using data not used in model development. It is used to test the model performance and that the calibration of the model has not produced biased emission estimates.
Verification	In terms of the inventory verification refers to the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help establish its reliability for the intended application of that inventory. Typically methods external to the inventory are used to verify the truth of the inventory, including comparisons with estimates made by other bodes. Verification as it pertains to modelling is a demonstration that the modelling formalism is correct. It is a check that calculations, inputs, and computer code is correct.
Venting	The process of releasing gas into the atmosphere without combustion. This may be done either at the production site or at the refinery or stripping plants. It is done to dispose of non-commercial gas or to relieve system pressure.

A8.3 Abbreviations

AAA	Aerosol Association of Australia
AAC	Australian Aluminium Council
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABARE	Australian Bureau of Agricultural and Resource Economics
ABR	Australian Business Register
ABS	Australia Bureau of Statistics
ACARP	Australian Coal Association Research Program
ACT	Australian Capital Territory
AD	Activity Data
ADB	Asian Development Bank
ADC	Aluminium Development Council
ADO	Automotive Diesel Oil
ADR	Australian Design Rule
AEC	Australian Energy Council
AELC	Australian Egg Corporation Ltd.
AEMO	Australian Energy Market Operator
AES	Australian Energy Statistics
AEZ	Agro Ecological Zones
AFIC	Australian Feeds Information Centre
AFRC	Agriculture and Food Research Council
AGA	Australian Gas Association
AGEIS	Australia Greenhouse Emissions Information System
AGO	Australian Greenhouse Office
AIHW	Australian Institute of Health and Welfare
ALFA	Australian Lot Feeders Association
ANAO	Australian National Audit Office
ANREU	Australian National Registry of Emissions Units
ANU	Australian National University
ANZSIC	Australia New Zealand Standard Industrial Classification
APEC	Asia Pacific Economic Corporation
API	American Petroleum Institute
APPEA	Australian Petroleum Production and Exploration Association
APS	Australian Petroleum Statistics
ARC	Agricultural Research Council
ARRBTR	Australian Road Research Board Transport Research
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.
ASRIS	Australian Soil Resource Information System
ASS	Acid Sulphate Soils
AUASB	Auditing and Assurance Standards Board
AUSLIG	Australian Surveying and Land Information Group
AVHRR	Advanced Very High Resolution Radiometer
Avtur	Aviation turbine fuel

AWTA	Australian Wool Testing Authority
BEF	Burning Efficiency
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BoM	Bureau of Meteorology
BTX	Benzene, Toluene, Xylene
BREE	Bureau of Resources and Energy Economics
BRS	Bureau of Rural Science
C&D	Construction and Demolition waste
C&I	Commercial and Industrial waste
CAAANZ	Conservation Agriculture Alliance of Australia and New Zealand
CAB	Change Advisory Board
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Use and Storage
CEF	Clean Energy Future package
CEM	Clean Energy Ministerial
CER	Clean Energy Regulator
CERI	Clean Energy Research Institute
CFTT	Centre for Forest Tree Technology
COBIT	Control Objectives for Information and related Technology
COD	Chemical Oxygen Demand
CP2	Kyoto Protocol/ Second Commitment Period
CPN	Conditional Probability Network
CRC SI	Cooperative Research Centre for Spatial Information
CRES	Centre for Resource and Environmental Studies
CRF	Common Reporting Format
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CUEDC	Composite Urban Emissions Drive Cycle
DAFF	Department of Agriculture, Fisheries and Forestry
DAWE	Department of Agriculture, Water and the Environment
DAWR	Department of Agriculture and Water Resources
DCC	Department of Climate Change
DCCEE	Department of Climate Change and Energy Efficiency
DE	Department of the Environment
DEDJTR	Department of Economic Development, Jobs, Transport and Resources
DoEE	Department of the Environment and Energy
DEEDI	Department of Employment, Economic Development and Innovation
DEM	Digital Elevation Model
DES	Data Exchange Standards
DEWHA	Department of Environment, Water, Heritage and the Arts
DIIS	Department of Industry, Innovation and Science
DIS	Department of Industry and Science
DISER	Department of Industry, Science, Energy and Resources
DIT	Department of Infrastructure and Transport
DM	Dry Matter
DMD	Dry Matter Digestibility

DMITRE	Department of Manufacturing, Innovation, Trade, Resources and Energy
DMIRS	Department of Mines and Petroleum Industry, Regulation and Safety
DNRM	Department of Natural Resources and Mines
DOC	Degradable Organic Carbon
DOCf	fraction of Degradable Organic Carbon dissimilated
DOM	Database Operations Manager
DRET	Department of Resources, Energy and Tourism
DSDBI	Department of State Development, Business and Innovation
DSITI	Queensland Department of Science, Information Technology and Innovation
E&P Forum	Exploration and Production Forum
EAC	Electricity
EDC	Emission Decay Curve
EDS	Early Dry Season
EF	Emission Factor
EGCFE	Expert Group on Clean Fossil Energy
EIS	Environmental Impact Statements
EITEI	Emissions Intensive Trade Exposed Industries EPA Environmental Protection Agency
ERIC	Environmental Research and Information Consortium Pty Ltd
ERT	Expert Review Team
ESAA	Energy Supply Association of Australia
ESAS	Electricity Sector Adjustment Scheme
EU ETS	European Union Emissions Trading Scheme
EVAO	Estimated Value of Agricultural Operations
FAO	Food and Agriculture Organisation
FITR	Fourier Transform Infrared Spectroscopy
FtRF	Filling the Research
FOD	First Order Decay
FORS	Federal Office of Road Safety
FPA	Forest Practices Authority
FullCAM	Full Carbon Accounting Model
GA	Geoscience Australia
G8	The Group of Eight
GCL	Geosynthetic Clay Liner
GCV	Gross Calorific Equivalents
GE	Gross Energy
GEDO	Greenhouse and Energy Data Officer
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GRDC	Grains Research and Development Corporation
GWA	George Wilkenfeld and Associates
GWP	Global Warming Potential
HDPE	High Density Polyethylene
IBRA	Interim Biogeographic Regionalisation for Australia
IDF	Industrial Diesel Fuel
IEA	International Energy Agency

IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
IAR	Initial Assessment Report
ISC	Interspecies correlation
ISO	International Organization for Standardization
IUFRO	International Union of Forest Research Organizations
JCP	Jobs and Competitiveness Program
JCPAA	Joint Committee of Public Accounts and Audit
KP	Kyoto Protocol
LDS	Late Dry Season
LKD	Lime Kiln Dust
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
LTO	Landing/Takeoff
LULUCF	Land use, land use change and forestry
M2M	Methane to Markets
MCF	Methane Correction Factor
MDI	Metered Dose Inhaler
MDP	Metropolitan Development Program
MLA	Meat and Livestock Australia
ME	Metabolisable Energy
MEF	Manure Emission Factor
MMS	Manure Management Systems
MRT	Mineral Resources Tasmania
MSW	Municipal Solid Waste
MVG	Major Vegetation Groups
MWTP	Municipal Wastewater Treatment Plants
NAILSMA	North Australian Indigenous Land & Sea Management Alliance
NATA	National Association of Testing Authorities
NCAS	National Carbon Accounting System
NEA	National Energy Administration
NFI	National Forest Inventory
NG	Natural Gas
NGERS	National Greenhouse and Energy Reporting Scheme
NGGI	National Greenhouse Gas Inventory
NGGIC	National Greenhouse Gas Inventory Committee
NIAES	National Institute for Agro-Environmental Sciences
NIR	National Inventory Report
NLWRA	National Land and Water Resources Audit NORP Nitrous Oxide Research Program
NRC	National Research Council
NSW	New South Wales
NT	Northern Territory
OECD	Organisation for Economic and Co-operation Development
OSCAR	Online System for Comprehensive Activity Reporting
PCC	Post Combustion Capture

PVC	Polyvinyl Chloride
QA/QC	Quality assurance/Quality control
QDME	Queensland Department of Mines and Energy
QDNRME	Queensland Department of Natural Resources, Mines and Energy
QLD	Queensland
RET	Department of Resources, Energy and Tourism
RIRDC	Rural Industries Research and Development Corporation
ROU	Recycled Organics Unit
RMSE	Root Mean Square Error
RRA	Refrigerant Reclaim Australia
RSA	Registry System Administrators
SA	South Australia
SCA	Standing Committee on Agriculture
SCaRP	Soil Carbon Research Program
SECV	State Electricity Commission of Victoria
SEEA	System of Environmental-Economic Accounting
SEF	Standard Electronic Format
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SIAR	Standard Independent Annual Review
SUV	Sports Utility Vehicle
SWDS	Solid Waste Disposal Site
TAS	Tasmania
TOC	Total Organic Carbon
UAG	Unaccounted for Gas
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VIC	Victoria
VKT	Vehicle Kilometres Travelled
VOC	Volatile Organic Compounds
WA	Western Australia
WALFA	Western Arnhem Land Fire Abatement
WBCSD	World Business Council for Sustainable Development
WMAA	Waste Management Association of Australia
WRI	World Resource Institute
WSAA	Water Services Association of Australia
YSLB	Years Since Last Burnt

ANNEX 9: References

A9.3.1 Volume 1

Executive Summary

IPCC (Intergovernmental Panel on Climate Change),

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Japan.

2014. 2013 Revised supplementary methods and good practice guidance arising from the Kyoto Protocol, IPCC Switzerland.

2014. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, IPCC Switzerland.

2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,

IPCC Switzerland.

1. Introduction and Inventory Context

ABS Australian Bureau of Statistics, 2020. *Australian National Accounts: National Income, Expenditure and Product, Dec 2020,* Cat. No. 5206.0, Canberra. https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/latest-release

CSIRO (Commonwealth Scientific and Industrial Research Organisation), 2011a, *Review of Confidential Data Handling Practices I.* CSIRO Mathematics, Informatics and Statistics, Canberra. 2011b, *Review of Confidential Data Handling Practices I.* CSIRO Mathematics, Informatics and Statistics, Canberra.

Department of Industry, Science, Energy and Resources (2021) Methane emissions in the Surat Basin, Quarterly Update of Australia's national greenhouse gas inventory: September 2020.

IPCC (Intergovernmental Panel on Climate Change), 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Japan.

2007, *Climate change 2007 – The scientific basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press.

2014. 2013 Revised supplementary methods and good practice guidance arising from the Kyoto Protocol, IPCC Switzerland.

2014. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, IPCC Switzerland.

2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC Switzerland.

Guendehou, S., 2009. *Australias 'National Greenhouse Gas Inventory 2007: Solid Waste Quality Assurance Review,* report to the Department of Climate Change.

2010. Australia's National Greenhouse Gas Inventory 2008: Solid Waste Review – Fraction of DOC dissimilated DOCf, report to the Department of Climate Change.

Hyder Consulting, 2007a. *AGO Factors and Methods Workbook – Waste Chapter Review,* unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

2007b. *Review of Methane Recovery and Flaring from Landfills,* unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

Luhar, A., David M. Etheridge, Zoë M. Loh, Julie Noonan, Darren Spencer, Lisa Smith, and Cindy Ong, (2020), *Quantifying methane emissions from Queensland's coal seam gas producing Surat Basin using inventory data and a regional Bayesian inversion*, Journal of Atmos. Chem. Phys., 20, 15487–15511, 2020 https://acp.copernicus.org/articles/20/15487/2020/

Lunarzewski, L., 2006. *Review of the Draft Australian Methodology for Estimating Greenhouse Gas Emissions from Flooding Decommissioned Coal Mines,* unpublished report to the Department of Environment and Heritage.

GHD, 2006a. *Review of liquid fuels* CO_2 *emissions factors.* Report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

2006b. *Review of Sectoral Models.* Report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

Meyer, C.P., 2004. *Establishing a consistent time-series of greenhouse gas emission estimates from savanna burning in Australia.* Final report to the Australian Greenhouse Office, December 2004, CSIRO Division of Atmospheric Research, Aspendale, Victoria, Australia, 58pp.

2011. *Review of the National Greenhouse Gas Emissions Methodology for Savanna Burning.* Report to the Commonwealth Department of Climate Change and Energy Efficiency, 52 p.

National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Cwlth), ComLaw, http://www.comlaw.gov.au/Details/F2011C00469

National Greenhouse and Energy Reporting (Audit) Determination 2009 (Cwlth), ComLaw., http://www.comlaw.gov.au/Details/F2010L00053/

O'Brien, 2006a. *Review of Onsite Industrial Wastewater Treatment.* O'Brien Consulting Greenhouse, Energy, Environment, report to the Australian Government Department of the Environment and Heritage, Canberra.

Orbital Australia, 2011a. *Literature Review of Uncertainty in Fuel Properties,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.

Todd, J., Gibbons, A., King, R., and Kinrade, P, 2003. *Estimating Greenhouse Gas Emissions from Residential Firewood Use Australia 1989/65 to 2000/01.* Report for Energy Strategies Pty Ltd and the Australian Greenhouse Office, Eco-Energy Options.

2005. *Carbon dioxide emissions from firewood combustion.* Unpublished report to the Australian Greenhouse Office.

2011. *Estimating Greenhouse Gas Emissions from Residential Firewood Use: Australia 1989/90 to 2010/11.* Eco-Energy Options Pty Ltd.

Tsaranu, M., 2007. *Report of quality assurance review of the Australias 'National Greenhouse Gas Inventory 2006: Industrial Processes Sector.* Report to the Australian Greenhouse Office.

White, D.H., Bowman, PJ., Morley, F.H.W., McManus, W.R., and Filan, S.J., 2002. *A check of the internal consistency of pasture and livestock data used to estimate levels of greenhouse gas emissions from the sheep and beef cattle industries.* Unpublished report to the Australian Greenhouse Office and CSIRO Sustainable Ecosystems, ASIT Consulting.

3. Energy

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 1990–2008. *Australian Commodity Statistics,* ABARES, Canberra.

ABS (Australian Bureau of Statistics) 1991a, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra. 2004, *Detailed Energy Statistics, Australia, 2001-02.* Catalogue No. 4648.0.55.001, Canberra.

ABS (Australian Bureau of Statistics) 2020, *National, State and Territory Population June 2020,* Catalogue No. 3101.0, Commonwealth of Australia, Canberra.

ABS (Australian Bureau of Statistics) 2020a, *National Income, Expenditure and Product*, Catalogue No. 5206.0, Commonwealth of Australia, Canberra.

2006, *Survey of Motor Vehicle Use – An Investigation into Coherence,* Research paper 9208.0.55.005, Commonwealth of Australia, Canberra.

2010a, *Australian Industry – Mining Commodities.* Catalogue No. 8155.0, Canberra.

2020, Motor Vehicle Census, Australia, 31 January 2020. Catalogue No. 9309.0, Canberra

2019, *Survey of Motor Vehicle Use Australia,* 12 months ended 30 June 2020, Catalogue No. 9208.0, Canberra.

2014, *International Trade Merchandise [data available on request],* Canberra.

ACARP (Australian Coal Association Research Program), 2011. *Guidelines for the implementation of NGER method2 or 3 for open cut coal mine fugitive GHG emissions reporting.* ACARP project C20006.

AEC (Australian Environment Council), 1988. *Air Emission Inventories (1985) for the Australian Capital Cities,* Report No. 22, Australian Government Publishing Service, Canberra.

AEC (Australian Energy Council), 2016–2019. *Electricity Gas Australia* (annual), Melbourne.

AGA (Australian Gas Association), 1988–94. *Gas Distribution Industry Performance Indicators* (annual), Canberra. 1988–2002, *Gas Industry Statistics* (annual), Canberra.

AGO, 2006a, *Technical Guidelines, Generator Efficiency Standards,* Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

2006b, *Coal mine methane.* Unpublished report prepared for the Australian Greenhouse Office by Barlow

Jonker Pty Ltd. Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

2007, *Energy Efficiency in Government Operations (EEGO) Policy,* Department of the Environment and Water Resources, Canberra.

2008, *Workbook for Fugitive Emissions (Fuel Production, Transmission, Storage and Distribution) 2.1.*

Allen, D. T.; Pacsi, A. P; Sullivan, D. W.; Zavala-Araiza, D.; Harrison, M.; Keen, K.; Fraser, M. P; Hill, A. D.; Sawyer, R. F.; Seinfeld, J. H, 2015a. *Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers,* Environ. Sci. Technol. 2015, 49 (1), 633-640.

Sullivan, D. W; Zavala-Araiza, D.; Pacsi, A. P;Harrison, M.; Keen, K.; Fraser, M. P; Hill, A. D.; Lamb, B. K.; Sawyer,R. F.; Seinfeld, J. H. (2015b). Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquid Unloadings, Environ. Sci. Technol. 2015, 49 (1), 641-648.

API (American Petroleum Institute), 2004. *Compendium of greenhouse gas emissions methodologies for the oil and gas industry*, Washington, USA.

2009, *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry.* URS Corporation, Texas, USA.

APPEA (Australian Petroleum Production and Exploration Association), 1990–2014. *Quarterly Drilling Statistics.* http://www.appea.com.au/industry-in-depth/industry-statistics/

1990–2014. *APPEA Annual Production Statistics.*

1997. *Greenhouse Gas Emissions and Action Plan Report* 1990–95, Canberra.

1998–2008. *APPEA Greenhouse Gas Emissions and Action Plan Report (annual),* Canberra.

2012–2015. *Quarterly CSG Statistics.*

Armstrong, W., Lunarzewski, L. and Creedy., D., 2006. *Australian decommissioned mine gas prediction.* Report for the Australian Coal Association Research Programme, ACARP project C14080.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc), 2001.

ASHRAE Handbook Fundamentals Inch-Pound Edition, ISBN 1-883413-87-7, 2001.

Australian Institute of Petroleum, 1996. Personal communication with Hugh Saddler.

BITRE (Bureau of Infrastructure, Transport and Regional Economics), 2002. *Report 107, Greenhouse Gas Emissions from Transport, Australian Trends to 2020,* Canberra.

2018, *Airport traffic data* 1985–86 to 2017/18, Canberra.

BREE (Bureau of Resources and Energy Economics), 2013a. *Australian Energy Statistics – Australian Energy Update 2013,* Canberra.

2013b, *Beyond the NEM and the SWIS: 2011–12 regional and remote electricity in Australia,* Canberra.

1996–2013, monthly series: *Australian Petroleum Statistics (APS).* http://www.bree.gov.au/publications/ australian-petroleum-statistics

2014, *Australian Energy Statistics – Australian Energy Update 2014,* Canberra.

Carnovale, F., Alviano, P, Carvalho, C., Deitch, G., Jiang, S., Macaulay, D, and Summers, M., 1991. *Air Emissions Inventory. Port Phillip Region: Planning for the Future,* Report SRS 91/001, Environment Protection Authority, Victoria, Melbourne

CASA (Civil Aviation Safety Authority), 2019. *Civil Aircraft Register.* http://www.casa.gov.au/

Cathles, Lawrence, Larry Brown, Milton Taam, Andrew Hunter, 2012. A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W. Howarth, R. Santoro, and Anthony Ingraffea, Climatic Change (2012) 113:525-535 DOI 10.1007/ s10584-011-0333-0, 2012.

Caulton, Dana, Paul B. Shepson, Renee L. Santoro, Jed P Sparks, Robert W. Howarth, Anthony R. Ingraffea, Maria O. L. Cambaliza, Colm Sweeney, Anna Karion, Kenneth J. Davish, Brian H. Stirm, Stephen A. Montz, and Ben R. Miller, 2013. *Toward a better understanding and quantification of methane emissions from shale gas development,* PNAS April 29, 2014 vol. 111 no. 17 6237–6242 http://www.pnas.org/ content/111/17/6237, 2013.

CER (Clean Energy Regulator), 2019. Data collated by the Clean Energy Regulator under the National Greenhouse and Energy Reporting system for 2009–2019. http://www.cleanenergyregulator.gov.au/ National-Greenhouse-and-Energy-Reporting/Pages/default.aspx

Coal Services Pty Ltd, 2021. *Australian Black Coal Statistics, unpublished.* http://www.coalservices.com.au/

Core Energy Group, 2015. *Gas Storage Facilities, Eastern and South Eastern Australia* – a report for the Australian Energy Market Operator (AEMO), February 2015.

Day, S., 2014. *Emission Factors for Estimating CSG Fugitive Emissions – Review of Recent Literature,* Report for the Department of Environment, June 2014.

Day, S., Dell'Amico, Fry, R., Javanmard Tousi, H., 2014. *Field Measurements of Fugitive Emissions from Equipment and Well Casings in Australian Coal Seam Gas Production Facilities.* CSIRO, Australia.

De Maria, S., 1992. *Unpublished report on Vehicle & Engine Monitoring & Analysis System (VEPMAS).* By the Energy and Engines Research Group, for buses running on compressed natural gas in Adelaide, Sydney and Brisbane.

Department of Defence, 2010–2020. *Personal communications regarding domestic fuel data consumption.* Department of Defence, Canberra, ACT.

Deslandes J., and Kingston E., 1997. Energy and Greenhouse Gas Data & Conversion Factors Relevant to BHP Operations. BHP Technical Note, April 1997.

Dixon, B., 1990. '*Methane losses from the Australian natural gas industry',* in D.J. Swaine (ed.) *Greenhouse and Energy,* CSIRO 1990.

DRET (Department of Resources, Energy and Tourism), 2012. *Energy use in the Australian Governments' operations* Department of Resources, Energy and Tourism, Canberra

DCCEE (Department of Climate Change and Energy Efficiency), 2012. *National Inventory Report 2010,* Department of Climate Change and Energy Efficiency, Canberra.

2011. *Energy use in the Australian Governments ' operations* Department of Resources, Energy and Tourism, Canberra.

DAWE (Department of Agriculture, Water and the Environment), 1998–2019. *National Pollutant Inventory,* http://www.npi.gov.au

DIR (Department of Industry and Resources), 2006. *Petroleum Guidelines – Drilling Fluid Management,* Western Australia.

DIS (Department of Industry and Science), EnergyConsult (2015) Report: Residential Baseline Study For Australia 2000–2030 https://www.energyrating.gov.au/document/report-residential-baseline-study-australia-2000–2030.

DIRD (Department of Infrastructure and Regional Development), 2014. *Australian Design Rules,* 1969–1988. http://www.infrastructure.gov.au/roads/motor/design/

DISER, Quarterly Update of Australia's national greenhouse gas inventory: June 2020, https://www.industry.gov.au/sites/default/files/2020-11/nggi-quarterly-update-june-2020.pdf

DIT (Department of Infrastructure and Transport), accessed 2012a. *Summary of Emission Requirements for New Petrol Passenger Cars 1972–2018.* http://www.infrastructure.gov.au/roads/environment/files/Emission_Standards_for_Petrol_Cars_1972_2018.pdf accessed 2012a, Emission Requirements for Diesel Heavy Duty Vehicles. http://www.infrastructure.gov.au/roads/environment/files/Standards_for_Diesel_HDVs.pdf

DMIRS (Department of Mines, Industry, Regulation and Safety, Western Australia, 2017. Statistical Digest 2016-17. http://dmp.wa.gov.au/Documents/About-Us-Careers/AboutUs-StatisticsDigest_2016-17.pdf

DNRM (Department of Natural Resources and Mines – Queensland), 2017. Coal mining production data, Mines and Energy, Brisbane. https://www.data.qld.gov.au/dataset/coal-industry-review-statistical-tables

DISER (Department of Industry, Science, Energy and Research), 2020. *Australian Energy Statistics – Australian Energy Update 2020,* Canberra.

DISER (Department of Industry, Science, Energy and Research), 2020. *Australian Petroleum Statistics 2019,* Canberra. https://www.energy.gov.au/government-priorities/energy-data/australian-petroleum-statistics

DRET (Department of Resources, Energy and Tourism), 2012. *Energy use in the Australian Governments' operations,* Department of Resources, Energy and Tourism, Canberra.

Driscoll, D., Milkovits, G. and Freudenberger, D., 2000. *'Impact of Use of Firewood in Australia'.* CSIRO Sustainable Ecosystems, Canberra.

DTI (Department of Trade and Investments), 2017. Well drilling data, Division of Resources and Energy, NSW. https://www.resourcesandgeoscience.nsw.gov.au/

E and P (Exploration and Production) Forum, 1994. *Methods for Estimating Emissions from E&P Operations,* The Oil Industry International Exploration and Equipment Forum, London. EEA (European Environment Agency), 2011. *EMEP/EEA air pollutant emission inventory guidebook.* Copenhagen.

EASA (European Aviation Safety Agency), 1975–2015. *International Civil Aviation Organization (ICAO) Aircraft*

Engine Emissions Databank. https://www.easa.europa.eu/

EEA (European Environment Agency), 2011. COPERT 4 – *Estimating emissions from road transport.* http://www.eea.europa.eu/publications/copert-4-2014-estimating-emissions

Energy Strategies, 2005. *Review of methodology for estimating Australias ' unaccounted for gas (UAFG) as calculated in the NGGI,* report to the Australian Greenhouse Office.

EPA (Victorian Environment Protection Authority), 1991. *Air Emissions Inventory for the Port Phillip Control Region, SRS 91/001,* Environment Protection Authority, Victoria, Melbourne.

EPA (NSW Environment Protection Authority), 1995. *Metropolitan Air Quality Study – Air Emissions Inventory,* Environment Protection Authority NSW.

ESAA (Energy Supply Association of Australia), 2005–2015. *Electricity Gas Australia* (Annual), Canberra.

Energy Quest 2020. *East Coast Gas Outlook to 2040 report*.

Energy Strategies, 2005. *Review of methodology for estimating Australias ' unaccounted for gas (UAFG) as calculated in the NGGI,* report to the Australian Greenhouse Office.

2007. Report on Chemical activity data collection and analysis, report to the Australian Greenhouse Office

EPA (NSW Environment Protection Authority), 1995. *Metropolitan Air Quality Study – Air Emissions Inventory,* Environment Protection Authority NSW.

2000. *State of the Environment 2000*, Environment Protection Authority, NSW.

EPA (Victorian Environment Protection Authority), 1991. *Air Emissions Inventory for the Port Phillip Control Region, SRS 91/001,* Environment Protection Authority, Victoria, Melbourne.

Farrington, V., 1988. *Air Emission Inventories (1985) for the Australian Capital Cities,* Australian Environment Council Report 22, AGPS, Canberra.

FORS (Federal Office of Road Safety), 1996. *Motor Vehicle Pollution in Australia* – Report on the National In-Service Vehicle Emissions Study, FORS Canberra.

Geoscience Australia, last accessed 2019. *Petroleum Wells Database.* http://dbforms.ga.gov.au/www/npm.well.search

Geological Survey of Victoria, 2020, *Drillhole database,* https://earthresources.vic.gov.au/geology-exploration/maps-reports-data/drillhole-database

Global-Roam, *NEMReview v6,* v6.3.151, 2009, Milton, Queensland.

GHD, 2006a. *Review of liquid fuels* CO_2 *emissions factors.* report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

2006b. *Review of Sectoral Models.* Report to the Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

Gras, J.L., 2002. *Emissions from Domestic Solid Fuel Burning Appliances, Technical Report No. 5;* CSIRO Report for Environment Australia.

Gray, K.M., and King L.R., 1989b. *National Fuelwood Study, the Commissioned Study on Fuelwood Use and Supply in Australia.* Department of Primary Industries and Energy, Canberra.

1991. *Emissions and Performance ofWoodheaters When Burning Softwoods.* Fuelwood Report No. 3; Centre for Environmental Studies, University of Tasmania, Hobart.

1993. *Carbon dioxide emissions from firewood combustion. Inhouse* Fuelwood Report No. 55, Centre for Environmental Studies, University of Tasmania.

2001. *Factors Influencing Residential Wood-Smoke Emissions: Hobart Survey.* Report for the Department of Primary Industries, Water and Environment, Hobart, January 2001.

2003. *Estimating Greenhouse Gas Emissions from Residential Firewood Use Australia 1989/65 to 2000/01.* Report for Energy Strategies Pty Ltd and the Australian Greenhouse Office, Eco-Energy Options.

2005. *Carbon dioxide emissions from firewood combustion.* Unpublished report to the Australian Greenhouse Office.

2008, *Woodheater Operation and Firewood Parameters: Australia.* Prepared for the Department of the Environment and Water Resources, EEO Report 08/01.

2011. *Estimating Greenhouse Gas Emissions from Residential Firewood Use: Australia 1989/90 to 2010/11.* Eco-Energy Options Pty Ltd.

Harrison, M. R., Shires, T. M., Wessels, J. K., Cowgill, R. M., 1996. *Methane Emissions from the Natural Gas Industry,* Vol.s 1-15, Final Report (1996); Gas Research Institute and Environmental Protection Agency: Washington, DC, GRI-94-0257 and EPA-600-R-96-080, 1996.

Hoekman, S.K., 1992. *Speciated Measurements and Calculated Reactivities of Vehicle Exhaust Emissions from Conventional and Reformulated Gasolines,* Environmental Science and Technology, Vol. 26, No. 10, p 2036, American Chemical Society.

Howarth, R., 2014. *A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas, Energy Science & Engineering Perspective,* published by the Society of Chemical Industry and John Wiley & Sons Ltd.

Hutchinson N., Piffl R., Bavaro M., Lehner M., and Pack D., 1993. *Environmental committee on natural gas leakage*, position report on methane emissions, AGA, Canberra.

HRL, 2013. *Latrobe Valley Brown Coal Mine Method One Default Fugitive Greenhouse Gas Emission Factor.* Unpublished report.

IEA (International Energy Agency), 1992. *Global methane and the coal industry,* OECD, Part 1, pp 34. Coal Industry Advisory Board.

1993. *Coal Research, NfO from Fuel Combustion.* IEAPER/06, ISMN 92-9029-227-X.

2005. *Energy Statistics Manual*, France.

International Civil Aviation Organisation (ICAO), 2004. ICAO *Aircraft Engine Emissions Databank,* January 2012 https://www.easa.europa.eu/

IPCC (Intergovernmental Panel on Climate Change), 1997. *Revised 1996IPCC Guidelines for National Greenhouse Gas Inventories*: Volume 1, Greenhouse Gas Inventory Reporting Instructions; Volume 2, Greenhouse Gas Inventory Workbook; Volume 3, Greenhouse Gas Inventory Reference Manual IPCC/ OECD/IEA, Paris, France.

2000. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Japan.

2006, *IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

Joint Coal Board, 1988–2000. *Australian Black Coal Statistics* (annual), Sydney.

Karion, Anna, Colm Sweeney, Eric A. Kort,§ Paul B. Shepson, Alan Brewer, Maria Cambaliza, Stephen A. Conley, Ken Davis, Aijun Deng, Mike Hardesty, Scott C. Herndon, Thomas Lauvaux, Tegan Lavoie, David Lyon, Tim Newberger, Gabrielle Petron, Chris Rella, Mackenzie Smith, Sonja Wolter, Tara I. Yacovitch, and Pieter Tans, 2015. *Aircraft-Based Estimate of Total Methane Emissions from the Barnett Shale Region* DOI: 10.1021/acs. est.5b00217 Environ. Sci. Technol. 2015, 49, 8124–8131, 2015.

Colm Sweeney, Gabrielle Petron, Gregory Frost, R. Michael Hardesty, Jonathan Kofler, Ben R. Miller, Tim Newberger, Sonja Wolter, Robert Banta, Alan Brewer, Ed Dlugokencky, Patricia Lang, Stephen A. Montzka,2 Russell Schnell, Pieter Tans, Michael Trainer, Robert Zamora and Stephen Conley, 2013. *Methane emissions estimate from airborne measurements over a western United States natural gas field,* Geophysical Research Letters, VOL. 40, 4393–4397, doi:10.1002/grl.50811, 2013.

Kort, Eric, Christian Frankenberg, Keeley R. Costigan, Rodica Lindenmaier, Manvendra K. Dubey, and Debra Wunch, 2014. *Four corners: The largest US methane anomaly viewed from space Geophysical Research Letters* RESEARCH LETTER 10.1002/2014GL061503, 2014.

La fleur, D, Forcey, T, Saddler, H and Sandiford, M., 2016. *A review of current and future methane emissions from Australian unconventional oil and gas production,* Melbourne Energy Institute, October 2016.

Leung, L., 2001. BHP, pers comm. regarding emission factor analysis of Port Kembla and Whyalla coking coals.

Lloyds' Register of Shipping, 1995. *Marine Exhaust Emissions Research Programme – Steady State Operation,* Lloyds' Register of Shipping, London, UK.

Luhar, A, Etheridge, D, Loh, Z, Noonan, J, Spencer, D, Day, S, et al., (2018) Characterisation of Regional Fluxes of Methane in the Surat Basin, Queensland. Final report. GISERA Greenhouse Gas Research. https://gisera.csiro.au/wp-content/uploads/2018/10/GHG-1-Final-Report.pdf

Luhar, A., David M. Etheridge, Zoë M. Loh, Julie Noonan, Darren Spencer, Lisa Smith, and Cindy Ong, (2020), *Quantifying methane emissions from Queensland's coal seam gas producing Surat Basin using inventory data and a regional Bayesian inversion*, Journal of Atmos. Chem. Phys., 20, 15487–15511, 2020 https://acp.copernicus.org/articles/20/15487/2020/

Luke Connell, David Etheridge, Terry Norgate and Neil Sherwood, 2012. *Fugitive Greenhouse Gas Emissions from Coal Seam Gas Production in Australia*, October.

Lunarzewski, L., 2005. *Gas Emission Curves for Sealed Goafs or Abandoned Mines,* report for the Australian Coal Association Research Programme, ACARP project C13007.

2006. *Review of the Draft Australian Methodology for Estimating Greenhouse Gas Emissions from Flooding Decommissioned Coal Mines,* unpublished report to the Department of Environment and Heritage.

Marchese, AJ, Timothy L. Vaughn, Daniel J. Zimmerle, David M. Martinez, Laurie L. Williams, Allen L. Robinson, Austin L. Mitchell, R. Subramanian,Daniel S. Tkacik, Joseph R. Roscioli,and Scott C. Herndon, 2015. *Methane Emissions from United States Natural Gas Gathering and Processing,* Environ. Sci. Technol. 2015, 49, 10718–10727.

Mark Dell'Amico, Robyn Fry and Hoda Javanmard Tousi, 2014. *Field Measurements of Fugitive Emissions from Equipment and Well Casings in Australian Coal Seam Gas Production Facilities,* Prepared for the Department of the Environment by the CSIRO, 2014.

Merrin, Z, Francesco, P (2019) *Unburned Methane Emissions from Residential Natural Gas Appliances,* Environ. Sci. Technol. 2019, 53, 9, 5473–5482.

Miller, Scot, Steven C. Wofsya, Anna M. Michalakb, Eric A. Kortc, Arlyn E. Andrewsd, Sebastien C. Biraude, Edward J. Dlugokenckyd, Janusz Eluszkiewiczf, Marc L. Fischerg, Greet Janssens-Maenhouth, Ben R. Milleri, John B. Milleri, Stephen A. Montzkad, Thomas Nehrkornf, and Colm Sweeney, 2013. *Anthropogenic emissions of methane in the United States,* PNAS December 10, 2013 vol. 110 no. 50 www.pnas.org/cgi/doi/10.1073/pnas.1314392110 20018–20022, 2013.

Ministry for the Environment, 2011. Unpublished report to DCCEE, *Review of components of Australia 's national inventory system.* New Zealand Government.

Mitchell, A. L.; Tkacik, D. S.; Roscioli, J. R.; Herndon, S. C.;Yacovitch, T. I.; Martinez, D. M.; Vaughn, T. L.; Williams, L.; Sullivan,M.; Floerchinger, C.; Omara, M.; Subramanian, R.; Zimmerle, D.;Marchese, A. J.; Robinson, A. L. (2015). *Measurements of Methane Emissions from Natural Gas Gathering Facilities and Processing Plants: Measurement Results,* Environ. Sci. Technol. 2015, 49 (5), 3219–3227.

Nisbet E. G., R. E. Fisher, D. Lowry, J. L. France, G. Allen, S. Bakkaloglu, T. J. Broderick, M. Cain, M. Coleman, J. Fernandez, G. Forster, P. T. Griffiths, C. P. Iverach, B. F. J. Kelly, M. R. Manning, P. B. R. Nisbet-Jones, J. A. Pyle, A. Townsend-Small, A.al-Shalaan, N. Warwick, and G. Zazzeri (2020), Methane Mitigation: Methods to Reduce Emissions on the Path to the Paris Agreement, Reviews of Geophysics, review article 10.1029/2019RG000675

NGGIC (National Greenhouse Gas Inventory Committee), 2004. *National Inventory Report and Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks: Energy (Fugitive Fuel Emissions),* Canberra.

NOPTA (National Offshore Petroleum Titles Administrator, (1990–2018), https://www.nopta.gov.au/

NSWRMS (New South Wales Roads and Maritime Services) (2018), Table 1.1.4 Motive Power by vehicle type – registered vehicles as at 31 December 2018, https://www.rms.nsw.gov.au/about/corporate-publications/ statistics/registrationandlicensing/tables/table114_2018q4.html

NSW Department of Regional New South Wales, 2020, *NSW Drillholes Petroleum,* https://data.nsw.gov.au/data/dataset/nsw-drillholes-petroleum

NT Department of Primary Industry and Resources, 2020, *Northern Territory Petroleum Wells,* https://data.nt.gov.au/dataset/strike---northern-territory-petroleum-wells

OECD (Organisation for Economic and Co-operation Development), 1991. *Estimation of Greenhouse Gas Emissions and Sinks.* Final Report from the OECD Experts Meeting, February 1991 (Revised August 1991), prepared for the IPCC, OECD.

Orbital Australia, 2010. *Emissions Factor Derivation from NISE2 Measurements of Vehicles from the Australian Fleet,* internal report to the Department of Climate Change and Energy Efficiency, December 2010.

2011a. *Literature Review of Uncertainty in Fuel Properties,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.

2011b. *Preparation ofWeighted GHG Results from Additional Data Sources,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.

2011c. *Additional Data Analysis for Greenhouse Gas Inventory – Search for Ethanol, LPG and Diesel Deterioration Rate Information,* internal report to the Department of Climate Change and Energy Efficiency, June 2011.

Paul Marvig, Stephen White, Brendan Halliburton, 2017. *Methane Emissions from CSG Well Completion Activities,* Report for the Department of Environment and Energy, February 2017.

Peischl, J, T. B. Ryerson, K. C. Aikin, J. A. de Gouw1,2, J. B. Gilman, J. S. Holloway, B. M. Lerner, R. Nadkarni, J. A. Neuman J. B. Nowak, M. Trainer, C. Warneke and D. D. Parrish, 2014. *Quantifying atmospheric methane emissions from the Haynesville, Fayetteville, and Northeastern Marcellus shale gas production regions*, Journal of Geophysical Research: Atmospheres Research Article 10.1002/2014JD022697, 2014.

Pekol Traffic and Transport, 2020, *Australian Transport Facts,* Centre for Transport, Energy and Environment, Queensland.

Petron, Gabrielle, Gregory Frost, Benjamin R. Miller, Adam I. Hirsch, Stephen A. Montzka,Anna Karion, Michael Trainer, Colm Sweeney, Arlyn E. Andrews, Lloyd Miller, Jonathan Kofler, Amnon Bar-Ilan, Ed J. Dlugokencky, Laura Patrick, Charles T. Moore Jr., Thomas B. Ryerson, Carolina Siso, William Kolodzey, Patricia M. Lang, Thomas Conway, Paul Novelli, Kenneth Masarie, Bradley Hall, Douglas Guenther, Duane Kitzis, John Miller, David Welsh, Dan Wolfe, William Neff, and Pieter Tans, 2012. *Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study,* Journal of Geophysical Research, VOL. 117, D04304, doi: 10.1029/2011JD016360, 2012.

Pitt and Sherry, 2013. *Independent Technical Review of a Proposed Brown Coal Mine Default Fugitive Emissions Factor.* Report for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Queensland Government, last accessed 2020. *Petroleum and gas production and reserve statistics.* https://data.qld.gov.au/dataset/petroleum-gas-production-and-reserve-statistics

2020, *Queensland borehole series,* https://www.data.qld.gov.au/dataset/queensland-borehole-series

Rella, C.; Tsai, T. R.; Botkin, C. G.; Crosson, E. R.; Steele, D., 2015. *Measuring emissions from oil and natural gas producing well pads in the Barnett Shale region using the novel mobile flux plane technique,* Environ. Sci. Technol. 2015, 49, 4742–4748, DOI: 10.1021/acs.est.5b00099, 2015.

Robyn Fry, Mark Dell'Amico, David Williams, Brendan Halliburton and Adrian Element, 2015. *Methane Emissions from Abandoned Boreholes in South Eastern Australia,* CSIRO, Energy, Newcastle, Australia, AGU Fall Meeting, 14-18 December 2015.

Roy Morgan 2019, *Roy Morgan Automotive Leading Indicators Report* -http://www.roymorgan.com/findings/8222-automotive-leading-indicators-october-2019-201912090538

Roy Morgan 2019, *Article No. 8085. http://www.roymorgan.com/findings/8085-new-car-buying-intentions-may-2019-201908130037*

Ruban, A.D., V.S. Zabourdyaev, G.S. Zabourdyaev and N.G. Matvienko., 2006, *Methane Russian Mines: Evaluation, Recovery and Use*, IPKON RAN, Moscow

Saddler, H., 2012. *Review of literature on international best practice for estimating greenhouse gas emissions from coal seam gas production*, August 2012. and Gothan, K., 2013. *Review of methods for the estimation of greenhouse gas emissions from diffuse sources associated with unconventional gas fields,* prepared for the Department of Climate Change and Energy Efficiency, August 2013.

Schneising, Oliver, John P. Burrows, Russell R. Dickerson, Michael Buchwitz, Maximilian Reuter, and Heinrich Bovensmann, 2014. *Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations,* Earth's future, Research Article 10.1002/2014EF000265, 2014.

South Australian Department for Energy and Mining, 2020, *South Australia Resources Information Gateway,* https://map.sarig.sa.gov.au/

Subramanian, R.; Williams, L.; Vaughn, T. L.; Zimmerle, D.;Roscioli, J. R.; Herndon, S. C.; Yacovitch, T. I.; Floerchinger, C.;Tkacik, D. S.; Mitchell, A. L.; Sullivan, M. R.; Dallmann, T. R.;Robinson, A. L., 2015. *Methane Emissions from Natural Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Protocol,* Environ. Sci. Technol. 2015, 49 (5), 3252–3261.

Tasmania Department of State Growth, 2020, *State Drilling Data*, https://www.mrt.tas.gov.au/products/digital_data/state_drilling_data_download

Thomson, S., 2010. Gas layering in the subsurface: Implications for greenhouse gas emissions, Proceedings of the 37th symposium on the geology of the Sydney basin. Hunter Valley, May 6-7, 2010.

Todd, J, 2011. Estimating Greenhouse Gas Emissions from Residential Firewood Use, Report Prepared for Australian Department of Climate Change, Eco-Energy Options Pty Ltd, Tasmania.

2005. Estimating Greenhouse Gas Emissions from Residential Firewood Use, Report Prepared for Energy Strategies Pty Ltd, ACT, Tasmania.

2003. Estimating Greenhouse Gas Emissions from Residential Firewood Use, Report Prepared for Energy Strategies Pty Ltd, ACT, Tasmania.

2001. Factors Influencing Residential Wood-Smoke Emissions: Hobart Survey. Report for the Department of Primary Industries, Water and Environment, Hobart.

1993. In-House Fuelwood Report : Carbon Dioxide Emissions from Firewood Combustion. Centre for Environmental Studies, University of Tasmania, Hobart.

Todd, J., Gibbons, A., King, R., and Kinrade, P., 1989a. *Measurement of Air Pollutants from Woodheaters.* NERDP Project Number 1186, Centre for Environmental Studies, University of Tasmania, Hobart.

Turner, A. J., D. J. Jacob, K. J. Wecht, J. D. Maasakkers, E. Lundgren, A. E. Andrews, S. C. Biraud, H. Boesch, K.W Bowman, N. M. Deutscher, M. K. Dubey, D.W. T. Griffith, F. Hase, A. Kuze, J. Notholt, H. Ohyama, R. Parker, V. H. Payne, R. Sussmann, C. Sweeney, V. A. Velazco, T. Warneke, P O. Wennberg, and D. Wunch, 2015. *Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data,* Atmos. Chem. Phys., 15, 7049–7069, 2015. doi:10.5194/ acp-15-7049–2015, 2015.

USEPA (United States Environment Protection Agency), 1995b. *Compilation of Air Pollutant Emission Factors, Vol 1, Stationary Point and Area Sources.* Fifth Edition, Research Triangle Park, NC, USA.

1991a. *Nonroad Engine and Vehicle Emission Study* – Report. Office of Air and Radiation, USEPA, Washington, DC.

1992. *Procedures for Emission Inventory Preparation, Vol IV: Mobile Sources.* Research Triangle Park, North Carolina, USA.

1995a. *Highway Vehicle Emission Estimates* – II. Office of Mobile Sources, USEPA, Research Triangle Park, North Carolina, USA.

1995b. *Compilation of Air Pollutant Emission Factors,* Vol 1, Stationary Point and Area Sources. Fifth Edition, Research Triangle Park, NC, USA.

1996. AP-42 *Compilation of Air Pollutant Emission Factors Vol 1 Stationary Point and Area Sources.* United States Environmental Protection Agency, available at https://www.epa.gov/chief

2015a. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2013,* April 2015.

2015b. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2013: Revision to Offshore Platform Emissions Estimate*, April 2015.

2016a. *Annexes to the Inventory of U.S. GHG Emissions and Sinks,* April 2016.

2016b. *Inventory of U.S. GHG Emissions and Sinks 1990–2014: Revision to Gathering and Boosting Station Emissions*, April 2016.

2016c. *Greenhouse Gas Reporting Program data.* https://www.epa.gov/ghgreporting/ghg-reporting-program-data-sets

2016d. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2014 Revisions to Natural Gas Transmission and Storage Emissions,* April 2016.

2017. *Annexes to the Inventory of U.S. GHG Emissions and Sinks,* April 2017.

WA Department of Industry and Resources, 2006. *Petroleum Guidelines, Drilling Fluids Management.* Environment Division, Perth.

WA Department of Mines, Industry Regulation and Safety, 2021, *WA Petroleum & Geothermal Information Management System,* https://wapims.dmp.wa.gov.au/wapims

Weeks, I.A., Galbally, I.E., Guo-hong, H. 1993, *Nitrous Oxide Emissions from Motor Vehicles in Australia.* Research Report to ANZECC, Final Report, CSIRO, Victoria.

Williams, D.J., Saghafi A., Lange A., and Drummond, M.S., 1993. *Methane emissions from open-cut mines and post-mining emissions from underground coal.* CSIRO Investigation report CET/IR173.

Williams, D.J Lama, R.D., and Saghafi, A., 1996. *Methane Emissions from Coal Mining.* International Energy Agency, Paris.

Zavala-Araiza Daniel, David Lyon, Ramon A. Alvarez, Virginia Palacios, Robert Harriss, Xin Lan, Robert Talbot, and Steven P Hamburg,, 2015. *Toward a Functional Definition of Methane Super-Emitters: Application to Natural Gas Production Sites,* Environmental Science and Technology, pubs.acs.org.est DOI: 10.1021/acs. est.5b00133 Environ. Sci. Technol. 2015, 49, 8167–8174, 2015.

Zimmerle, D, Vaughn, T, Luck, B, Lauderdale, T, Keen, K, Harrison, M Marchese, A, Williams, L, Allen A (2020) Methane emissions from gathering compressor stations in the United States, Environ. Sci. Technol. 2020, 54, 12, 7552-7561.

Zimmerle, D. J.; Williams, L. L.; Vaughn, T. L.; Quinn, C.; Subramanian, R.; Duggan, G. P; Willson,

B. D.; Opsomer, J. D.; Marchese, A. J.; Martinez, D. M.; Robinson, A. L., 2015. *Methane emissions from the natural gas transmission and storage system in the United States,* Environ. Sci. Technol. 2015, DOI: 10.1021/ acs. est.5b01669, 2015.

4. Industrial Processes and Product Use

AAC (Australian Aluminium Council), 2007. *Sustainability Report 2006,* AAC Canberra.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), various. *Australian Commodity Statistics,* ABARES, Canberra.

ABS (Australian Bureau of Statistics) 1991a, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra. 2000, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra.

2008a, *Australian Demographic Statistics,* Catalogue No. 3101.0, Canberra.

2008b, *Environmental Issues: Energy Use and Conservation, Mar 2008*, 4602.0.55.001, Canberra.

2012, *Australian Economic Indicators.* Catalogue No. 1350.0, Canberra.

2014, *Environmental Issues: Energy Use and Conservation, Mar 2014*, 4602.0.55.001, Canberra.

2019, *International Trade Merchandise* [data available on request], Canberra.

2019a, *Motor Vehicle Census,* Australia, 31 January 2019. Catalogue No. 9309.0, Canberra

Beyond Neutral, 2008. *Greenhouse Gas Inventory for Industrial Processes – Cement, Aluminium, Lime and Titanium Dioxide/Synthetic Rutile – 2007Inventory.* Unpublished report submitted to the Australian Greenhouse Office. O'Brien Consulting Greenhouse, Energy, Environment, Canberra.

Bluescope Steel, 2014. *Financial/Production History,* https://www.bluescope.com/investors/financial-information/

Burnbank Consulting, 2000. *Synthetic gas use in non-Montreal Protocol industries.* Australian Greenhouse Office, April 2000.

2002*, Inventories and projections of ozone depleting substances and synthetic greenhouse gases used in Montreal Protocol industries.* Environment Australia, Canberra.

CIF (Cement Industry Federation), 2003. *Cement Industry Environment Report.* Cement Industry Federation. 2009, *Australian Cement Industry sustainability Report 2009,* Cement Industry Federation.

CSIRO (Commonwealth Scientific and Industrial Research Organisation), 2019. *Australian PFC, HFCandSF$_6$ emissions.* CSIRO Light Metals Flagship and Marine and Atmospheric Research, Victoria.

2011, *Review of Confidential Data Handling Practices I.* CSIRO Mathematics, Informatics and Statistics, Canberra.

DCC (Department of Climate Change), 2006, *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006.* Department of Climate Change, Canberra.

DEWHA (Department of the Environment, Water, Heritage and the Arts), 2005–2008. Unpublished data on hydrofluorocarbon imports: in bulk and pre-charged equipment, Canberra.

DISER (Department of Industry, Science, Energy and Resources), 2020, *Resources and Energy Quarterly December 2020,* Canberra

DISER (Department of Industry, Innovation and Science Industry, Science, Energy and Resources), 2020. *Australian Energy Statistics – Australian Energy Update 2020,* Canberra.

EITEIs, 2007 and 2008. Data collated by the Department of Climate Change under Emissions Intensive Trade Exposed Industries Program. EEA (European Environment Agency), 2009. *EMEP/EEA air pollutant emission inventory guidebook.* Copenhagen.

EMEP/EEA 2016 *air pollutant emission inventory guidebook 2016,* EEA Report No 21/2016

ENA (Energy Networks Association), 2008, *ENA Industry Guideline for SF_6Management,* ENA DOC 022-2008

EnerGreen Consulting, 2009 and 2008. *Greenhouse Gas Inventory for Industrial Processes and Solvents and Other Product Use,* EnerGreen Consulting, Nov 2009.

2011. *Nitrous Oxide Emissions from Nitric Acid Production: A Review of Emissions Abatement Technology,* EnerGreen Consulting April 2011.

EPA (NSW Environment Protection Authority), 1995. *Metropolitan Air Quality Study – Air Emissions Inventory,* Environment Protection Authority NSW.

2000. *State of the Environment 2000,* Environment Protection Authority, NSW. (https://www.epa.nsw.gov.au/about-us/publications-and-reports/state-of-the-environment).

Expert Group, 2013. *Cold Hard Facts 2, A Study of the refrigeration air conditioning industry in Australia.* Report to the Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Expert Group 2018, *Cold Hard Facts 3 - Review of the Refrigeration and Air Conditioning Industry in Australia.* https://www.environment.gov.au/protection/ozone/publications/cold-hard-facts-3

Fisher and Paykel, 2010. *Annual Report 2010.*

GHD, 2009c. *Report for emissions from the production of cement, lime, magnesia, synthetic rutile and aluminium in the industrial processes sector.* Report to the Department of Climate Change.

Grjotheim, K., and Welch B.J., 1980. *Aluminium Smelter Technology: A Pure and Applied Approach,* Aluminium Verlag GMBH, Dusseldorf.

International Aluminium Institute, 2005. *The International Aluminium Institutes Report on the Aluminium*

Industrys ' Global Perfluorocarbon Gas Emissions Reduction Programme – Results of the 2003 Anode Effect Survey. International Aluminium Institute, New Zealand House, London.

2006. *The Aluminium Sector Greenhouse Gas Protocol,* Addendum to the WRI/WBCSD GHG Prototcol, International Aluminium Institute.

2008. *Protocol for Measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminum Production,* International Aluminium Institute, New Zealand House, London.

IPCC (Intergovernmental Panel on Climate Change), 1996. *Climate Change 1995: The Science of Climate Change.* Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge.

1997. *Revised 1996IPCC Guidelines for National Greenhouse Gas Inventories:* Volume 1, Greenhouse Gas Inventory Reporting Instructions; Volume 2, Greenhouse Gas Inventory Workbook; Volume 3, Greenhouse Gas Inventory Reference Manual IPCC/OECD/IEA, Paris, France.

2000. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Japan. 2006 *IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

2010. *Use of models and facility-level data in greenhouse gas inventories,* report of IPCC expert meeting on the use of models and measurements in greenhouse gas inventories 9–11 Aug 2010, Sydney Australia. Japan IGES.

2014. 2013 *Revised supplementary methods and good practice guidance arising from the Kyoto Protocol,* IPCC Switzerland.

Kirk-Othmer, 1999. *Concise Encyclopedia of Chemical Technology,* Fourth Edition, John Wiley & Sons, Inc. USA.

Onesteel, 2009. *2009 Annual Report.* http://www.annualreports.com/HostedData/AnnualReportArchive/a/ASX_A.RL2.0.0.9.pdf

Rio Tinto, 2009. *2009 Annual report.* https://www.riotinto.com/invest/reports

Ryan, W.G., and Samarin, A., 1992. *Australian Concrete Technology,* Longman Cheshire, Melbourne. South32 Annual Reports – https://www.south32.net/investors-media

Transgrid 2011 *Transgrid network management plan 2011–2016–* https://www.transgrid.com.au/news-views/publications/network-management-plan/Documents/TransGrid%20Network%20Management%20Plan%202011–2016(2).pdf

Treadrea, P. 1995, *'The Environmental Consequences of Urban and Rural Bituminous Practices',* Australian Road Research Board Transport Research (ARRBTR), Melbourne.

Tsaranu, M., 2007. Report of quality assurance review of the Australia's National Greenhouse Gas Inventory 2006: Industrial Processes Sector. Report to the Australian Greenhouse Office.

USEPA (United States Environment Protection Agency), 1985. *Compilation of Air Pollutant Emission Factors,* Vol 1, Stationary Point and Area Sources, Fourth Edition, Research Triangle Park, North, USA.

1989. *Compilation and Speciation of National Emissions Factors for Consumer/Commercial Solvent Use.* EPA-450/2-89-008.

1991b. *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone.* Volume 1: General Guidance for Stationary Sources. EPA-450/4–91–016. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

1995b. *Compilation of Air Pollutant Emission Factors,* Vol 1, Stationary Point and Area Sources. Fifth Edition, Research Triangle Park, NC, USA.

1997. *Emission Inventory Improvement Program,* Document Series Volume 3 – Chapter 6, https://www.epa.gov/air-emissions-inventories/volume-3-area-sources-and-area-source-method-abstracts

2008. *Protocol for Measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production),* Washington, D.C. and London, U.K.

Vinyl Council Australia website, last accessed May 2020. *PVC Safe Manufacturing > Manufacturing Process.* https://vinyl.org.au/about-vinyl/manufacturing-process

WBCSD (World Business Council for Sustainable Development), 2005. *The Cement* CO_2*Protocol,* CO_2*accounting and Reporting Standard for the Cement Industry.* Cement Sustainability Initiative, Climate Protection Task Force, Protocol Guidance Document Version 2.0.

5. Agriculture

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020a. Australian Commodity Statistics, June 2020, Canberra. [Accessed 14 July 2020]

ABARES, 2020b. Australian Crop Report. December 2020, Canberra. [Accessed 10 December 2020]

ABARES, 2020c. MLA Farm Survey Data – Lambing rates, http://apps.agriculture.gov.au/mla/. [Accessed 14 July 2020]

ABS (Australian Bureau of Statistics), 1999. Agriculture 1997-98. Catalogue no. 7113.0, Canberra.

ABS, 2007. Selected Agricultural Commodities, Australia. 2005-06. Catalogue no. 7112.0, Canberra.

ABS, 2018. Land Management and Farming in Australia, 2016–17. Catalogue no. 4627.0, Canberra. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4627.0>. [Accessed 10 January 2020]

ABS, 2020a. Agricultural Commodities, Australia, 2018–19. Catalogue no. 7121.0, Canberra. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/7121.0>. [Accessed 25 August 2020]

ABS, 2020b. Livestock Products – chicken meat produced, Australia, January–March 2020, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/7215.0> [Accessed 20 May 2020]

ABS, 2020c. Livestock Products – livestock slaughtered, Australia, January-March 2020, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/7215.0> [Accessed 5 August 2020]

ABS, 2020d. Water use in Australia, 2018-19, Catalogue no. 4618.0, Canberra. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4618.0>. [Accessed 31 July 2020]

AECL (Australian Egg Corporation Limited), 2012. Egg industry overview – 2011/2012, Sydney, NSW. <https://www.australianeggs.org.au>. [Accessed May 2019]

AFRC (Agriculture and Food Research Council), 1990. Nutritive requirements of ruminant animals: energy. Agriculture and Food Research Council Technical Committee on Responses to Nutrients, Report Number 5. Nutrition Abstracts and Reviews (Series B), vol. 60, pp. 729-804.

ALFA (Australian Lot Feeders Association), 2020. ALFA/MLA feedlot Survey Quarterly Reports, July-September 2020, <http://www.feedlots.com.au/industry/quarterly-survey>. [Accessed 20 October 2020]

ARC (Agricultural Research Council), 1980. The nutrient requirements of ruminant livestock. Agricultural Research Council Technical Review, Commonwealth Agricultural Bureau, Farnham Royal.

Australian Soil Classification, second edition, 2016. CSIRO Publishing, Canberra, https://www.clw.csiro.au/aclep/asc_re_on_line_V2/soilhome.htm

AWTA (Australian Wool Testing Authority), 2020. AWTA Key Test Data September 2020-21, https://www.awtawooltesting.com.au/index.php/en/statistics/key-test-data-new/monthly-report/ pdf-version-monthly-reports. [Accessed 20 October 2020]

Barton, L., Kiese, R., Gatter, D., Butterbach-Bahl, K., Buck, R., Hinz, C. and Murphy, D.V., 2008. Nitrous oxide emissions from a cropped soil in a semi-arid climate. Global Change Biology, vol. 14, pp. 177-192.

Bouwman, A.F., Boumans, L.J.M. and Batjes N.H., 2002. Emissions of N_2O and NO from fertilized fields: Summary of available measurement data. Global Biogeochemical Cycles, vol. 16, pp. 1058, doi:10.1029/2001GB001811.

Bray, S., Walsh, D., Hoffmann, M., Henry, B., Eady, S., Collier, C., Pettit, C., Navarro, J. and Corbet, D., 2015. Desktop research project to provide data on liveweight and liveweight gain in the beef cattle sector in Queensland and the Northern Territory. Department of Agriculture and Fisheries, Rockhampton, Queensland.

Brouwer, E., 1965. Report of sub-committee on constants and factors in energy metabolism, Proceedings of the 3rd International Symposium on Energy Metabolism. ed. K.L. Blaxter, European Association for Animal Production, Scotland 1964, Publication No.11, pp. 441-443.

Cabaraux, J.F., Philippe, F.X., Laitat, M., Canart, B., Vandenheede, M. and Nicks, B., 2009. Gaseous emissions from weaned pigs raised on different floor systems. Agriculture, Ecosystems and Environment, vol. 130, no. 3-4, pp. 86-92.

Canegrowers Association Queensland, 2020. Sugar Cane Production 2018-19. Unpublished data. Annual data related to sugar cane production provided to the Department of Industry, Science, Energy and Resources.

Charmley, E., Williams, S.R.O., Moate, P.J., Hegarty, R.S., Herd, R.M., Oddy, H., Reyenga, P, Staunton, K.M., Anderson, A. and Hannah, M.C., 2015. A universal relationship to predict methane production of forage-fed cattle in Australia. Animal Production Science, CSIRO, <http://dx.doi.org/10.1071/AN15365> [Accessed 10 January 2019]

Christensen, K. and Thorbek, G., 1987. Methane excretion in the growing pig. British Journal of Nutrition, vol. 57, pp. 355-361.

Christie, K.M., Gourley, C.J.P., Rawnsley, R.P., Eckard, R.J. and Awty, I.M., 2012. Whole-farm systems analysis of Australian dairy farm greenhouse gas emissions. Animal Production Science, vol. 52, pp. 998-1011.

Dairy Australia, 2019. Australian Dairy Industry in Focus 2019, <https://www.dairyaustralia.com.au/industry/ farm-facts/in-focus>, [Accessed 25 May 2020]

Dairy Technical Working Group, 2015. Review of the methods and data used to estimate dairy cattle emissions in the national inventory. A report to the Department of the Environment.

DCC (Department of Climate Change), 2006, Australian methodology for the estimation of greenhouse gas emissions and sinks 2006: Industrial processes. Department of Climate Change, Canberra.

DCC (Department of Climate Change), 2009, Survey of the Australian Wastewater Treatment Industry 2009. Department of Climate Change, Canberra.

DEWR (Department of the Environment and Water Resources), 2007. National Pollutant Inventory emission estimation technical manual for intensive livestock – Beef Cattle Version 3.1, May 2007. DEWR, Canberra. http://www.npi.gov.au/resource/emission-estimation-technique-manual-intensive-livestock-beef-cattle-version-31 [Accessed 5 December 2013]

DSEWPC (Department of Sustainability, Environment, Water, Population and Communities), 2013. National Pollution Inventory emission estimation technical manual for intensive livestock – Poultry raising, Version 3, June 2013, DSEWPC, Canberra.

FIFA (Fertilizer Industry Federation of Australia), 2020. Unpublished data for 2018-19. Annual fertiliser data to calculate fraction of N fertiliser by production system, provided by FIFA to the Department of Industry, Science, Energy and Resources.Flessa, H., Dorsch, P., Beese, F., Koenig H. and Bouwman A.F., 1996. Influence of cattle wastes on nitrous oxide and methane fluxes in pasture land, Journal of Environmental Quality, vol. 25, pp. 1366–1370.

Fortes, C., Vitti, A.C., Otto, R., Ferreira, D.A., Franco, H.C.J. and Trevelin, P.C.O., 2013. Contribution of nitrogen from sugarcane harvest residues and urea for crop nutrition. Scienta Agricola, vol. 70(5), pp. 313–320

Freer, M., Moore, A.D. and Donnelly, J.R., 1997. GRAZPLAN: Decision support systems for Australian gazing enterprises II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS, Agricultural Systems, vol. 54, pp. 77-126.

FSA Consulting, 2007. Reviewing ammonia emission factors for deep litter piggeries. Report prepared for the Department of the Environment and Water Resources.

Galbally, I.E., Meyer, C.P., Bentley, S., Weeks, I., Leuning, R., Kelly, K., Phillips, F., Barker-Reid, F., Gates, W., Baigent, R., Eckard R. and Grace, P., 2005. A study of environmental and management drivers of non-CO_2 greenhouse gas emissions in Australian agro-ecosystems, Environmental Sciences, vol. 2, pp. 133-142.

Galbally, I.E., Meyer, C.P, Wang, Y-P, Weeks, I.A., Smith, C., Howden, S.M., Elsworth, C.M., Petraitis, B., Johnson, E., McLachlan, G., Huang G. and McKenney, D.L., 1994. RIRDC Project CSD-47A – The role of legume pasture in greenhouse gas emissions from Australia. Final report, CSIRO Division of Atmospheric Research, Victoria, Australia 56pp.

Gopalan, P., Jensen, P.D. and Batstone, D.J., 2013. Biochemical methane potential of beef Feedlot manure: Impact of manure age and storage. Journal of Environmental Quality, vol. 42, 1205-1212.

Graham, N.M., 1964a. Energetic efficiency of fattening sheep. I. Utilization of low-fibre and high-fibre food mixtures. Australian Journal of Agricultural Research, vol. 15, pp. 100–112.

Graham, N.M., 1964b. Energetic efficiency of fattening sheep. II. Effects of undernutrition, Australian Journal of Agricultural Research, vol. 15, pp. 113–126.

Graham, N.M., 1967. The net energy value of three subtropical forages. Australian Journal of Agricultural Research, vol. 18, pp. 137–147.

Graham, N.M., 1969. The net energy value of artificially dried subterranean clover harvested before flowering, Australian Journal of Agricultural Research, vol 20, pp. 365–373.

Grinham et al., 2018. The importance of small artificial water bodies as sources of methane emissions in Queensland, Australia. Hydrology and Earth System Sciences, vol. 22, pp. 5281–5298.

Hops Products Australia, 2020. Annual Hops production in Australia (2019–20). Unpublished data provided to the Department of Industry, Science, Energy and Resources.

Howden, S.M., 2001. Analysis of National Livestock Statistics: Assessment for systematic reporting bias, in F. Ghassemi, D.H. White, S. Cuddy and T. Nakanishi (eds) Integrating models for natural resources Management across disciplines, issues and scales. Proceedings of the International Congress on Modelling and Simulation, December 2001, Canberra. Modelling and Simulation Society of Australia and New Zealand, Canberra. pp. 1841–1846.

Howden, S.M. and Barrett, D., 2003. Review of Australian methodology for estimating greenhouse gas emissions from livestock: Analysis of Tasmania and National Beef and Dairy Herd Data, CSIRO, report prepared for the Australian Greenhouse Office.

Howden, S.M., White, D.H., and Hegarty, R., 2002. The review of the National Greenhouse Gas Inventory for Australian Livestock, CSIRO Sustainable Ecosystems, Report prepared for the Australian Greenhouse Office.

Howden, S.M., White, D.H., McKeon, G.M., Scanlan, J.C., and Carter J.O., 1994. Methods for Exploring Management Options to Reduce Greenhouse Gas Emissions from Tropical Grazing Systems, Climatic Change, vol. 27, pp. 49–70.

Hunter, R.A., 2007. Methane production by cattle in the tropics, British Journal of Nutrition, vol. 98, pp. 657.

Hurst, D.F. and Cook, G.D., 1994. Trace gas emissions from biomass burning in tropical Australian savannas, Journal of Geophysical Research, vol. 99, pp. 16441–16456.

Hurst, D.F., Griffith D.W.T., Carras, J.N., Williams, D.J. and Fraser, P.J., 1994. Measurements of trace gases emitted by Australian savanna fires during the 1990 dry season, Journal of Atmospheric Chemistry, vol. 18, pp. 33-56.

Incitec Pivot Fertilisers, 2018. Unpublished data related to nitrogen and phosphorous rates in sugarcane (2016-17), provided to the Department of the Environment and Energy.

IPCC (Intergovernmental Panel on Climate Change), 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 1, Greenhouse Gas Inventory Reporting Instructions; Volume 2, Greenhouse Gas Inventory Workbook; Volume 3, Greenhouse Gas Inventory Reference Manual IPCC/OECD/ IEA, Paris, France.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds).

IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P and Federici, S. (eds). Published: IPCC, Switzerland.

Janzen, H.H., Beauchemin, K.A., Bruinsma, Y., Campbell, C.A., Desjardins, R.L., Ellert, B.H. and Smith, E.G., 2003. The fate of nitrogen in agroecosystems: An illustration using Canadian estimates, Nutrient Cycling in Agroecosystems, vol. 67, pp. 85-102.

King, R.H. and Brown, W.G., 1993. Interrelationships between dietary protein level, energy intake and nitrogen retention in pregnant gilts, Journal of Animal Science, vol. 71, pp. 2450–2456.

King, R.H, Toner, M.S., Dove, H., Atwood, C.S. and Brown, W.G., 1993. The response of first-litter sows to dietary protein level during lactation, Journal of Animal Science, vol. 71, pp. 2457–2463.

Kirchgessner, M., Kreuzer, M., Muller, H.L. and Windisch, W., 1991. Release of methane and of carbon dioxide by the pig, Agribiological Research, vol. 44, pp. 103–113.

Kurihara, M., Magner, T., Hunter, R.A. and McCrabb G.J., 1999. Methane production and energy partition of cattle in the tropics, British Journal of Nutrition, vol. 81, pp. 263–272.

Leuning, R., Baker, S.K., Jamie, I.M., Hsu, C.H., Klien, L., Denmead, O.T. and Griffith, D.W.T., 1999. Methane emissions from free-range sheep: a comparison of two measurement methods. Atmospheric Environment, vol. 33, pp. 1357–1365.

Loh, Z., Chen, D., Bai, M., Naylor, T., Griffith, D., Hill, J., Denmead, T., McGinn, S. and Edis, R., 2008. Measurement of greenhouse gas emissions from Australian feedlot beef production using open-path spectroscopy and atmospheric dispersion modelling, Australian Journal of Experimental Agriculture, vol. 48, no. 2, pp. 244-247.

Margan, D.E., Graham, N. M. and Searle, T.W., 1987. Energy values of whole oats grain in adult wether sheep, Australian Journal of Experimental Agriculture, vol. 27, pp. 223-230.

Margan, D.E., Graham, N. M. and Searle, T.W., 1985. Energy values of whole lucerne (Medicago sativa) and of its stem and leaf fractions in immature and fully grown sheep. Australian Journal of Experimental Agriculture, vol. 25, pp. 783-790.

Margan, D.E., Graham, N. M., Minson, D.J. and Searle, T.W., 1988. Energy and protein values of four forages, including a comparison between tropical and temperate species. Australian Journal of Experimental Agriculture, vol. 28, pp. 729-736.

McGahan, E.J., Casey, K.D., van Sliedregt, H., Gardner, E.A., Watts, P.J. and Tucker, R.W., 2004. Beefbal – A nutrient balance model for feedlots, version 1.1, Department of Primary Industries, Toowoomba.McGinn, S.M., Chen, D., Loh, Z., Hill, J., Beauchemin, K.A. and Denmead, O.T., 2008. Methane emissions from feedlot cattle in Australia and Canada, Australian Journal of Experimental Agriculture, vol. 48, pp. 183–185.

Minson, D.J. and McDonald, C.K., 1987. Estimating forage intake from the growth of beef cattle. Tropical Grasslands, vol. 21, pp 116–122.

MLA (Meat and Livestock Australia), 2002. 2002 Lamb Survey. Market Information Services, MLA Australia.

MLA, 2012. National guidelines for beef cattle feedlots in Australia. 3rd Edition, Meat & Livestock Australia, Sydney.

Moe, P.W. and Tyrrell, H.F., 1979. Methane production in dairy cows. Journal of Dairy Science, vol. 62, pp. 1583–1586.

Morris, D.R. and Tai, P.Y.P., 2004. Water table effects on sugarcane root and shoot development. Journal American Society Sugar Cane Technologies, vol. 24, pp. 41–59

Moss, A.R., 1993. Methane: Global warming and production by animals. Chalcombe Publications, Canterbury, UK, 105pp.

Mulholland, J.G., Coombe, J.B., Freer M. and McManus, W.R., 1976. An evaluation of cereal stubbles for sheep production. Australian Journal of Agricultural Research, vol. 27, pp. 881–893.

National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Cwlth), ComLaw, http://www.comlaw.gov.au/Details/F2011C00469.

NGGIC (National Greenhouse Gas Inventory Committee), 1996. The Australian methodology for the estimation of greenhouse gas emissions and sinks, Workbook for Livestock, National Greenhouse Gas Inventory Committee Workbook 6.1, Canberra.

NGGIC (National Greenhouse Gas Inventory Committee), 2007. Australian methodology for the estimation of greenhouse gas emissions and sinks 2006: Agriculture, Canberra.

Nicks, B., Laitat, M., Farnir, F., Vandenheede, M., Desiron, A., Verhaeghe, C. and Canart, C., 2003. Emissions of ammonia, nitrous oxide, methane, carbon dioxide and water vapour in the raising of weaned pigs on straw-based and sawdust-based deep litters. Animal Research, vol. 52, pp. 99–107.

Nicks, B., Laitat, M., Farnir, F., Vandenheede, M., Verhaeghe, C. and Canart, C., 2004. Gaseous emissions in the raising of weaned pigs on fully slatted floor or on straw-based deep litter. Proceedings of the International Society for Animal Health Hygiene, pp. 69-70.

NSW Sunshine Sugar, 2020. Unpublished 2018-19 data related to crop production of sugarcane and percentage of sugarcane burned in NSW' provided to the Department of Industry, Science, Energy and Resources.

Oenema, O., Velthoft, G.L., Yamulki S. and Jarvis, S.C., 1997. Nitrous oxide emissions from grazed grassland. Soil Use and Management, vol. 13, pp. 288-295.

Ollivier, Q.R., Maher, D.T., Pitfield, C. and Macreadie, P.I., 2019. Punching above their weight: Large release of greenhouse gases from small agricultural dams. Global Change Biology, vol. 25(2), pp. 721-732.

Parker, D.B., Waldrip, H., Casey, K., Woodbury, B., Spiehs, M., Webb, K. and Willis, W. (2018). How do temperature and rainfall affect nitrous xxide emissions from open-lot beef cattle feedyard pens? Transactions of the ASABE, vol. 61, pp. 1049–1061. https://doi.org/10.13031/trans.12788

Philippe, F.X., Cabaraux, J.F. and Nicks, B., 2011. Ammonia emissions from pig houses: Influencing factors and mitigation techniques. Agriculture, Ecosystems & Environment, vol. 141(3-4), pp. 245-260.

Philippe, F.X., Canart, B., Laitat, M., Wavreille, J., Bartiaux-Thill, N., Nicks, B. and Cabaraux, J.F., 2010. Effects of available surface on gaseous emissions from group-housed gestating sows kept on deep litter, Animal, vol. 4(10), pp. 1716–1724.

Philippe, F.X., Laitat, M., Canart, B., Vandenheede, M. and Nicks, B., 2007. Comparison of ammonia and greenhouse gas emissions during the fattening of pigs, kept either on fully slatted floor or on deep litter. Livestock Science, vol. 111(1-2), pp. 144-152.

Philippe, F.X., Laitat, M., Nicks, B. and Cabaraux, J.F., 2012. Ammonia and greenhouse gas emissions during the fattening of pigs kept on two types of straw floor. Agriculture, Ecosystems & Environment, vol. 150, pp. 45-53.

Raupach, M., Kirby, M., Briggs, P. and Barrett, D., 2000. Balancing the Australian biosphere: continental budgets of water, carbon, nitrogen and phosphorus. Project 5.4A. Final report to the National Land and Water Resources Audit, Canberra.

Redding, M., Devereux, J., Phillips, F., Lewis, R., Naylor, T., Kearton, T., Hill, J.V. and Weidemann, S., 2015. Field measurement of beef pen manure methane and nitrous oxide emissions reveals a surprise for inventory calculations. Journal of Environmental Quality, vol. 44, pp. 720-728.

Robinson, D.W. and Kirkby, C.A., 2002. Maize stubble management survey: summary of results. CSIRO Land and Water Technical Report 13/02, CSIRO Land and Water, Canberra.

Rotz, C.A., 2004. Management to reduce nitrogen losses in animal production. Journal Animal Science, vol. 82, pp. 119-137.

SCA (Standing Committee on Agriculture), 1990. Feeding standards for Australian livestock, Ruminants. SCA ruminant sub-committee, CSIRO Australia.

Scherbak, I. and Grace, P., 2014. Determination of emission factors for estimating fertiliser-induced nitrous oxide emissions from Australia's rural production systems. Report to the Department of the Environment.

Scherbak, I., Grace, P., Macdonald, B., Scheer, C. and Rowlings, D., 2014. Determination of emission factors for estimating nitrous oxide emissions from Australia's cotton industry, Report to the Department of the Environment.

Shorten, P.R. and Redding, M.R., submitted. Models fitted to manure emissions contract with inventory. Journal of Environmental Quality, Submitted for publication 30/5/2014, pp. 32.Skerman, A., 2000, Reference manual for the establishment and operation of beef cattle feedlots in Queensland, Information Series QI99070, Queensland Cattle Feedlot Advisory Committee (FLAC), Department of Primary Industries, Toowoomba, QLD.

Skerman, A., Willis, S., Marqardt, B. and McGahan, E., 2013. 'PigBal4 user manual', Version 2.3, Department of Agriculture, Fisheries and Forestry, State of Queensland.

Snowdon, P., Ryan, P. and Raison, J., 2005. Review of C:N ratios in vegetation, litter and soil under Australian native forests and plantations. National Carbon Accounting System Technical Report No. 45 (60pp), Australian Greenhouse Office, Canberra.

Stewart, J.B., Smart, R.V., Barry, S.C. and Veitch, S.M., 2001. 1996/97 Land Use of Australia – Final Report for Project BRR5. National Land and Water Resources Audit, Canberra.

Sun, J., Bai, M., Shen, J., Griffith, D.W.T., Denmead, O.T., Hill, J., Lam, S.K., Mosier, A.R. and Chen, D., 2016. Effects of lignite application on ammonia and nitrous oxide emissions from cattle pens. Science of the Total Environment, vol. 565, pp. 148–154. https://doi.org/10.1016/j.scitotenv.2016.04.156

Sunshine Sugar, 2020. Unpublished data related to crop production of sugar cane and percentage of sugar cane burned in NSW (2018-19) provided to the Department of Industry, Science, Energy and Resources.

Tucker, R.W., Lott, S.C., Watts, P.J., and Jukes, P.D., 1991. Lot feeding in Australia – a survey of the Australian lot feeding industry. Information Series QI91019, Department of Primary Industries, Brisbane.

Tucker, R.W., McGahan, E., Galloway, J.L. and O'Keefe, M.F., 2010. National environmental guidelines for piggeries – Second edition, APL Project 1832, Australian Pork Ltd, Deakin.

van Sliedregt, H., McGahan, E. and Casey, K., 2000. Predicting waste production from feedlot cattle. Unpublished confidential report prepared for Cattle and Beef CRC (Meat Quality) Sub-Program 6 – Feedlot Waste Management, DPI Intensive Livestock Environmental Management Services, Toowoomba, Queensland.

Waldrip, H.M., Todd, R.W., Parker, D.B., Cole, N.A., Rotz, C.A. and Casey, K.D. 2016. Nitrous oxide emissions from open-lot cattle feedyards: A review. Journal of Environmental Quality, vol. 45, pp. 1797–1811. https://doi.org/10.2134/jeq2016.04.0140

Watts, P., McGahan, E., Bonner, S.L. and Wiedemann, S., 2012. Feedlot mass balance and greenhouse gas emissions – A literature review. Final report, Project B.FLT.0361, Meat & Livestock Australia, Sydney.

Watts, P.J. and Tucker, R.W., 1994. Designing better feedlots, Conference and Workshop Series QC94002, Department of Primary Industries, Brisbane.

White, D.H., Bowman, P.J., Morley, F.H.W., McManus, W.R. and Filan, S.J., 1983. A simulation model of a breeding ewe flock. Agricultural Systems, vol. 10 pp. 149–189.

White, D.H., 2002. A check of the internal consistency of pasture and livestock data used to estimate levels of greenhouse gas emissions from the sheep and beef cattle industries. Unpublished report to the Australian Greenhouse Office and CSIRO Sustainable Ecosystems, ASIT Consulting.

Whittemore, C., 1993. Energy value of feedstuff's for pigs. The science and practice of pig production. Longmans Scientific and Technical Publications, USA.

Wiedemann, S. and Longworth, E., 2020. Review of nitrous oxide emission factors used in the National Inventory Report for estimating GHG from feedlots. Report to the Department of Industry, Science, Energy and Resources, Meat and Livestock Australia, North Sydney.

Wiedemann, S., McGahan, E. and Murphy, C., 2012. Energy, water and greenhouse gas emissions in Australian pork supply chains: A life cycle assessment, Pork Co-operative Research Centre, Adelaide.

Wiedemann, S., Sullivan, T. and McGahan, E.J., 2014. GHG Prediction methods for feedlots, poultry and pigs. Technical report for the Department of Environment Greenhouse Gas Inventory Team, FSA Consulting Report 8199/1.

Williams D.J., 1993. Methane emissions from the manure of free-range dairy cows. Chemosphere, vol. 26, pp. 179-187.

Williams, Y. and Wright, A., 2005. Variation in methane output between sheep. Abstracts Greenhouse 2005: Action on Climate Change, Melbourne, Victoria, 13-17 November 2005. CSIRO, Australia, pp. 110.

Yamulki, S. and Jarvis, S.C., 1997. Nitrous oxide emissions from excreta form a simulated grazing pattern and fertiliser application to grassland. Gaseous emissions from grasslands, eds: S.C. Jarvis and B.F. Pain, CAB International, Wallingford, UK, pp. 195-199.

A1.1.1 Volume 2

6. Land Use, Land Use Change and Forestry

ABARES (Bureau of Rural Sciences), 2008. *State of the Forests Report 2008.* A five-yearly report produced by the Montreal Process Implementation Group for Australia on behalf of the Australian state and territory governments.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2013, *Australia's State of the Forests Report 2013,* a five-yearly report produced by the Montreal Process Implementation Group for Australia and the National Forest Inventory Steering Committee on behalf of the Australian, state and territory governments.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2014. *Catchment Scale Land Use of Australia – Update March 2014,* Canberra.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2016, *Australia's plantations 2016 dataset,* Canberra.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2017. *Catchment Scale Land Use of Australia – Update September 2017,* Canberra.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2018, *Australian fisheries and aquaculture statistics 2017,* Fisheries Research and Development Corporation project 2018- 134, Canberra, Available at: http://www.agriculture.gov.au/abares/research-topics/fisheries/fisheries-data#australian-fisheries-and-aquaculture-statistics-2017 [Accessed 14 December, 2018].

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2019, *Australia's State of the Forests Report 2018*, A five-yearly report produced by the Montreal Process Implementation Group for Australia and the National Forest Inventory Steering Committee on behalf of the Australian, state and territory governments.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020a, *Australian Forest and Wood Products Statistics, ABARES technical report,* Canberra, July 2020.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020b, *Australian plantation statistics 2020 update*, Canberra

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), n.d. *National scale land use data,* Canberra, http://www.agriculture.gov.au/abares/aclump/land-use/data-download [Accessed 15 February 2017]

ABS (Australian Bureau of Statistics), 2010. *Australian statistical geography standard (ASGS): Volume 1 – main structure and greater capital city statistical areas.* Australian Bureau of Statistics, Canberra.

ABS (Australian Bureau of Statistics), 2013a *7121.0 – Agricultural Commodities, Australia, 2010–11* Available at: https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia [Accessed 22 April 2016].

ABS (Australian Bureau of Statistics), 2013b *4630.0 – Agricultural Resource Management Practices, Australia, 2011–12.* Available at: http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/4630.0 [Accessed 24 May 2015].

ABS (Australian Bureau of Statistics), 2018 *7121.0 – Agricultural Commodities, Australia, 2017–18* Available at: https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia [Accessed 18 March 2019].

ABS (Australian Bureau of Statistics), 2017a 4627.0 – *Land Management and Farming in Australia, 2016–17* Available at: https://www.abs.gov.au/statistics/industry/agriculture/land-management-and-farming-australia [Accessed 18 March 2018].

ABS (Australian Bureau of Statistics) 2017b *4680.0 – Experimental Envionmental-Economic Accounts for the Great Barrier Reef, 2017* Available at: https://www.abs.gov.au/statistics/environment/environmental-management/experimental-environmental-economic-accounts-great-barrier-reef/2017

ABS (Australian Bureau of Statistics). 2020. '4618.0 – *Water Use on Australian Farms, 2017–18',* Australian Government, https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms [Accessed 12 February 2020].

Ajani, J. and Comisari, P., 2014. *Towards a comprehensive and fully integrated stock and flow framework for carbon accounting in Australia,* a discussion paper, Australian National University, Canberra.

Alvey, S., Bagayoko, M., Neumann, G., Buerkert, A., 2001. *Cereal/legume rotations affect chemical properties and biological activities in two West African soils.* Plant and Soil 231: 45-54.

Andreae, M.O and Merlot, P, 2001. *Emission of trace gases and aerosols from biomass burning.* Global Biogeochemical Cycles, 15(4): 955-966.

AUSLIG (Australian Surveying and Land Information Group), 2001. *Digital Elevation Model of Australia, version 2.0.* Canberra, Australia.

Australian Broadcasting Corporation (ABC) Library Sales, 2015 ©. *Land clearing in Queensland was made easier under the LNPs ' Campbell Newman, but Labor wants to change that.* http://www.abc.net.au/news/ 2015-09-17/land-clearing-in-queensland-was-made-easier-under-the-lnp/6782238 Photo by McCarthy, M. for ABC Sunshine Coast.

Baillie, C. 2008, "Assessment of evaporation losses and evaporation mitigation technologies for on farm water storages across Australia". In *Irrigation Matters Series,* 52. National Center for Engineering in Agriculture.

Baker, T.G., and Attiwill, P.M., 1985. *Above-ground nutrient distribution and cycling in Pinus radiata D. Don and Eucalyptus obliqua L'Herit. forests in southeastern Australia,* Forest Ecology and Management, 13:41–52.

Baker-Blocker, Anita, Thomas M. Donahue, and Khalil H. Mancy. 1977. 'Methane flux from wetlands areas', Tellus, 29: 245-50.

Baldock, J., Karunaratne, S., Reddy, S., Shepherd, N., 2021. *Application of the IPCC Tier2 SOC model to Australian Croplands.* CSIRO, Australia.

Baldock, J.A., Sanderman, J., Macdonald, L.M., Puccini, A., Hawke, B., Szarvas, S. and McGowan, J., 2013. *Quantifying the allocation of soil organic carbon to biologically significant fractions.* Soil Research, 51(8), pp.561-576

Barrett, D. J., Galbally, I. E. and Graetz, R. D. 2001 *Quantifying uncertainty in estimates of C emissions from above-ground biomass due to historic land-use change to cropping in Australia.* Global Change Biology 7(8):883-902

Barson, M., Randall, L. and Bordas, V. 2000 *Land cover change in Australia,* Bureau of Rural Sciences, Australian Government, Canberra.

Bolinder, M., Janzen, H., Gregorich, E., Angers, D., VandenBygaart, A, 2007. An *approach for estimating net primary productivity and annual carbon inputs to soil for common agricultural crops in Canada.* Agriculture, Ecosystems and Environment 118, 29-42.

Boomsma, D.B., and Hunter, I.R., 1990. *Effects of water, nutrients and their interactions on tree growth, and plantation forest management practices in Australasia: a review.* Forest Ecology and Management 30: 455-476.

Brack, C.L. and Richards, G.P., 2002. *Carbon Accounting Model for Forests in Australia.* Environmental Pollution, 116: 187-194.

Brack, C.L., Richards, G.P. and Waterworth, R.M., 2006. *Integrated and comprehensive estimation of greenhouse gas emissions from land systems.* Sustainability Science, 1: 91-106.

Bray, J., 1962. *Root production and the estimation of net productivity.* Department of Botany, University of Toronto, Toronto 5, Ontario. September 14.

Bradstock, R., Gill, A., Williams, R., 2012. *Flammable Australia. Fire Regimes, Biodiversity and Ecosystems in a Changing World.* CSIRO Publishing.

Breiman, L., 2001. *Random Forests, Machine Learning,* 45(1), 5-32.

Bridgewater, P. B. and Cresswell, I.D., 1999. *Biogeography of mangrove andsaltmarsh vegetation: implications for conservation and management in Australia.* Mangroves and Salt Marshes 3(2): 117-125.

Bulinski, J., Enright, R. and Tomsett, N., 2016. *Tree Clearing in Australia: Its 'contribution to Climate Change.* CO_2 Australia, a report to the Wilderness Society.

Bureau of Meteorology. *El Nino Southern Oscillation Index.* http://www.bom.gov.au/climate/enso/soi/

Bureau_of_Meteorology. 2016. *Average annual & monthly maximum, minimum, & mean temperature,* Australian Government, Accessed 11/02/2020. http://www.bom.gov.au/jsp/ncc/climate_averages/ temperature/index.jsp?maptype=6&period=an.

Burrows, W., Hoffman, B., Compton, J., and Back, P., 2001. *Allometric Relationships and Community Biomass Stocks in White Cypress Pine (Callitris glaucophylla) and Associated Eucalypts of the Carnarvon Area – South Central Queensland.* National Carbon Accounting System Technical Report No. 33, Australian Greenhouse Office, Canberra.

Burrows, W., Henry, B.K., Back, PV., Hoffmann, T.B., Tait, L.J., Anderson, E.R., Menke, N., Danaher, T., Carter, J.O., and McKeon, G.M., 2002. *Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications.* Global Change Biology 48, 769-784.

Butler, A. and Jernakoff, P., 1999 *Seagrasses in Australia: strategic review and development of an R & Dplan.* (FRDC Project 98/223) CSIRO Publishing, Collingwood, Victoria.

Bryant, G., Campbell, N.A., Chia, J., Furby, S., Kiiven, H.J., Richards, G.P, Wallace, J. and Wu, X., 2003. *Notes on Mapping and Monitoring Forest Change in Australia Using Remote Sensing and Other Data.* In the 30th International Symposium of Remote Sensing and the Environment, Hawaii, November 10-14.

Bryant, K.L., Wilson, P.R., Biggs, A.J.W., Brough, D.M., and Burgess, J.W., 2008. *Soil Indicators of Queensland Wetlands: Statewide assessment and methodology.* Queensland Department of Natural Resources and Water, Brisbane.

Caccetta, PA. and Furby, S., 2004. *Monitoring Sparse Perennial Vegetation Cover.* In The 12th Australasian Remote Sensing and Photogrammetry Conference Proceedings, Fremantle, Western Australia, 18-22 October.

Caccetta, P.A. and Chia, J., 2004. *Remote Sensing Methods for Plantation Attribution – Experiments and results for Mapsheet Si50.* CSIRO Mathematical and Information Sciences.

Caccetta, P.A., 1997. *Remote sensing, geographic information systems (GIS) and Bayesian knowledge-based methods for monitoring land condition,* PhD thesis, Curtin University of Technology, pp 184-203.

Campbell, Stuart J., and Len J. McKenzie. 2004. *Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia,* Estuarine, Coastal and Shelf Science, 60: 477-90.

Casper, Peter, Stephen C. Maberly, Grahame H. Hall, and Bland J. Finlay. 2000. *Fluxes of methane and carbon dioxide from a small productive lake to the atmosphere,* Biogeochemistry, 49: 1–19.

Chappell, A., and Baldock, J., 2017. *Modelling Australian soil organic carbon dynamics.* Report to the Australian Government, Department of Environment. CSIRO, Australia.

Commonwealth of Australia n.d. *Land Sector Technical Reports.* Prepared for the Department of the Environment, Canberra Australia. Available at: http://fullcam.com/FullCAMServer2020/Help/

Coops, N.C., Waring, R.H. Brown, S. and Running, S.W. 2001 *Comparisons of predictions of net primary productivity and seasonal patterns in water use derived with two forest growth models in south-western Oregon.* Ecological Modelling. 142:61–8.

Coops, N.C., Waring, R.H., and Landsberg, J.J., 1998. *Assessing forest productivity in Australia and New Zealand using a physiologically-based model driven with averaged monthly weather data and satellite derived estimates of canopy photosynthetic capacity.* Forest Ecology and Management 104:113–127.

Cresswell, I., 2012. *Towards an understanding of mangrove diversity in Australia.* Murdoch University.

Crossman, S., Li, O. 2015. *Surface Hydrology Polygons (National).* Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/83135. [Accessed 01 June, 2018]

Davidson, R. *Effects of soil nutrients and moisture on root/shoot ratios in Lolium perenne L. and Trifolium repens L.* CSIRO Pastoral Research Laboratory, Armidale, NSW, Australia. 28 December 1968.

Delmas, R., Lacaux, J.P., and Brocard, D., 1995. *Determination of biomass burning emission factors: methods and results.* Environmental Monitoring and Assessment, 38, 181–204.

Department of Agriculture and Fisheries, Queensland Government, 2017. *Supplements for scrub feeding beef cattle,* https://www.daf.qld.gov.au/business-priorities/agriculture/disaster-recovery/drought/managing/supplements-for-scrub-feeding-beef-cattle, May 2020.

Department of Jobs, Precincts and Regions, Victorian Government, 2020. *Harvested Logging Coupes*. DPJR Regulation and Compliance Group, 30 January 2020.

Department of Natural Resources and Mines (DNRM), 2013. *Managing fodder harvesting – A self-assessable vegetation clearing code.* Queensland Government.

Department of Science, Information Technology and Innovation (DSITI), Queensland Government 2015. *Land cover change in Queensland 2012 – 13 and 2013 – 14: a Statewide Landcover and Trees Study* (SLATS) report. Queensland Government, Brisbane.

Department of Science, Information Technology and Innovation (DSITI), 2015(a) *Wooded extent and foliage projective cover – Queensland 2013,* Queensland Government, Brisbane.

Department of Science, Information Technology and Innovation (DSITI), 2018 *Statewide Landcover and Trees Study, 2016–17 and 2017–18,* Queensland Government, Brisbane.

Department of the Environment, 2016. *'Quarterly Update at Australias' National Greenhouse Inventory'.* September 2015.

Devereux, D., Furby, S., and Caccetta, P., 2013. *ARG25 – NCAS-LCCP Geometric and Radiometric Interoperability.* CSIRO Technical Report.

Eamus, D., McGuiness, K. and Burrows, W., 2000. *Review of Allometric Relationships for Woody Biomass for Queensland, the Northern Territory and Western Australia.* National Carbon Accounting System Technical Report No. 5a (60pp). Australian Greenhouse Office, Canberra.

Eastham, J., Rose, C. *Tree/pasture interactions at a range of tree densities in an agroforestry experiment. I rooting patterns.* Aust. J. Res., 1990, 41, 683–95.

Erftemeijer, Paul L. A., and Roy R. Robin Lewis. 2006. *Environmental impacts of dredging on seagrasses:* A review, Marine Pollution Bulletin, 52: 1553-72

ERIC (Environmental Research and Information Consortium Pty Ltd), 2001. *Rates of Clearing of Native Woody Vegetation 1997–2000.* (22pp) Report to the NSW Department of Land and Water Conservation, Parramatta.

Fairman, T., Nitschke, C. and Bennett, L., 2015. *Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests.* International Journal of Wildland Fire.

Fensham, R, Fairfax, R and Dwyer M, 2012. *Potential aboveground biomass in drought-prone forest used for rangeland pastoralism,* Ecological Applications, 22(3), 2012, pp. 894-908

Federici, S., 2016a. *REPORT on the Services Agreement for a review of specific land sector elements of Australias' NGHGI. Forest land – Treatment of natural disturbances.* A report to the Department of the Environment.

Federici, S., 2016b. *REPORT on the Services Agreement for a review of specific land sector elements of Australias' NGHGI. Forest land – Forest conversion.* A report to the Department of the Environment.

Ferguson, I., Fox, J.C., Baker, T., Stackpole, D., and Wild, I., 2002. *Plantations of Australia – Wood Availability 2001–2004.* Bureau of Rural Sciences, Canberra, Australia.

Ford, A., 2004. *Site quality for Pinus radiata D. Don: Southern Tablelands NSW.* School of Resources, Environment and Society, Australian National University, Canberra, ACT.

Forestry Corporation of New South Wales, 2020. *Event Polygon Harvesting History Data from 1950.* Sydney, NSW.

Forestry Tasmania, 2008. *2008 Report – Sustainable forest management.* Forestry Tasmania, Hobart, Tasmania.

Forests NSW (New South Wales), 2008. *Forests NSW: Annual Report 2007-08.* Forests NSW, Sydney, Australia.

FPA (Forest Practices Authority), 2007. *The Annual Report of the Forest Practices Authority 2006–07.* Tasmania, Australia.

Furby, S., 2002. *Land Cover Change: Specifications for Remote Sensing Analysis.* National Carbon Accounting System Technical Report No. 9 (236pp), Australian Greenhouse Office, Canberra.

Furby, S.and Woodgate, P, 2002. *Pilot Testing of Remote Sensing Methodology for Mapping Land Cover Change.* National Carbon Accounting System Technical Report No. 16 (354pp), Australian Greenhouse Office, Canberra.

Furby, S., 2016. *General Guidelines for Thresholding Images Using Image Matching, Version 13,* Unpublished Report, CSIRO Data61

Gifford, R., 2000a. *Carbon Content of Woody Roots: Revised Analysis and a Comparison with Woody Shoot Components (Revision 1).* National Carbon Accounting System Technical Report No. 7 (10pp). Australian Greenhouse Office, Canberra.

Gifford, R., 2000b. *Carbon Content of Aboveground Tissues of Forest and Woodland Trees.* National Carbon Accounting System Technical Report No. 22 (28pp). Australian Greenhouse Office, Canberra.

Gower, S.T., Gholz, H.L., Nakane, K., and Baldwin, V.C., 1994. *Production and allocation patterns of pine forests.* Ecological Bulletins 43: 115-135.

Graetz, R. D., Wilson, M. A., and Campbell, S. K., 1995. *Landcover disturbance over the Australian continent.* Biodiversity Unit, Department of the Environment, Sport and Territories, Canberra.

Gregory, P., McGowan, M., Biscoe, P., Hunter, B, 1978. *Winter relations of winter wheat. 1. Growth of the root system.* J. agric. Sci., Camb, 91, 91–102.

Gregory, P., Palta, J., Batts, G, 1997. *Root systems and root:mass ratio – carbon allocation under current and projected atmospheric conditions in arable crops.* Plant and Soil 187, 221–228.

Grierson, P.F., Williams, K., and Adams, M.A., 2000. *Review of Unpublished Biomass Related Information: Western Australia, South Australia, New South Wales and Queensland.* National Carbon Accounting System Technical Report No. 25 (114pp). Australian Greenhouse Office, Canberra.

Griffin, E. A., Verboom, W H., and Allen, D., 2002. *Paired Site Sampling for Soil Carbon Estimation – WA.* National Carbon Accounting System Technical Report No. 38, Australian Greenhouse Office, Canberra.

Grinham, A., S. Albert, N. Deering, M. Dunbabin, D. Bastviken, B. Sherman, C. E. Lovelock, and C. D. Evans. 2018. *The importance of small artificial water bodies as sources of methane emissions in Queensland, Australia,* Hydrol. Earth Syst. Sci. Discuss, 22: 5281–98.

Guerschman, J. P, Hill, M.J., Renzullo, L.J., Barrett, D.J., Marks, A.S., Botha, E.J., 2009. *Estimating fractional cover of photosynthetic vegetation, non-photosynthetic vegetation and bare soil in the Australian tropical savanna region upscaling the EO-1 Hyperion and MODIS sensors.* Remote Sensing of Environment, 113(5): 928–945.

Hamblin, A.P., 2001. *Land, Department of the Environment and Heritage, Canberra*

Harms, B. and Dalal, R., 2003. *Paired Site Sampling for Soil Carbon Estimation – Qld.* National Carbon Accounting System Technical Report No. 37, Australian Greenhouse Office, Canberra.

Harms, B., Dalal, R.C. and Cramp, A.P,. 2005. *Changes in Soil Carbon and Soil Nitrogen after Tree Clearing in the Semi-arid Rangelands of Queensland.* Australian Journal of Botany (53) 639–650.

Haynes, C. D., 1985. *The pattern and ecology of munwag: traditional Aboriginal fire regimes in north-central Arnhem Land.* Proceedings of the Ecological Society of Australia, 13, pp 203–214.

Haynes, R.J. and Goh, K.M., 1980. *Variation in the nutrient content of leaves and fruit with season and crown position for two apple varieties.* Australian Journal of Agricultural Research 31(4) 739–748

Henzell, T., 2007. *Australian Agriculture Its History and Challenges,* CSIRO Publishing.

Hickey, J.E., 1994. *A floristic comparison of vascular species in Tasmanian old growth mixed forest with regeneration resulting from logging and wildfire.* Australian Journal of Botany, 42: 383–404.

Hill, J., Simpson, R., Moore, A., Chapman, D, 2006. *Morphology and response of roots of pasture species to phosphorus and nitrogen nutrition.* Plant and Soil, 286:7–19.

Hill, M.J., and Donald, G.E., 1998. *Australian Temperate Pastures Database.* CSIRO, CD ROM, Canberra.

Hingston, F.J., Dimmock, G.M., and Turton, A.G., 1981. *Nutrient distribution in a jarrah (Eucalyptus marginate Donn Ex Sm.) ecosystem in south-west Western Australia.* Forest Ecology and Management, 3: 183–207.

Hirte, J., Leifeld, J., Abiven, S., Mayer, J, 2018. *Maize and wheat root biomass, vertical distribution, and size class as affected by fertilization intensity in two long-term field trials.* Field Crops Research 216, 197–208.

Hurst, D.F., Griffith D.W.T., Carras, J.N., Williams, D.J., and Fraser, PJ., 1994a. *Measurements of trace gases emitted by Australian savanna fires during the 1990 dry season,* Journal of Atmospheric. Chemistry, 18, pp 33-56.

Hurst, D.F. and Cook, G.D., 1994b. *Trace gas emissions from biomass burning in tropical Australian savannas,* Journal of Geophysical Research, 99, pp 16441–16456.

Hurst, D.F. and Cook, G.D., 1996. *Trace gas emissions from biomass burning in Australia,* Biomass Burning and Global Change, Ed. J.S. Levine, M.I.T Press, USA. Vol 2 p787–792.

Hutchinson, M. and Xu, T., 2019. *Report to Department of Environment and Energy on Provision of Spatially Distributed Climate and Forest Productivity Data for the National Inventory System – 2018,* Fenner School of Environment and Society, Australian National University.

Ilic, J., Boland, D.J., McDonald, M., and Downes, G., 2000. *Wood Density – State of Knowledge.* National Carbon Accounting System Technical Report No. 18 (55pp). Australian Greenhouse Office, Canberra.

IPCC (Intergovernmental Panel on Climate Change), 1996. *Climate Change 1995: The Science of Climate Change.* Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change), 1997. *Revised 1996IPCC Guidelines for National Greenhouse Gas Inventories:* Volume 1, Greenhouse Gas Inventory Reporting Instructions; Volume 2, Greenhouse Gas Inventory Workbook; Volume 3, Greenhouse Gas Inventory Reference Manual IPCC/ OECD/IEA, Paris, France.

IPCC (Intergovernmental Panel on Climate Change), 2000. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Japan.

IPCC (Intergovernmental Panel on Climate Change), 2003. *Good Practice Guidance on Land Use, Land Use Change and Forestry,* Japan.

IPCC (Intergovernmental Panel on Climate Change), 2006. *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

IPCC (Intergovernmental Panel on Climate Change), 2010. *Use of models and facility-level data in greenhouse gas inventories,* report of IPCC expert meeting on the use of models and measurements in greenhouse gas inventories 9-11 Aug 2010, Sydney Australia. Japan IGES.

IPCC (Intergovernmental Panel on Climate Change), 2014(a). *2013 Revised supplementary methods and good practice guidance arising from the Kyoto Protocol,* IPCC Switzerland.

IPCC (Intergovernmental Panel on Climate Change), 2014(b) *2013 Supplement to the 2006IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands,* Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.

IPCC (Intergovernmental Panel on Climate Change), 2019. *2019 Refinement to the 2006IPCC Guidelines for National Greenhouse Gas Inventories*, Japan.

Jaakko Pöyry Consulting, 1999. *National Carbon Accounting System – Usage and Liecycle of Wood Products.* NCAS Technical Report No.8. Canberra.

Jaakko Pöyry Consulting, 2000. *Analysis of Wood Product Accounting Options for the National Carbon Accounting System.* National Carbon Accounting System Technical Report No. 24 (37pp). Australian Greenhouse Office, Canberra.

Jackson, R., Canadell, J., Ehleringer, J., Mooney, H., Sala, O., Schulze, E., 1996. *A global analysis of root distributions for terrestrial biomes.* Oecologia, 108:389-411.

Janik, L., Spouncer, L., Correll, R., and Skjemstad, J., 2002. *Sensitivity analysis of the Roth-Csoil carbon model (Ver. 26.3 Excel©)'.* National Carbon Accounting System Technical Report No. 30, Australian Greenhouse Office, Canberra.

Jenkinson, D.S., Adams, D.E. and Wild, A., 1991. *Model Estimates of* CO_2 *Emissions from Soil in Response to Global Warming.* Nature, 351: 304–306.

Jenkinson, D.S., Hart, P.B.S., Rayner, J.H., and Parry, L.C., 1987. *Modelling the Turnover of Organic Matter in Long-Term Experiments at Rothamsted.* INTERCOL Bulletin 15: 1–8.

Johnson, J., Allamaras, R., Reicosky, D, 2006. *Estimating source carbon from crop residues, roots and rhizodeposits using the nutrient grain-yield database.* Agronomy Journal, American Society of Agronomy. April 11, 2006.

Jones, S., Lowell, K.E., Woodgate, P, Buxton, L., Mager, A., and Liebchen, S., 2004. *Update on the National Carbon Accounting System Continuous Improvement and Verification Methodology.* National Carbon Accouting System Technical Report 46, Australian Greenhouse Office.

Keating, B.A., Carberry, P.S., Hammer, G. L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J. N.G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J.P, Silburn, M., Wang, E., Brown, S., Bristow, K. L., Asseng, S., Chapman, S., McCown, R.L., Freebairn, D. M., Smith, C. J., 2003. An *overview of APSIM, a model designed for farming systems simulation.* European Journal of Agronomy, 18: 267-288.

Keith, H., Barrett, D., and Keenan, R., 2000. *Review Allometric Relationships for Woody Biomass for New South Wales, the Australian Capital Territory, Victoria, Tasmania and South Australia.* National Carbon Accounting System Technical Report No. 5b (119pp). Australian Greenhouse Office.

Kelly, Carol A., and David P. Chynoweth. 1981. *The contributions of temperature and of the input of organic matter in controlling rates of sediment methanogenesis,* Limnology and Oceanography, 26: 891-97.

Kettle B., 2017. *Seagrasses and capital dredging: Pilot Project for Addition to Australias ' National Greenhouse Inventory.* Unpublished report to Land Inventory Unit, National Inventory Systems and International Reporting Branch, Department of the Environment and Energy. Babel-sbf Pty Ltd, Brisbane, Australia. 24pp.

Kesteven, J., Landsberg, J., and URS Consulting, 2004. *Developing a national forest productivity model.* National Carbon Accounting System Technical Report No.23, Australian Greenhouse Office, Canberra.

Kiiveri, H., Caccetta, P., Campbell, N., Evans, F., Furby, S., and Wallace, J., 2003. *Environmental Monitoring Using a Time Series of Satellite Images and Other Spatial Data Sets,* in D. D. Denison , M. H. Hansen, C. Holmes, B. Mallick, B. Yu (Eds), Nonlinear Estimation and Classification, Lecture Notes In Statistics, New York, Springer Verlag, 2003, ISSU 171, pages 49-62.

Kiiveri, H., Caccetta, PA., and Evans, F., 2001. *Use of conditional probability networks for environmental monitoring,* International Journal of Remote Sensing, Volume 22: 1173–1190.

Kroodsma, D. A. and Field, C. B., 2006. *Carbon sequestration in California agriculture, 1980–2000.* Ecological Applications, 16(5): 1975–1985

Landsberg, J.J., 1986. *Coupling of Carbon, Water and Nutrient Interactions in Woody Plant Soil Systems.* Tree Physiology 2.

Landsberg, J.J. and Gower, S.T., 1997. *Applications of Physiological Ecology to Forest Management'.* Academic Press: San Diego Press. 354pp.

Landsberg, J.J. and Waring, R.H., 1997. *A generalized model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance, and partitioning.* Forest Ecology and Management, 95: 209–228.

Law, B.E., Sun, O.J., Campbell, J., Van Tuyl, S., and Thornton, P.E., 2003. *Changes in carbon storage and fluxes in a chronosequence of ponderosapine.* Global Change Biology 9: 510–524.

Lawrence, A.J., Baker, E., Lovelock, C.E., 2012. *Optimizing and managing coastal carbon: Comparative sequestration and mitigation opportunities across Australias ' landscapes and land uses,* FRDC Report 2011/084, Fisheries Research and Development Corporation.

Llewellyn, R.S., D'Emden, F., and Gobbett, D., 2009. *Adoption of no-till and conservation farming practices in Australian grain growing regions: current status and trends.* Preliminary report for SA No-till Farmers Association and CAAANZ, South Australia.

Llewellyn R.S., D'Emden F.H., Kuehne G., 2012. *Extensive use of no-tillage in grain growing regions of Australia.* Field Crops Research, 132, 204-212.

Lovatt, C.J., 1996. *Nitrogen allocation within the 'Hass'avocado.* California Avocado Society 1996 Yearbook 80: 75-83.

Lovelock, C.E., Evans, E., Barros, N., Prairie, Y., Alm, J., Bastviken, D., Beauilieu, J. J., Garneau, M., Harby, A., Harrison, J., Pare, D., Raadal, H. L., Sherman, B., Zhang, C., Ogle, S. M., 2019, Chapter 7: Wetlands, in *2019 Refinement to the 2006IPCC Guidelines for National Greenhouse Gas Inventories.* Japan

Lowell, K., 2014 *Verification of National Carbon Accounting System (NCAS) land cover change maps,* unpublished report, Cooperative Research Centre for Spatial Information, Melbourne, Australia.

Lowell, K., Buxton, L., Fintelman, R., Ching, J., Arya, T., and Jones, S., 2012. *Update of the national carbon accounting system continuous improvement and verification methodology:* 2002–2010 unpublished research report by the Cooperative Research Centre for Spatial Information and RMIT University Australia, November 2012.

Lowell, K.E., Woodgate, P., Jones, S. and Richards, G.P., 2003. *Continuous Improvement of the National Carbon Accounting System Land Cover Change Mapping.* National Carbon Accounting System Technical Report 39, Australian Greenhouse Office, p. 36.

Lowell, K.E., Richards, G.P., Woodgate, P, Jones, S., and Buxton, L., 2005. *Fuzzy Reliability Assessment of Multi-Period Land-cover Change Maps.* Photogrammetric Engineering and Remote Sensing. 71:939-945.

Lucas, R.M., King, S., *et al.,* 1997. *The role of Australias ' native forests in carbon sequestration: Tasmania as a case study.* Report to the Department of Environment, Sports and Territories, Canberra, Australia.

Luo, Z., Wang, E., Zheng, H., Baldock, J.A., Sun, O.J., Shao, Q., 2015. *Convergent modelling of past soil organic carbon stocks but divergent projections.* Biogeosciences, 12:4373–4383.

Lynch, D., Cuff, N. and Russell-Smith J., 2015. *Vegetation fuel type classification for lower rainfall savanna burning abatement projects.* Carbon Accounting and Savanna Fire Management, Eds: B.P. Murphy, A.C. Edwards, M.Meyer and J. Russell-Smith, CSIRO Publishing, Clayton Sth, Victoria, Australia, pp 73 – 96.

Lyu, Y., Tang, H., Li, H., Zang, F., Rengel, Z., Whalley, W., Shen, J., 2016. *Major crop species show differential balance between root morphological and physiological responses to variable phosphorus supply.* Frontiers in Plant Science, Volume 7, Article-1939.

Ma, S., Li, F., Xu, B., Huang, Z., 2010. *Effect of lowering the root/shoot ratio by pruning roots on water use efficiency and grain yield of winter wheat.* Field Crops Research, 115, 159-164.

Mackensen, J., and Bauhus, J., 1999. *The Decay of Coarse Woody Debris.* National Carbon Accounting System Technical Report No. 6 (41pp). Australian Greenhouse Office, Canberra.

Mackensen, J., Bauhus, J., and Webber, E., 2003. *Decomposition rates of coarse woody debris – A review with particular emphasis on Australian species.* Australian Journal of Botany 51: 23-37.

Manschadi, A., Hammer, G., Christopher, J., deVoil, P., 2008. *Genotypic variation in seedling root architectural traits and Implications for drought adaption in wheat (triticum aestivum L.).* Plant Soil, 303:115-129.

Marini, R.P. and Sowers, D.S., 2000. *Peach Tree Growth, Yield, and Profitability as Influenced by Tree Form and Tree Density.* HortScience, 35(5):837–842.

MBAC Consulting, 2003, *CSIRO Plantation Imagery Verification.* Australian Greenhouse Office. Unpublished report, Canberra, Australia.

McKenzie, N. J., Ryan, P. J., Fogarty, P., and Wood, J., 2000b. *Sampling Measurement and Analytic Protocols for Carbon and Litter Estimation.* National Carbon Accounting System Technical Report No. 14 (66pp). Australian Greenhouse Office, Canberra.

McKenzie, N. J., Jacquier, D.W., Ashton, L.J., and Cresswell, H.P., 2000a. *Estimation of Soil Properties Using the Atlas of Australian Soils.* CSIRO Land and Water Technical Report 11/00.

McMurtrie, R.E., Leuning, R., Thompson, W.A., and Wheeler, A.M., 1992. *A Model of Canopy Photosynthesis and Water-Use Incorporating a Mechanistic Formulation ofLeaf CO Exchange.* Forest Ecology and Management. 52:261-278.

Meehan, AJ, and Ronald John West. 2002. *Seagrasses in Southern NSW Estuaries: Their Ecology, Conservation, Restoration and Management* (University of Wollongong)

Meyer, C.P., 2004. *Establishing a consistent time-series of greenhouse gas emission estimates from savanna burning in Australia.* Final report to the Australian Greenhouse Office, December 2004, CSIRO Division of Atmospheric Research, Aspendale, Victoria, Australia, 58pp.

Meyer, C.P., and Cook G.D., 2011. *Seasonality in Greenhouse Gas Emission Factors from Savanna fires.* Final Report to NAILSMA, February 2011, CSIRO Marine and Atmospheric Research, Aspendale, Victoria, Australia, 60 p.

Meyer, C.P.,and Cook, G.D., 2015. *Biomass combustion and emission processes in the northern Australian savannas.* Carbon Accounting and Savanna Fire Management, Eds: B.P. Murphy, A.C. Edwards, M. Meyer, and J. Russell-Smith, CSIRO Publishing, Clayton Sth, Victoria, Australia, 2015, pp 185-218.

Meyer, C.P.,Cook G. D., Reisen F., Smith T. E. L., Tattaris M., Russell-Smith J., Maier S. W., Yates C., and Wooster M. J., 2012. *Direct measurements of the seasonality of emission factors from savanna fires in northern Australia.* Journal of Geophysical Research, 117, D20305, doi:10.1029/2012JD017671.

Meyer, C.P.M., Cook, G.D. and Powell, J., 2015. *Australias 'National Greenhouse Gas Inventory 2013: Agriculture.* Final report to the Department of the Environment. CSIRO Oceans and Atmosphere, Aspendale. 66p.

Mohren, G.M.J., and Goldewijk, K.C.G.M., 1990. CO_2*Fix: a dynamic model of the* CO_2 *fixation in forest stands.* Rapport 624, De Dorschkamp, Research Institute of Forestry and Urban Ecology, Wageningen, 96pp.

Mokany, K., Raison, R.J., and Prokushkin, A.S., 2006. *Critical analysis of root:shoot ratios in terrestrial biomes.* Global Change Biology 12: 84–86

Moore, S., Lawrence, K., 2013. *The effect of soil texture and irrigation on Rotylenchulus reniformis and cotton.* Journal of Nematology 45(2):99–105.

Morgan, K.T., Scholberg, J.M.S., Obreza, T.A., Wheaton, T.A., 2006 *Size, Biomass, and Nitrogen Relationships with Sweet Orange Tree Growth.* J. Amer. Soc. Hort. Sci 131(1): 146–156

Murphy, B., Rawson, A., Ravenscroft, L. Rankin, M. and Millard, R., 2002. *Paired Site Sampling for Soil Carbon Estimation – NSW.* National Carbon Accounting System Technical Report No. 34, Australian Greenhouse Office, Canberra.

Murphy, T., Jones, G., Vanclay, J., and Glencross, K., 2013. *Preliminary carbon sequestration modelling for the Australian macadamia industry.* Agroforestry Systems, 87, 689–698.

Mutendeudzi, M., Dillon, R., Davey, S. and Read, S. 2014. *Harvesting likelihood on 'Forest Management Land' 1990-2009: Report to client prepared for the Department of Environment.* ABARES, Canberra.

Myers, B.J., Theiveyanathan, S., O'Brien, N.D., and Bond, W.J., 1996. *Growth and water use of Eucalyptus grandis and Pinus radiata plantations irrigated with effluent.* Tree Physiology 16:211–219.

Nahar, K., 2017. *Understanding the contribution of root traits for phosphorus responsiveness of wheat.* Thesis (Ph.D.) (Research by Publication) – University of Adelaide, School of Agriculture, Food and Wine.

Natchimuthu, Sivakiruthika, Balathandayuthabani Panneer Selvam, and David Bastviken. 2014. *Influence of weather variables on methane and carbon dioxide flux from a shallow pond,* Biogeochemistry, 119: 403–13.

NLWRA (National Land and Water Resources Audit), 2001. *Australian Native Vegetation Assessment 2001,* National Land and Water Resources Audit, Canberra.

O'Connell, A.M., 1997. *Decomposition of slash residues in thinned regrowth eucalypt forest in Western Australia.* Journal of Applied Ecology, 34: 111–122.

Olupot, G., Barnes, P, Daniel, H., Lockwood, P, McHenry, M., Mcleod, M., Kristiansen, P, King, K., 2010. *Can root biomass of grasses in NSW be predicted from shoot biomass yields?* Proceedings of the 16th Biennial Conference of the Australian Rangeland Society, Bourke (Australian Rangelands Society: Perth).

Palisade Corporation, 2005. *@Risk Version 4.1.* Ithaca, NY, USA.

Panneer Selvam, Balathandayuthabani, Sivakiruthika Natchimuthu, Lakshmanan Arunachalam, and David Bastviken. 2014. *Methane and carbon dioxide emissions from inland waters in India – implications for large scale greenhouse gas balances,* Global Change Biology, 20: 3397–407.

Paul, K. and Roxburgh, S., 2017. *FullCAM: building capability via data-informed parameters.* CSIRO

Paul, K. and Roxburgh, S., 2019. *Spatial-temporal simulation of fires within the Australian National Greenhouse Gas Inventory. Report prepared for the Department of Environment and Energy.* CSIRO, Land and Water, Canberra.

Paul, K., Polglase, P, Coops, N., O'Connell, T., Grove, T., Medlam, D., Carlyle, C., May, B., Smethurst, P, and Baillie, C., 2002a. *Modelling Change in Soil Carbon Following Afforestation or Reforestation: Preliminary Simulations Using GRC3 and Sensitivity Analysis.* National Carbon Accounting System Technical Report No. 29 (106pp), Australian Greenhouse Office, Canberra.

Paul, K., Polglase, P.J., Nyakuengama, J.G. and Khanna, P.K., 2002b. *Change in soil carbon following afforestation.* Forest Ecology and Management. 168: 241–257.

Paul, K., Polglase, PJ., and Richards G.P, 2003b. *Predicting Change in Soil Carbon following Afforestation or Reforestation.* Forestry Ecology and Management, 177: 485–501.

Paul, K., and Polglase, PJ., 2004a. *Prediction of decomposition of litter under eucalypts and pines using the FullCAM model.* Forest Ecology and Management, 191: 73–92.

Paul, K., and Polglase P.J., 2004b. *Calibration of the Roth C model to turnover of soil carbon under eucalypts and pines.* Australian Journal of Soil Research, 42: 883–895.

Paul, K.I., Roxburgh, S.H., Engalnd, J.R., de Ligt, R., Larmour, J.S., Brooksbank, K., Murphy, S., Ritson, P, Hobbs, T., Lewis, T., Preece, N.D., Cunningham, S.C., Read, Z., Clifford, D., Raison, R.J., 2015a. *Improved models for estimating temporal changes in carbon sequestration in above-ground biomass of mixed-species environmental plantings.* Forest Ecology and Management, 338, 208–218

Paul, K.I., Roxburgh, S.H., de Ligt, R., Ritson, P Brooksbank, K., Peck, A., Wildy, D.T., Mendham, D., Bennett, R., Bartle, J., Larmour, J.S., Raison, R.J., England, J.R., Clifford, D., 2015b. *Estimating temporal changes in carbon sequestration in plantings of mallee eucalypts: Modelling improvements.* Forest Ecology and Management, 335, 166–175.

Paul, K., England, J.R., Baker, T.G., Cunningham, S.C., Perring, M.P., Polglase, PJ., Wilson, B., Cavagnaro, T.R., Lewis, T., Read, Z., Madhavan, D.B. and Herrmann, T., 2018. *Using measured stocks of biomass and litter carbon to constrain modelled estimates of sequestration of soil organic carbon under contrasting mixed-species environmental plantings.* Science of the Total Environment, 615, 348–359.

Paul, K. and Roxburgh, S., 2019a. *Spatial-temporal simulation of fires within the Australian National Greenhouse Gas Inventory.* Report prepared for the Department of the Environment and Energy. CSIRO Land and Water, Canberra.

Paul, K. and Roxburgh, S., 2019b. *FullCAM simulation of clearing or harvesting and subsequent slash-burns: Standing dead implementation.* Report prepared for the Department of the Environment and Energy. CSIRO Land and Water, Canberra.

Paul, K. and Roxburgh, S., 2019c. *Predicting yields of woody biomass in land restoration projects across Australia.* Report for Department of the Environment and Energy. CSIRO Agriculture, Canberra, Australia.

Paul, K.I. and Roxburgh, S.H., 2020. *Predicting carbon sequestration of woody biomass following land restoration.* Forest Ecology and Management 460 (2020) 117838.

Poeplau, C., Katterer, T., 2017. *Is soil texture a major controlling factor of root:shoot ratio in cereals?* European Journal of Soil Science, 68: 964-970.Polglase, P.J., Paul, K.I., Khanna, PK., Nyakuengama, J.G., O'Connell, A.M., Grove, T.S., and Battaglia, M., 2000. *Change in Soil Carbon Following Afforestation and Reforestation.* National Carbon Accounting System Technical Report No. 20 (89pp) Australian Greenhouse Office, Canberra.

Polglase, P.J., Snowdon, P., Theiveyanathan, T., Paul, K.I., Raison, R.J., Grove, T., and Rance, S.J., 2004. *Calibration of the FullCAM model to Eucalyptus globulus and Pinus radiata and uncertainty analysis.* Nation Carbon Accounting System Technical Report No. 40, Australian Greenhouse Office, Canberra.

Potter, C.S., Randerson, J.T., Field, C.B., Matson, P.A., Vitousek, PM., Mooney, H.A., and Klooster, S.A., 1993. *Terrestrial ecosystem production: a process model based on global satellite and surface data.* Global Biogeochemical Cycles 7:811-841.

Preen, A. R., W. J. Lee Long, and R. G. Coles. 1995. *Flood and cyclone related loss, and partial recovery, of more than 1000 km^2 of seagrass in Hervey Bay, Queensland, Australia,* Aquatic Botany, 52: 3-17.

Pressey, R.L. and Middleton, M.J. 1982. *Impacts of flood mitigation works on coastal wetlands in New South Wales.* Wetlands Australia 2: 27–44

Raison, R.J., Keith, H., Barrett, D., Burrows, W., and Grierson, P.F., 2003. *Spatial Estimates of Biomass in 'Mature' Native Vegetation.* National Carbon Accounting System Technical Report 44, Australian Greenhouse Office, Canberra, Australia, p. 56.

Raison, R.J. and Squire, R., 2008. *Forest Management in Australia: Implications for Carbon Budgets.* National Carbon Accounting System Technical Report No 32, Australian Greenhouse Office, Canberra, Australia.

RBA (Reserve Bank of Australia), 2015a *Exchange Rates – Monthly – January 2010 to latest complete month of current year* [online] Available at: http://www.rba.gov.au/statistics/historical-data.html#exchange-rates [Accessed 21 April 2016]

RBA (Reserve Bank of Australia), 2015b Exchange Rates – *Exchange Rates – Monthly – July 1969 to December 2008* [online] Available at: http://www.rba.gov.au/statistics/historical-data.html#exchange-rates [Accessed 21 April 2016]

Richards, G.P, 2001. *The FullCAM Carbon Accounting Model: Development, Calibration and Implementation for the National Carbon Accounting System.* National Carbon Accounting System Technical Report No. 28 (50pp), Australian Greenhouse Office, Canberra.

Richards, G.P. and Brack, C., 2004. *A continental biomass stock and stock change estimation approach for Australia.* Australian Forestry. 67:284–288.

Richards, G.P. and Evans, D., 2004. Development of a carbon accounting model (FullCAM Vers. 1.0) for the Australian continent. Australian Forestry, 67:277-283.

Richards, G.P. and Evans, D.W., 2000a. *CAMFor User Manual v 3.35.* National Carbon Accounting System Technical Report No. 26 (47pp), Australian Greenhouse Office, Canberra.

Richards, G.P. and Evans, D.W., 2000b. *CAMAg National Carbon Accounting System* (electronic model) Australian Greenhouse Office, Canberra.

Richards, G.P. and Evans, D.W., 2000c. *GRC3 National Carbon Accounting System* (electronic model) Australian Greenhouse Office, Canberra.

Rogers, H., Prior, S., Runion, G., Mitchell, R., 1996. *Root to shoot ratio of crops as influenced by* CO_2. Plant and Soil 187:229–248.

Roxburgh, S., Volkova, L., Surawski, N., Meyer, M. and Weston, C., 2015. *Review of Fuel Loads, Burn Efficiencies, Emissions Factors and Recovery Functions used to Estimate Greenhouse Gas Emissions and Removals Associated with Wildfire on Temperate Forested Lands.* CSIRO technical Report. Report for Department of the Environment and Energy, Canberra, Australia.

Roxburgh, S., Paul, K., Lucas, R., Armston, J., Sun, S., 2016. *Empirical Relationship – Above-Ground Biomass and the Long-Term Forest Productivity Index.* CSIRO

Roxburgh, S., Karunaratne, S., Paul, K., Lucas, R., Armston, J., Sun, S., 2017. *A revised above-ground maximum biomass layer for Australias ' national carbon accounting system.* CSIRO

Roxburgh, S, England, J, Paul, K., 2019. Recalibration of the Tree Yield Formula in FullCAM for plantations. CSIRO, Australia.

Roxburgh, S., Karunaratne, S., Paul, K., Lucas, R., Armston, J., Sun, J., 2019. A *revised above-ground maximum biomass layer for the Australian continent.* Forest Ecology and Management. 432:264-275.

Roxburgh, S. and Paul, K., 2019a. *Improved FullCAM-prediction of woody growth increments.* Report for Department of the Environment and Energy. CSIRO Agriculture, Canberra, Australia.

Roxburgh, S. and Paul, K., 2019b. *Accuracy and representativeness of FullCAM predicted above-ground biomass at the site-scale.* Report for Department of the Environment and Energy. CSIRO Land and Water, Canberra, Australia.

Ruimey, A., Saugier, B., and Dedieu, G., 1994. *Methodology for the estimation of terrestrial net primary production from remotely sensed data.* Journal of Geophysical Research, 99:5263–5283.

Russell-Smith, J., Lucas, D., Gapindi, M., Gunbunuka, B., Kapirigi, N., Namingum, G., Lucas, K., Giuliani, P, Chaloupka, G., 1997. *Aboriginal resource utilization and fire management practice in western Arnhem Land, monsoonal northern Australia: notes for prehistory and lessons for the future.* Human Ecology, 25, 159–195. doi:10.1023/A:1021970021670.

Russell-Smith, J., Murphy, B.P, Meyer, C.P, Cook G.D., Maier S., Edwards A.C., Schatz J., and Brocklehurst, 2009. *Improving estimates of savanna burning emissions for greenhouse accounting in northern Australia: limitations, challenges, applications.* International Journal of Wildland Fire, 18(1), pp1–18.

Russell-Smith, J., Yates, C.P, Edwards, A.C., Evans, J., Meyer, C.p. and Edwards, A.C., 2015. *Application of a lower rainfall savanna burning emissions abatement methodology.* Carbon Accounting and Savanna Fire Management, Editors: B.P Murphy, A.C. Edwards, M. Meyer and J. Russell-Smith, CSIRO Publishing, Clayton Sth, Victoria, Australia, pp 219–234.

Russell-Smith, J., Ryan, M.G., Binkley, D., and Fownes, J.H., 1997. *Age-related decline in forest productivity: pattern and process.* Advances in Ecological Research, 27: 213–262.

Sainju, U., Allen, B., Lenssen, A., Ghimire, R., 2017. *Root biomass, root/shoot ratio, and soil water content under perennial grasses with different nitrogen rates.* Field Crops Research, 2010: 183–191.

Saintilan, N. and Rogers, K. (2013). *The significance and vulnerability of Australian saltmarshes: implications for management in a changing climate.* Marine and Freshwater Research, 64 (1), 66–79.

Savage, J, and Hobsbawn, P (2015) *Australian fisheries and aquaculture statistics 2014,* Fisheries Research and Development Corporation project 2014/245. ABARES, Canberra.

Schlapfer, B. and Ryser, P, 1996. *Leaf and root turnover of three ecologically contrasting grass species in relation to their performance along a productivity gradient.* Oikos, Vol. 75, No. 3, 398–406.

Semeniuk, V. 1980. *MangroveZonation Along an Eroding Coastline in King Sound, North-Western Australia,* Journal of Ecology, 68: 789–812.

Sheriff, D.W., Mattay, J.P., and McMurtrie, R.E., 1996. *Modeling productivity and transpiration of Pinus radiata: climatic effects.* Tree Physiology, 16: 183–186.

Shi, Pei-Jian, Lei Chen, Cang Hui, and Henri D. Grissino-Mayer. 2016. *Capture the time when plants reach their maximum body size by using the beta sigmoid growth equation,* Ecological Modelling, 320: 177–81.

Siddique, K., Belford, R., Tennant, D., 1990. *Root shoot ratios of old and modern, tall and semi-dwarf wheats in a Mediterranean environment.* Plant and Soil 121, 89–98.

Skjemstad, J., and Spouncer, L., 2002. *Estimating Changes in Soil Carbon Resulting from Changes in Land Use.* National Carbon Accounting System Technical Report No. 36, Australian Greenhouse Office, Canberra.

Skjemstad, J., and Spouncer, L., 2003. *Integrated Soils Modelling for the National Carbon Accounting System.* National Carbon Accounting System Technical Report No. 36, Australian Greenhouse Office, Canberra, Australia.

Skjemstad, J., and Spouncer, L.R., Cowie, B. and Swift, R.S., 2004. Calibration of the Rothamsted organic carbon turnover model (RothC ver. 26.3), using measurable soil organic carbon pools. Australian Journal of Soil Research (2004), 42, 79-88.

Smith, D., Inman-Bamber, N., Thorburn, P., 2005. *Growth and function of the sugarcane root system.* Field Crops Research 92, 169–183.

Smith, Timothy M. , Paul H. York, Peter I. Macreadie, Michael J. Keough, D. Jeff Ross, and Craig D. H. Sherman. 2016. *Recovery pathways from small-scale disturbance in a temperate Australian seagrass,* Mar Ecol Prog Ser, 542: 12

Snowdon, P, 2002. *Modeling Type 1 and Type 2 growth responses in plantations after application of fertilizer or other silvicultural treatments.* Forest Ecology and Management, 163: 229-244.

Snowdon, P, Eamus, D., Gibbons, P, Khanna, PK., Keith, H., Raison, R.J., and Kirschbaum, M.U.F., 2000. *Synthesis of allometrics, review of root biomass, and design of future woody biomass sampling strategies.* National Carbon Accounting System Technical Report No. 17 (142pp). Australian Greenhouse Office.

Snowdon, P., Raison, J., Keith, H., Ritson, P, Grierson, P., Adams, M., Montagu, K., Bi, H., Burrows, W., and Eamus, D., 2002. *Protocol for Sampling Tree and Stand Biomass. National Carbon Accounting System Technical Report No. 31 (72pp),* Australian Greenhouse Office, Canberra.

Snowdon, P., Ryan, P., and Raison, J., 2005. *Review of C:NRatios in Vegetation, Litter and Soil under Australian Native Forests and Plantations.* National Carbon Accounting System Technical Report No. 45 (60pp), Australian Greenhouse Office, Canberra.

Snowden, P. and Waring, H.D., 1984. *Long-term nature of growth responses obtained to fertilizer and weed control applied at planting and their consequences for forest management.* Grey, D.C., Shonau, A.P.G., Shutz, C.J. (Eds.), Proceedings of the IUFRO Symposium on Site and Productivity of Fast Growing Plantations, 30 April to 11 May, Pretoria and Pietermaritzberg, South Africa. Forest Research Institute, Pretoria, pp 701-711.

Snowdon, P, and James, R., 2008. *Historical development of silvicultural practices in plantations.* Raison, R.J. and Squire, R. (Eds.), *Forest management in Australia: Implications for carbon budgets.* National Carbon Accounting System Technical Report No. 32, Australian Greenhouse Office, Canberra, Australia. Spencer, R., Keenan, R., Ranatunga, K., and Wood, M., 2001. *Plantation Projections in Australia.* (Unpublished report).

Steingrobe, B., Schmid, H., Gutser, R., Claassen, N., 2001. *Root production and root mortality of winter wheat grown on sandy and loamy soils in different farming systems.* Biol Fertil Soils, 33:331-339.

Swift, R., and Skjemstad, J., 2002. *Agricultural Land Use and Management Information.* National Carbon Accounting System Technical Report No. 13 (446pp). Australian Greenhouse Office, Canberra.

Taylor, M., 2015, *Bushland destruction rapidly increasing in Queensland,* WWF Report.

Tothill, J.C., and Gillies, C., 1992. The *pasture lands of northern Australia. Their condition, productivity and sustainability.* Report to Meat Research Corporation. Tropical Grassland Society of Australia Occasional Publication No.5. St Lucia, Queensland. 115 pp.

Trewin, D., 2005 *Census of Population and Housing: Socio-Economic Indexes for Areas ' (SEIFA) Australia 2001* (Technical Paper; Cat. No. 2039.0.55.001). Canberra, Australian Bureau of Statistics.

Turner, B., 1984. *Potential productivity gains in Australian east coast Pinus radiataplantations.* Grey, D.C., Shonau, A.P.G., Shutz, C.J. (Eds.), Proceedings of the IUFRO Symposium on Site and Productivity of Fast Growing Plantations, April 30–May 11, Pretoria and Pietermaritzberg, South Africa. Forest Research Institute, Pretoria, pp 947-956.

Turner, B. and James, R., 1997. *Forecasting of wood flows from Australias 'plantations* – a report to the 1997 National Plantation Inventory. Bureau of Rural Sciences, Canberra, Australia.

Turner, B. and James, R., 2002. *Derivation of indicative yields for major plantation species.* In: Richards, G. (Ed) *Biomass Estimation: Approaches for Assessment of Stocks and Change.* National Carbon Accounting System Technical Report no. 27, Australian Greenhouse Office, Canberra, pp 71-77.

Turner, B. Lambert, M.J., Hopmans, P., and McGrath, J. 2001. *Site variation in Pinus radiata plantations and implications for site specific management.* New Forests 21: 249-282.

UN (United Nations), European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organization for Economic Co-operation and Development and the World Bank, 2014a. *System of Environmental-Economic Accounting 2012 – Central Framework.* New York.

UN (United Nations), European Union, Food and Agriculture Organization of the United Nations, Organization for Economic Co-operation and Development and World Bank Group, 2014b. *System of Environmental- Economic Accounting 2012 – Experimental Ecosystem Accounting.* New York.

Unkovich, M., Baldock, J. and Marvanek, S., 2009. *Which crops should be included in a carbon accounting system for Australian agriculture?* Crop and Pasture Science 60: 617-626.

Unkovich, M., Baldock, J. A., and Farquharsan R., 2014. *Estimating historical crop yields on a regional scale using a simple water-driven productivity model.* (unpublished report) CSIRO, Australia

Unkovich, M., Baldock, J. and Forbes, M., 2010. *Variability in harvest index of grain crops and potential significance for carbon accounting: examples from Australian agriculture.* Advances in Agronomy 105: 173-219.

van Bergen, Tamara J. H. M., Nathan Barros, Raquel Mendon^a, Ralf C. H. Aben, Inge H. J. Althuizen, Vera Huszar, Leon P. M. Lamers, Miquel Lürling, Fabio Roland, and Sarian Kosten. 2019. *Seasonal and diel variation in greenhouse gas emissions from an urban pond and its major drivers,* Limnology and Oceanography, 64: 2129-39.

Vanderklift, M, D Bearham, M Haywood, R McCallum, J McLaughlin, K McMahon, N Mortimer, and P Lavery. 2017. *Recovery mechanisms: understanding mechanisms ofseagrass recovery following disturbance.* In, 25. Perth, WA: Western Australian Marine Science Institution.

Vic Forests (Victoria Forests) 2008. *Vic Forests: Annual Report 2008.* Victoria, Australia.

Villalobos, FJ., Testi, L., Hidalgo, J., Pastor, M., Orgaz, F., 2006. *Modelling potential growth and yield of olive (Olea europaea L.) canopies.* European Journal of Agronomy, 24(4): 296-303

Viscarra Rossel, R.A., and Webster, R., 2012. *Predicting soil properties from the Australian soil visible-near infrared spectroscopic database.* European Journal of Soil Science, vol. 63, no. 6, pp. 848–60.

Viscarra Rossel, R.A., Bui, E.N., and Baldock, J.A., 2014. *Spatial estimates of organic carbon storage to support national carbon accounting and monitoring under climate change.* Global Change Biology, 20(9): 2953–2970.

Viscarra Rossel, R.A., Chen, H., and Hicks, W., 2015a. *Prediction of spatial distribution of soil attributes to depth from Australian site and covariate data.* Soil Research, in preparation.

Viscarra Rossel, R.A., Chen, C., Grundy, M., Searle, R., Clifford, D., and Campbell, P.H., 2015b. *The Australian three-dimensional soil grid: Australias ' contribution to the GlobalSoilMap project.* Soil Research 53(8): 845–864.

Wakeel, A., Tahir Aziz, Tariq Aziz, Anwar-ul-Hassan., 2017. *Growth and potassium uptake by Maize (Zea mays L.) in three soils differing in clay contents.* Emirates Journal of Food and Agriculture, Vol. 17, no. 1, pp. 57–62.

Ward, P., Palta, J., Waddell, H., 2011. *Root and shoot growth by seedlings of annual and perennial medic, and annual and perennial wheat.* Crop and Pasture Science, 62:367–373.

Waring, R.H. Brown, S. and Running, S.W., 2001. *Comparisons of predictions of net primary productivity and seasonal patterns in water use derived with two forest growth models in south-western Oregon.* Ecological Modelling, 142:61-68.

Waterworth, R.M., Brookhouse, M.T., Kesteven, J., 2005. *Use of tree ring data to test a broad-scale model of forest productivity in Australia.* Innes, J.L., Edwards, I.K., Wilford, D.J. (Eds.), IUFRO 2005. The International Forestry Review, Brisbane, Australia, p. 76.

Waterworth, R.M., Richards, G.P., Brack, C.L. and Evans, D.M.W., 2007. *A generalised process-empirical hybrid model for predicting forest growth.* Forest Ecology and Management 238, 231-243.

Waterworth, R.M., and Richards, G.P., 2008. *Implementing Australian forest management practices into a full carbon accounting model.* Forest Ecology and Management 255: 2434–2443.

Waterworth, R.M., Keith, H. and Wild-River, S., 2015 *Review of Australian forest classification systems for use in emissions estimation.* Report produced for the Department of the Environment. The Australian National University, Canberra.

Webb, A., 2002. *Pre-clearing soil carbon levels in Australia.* National Carbon Accounting System Technical Report No. 12 (204pp). Australian Greenhouse Office.

West, P.W., and Mattay, J.P., 1993. *Yield prediction models and comparative growth rates for 6 eucalypt species.* Australian Forestry 56(3): 211-225.

Williams, J., McCool, D., Reardon, C., Douglas Jr., C., Albrecht, S., Rickman, R., 2013. *Root shoot ratios and belowground biomass distribution for Pacific Northwest dryland crops.* Journal of Soil and Water Conservation, Vol. 68 no. 5:349-360.

Witt, GB, Noel, M, Bird, M, Beeton, R, Menzies, N (2011) Carbon sequestration and biodiversity restoration potential of semi-arid mulga lands of Australia interpreted from long-term grazing exclosures, Journal of Agriculture, Ecosystems and Environment

Woldendorp, G., and Keenan, R.J., 2005. *Coarse woody debris in Australian forest ecosystems: A review.* Austral Ecology 30: 834–843.

Wu, P. P.-Y., K. Mengersen, K. McMahon, G. A. Kendrick, and M. J. Caley. 2015. *Predicting the temporal response of seagrass meadows to dredging using Dynamic Bayesian Networks.* In 21st International Congress on Modelling and Simulation (MODSIM2015), 1282–88. Gold Coast, Australia: MSSANZ.

Wu, X., Furby, S., and Wallace, J., 2004. *An Approach for Terrain Illumination Correction.* In The 12th Australasian Remote Sensing and Photogrammetry Conference Proceedings, Fremantle, Western Australia, 18–22 October.

Ximenes, F., and Gardner, D., 2005a. *Recovery of Biomass as Green Sawn Boards after Milling of Spotted Gum (Corymbia maculata) Sawlongs from NSW South Coast Forests.* National Carbon Accounting System Technical Report No. 48, Australian Greenhouse Office, Canberra, Australia.

Ximenes, F., Gardner, D., and Marchant, J., 2005b. *Total biomass measurement and recovery of biomass in log products in Spotted Gum (Corymbia maculata) forests of SE NSW.* National Carbon Accounting System Technical Report No. 47, Australian Greenhouse Office, Canberra.

Ximenes, F., Gardner, D., and Richards, G.P., 2006. *Total above-ground biomass and biomass in commercial logs following the harvest of Spotted Gum (Corymbia maculata) forests of SE NSW.* Australian Forestry, 69: 213–222.

Ximenes, F., Gardner, W.D., and Kathuria, A., 2008a. *Proportion of aboveground biomass in commercial logs and residues following the harvest of five commercial forest species in Australia.* Forest Ecology and Management, 256: 335-346.

Ximenes, F., Huiquan, B., Cameron, N., Coburn, R., Maclean, M., Sargeant, D., Matthew, M., Roxburgh, S., Ran, M., Williams, J., and Boer, K., 2016. *Carbon stocks and flows in native forests and harvested wood products in SE Australia.* Report prepared for Forest and Wood Products Australia, Melbourne.

Yin, Xinyou, J. A. N. Goudriaan, Egbert A. Lantinga, J. A. N. Vos, and Huub J. Spiertz. 2003. 'A Flexible Sigmoid Function of Determinate Growth', Annals of Botany, 91: 361-71.

Zhang, Mi, Qitao Xiao, Zhen Zhang, Yunqiu Gao, Jiayu Zhao, Yini Pu, Wei Wang, Wei Xiao, Shoudong Liu, and Xuhui Lee. 2019. *Methane flux dynamics in a submerged aquatic vegetation zone in a subtropical lake,* Science of the Total Environment, 672: 400–09.

7. Waste

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020 *Australian Forest and Wood Products Statistics, March and June quarter 2020,* Canberra.

ABS (Australian Bureau of Statistics), *Australian Demographic Statistics,* Catalogue No. 3101.0.

AIHW (Australian Institute of Health and Welfare), 2002. *Apparent Consumption of Nutrients Australia 1997–98,* Canberra

Amlinger, F., Peyr, S. and Cuhls, C., 2008. *Greenhouse gas emissions from composting and mechanical biological treatment;* Waste Management and Research 26:47.

Australian Plantation Products and Paper Industry Council, 2006. *Australian Paper Industry Statistics* 2004–2005.

Baldwin, G. and Scott, P.E., 1991. *Investigations into the Performance of Landfill Gas Flaring Systems in the UK.* Proceedings Sardinia 91, 3rd International Landfill Symposium, Sardinia, Italy, 14-18 October 1991.

Bange, H., 2006. *Nitrous Oxide and Methane in European Coastal Waters.* Estuarine Coastal and Shelf Science, vol 70 (3), pp361–374.

Bariaz, M.A., 1998. *Carbon Storage during Biodegradation of Municipal Solid Waste Components in Laboratory-scale Landfills,* Global Biochemical Cycles, 12(2), 373–380. 2005, *Note to ICF consulting,* dated June 29, 2005. *Corrections to Previously Published Carbon Storage Factors.* Note to Parties Interested in Carbon Sequestration from Municipal Solid Waste, dated February 28, 2008.

Barnes, J. and Owens, N. J. P, 1998. *Denitrification and nitrous oxide concentrations in the Humber estuary, UK, and adjacent coastal zones.* Marine Pollution Bulletin, vol 37 (3-7), pp247–260.

Bateman, S., 2009. *Evaluation of Landfill Gas Collection Efficiency at the Wollert Landfill, Melbourne.* Presented at the 3rd National Landfill and Transfer Stations Conference, Hobart.

Blue Environment, 2010. *Review of DOCf factors outlined in National Inventory Report 2008.* Report for the Department of Climate Change and Energy Efficiency.

2016, *Uncertainty analysis in the national greenhouse accounts, waste and wastewater sector.* Report for the Department of the Environment.

Bouwman, A.F., Boumans, L.J.M. and Batjes N.H., 2002. *Emissions of* N_2O *and NO from fertilized fields:* Summary of available measurement data. *GlobalBiogeochemical Cycles,* 16, 1058, doi:10.1029/2001GB001811.

CER (Clean Energy Regulator), 2020. *Data collated by the Clean Energy Regulator under the National Greenhouse and Energy Reporting system for 2009–2019.* http://www.cleanenergyregulator.gov.au/NGER/Pages/default.aspx

DCC (Department of Climate Change), 2009, *Survey of the Australian Wastewater Treatment Industry 2009.* Department of Climate Change, Canberra.

de Looper, M. and Bhatia, K., 1998. *International health – how Australia compares.* Australian Institute of Health and Welfare, Commonwealth of Australia, Canberra, Australia.

Department of Industry, Science, Resources and Energy *Australian Energy Statistics.* 2020.

Department of National Development, 1969. *Compendium of Australian forest products* 1935–36 to 1966–67, Canberra.

DEWHA (Department of the Environment, Water, Heritage and the Arts), 2009. *National Waste Overview 2009.* http://www.nepc.gov.au/system/files/resources/cc88088d-e2a3-449e-9a04-f87f46e3d2e1/files/wastemgt-natwaste-overview-print-ver-200911.pdf

Dever, S., Roberts, A. and Cooksley, G., 2009. *Evaluation of Landfill Gas Emissions at Newcastle City Councils' Summerhill WMC Landfill via Direct Measurement and using NGER Method-1.* Presented at the 3rd National Landfill and Transfer Stations Conference, Hobart.

DHV, 2010. *Update of emission factors for* N_2O *and* CH_4 *for composting, anaerobic digestion and waste incineration,* Netherlands.

Doorn, M.R.J. and Barlaz, M.A., 1995. *Estimate of Global Methane Emissions from Landfills and Open Dumps.* USEPA, Washington.

DSEWPaC and Blue Environment Pty Ltd, 2013. *Waste generation and resource recovery in Australia Reporting period2010/11,* Final report version 2.6, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Duffy, Nelson and Williams, 1995. *Trace Organic Composition of Landfill Gas.* Report to NSW Environmental Research Trusts. CSIRO. Sydney.

Foley, J. and Lant, P., 2007. *Fugitive Greenhouse Gas Emissions from Wastewater Systems,* Water Services Association of Australia, WSAA Literature Review No.1, December 2007.

Gardner, W.D., Ximenes, F., Cowie, A., Marchant, J.F., Mann, S., and Dods, K., 2004. *Decomposition of Wood Products in the Lucas Heights Landfill Facility,* 3rd Intercontinental Landfill Research Symposium. Japan (2004).

GHD, 2010. *Report for Review of DOCf values used in the Australian National Greenhouse Accounts,* report to the Department of Climate Change.

2009a. *Report for National Greenhouse Accounts 2008: Methane Capture from Landfills,* report to the Department of Climate Change.

2008. Report for review of current municipal waste and commercial and industrial waste mix composition in the NGER Measurement Determination. Report to the Department of Climate Change, January 2008.

Golder Associates, 2009. *Kimbriki Recycling and Waste Facility – Landfill Gas Emissions Assessment.* Report for Kimbriki recycling and waste management facility, NSW.

Guendehou, S., 2010. *Australias 'National Greenhouse Gas Inventory 2008: Solid Waste Review – Fraction of DOC dissimilatedDOCf,* report to the Department of Climate Change.

2009. *Australias 'National Greenhouse Gas Inventory 2007: Solid Waste Quality Assurance Review,* report to the Department of Climate Change.

Hyder Consulting, 2007a. *AGO Factors and Methods Workbook – Waste Chapter Review,* unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

2007b. *Review of Methane Recovery and Flaring from Landfills,* unpublished report to the Australian Greenhouse Office, Hyder Consulting Sydney.

2008. *Composition of commercial & industrial and municipal waste to landfill,* report to the Department of Climate Change, January 2008.

2009. *Review of first order decay model parameters Fraction of degradable organic carbon dissimilated (DOCf)* report to the Department of Climate Change.

2010. *Greenhouse Accounts: Emissions from solid waste disposal – DOCf,* Report to the Department of Climate Change and Energy Efficiency.

IPCC (Intergovernmental Panel on Climate Change), 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories:* Volume 1, Greenhouse Gas Inventory Reporting Instructions; Volume 2, Greenhouse Gas Inventory Workbook; Volume 3, Greenhouse Gas Inventory Reference Manual IPCC/ OECD/IEA, Paris, France.

2000. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Japan. 2006. *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

Jaakko Pöyry Consulting, 1999. *National Carbon Accounting System – Usage and Lifecycle of Wood Products.* NCAS Technical Report No.8. Canberra.

2000. *Analysis of Wood Product Accounting Options for the National Carbon Accounting System.* National Carbon Accounting System Technical Report No. 24 (37pp). Australian Greenhouse Office, Canberra.

Lamborn, J., 2009. *Characterisation of municipal solid waste composition into model inputs.* Third international workshop "Hydro-Physico-Mechanics of Landfills" Braunschweig, Germany, March 2009.

Micales, J.A., and Skog, K.E., 1996. *The decomposition of forest products in landfills.* International Biodeterioration and Biodegradation, 39 (2–3): pp 145–158.

National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Cwlth), ComLaw, http://www.comlaw.gov.au/Details/F2011C00469

NGGIC (National Greenhouse Gas Inventory Committee), 1995. *The Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook for Landfill, Wastewater and Other Waste Activities,* National Greenhouse Gas Inventory Committee Workbook 8.0, Canberra.

O'Brien, 2006a. *Review of Onsite Industrial Wastewater Treatment.* O'Brien Consulting Greenhouse, Energy, Environment, report to the Australian Government Department of the Environment and Heritage, Canberra.

2006b. *Solvent and Clinical Waste Incineration in Australia,* O'Brien Consulting Greenhouse, Energy, Environment, report to the Australian Government Department of the Environment and Heritage, Canberra.

Punshon, S., and Moore, R. M., 2004. *Nitrous oxide production and consumption in a eutrophic coastal embayment,* Marine Chemistry, vol 91(1-4), pp37–51.

Recycled Organics Unit, University of New South Wales, 2009. *Organics recycling in Australia – Industry statistics 2009,* Recycled Organics Unit, Sydney.

Sydney Water, last accessed November 2020. *Wastewater network map.* https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/webasset/zgrf/mdq1/~edisp/dd_045245.pdf

Sydney Water, last accessed November 2020. *Wastewater treatment plants.* https://www.sydneywater.com.au/SW/water-the-environment/how-we-manage-sydney-s-water/wastewater-network/wastewater-treatment-plants/index.htm

Wang X, Padgett J.M, De la Cruz F.B, Barlaz M.A 2011 – *Wood biodegradation in laboratory-scale landfills* – Environmental Science and Technology

WMAA (Waste Management Association of Australia), 2007. *National landfill survey results.*

WSAA (Water Services Association of Australia), 2005. Facts 2005 – *The Australian Urban Water Industry,* Melbourne.

Ximenes, F., Gardner, W.D., and Cowie, A.L., 2008b. The *decomposition of wood products in landfills in Sydney, Australia.* Waste Management, 2008, doi:10.1016/j.wasman.2007.11.006.

Brooks, P, Wilson, C. and Giles, D., 2013. *Carbon Storage in Engineered Wood Products in Landfills.* Forest & Wood Products Australia.

Zhang, G., Zhang, J., Ren, J., Li, J. and Liu, S., 2008. *Distributions andsea-to-air fluxes of methane and nitrous oxide in the North East China Sea in Summer.* Mar. Chem. 110: 42-55.

A1.1.2 Volume 3

11. Kyoto Protocol LULUCF

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2013, *Australia's State of the Forests Report 2013,* Five-yearly report prepared by the Montreal Process Implementation Group for Australia and the National Forest Inventory Steering Committee on behalf of the Australian, state and territory governments.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020, *Australian Forest and Wood Products Statistics, March and June quarters 2020,* Canberra

Atwell, B.J., RE. Kriedemann, and C.G.N. Turnbull (1999) *Plants in Action: adaption in nature, performance in cultivation*, Macmillan Education Australia, Melbourne.

DCCEE (Department of Climate Change and Energy Efficiency), 2011 *Energy use in the Australian Governments' operations* Department of Resources, Energy and Tourism, Canberra.

Department of the Environment, 1992. *National Strategy for Ecologically Sustainable Development,* prepared by the Ecologically Sustainable Development Steering Committee for the Council of Australian Governments

Department of Jobs, Precincts and Regions, 2020. *Harvested Logging Coups (One layer per logging season).* State Government of Victoria. Available at data.vic.gov.au

Federici, S., 2016. REPORT on the Services Agreement for a review of specific land sector elements of Australia's NGHGI. Forest land – Treatment of natural disturbances. A report to the Department of the Environment

FFMG (Forest Fire Management Group), 2014. *National Bushfire Management Policy Statement for Forests and Rangelands*, prepared for the Council of Australian Governments

Finn, B., Mutendeudzi, M., Davey, S., and Read, S., 2015. *Salvage harvesting likelihood.* A report prepared for the Australian Government Department of the Environment, Canberra, Australia

IPCC (Intergovernmental Panel on Climate Change), *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

2014. 2013 *Revised supplementary methods and good practice guidance arising from the Kyoto Protocol,* IPCC Switzerland.

KPMG, 2019. *Australian Pine Log Price Index (Stumpage). January to June 2019.* Public version.

Roxburgh, S., Volkova, L., Surawski, N., Meyer, M. and Weston, C., 2015. *Review of fuel loads, burn efficiencies, emissions factors and recovery functions used to estimate greenhouse gas emissions and removals associated with wildfire on temperate forested lands,* CSIRO.

Soto-Berelov, M., Jones, S. and Gupta, V., 2015. *Validation of AVHRR and MODIS Coarse Resolution Burnt Area Products across Australian Southern Forests.* Report produced for the Department of Environment. School of Mathematical and Geospatial Sciences, RMIT University, Victoria.

Viscarra Rossel, R.A., 2014. *Applications of proximal sensing to soil science.* European Journal of Soil Science, 65(6): 815

Viscarra Rossel, R.A., Webster, R., Bui, E.N., and Baldock, J.A., 2014. *Spatial estimates of organic carbon storage to support national carbon accounting and monitoring under climate change.* Global Change Biology, 20(9): 2953–2970.

12. Information on accounting of Kyoto units

Australian National Registry of Emissions Units Regulations 2011 (Cwlth), ComLaw, https://www.legislation.gov.au/Series/F2011L02585

DOE (Department of the Environment), 2015. *National Inventory Report 2013,* Department of the Environment Canberra.

15. Minimisation of adverse impacts in accordance with Article 3.14

Stern, N 2006, *Stern Review on the Economics of Climate Change–a report to the Prime Minister of the United Kingdom and Exchequer on the Economics of Climate Change,* London. *Garnaut, R 2008, The Garnaut Climate Change Review–Final Report,* Commonwealth of Australia, Cambridge University Press, Melbourne

Garnaut, R 2011, *The Garnaut Review 2011,* Commonwealth of Australia, Cambridge University Press, Melbourne

Annex 1: Key category analysis

IPCC (Intergovernmental Panel on Climate Change), 2006. *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

2014. 2013 *Revised supplementary methods and good practice guidance arising from the Kyoto Protocol,* IPCC Switzerland.

Annex 2: Uncertainty analysis

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), 2020, *Australian Forest and Wood Products Statistics Datasets, 2020,* ABARES technical report November 2020, Canberra.

Burnbank Consulting, 2007, *Uncertainty analysis – solid waste.* Burnbank Consulting Pty. Ltd, 15 January 2007.

CSIRO (Commonwealth Scientific and Industrial Research Organisation), 2005, *Australian Greenhouse*

Information System: Quantitative Estimates of Uncertainty. CSIRO Atmospheric Research, Aspendale Victoria.

IPCC (Intergovernmental Panel on Climate Change), 2006. *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

Annex 3: Black Carbon Inventory

Commission for Environmental Protection, 2015, *North American Black Carbon Emissions Estimation Guidelines: Recommended Methods for Estimating Black Carbon Emissions,* Canada

Environment and Climate Change Canada, 2018, *Canadas 'Black Carbon Inventory 2018 Edition,* Canada

U.S. Environmental Protection Agency, 2016, *SPECIATE Version 4.5 Database Development Documentation,* United States of America

European Environment Agency, 2017, *EMEP/EEA air pollutant emission inventory guidebook 2016 – Last Update June 2017,* European Union

Department of the Environment, Water, Heritage and the Arts, 2008, *Emission estimation technique manual for Combustion engines Version 3.0,* Australia

Annex 5: Assessment of completeness

IPCC (Intergovernmental Panel on Climate Change), 2006. *2006IPCC Guidelines for National Greenhouse Gas Inventories,* Japan.

Annex 6: Additional Information: Quality controls including Australia's National Carbon Balance

UN (United Nations), European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organization for Economic Co-operation and Development and the World Bank, 2014a. *System of Environmental-Economic Accounting 2012 – Central Framework.* New York.

UN (United Nations), European Union, Food and Agriculture Organization of the United Nations, Organization for Economic Co-operation and Development and World Bank Group, 2014b. *System of Environmental- Economic Accounting 2012 – Experimental Ecosystem Accounting.* New York.

Annex 7: Description of Australia's National Registry

Australian National Registry of Emissions Units Act 2011 (Cwlth), ComLaw, https://www.legislation.gov.au/ Series/C2011A00099

Australian National Registry of Emissions Units Regulations 2011 (Cwlth), ComLaw, https://www.legislation.gov.au/Series/F2011L02585

industry.gov.au