Ministry for the Environment
Manatū Mō Te Taiao

New Zealand's Greenhouse Gas Inventory 1990–2011



New Zealand Government

Fulfilling reporting requirements under the
United Nations Framework Convention on Climate Change
and New Zealand's submission
under Article 7.1 of the Kyoto Protocol.

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Executive summary

ES.1 Background

New Zealand's Greenhouse Gas Inventory is the official annual report of all anthropogenic (human induced) emissions and removals of greenhouse gases in New Zealand. The inventory measures New Zealand's progress against obligations under the United Nations Framework Convention on Climate Change (Climate Change Convention) and the Kyoto Protocol.

The inventory reports emissions and removals of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The indirect greenhouse gases, carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOCs) are also included. Only emissions and removals of the direct greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) are reported in total emissions under the Climate Change Convention and accounted for under the Kyoto Protocol. The gases are reported under six sectors: energy; industrial processes; solvent and other product use; agriculture; land use, land-use change and forestry (LULUCF); and waste.

This submission includes a complete time series of emissions and removals from 1990 through to 2011 (the current inventory year) and supplementary information required for the Kyoto Protocol. Consistent with the Climate Change Convention reporting guidelines, each inventory report is submitted 15 months after conclusion of the calendar year reported, allowing time for data to be collected and analysed.

Reporting of afforestation, reforestation and deforestation activities since 1990 (Article 3.3 activities under the Kyoto Protocol) is mandatory during the first commitment period of the Kyoto Protocol for Annex 1 Parties. Reporting on forest management, cropland management, grazing land management and revegetation is voluntary for the first commitment period (Kyoto Protocol Article 3.4). New Zealand will account for Article 3.3 activities at the end of the first commitment period. New Zealand did not elect to account for any of the Article 3.4 activities during the first commitment period.

ES.2 National trends

Total (gross) emissions

Total emissions include those from the energy, industrial processes, solvent and other product use, agriculture and waste sectors, but do not include net removals from the LULUCF sector. Reporting of total emissions excluding the LULUCF sector is consistent with the reporting requirements of the Climate Change Convention.[1]

[1] UNFCCC. 2006. FCCC/SBSTA/2006/9. *Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual*

1990–2011

In 1990, New Zealand's total greenhouse gas emissions were 59,643.1 Gg carbon dioxide equivalent (CO_2-e). In 2011, total greenhouse gas emissions had increased by 13,191.9 Gg CO_2-e (22.1 per cent) to 72,834.9 Gg CO_2-e (figure ES 2.1.1). From 1990 to 2011, the average annual growth in total emissions was 1.0 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were: dairy cattle enteric fermentation,[2] road transport, agricultural soils, and consumption of halocarbons and SF_6.

2010–2011

Since 2010, New Zealand's total greenhouse gas emissions increased by 987.2 Gg CO_2-e (1.4 per cent). The size of the overall increase is small because, although emissions from the industrial processes and agriculture sectors rose, there was a decrease in emissions from the energy sector.

The decrease in energy emissions is primarily due to a decrease in emissions from electricity generation. The main drivers that led to the decrease in emissions from electricity generation were:

- a reduction in national electricity demand in the wake of the February 2011 Canterbury earthquake
- an increase in electricity supply from wind generation following the commissioning of two new wind farms.

The continued increase in emissions from the consumption in HFCs was the main driver in the rise of emissions from industrial processes. Since 2010, emissions from the consumption of HFCs increased by 807.4 Gg CO_2-e (74.9 per cent). This large increase in HFC emissions is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

The continued increase in the national dairy cattle population (259,051 or 4.4 per cent over 2010 levels) led to the increase in agricultural emissions of methane and nitrous oxide. The dairy industry is the main user of nitrogen fertiliser in New Zealand, therefore, with a favourable milk price, there was an increase in the volume of nitrogen applied as fertiliser in 2011 (27,303 tonnes nitrogen (N) or 7.6 per cent). This resulted in an additional increase of nitrous oxide emissions.

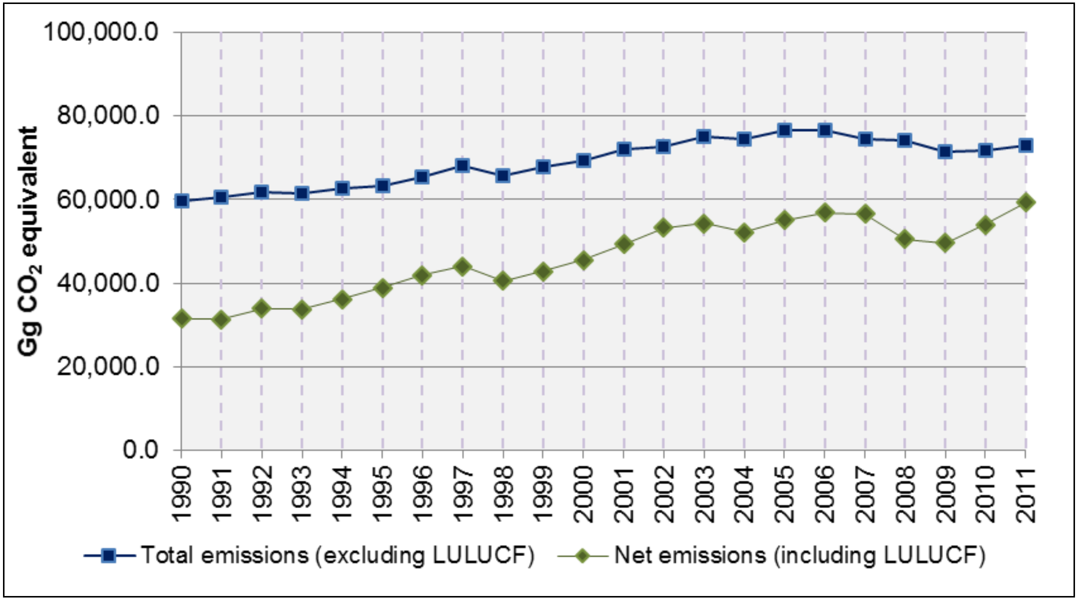
Net emissions – Climate Change Convention reporting

Net emissions include emissions from the energy, industrial processes, solvent and other product use, agriculture and waste sectors, together with emissions and removals from the LULUCF sector.

In 1990, New Zealand's net greenhouse gas emissions were 31,530.4 Gg CO_2-e. In 2011, net greenhouse gas emissions had increased by 27,764.4 Gg CO_2-e (88.1 per cent) to 59,294.7 Gg CO_2-e (figure ES 2.1.1).

[2] Methane emissions produced from ruminant livestock.

Figure ES 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2011



Accounting under the Kyoto Protocol

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol*.[3] The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time series of emissions reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 3.7 per cent lower than the 1990 level of 61,912.9 Gg CO_2-e, which was estimated in 2006 and used in the initial assigned amount calculation.

In 2011, net removals were 16,765.5 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section 2.5 for further detail). The accounting quantity for 2011 was 16,876.9 Gg CO_2-e. This is different from net removals because debits resulting from harvesting of afforested and reforested land during the first commitment period are limited to the level of credits received for that land.

ES.3 Gas trends

The relative proportions of greenhouse gases emitted by New Zealand have changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's total emissions in 1990, in 2011, CO_2 was the major greenhouse gas in New Zealand's emissions profile (table ES.3.1.1). This growth in emissions of CO_2 corresponds with growth in emissions from the energy sector.

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[3] Ministry for the Environment. 2006. *New Zealand's Initial Report under the Kyoto Protocol: Facilitating the calculation of New Zealand's assigned amount and demonstrating New Zealand's capacity to account for its emissions and assigned amount in accordance with Article 7 paragraph 4 of the Kyoto Protocol*. Wellington: Ministry for the Environment.

Table ES 3.1.1 **New Zealand's total (gross) emissions by gas in 1990 and 2011**

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2011	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	25,047.1	33,162.2	+8,115.2	+32.4
CH_4	25,650.3	27,050.1	+1,399.8	+5.5
N_2O	8,300.6	10,689.7	+2,389.1	+28.8
HFCs	NO	1,885.1	+1,885.1	NA
PFCs	629.9	30.2	–599.7	–95.2
SF_6	15.2	17.6	+2.4	+15.9
Total	**59,643.1**	**72,834.9**	**+13,191.9**	**+22.1**

Note: Total emissions exclude net removals from the LULUCF sector. The per cent change for hydrofluorocarbons is not applicable (NA) as production of hydrofluorocarbons in 1990 was not occurring (NO). Columns may not total due to rounding.

ES.4 Sector trends

The agriculture sector contributed the largest proportion of total emissions in 2011 (table ES.4.1.1 and figure ES.4.1.1). The proportion of emissions from the agriculture sector has generally been decreasing since 1990, while the proportion of emissions from the energy sector increased (figure ES.4.1.2) until 2008. Emissions from agriculture have increased from 2009 to 2011 due to greater demand for New Zealand agricultural produce in the dairy sector and a favourable milk price. This led to an increase in the dairy cattle population and the amount of nitrogen applied as fertiliser to agricultural soils resulting in an increase of methane and nitrous oxide emissions from the sector.

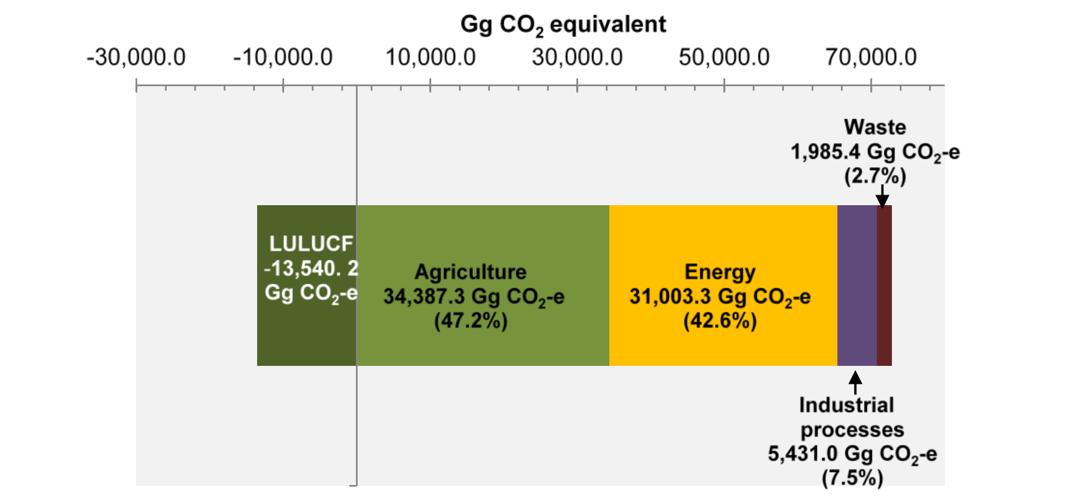
Meanwhile, the energy sector has experienced the greatest increase over the period 1990–2008 (figure ES.4.1.3). Energy emissions have increased approximately two-and-a-half times as much as those from the agriculture sector. The energy sector has had the most influence on the trend in total emissions between 1990 and 2008 becoming the largest contributing sector to total emissions in 2008 (figure ES.4.1.4). However, from 2009 to 2011, the contribution of emissions from the energy sector decreased by approximately 1 per cent a year. The decrease reflects effects of the global recession, recent earthquakes and the closure of coal mines following accidents, as well as greater investment in renewable energy sources in New Zealand.

Table ES 4.1.1 **New Zealand's emissions by sector in 1990 and 2011**

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2011	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,487.7	31,003.3	+7,515.6	+32.0
Industrial processes	3,392.8	5,431.0	+2,038.1	+60.1
Solvent and other product use	41.5	27.9	–13.6	–32.8
Agriculture	30,661.9	34,387.3	+3,725.4	+12.1
Waste	2,059.1	1,985.4	–73.7	–3.6
Total (excluding LULUCF)	**59,643.1**	**72,834.9**	**+13,191.9**	**+22.1**
LULUCF	–28,112.7	–13,540.2	+14,572.5	+51.8
Net Total (including LULUCF)	**31,530.4**	**59,294.7**	**+27,764.4**	**+88.1**

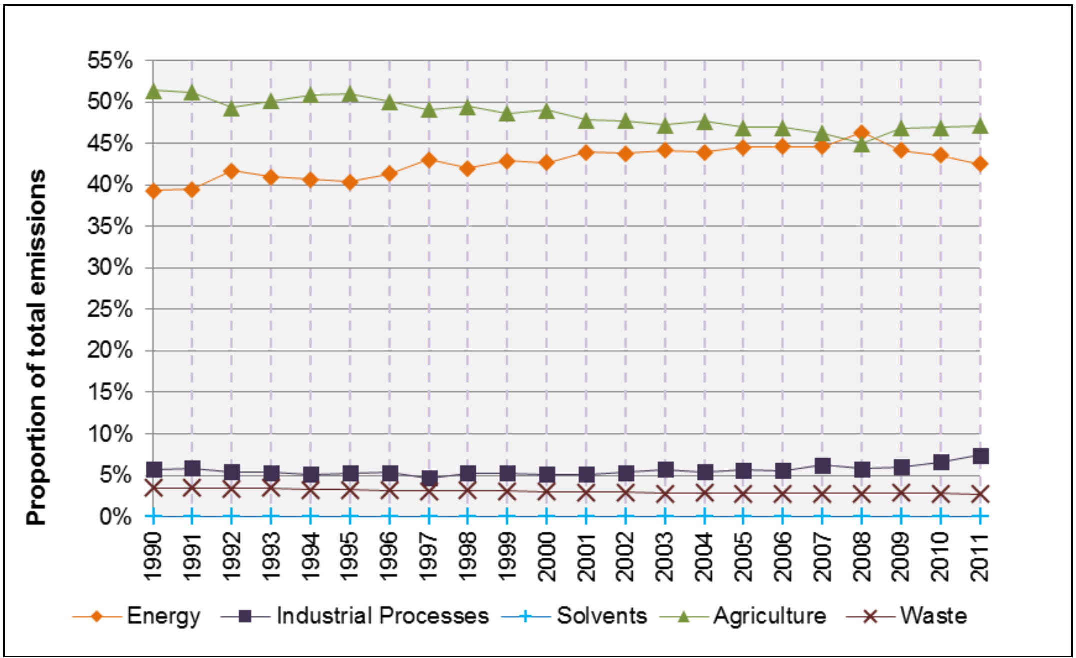
Note: Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding.

Figure ES 4.1.1 New Zealand's emissions by sector in 2011



Note: Emissions from the solvent and other product use sector are not represented in this figure. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7).

Figure ES 4.1.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2011



Note: Total emissions exclude net removals from the LULUCF sector.

Figure ES 4.1.3 Change in New Zealand's emissions by sector in 1990 and 2011

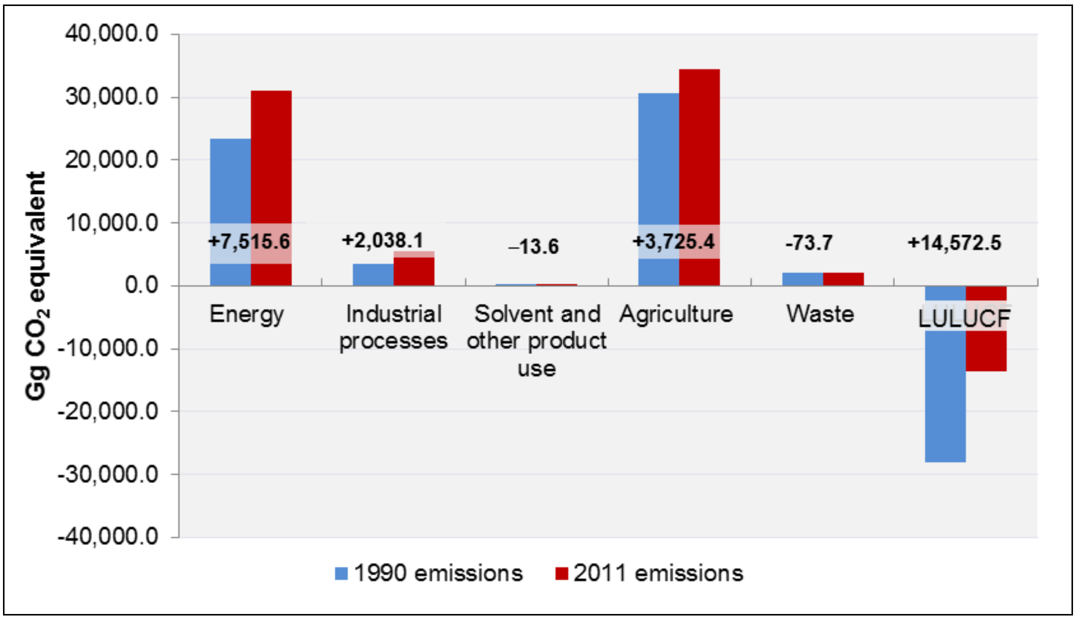
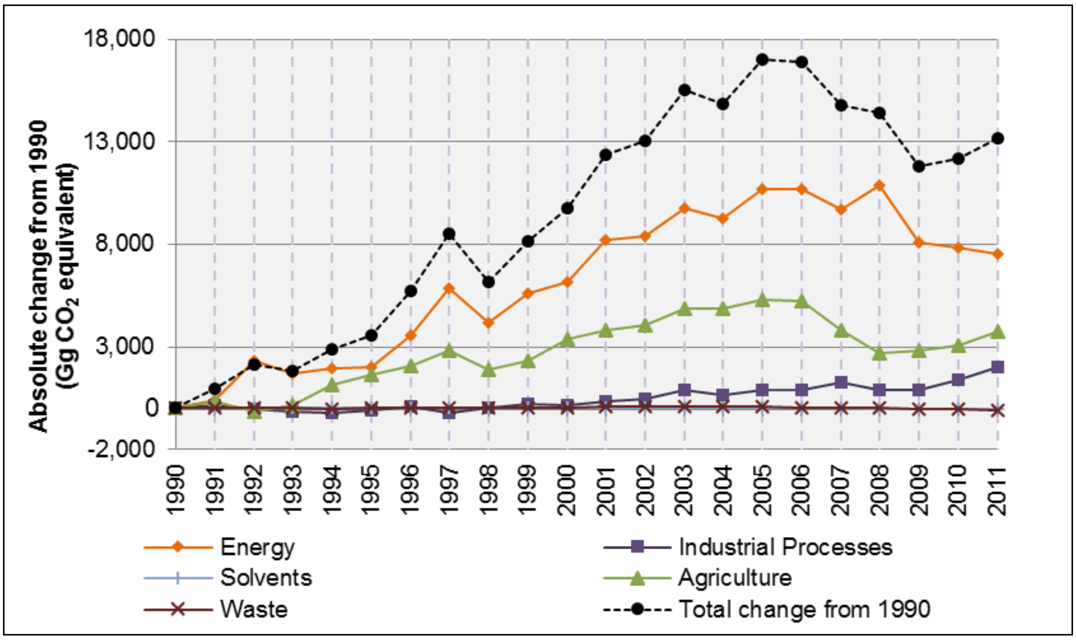


Figure ES 4.1.4 Absolute change in New Zealand's total emissions by sector from 1990 to 2011



Note: Total emissions exclude net removals from the LULUCF sector.

Energy (chapter 3)

2011

The energy sector was the source of 31,003.3 Gg CO_2-e (42.6 per cent) of total emissions in 2011. The largest sources of emissions in the energy sector were road transportation, contributing 12,569.8 Gg CO_2-e (40.5 per cent), and public electricity and heat production, contributing 5,127.9 Gg CO_2-e (16.5 per cent) to energy emissions.

1990–2011

In 2011, energy emissions had increased by 7,515.6 Gg CO_2-e (32.0 per cent) from the 1990 level of 23,487.7 Gg CO_2-e. This growth in emissions is primarily from road transportation, which increased by 5,162.8 Gg CO_2-e (69.7 per cent), and public electricity and heat production, which increased by 1,655.9 Gg CO_2-e (47.7 per cent).

2010–2011

Since 2010, emissions from the energy sector decreased by 314.1 Gg CO_2-e (1.0 per cent). This is primarily due to a 316.8 Gg CO_2-e (5.8 per cent) decrease in emissions from public electricity and heat production as a result of:

- the Canterbury earthquake in February 2011:
  - population reduction in the region resulted in a drop in regional residential energy demand. This was observed primarily in electricity and gasoline statistics
  - damage to infrastructure led to demolition or closure of much of the Christchurch central business district, resulting in reduced commercial electricity demand
- a 20 per cent increase in generation from wind following the commissioning of two new wind farms in 2011. This had the effect of using wind-generated energy in place of the most expensive generation (thermal), having a total net reduction in greenhouse gas emissions.

There was also a 222.2 Gg CO_2-e (8.7 per cent) decrease in sector fugitive emissions. This was primarily due to reduced activity in subcategory coal mining and handling as a result of:

- Pike River Mine being sealed in January 2011 due to explosions in November 2010
- nearby Spring Creek Mine suspending its coal production in November 2010 to May 2011 to accelerate work on a safety improvement programme.

Industrial processes (chapter 4)

2011

The industrial processes sector contributed 5,431.0 Gg CO_2-e (7.5 per cent) of total emissions in 2011. The largest source of industrial process emissions is the metal production category (CO_2 and PFCs), contributing 42.2 per cent of industrial processes sector emissions in 2011.

1990–2011

Emissions from industrial processes in 2011 had increased by 2,038.1 Gg CO_2-e (60.1 per cent) above the 1990 level of 3,392.8 Gg CO_2-e. This increase has largely been driven by emissions from the consumption of halocarbons and SF_6 category, with an increase in these emissions of 1,890.4 Gg CO_2-e. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

2010–2011

Since 2010, emissions from the industrial processes sector increased by 666.8 Gg CO_2-e (14.0 per cent). The main emission source that drove this increase was the consumption of HFCs. Since 2010, emissions from the consumption of HFCs increased by 807.4 Gg

CO_2-e (74.9 per cent). This large increase in HFC emissions is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

Solvent and other product use (chapter 5)

In 2011, the solvent and other product use sector was responsible for 27.9 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products use sector are negligible compared with other sectors.

Agriculture (chapter 6)

2011

The agriculture sector was the largest source of emissions in 2011, contributing 34,387.3 Gg CO_2-e (47.2 per cent) of total emissions. New Zealand has an unusual emissions profile amongst developed countries. In many other developed countries, agricultural emissions are typically around 12 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2011 were enteric fermentation and nitrous oxide emissions from agricultural soils.

1990–2011

In 2011, New Zealand's agricultural emissions increased by 3,725.4 Gg CO_2-e (12.1 per cent) from the 1990 level of 30,661.9 Gg CO_2-e. This increase is largely due to the increase in enteric fermentation emissions from dairy cattle and N_2O emissions from agricultural soils.

2010–2011

Since 2010, emissions from the agriculture sector increased 665.0 Gg CO_2-e (2.0 per cent). This was due to greater demand for New Zealand agricultural produce in the dairy sector, which led to an increase in the dairy cattle population and the amount of nitrogen applied as fertiliser. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a favourable milk price, there was an increase in both dairy population and the sale and use of nitrogen fertiliser in 2011.

LULUCF under the Climate Change Convention (chapter 7)

2011

In 2011, net removals from the LULUCF sector under the Climate Change Convention were 13,540.2 Gg CO_2-e. The highest contribution to removals in 2011 was from land converted to forest land. In 2011, net removals for land converted to forest land were 27,221.3 Gg CO_2-e. This is largely due to the removals from the growth of first rotation forests.

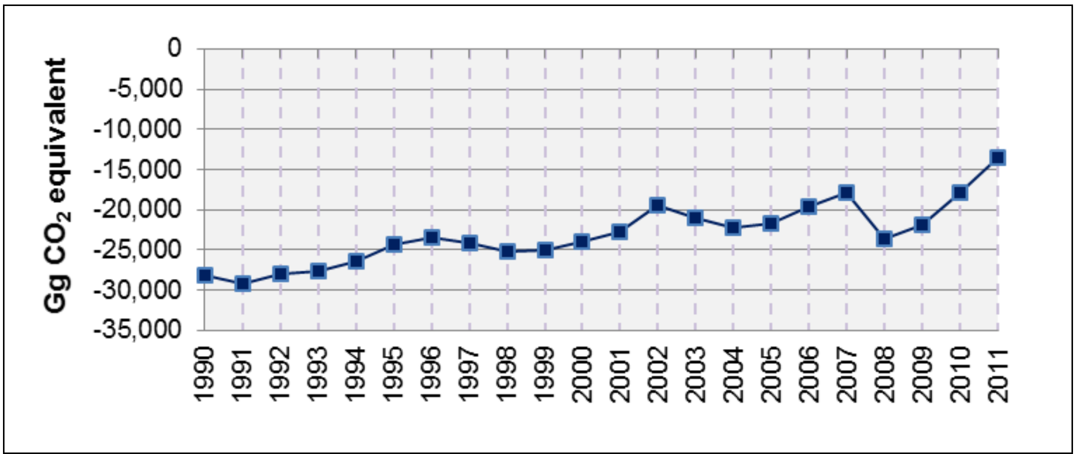
The largest source of emissions in LULUCF is from forest land remaining forest land. In 2011, net emissions for forest land remaining forest land contributed 9,480.1 Gg CO_2-e. This is largely due to the emissions from harvesting exceeding removals from growth of these forests during 2011.

1990–2011

From 1990 to 2011, net removals from LULUCF decreased by 14,572.5 Gg CO_2-e (51.8 per cent) from the 1990 level of –28,112.7 Gg CO_2-e. This decrease in net removals is largely the result of increased harvesting of plantation forests as a larger proportion of the estate reaches harvest age.

The fluctuations in net removals from LULUCF across the time series (figure ES 4.1.5) are influenced by harvesting and deforestation rates. Harvesting rates are driven by a number of factors particularly tree age and log prices. Deforestation rates are driven largely by the relative profitability of forestry compared with alternative land uses. The decrease in net removals between 2004 and 2007 was largely due to the increase in the planted forest deforestation that occurred leading up to 2008, before the introduction of the New Zealand Emissions Trading Scheme (NZ ETS).[4] The decrease in net removals since 2008 is due to the increasing harvesting that has been occurring in pre-1990 planted forests.

Figure ES 4.1.5 New Zealand's LULUCF sector net removals from 1990 to 2011



2010–2011

Since 2010, net removals from LULUCF decreased by 4,274.2 Gg CO_2-e (24.0 per cent). This decrease in net removals is largely the result of an increase in harvesting of pre-1990 planted forest and increased new planting. New planting resulted in emissions due to a loss of biomass associated with the previous land use and a loss of soil carbon with the land-use change to forestry, outweighing removals by forest growth.

Waste (chapter 8)

The waste sector contributed 1,985.4 Gg CO_2-e (2.7 per cent) to total emissions in 2011. Emissions from the waste sector have decreased by 73.7 Gg CO_2-e (3.6 per cent) from the 1990 level of 2,059.1 Gg CO_2-e. This reduction occurred in the solid waste disposal on land category and is likely a result of initiatives to improve solid waste management practices.

[4] The New Zealand Emissions Trading Scheme included the forestry sector as of 1 January 2008.

ES.5 Activities under Article 3.3 of the Kyoto Protocol

Estimates of removals and emissions under Article 3.3 of the Kyoto Protocol are included in the 2011 inventory (table ES 5.1.1).

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2011 was 599,269 hectares. The net area is the total area of post-1989 forest (618,053 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (18,784 hectares). Net removals from this land in 2011 were 18,440.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2011 was 105,512 hectares. The area subject to deforestation in 2011 was 3,700 hectares. In 2011, deforestation emissions were 1,674.6 Gg CO_2-e, compared with 1,029.4 Gg CO_2-e in 2010 (a 62.7 per cent increase). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2011 as a result of deforestation since 1990. Lagged emissions include the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table ES 5.1.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2008–2011

Source	2008	2009	2010	2011
Afforestation/reforestation (AR)				
Net cumulative area since 1990 (ha)	580,765.01	583,964.82	588,768.97	599,269.00
Area in calendar year (ha)	1,900.00	4,300.00	6,000.00	12,000.00
Net removals from AR land not harvested in CP1 (Gg CO_2-e)	–18,199.48	–18,293.56	–18,455.91	–18,551.52
Emissions from AR land harvested in CP1 (Gg CO_2-e)	82.42	96.24	106.08	111.43
Net removals in calendar year (Gg CO_2-e)	**–18,117.06**	**–18,197.32**	**–18,349.83**	**–18,440.09**
Deforestation				
Net cumulative area since 1990 (ha)	95,937.27	99,195.93	101,811.91	105,511.91
Area in calendar year (ha)	3,467.00	3,259.00	2,616.00	3,700.00
Emissions in calendar year (Gg CO_2-e)	1,586.19	1,368.06	1,029.40	1,674.62
Total area subject to afforestation, reforestation and deforestation	**676,702.28**	**683,160.76**	**690,580.88**	**704,780.91**
Net removals (Gg CO_2-e)	**–16,530.87**	**–16,829.26**	**–17,320.43**	**–16,765.48**
Accounting quantity (Gg CO_2-e)	**–16,613.29**	**–16,925.50**	**–17,426.50**	**–16,876.91**

Note: The areas stated are as at 31 December. They are net areas, that is, areas of afforestation and reforestation that were deforested during the period are only included in the figures as deforestation. Afforestation/reforestation refers to new forest established since 1 January 1990. Deforestation includes deforestation of natural forest, pre-1990 planted forest and post-1989 forest. Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Columns may not total due to rounding.

ES.6 Improvements introduced

The largest improvements in the accuracy of emissions and removals, made to *New Zealand's Greenhouse Gas Inventory* following the 2012 submission, were made in the LULUCF and energy sectors. Chapter 10 provides a summary of all recalculations made to the estimates.

Improvements made to the national system are included in chapter 13 and improvements made to New Zealand's national registry are included in chapter 14.

LULUCF – Forest land (sections 7.1.5 and 7.3.5)

The main differences between this submission and previous estimates of New Zealand's LULUCF net removals reported in the 2012 submission are the result of (in decreasing order of magnitude):

- the activity data used to estimate harvesting emissions in pre-1990 planted forests being scaled by 17 per cent throughout the time series to account for differences in forest definitions used in the inventory and the source of the activity data[5]
- the correction of an error detected in the calculation process when upgrading to the Forest Carbon Predictor, version 3 for last year's submission, which affected the implementation of the new post-1989 planted forest yield table
- continued improvements to the 1990 and 2008 land-use maps. Mapping data provided from the NZ ETS was integrated into the 1990 and 2008 maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- emissions being reported for controlled burning in forest land remaining forest land for the first time in the 2013 submission. Estimates are provided for the burning of post-harvest residues prior to restocking.

Energy – Emission factor for solid fuels (section 3.3.1)

The most significant recalculation in the energy sector was a review of CO_2 emission factors for solid fuels across the time series from 1990–2011.

Emission factors for solid fuels have been updated for this submission across the time series from 1990 to 2011. A comprehensive list of carbon content by coal mining is not currently available. However, a review of New Zealand's coal emission factors in preparation for the NZ ETS[6] recommended re-weighting the current default emission factors to 2007 production rather than continue with those in the New Zealand Energy Information Handbook.[7] A comparison of the original and updated emission factors can be found in table 3.3.1 of this submission. This has resulted in changes in emissions from solid fuel combustion across all sectors, including public electricity and heat production.

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5 See section 7.3 for details.

6 CRL Energy Ltd. 2009. *Reviewing Default Emission Factors in Draft Stationary Energy and Industrial Processes.* Contract report prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

7 Baines JT. 1993. New Zealand Energy Information Handbook. Christchurch: Taylor Baines and Associates.

ES.7 National registry

In January 2008, New Zealand’s national registry was issued with New Zealand’s assigned amount of 309,564,733 metric tonnes of carbon dioxide equivalent (CO_2-e). At the end of 2012, there were 306,041,662 assigned amount units. During 2012, no Kyoto Protocol units were expired, replaced or cancelled.

Contents

Tables

Figures

General notes

Units

Standard metric prefixes used in this inventory are:

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

Emissions are generally expressed in gigagrams (Gg) in the inventory tables:

1 gigagram (Gg) = 1000 tonnes = 1 kilotonne (kt)

1 megatonne (Mt) = 1,000,000 tonnes = 1000 Gg

Gases

CO_2	carbon dioxide
CH_4	methane
HFCs	hydrofluorocarbons
N_2O	nitrous oxide
PFCs	perfluorocarbons
SF_6	sulphur hexafluoride
CO	carbon monoxide
NMVOCs	non-methane volatile organic compounds
NO_x	oxides of nitrogen
SO_2	sulphur dioxide

Global warming potentials

The global warming potential is an index representing the combined effect of the differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing thermal infrared radiation.[8]

The Climate Change Convention reporting requirements[9] stipulate that the 100-year global warming potentials contained in the IPCC Second Assessment Report are used in

[8] IPCC. 2007. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K, Tignor MB, Miller HL (eds). *Climate Change 2007: The physical science basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. United Kingdom: Cambridge University Press.

[9] UNFCCC. 2006. FCCC/SBSTA/2006/9. *Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (following incorporation of the provisions of decision 13/CP.9)*.

national inventories.[10] The indirect effects on global warming of a number of gases (CO, NO_x, SO_2 and NMVOCs) cannot currently be quantified, and, consequently, these gases do not have global warming potentials. In accordance with the Climate Change Convention reporting guidelines,[11] indirect greenhouse gases that do not have global warming potentials are reported in the inventory but are not included in the inventory emissions total.

Common global warming potentials (100-year time period)

(refer to http://unfccc.int/ghg_emissions_data/items/3825.php)

CO_2 = 1	HFC-32 = 650
CH_4 = 21	HFC-125 = 2800
N_2O = 310	HFC-134a = 1300
CF_4 = 6500	HFC-143a = 3800
C_2F_6 = 9200	HFC-227ea = 2900
SF_6 = 23,900	

Conversion factors

From element basis to molecular mass	From molecular mass to element basis
$C \rightarrow CO_2$: C × 44/12 (3.67)	$CO_2 \rightarrow C$: CO_2 × 12/44 (0.27)
$C \rightarrow CH_4$: C × 16/12 (1.33)	$CH_4 \rightarrow C$: CO_2 × 12/16 (0.75)
$N \rightarrow N_2O$: N × 44/28 (1.57)	$N_2O \rightarrow N$: N_2O × 28/44 (0.64)

Notation keys

In the common reporting format tables, the following standard notation keys are used.

C	Confidential: where reporting of emissions or removals at a disaggregated level could lead to the disclosure of confidential information.
IE	Included elsewhere: where emissions or removals are estimated but included elsewhere in the inventory. Table 9 of the common reporting format tables details the source category where these emissions or removals are reported.
NA	Not applicable: when the activity occurs in New Zealand 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 New Zealand but there is no data or methodology available to derive an estimate of emissions. This can also apply to negligible emissions.
NO	Not occurring: when the activity or process does not occur in New Zealand.

[10] IPCC. 1995. Houghton JT, Meira Filho LG, Callender BA, Harris N, Kattenberg A, Maskell K (eds). *Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change*. United Kingdom: Cambridge University Press.

[11] UNFCCC. 2006. FCCC/SBSTA/2006/9. *Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (following incorporation of the provisions of decision 13/CP.9)*.

PART I: ANNUAL INVENTORY SUBMISSION

Chapter 1: Introduction

1.1 Background

Greenhouse gases in the Earth's atmosphere trap warmth from the sun and make life as we know it possible. However, since the industrial revolution (about 1750) there has been a global increase in the atmospheric concentration of greenhouse gases including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2007). In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that most of the increase in global average temperatures since the mid-20th century is very likely due to the observed increase in greenhouse gas concentrations (IPCC, 2007). This increase is attributed to anthropogenic sources (human activity), particularly the burning of fossil fuels and land-use change.

The IPCC has projected that continued greenhouse gas emissions at, or above, current rates will cause further warming and induce many changes in the global climate system during the 21st century.

1.1.1 The United Nations Framework Convention on Climate Change

The science of climate change is assessed by the IPCC. In 1990, the IPCC concluded that human-induced climate change was a threat to our future. In response, the United Nations General Assembly convened a series of meetings that culminated in the adoption of the United Nations Framework Convention on Climate Change (Climate Change Convention) at the Earth Summit in Rio de Janeiro in May 1992.

The Climate Change Convention has been signed and ratified by 194 nations, including New Zealand, and took effect on 21 March 1994.

The main objective of the Climate Change Convention is to achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (United Nations, 1992).

All countries that ratify the Climate Change Convention (henceforth called 'Parties') are required to address climate change including monitoring trends in anthropogenic greenhouse gas emissions. The annual inventory of greenhouse gas emissions and removals fulfils this obligation. Parties are also obligated to protect and enhance carbon sinks and reservoirs, for example, forests, and implement measures that assist in national and/or regional climate change adaptation and mitigation. In addition, Parties listed in Annex II[12] to the Climate Change Convention commit to providing financial assistance to non-Annex I Parties (developing countries).

[12] Annex II to the Climate Change Convention (a subset of Annex I) lists the Organisation for Economic Co-operation and Development member countries at the time the Climate Change Convention was agreed.

Annex I[13] Parties that ratified the Climate Change Convention also agreed to non-binding targets, aiming to return greenhouse gas emissions to 1990 levels by the year 2000. Only a few Annex I Parties made appreciable progress towards achieving this aim. The international community recognised that the existing commitments in the Climate Change Convention were not enough to ensure greenhouse gas levels would be stabilised at a safe level. More urgent action was needed. In response, in 1995, Parties launched a new round of talks to provide stronger and more detailed commitments for Annex I Parties. After two-and-a-half years of negotiations, the Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997. New Zealand ratified the Kyoto Protocol on 19 December 2002. The Protocol came into force on 16 February 2005.

1.1.2 The Kyoto Protocol

The Kyoto Protocol shares and expands upon the Climate Change Convention's objective, principles and institutions. Only Parties to the Climate Change Convention that have also become Parties to the Protocol (by ratifying, accepting, approving or acceding to it) are bound by the Protocol's commitments. The objective of the Kyoto Protocol is to reduce the aggregate emissions of six greenhouse gases from Annex I Parties by at least 5 per cent below 1990 levels in the first commitment period (2008–2012). New Zealand's target in the first commitment period is to return emissions to 1990 levels[14] on average over the commitment period or otherwise take responsibility for the excess.

The eighth session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (Doha, Qatar, November to December 2012) agreed amendments to the Kyoto Protocol for the second commitment period, including an amended Annex B for commitments for the second commitment period (2013–2020). New Zealand will take a commitment under the Climate Change Convention during the transition period to 2020 and therefore does not have a commitment listed in the amended Annex B of the Kyoto Protocol for the second commitment period.

A Party with a commitment under the Kyoto Protocol (as listed in Annex B of the Kyoto Protocol) must hold sufficient assigned amount units[15] to cover its total emissions during the commitment period at the point that compliance is assessed after the end of the commitment period. A Party's assigned amount comprises assigned amount units, removal units from land use, land-use change and forestry (LULUCF) activities under Article 3.3 or 3.4 activities of the Kyoto Protocol and any other units acquired under the flexibility mechanisms of the Kyoto Protocol. Flexibility mechanisms include the Clean Development Mechanism, Joint Implementation and the trading of assigned amount units between Annex I Parties. Further information on these mechanisms, review and compliance procedures can be obtained from the website of the Climate Change Convention (www.unfccc.int). The Kyoto Protocol compliance equation for the first commitment period as applied to New Zealand is depicted in figure 1.1.1.

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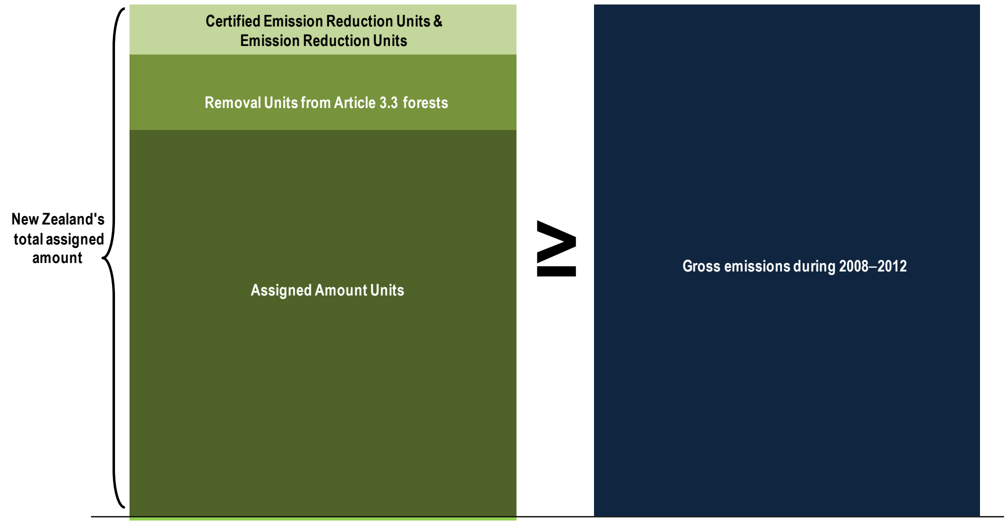
[13] Annex I to the Climate Change Convention lists the countries included in Annex II, as defined above, together with countries defined at the time as undergoing the process of transition to a market economy, commonly known as 'economies in transition'.

[14] New Zealand's target under the Kyoto Protocol is a responsibility target. A responsibility target means that New Zealand can meet its target through a mixture of domestic emission reductions, the storage of carbon in forests and the purchase of emissions reductions in other countries through the emissions trading mechanisms established under the Kyoto Protocol. The target is based on total gross emissions from the energy, industrial processes, solvent and other product use, agriculture and waste sectors.

[15] Total quantity of valid emissions allowances (Kyoto units) held by a Party within its national registry.

Figure 1.1.1 The compliance equation under Article 3.1 of the Kyoto Protocol for the first commitment period as applied to New Zealand (2008–2012)



Note: Gross emissions include emissions from energy, agriculture, waste, industrial processes and solvent and other product use but exclude emissions from deforestation. Deforestation emissions are netted from removals under Article 3.3.

For the first commitment period, New Zealand's initial assigned amount is the gross greenhouse gas emissions estimated for 1990 multiplied by five. The assigned amount is fixed for the duration of the commitment period. The quantity of the assigned amount is issued in units known as assigned amount units (or AAUs). The initial assigned amount does not include emissions and removals from the LULUCF sector unless this sector was a net source of emissions in 1990. In New Zealand, the LULUCF sector was not a net source of emissions in 1990. Carbon sinks that meet Kyoto Protocol requirements for afforestation and reforestation create removal units (popularly known as carbon credits) and these are added to a Party's assigned amount. Units must be cancelled for any harvesting and deforestation emissions if emissions exceed removals.

Reporting and accounting of afforestation, reforestation and deforestation activities since 1990 (Article 3.3 activities under the Kyoto Protocol) is mandatory during the first commitment period of the Kyoto Protocol. Afforestation, reforestation and deforestation activities are defined below. The definitions are consistent with decision 16/CMP.1 (UNFCCC, 2005a).

(a) Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of seed sources.

(b) Reforestation is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

(c) Deforestation is the direct human-induced conversion of forested land to non-forested land.

Accounting for forest management, cropland management, grazing land management and revegetation activities under Article 3.4 of the Kyoto Protocol is voluntary during the first commitment period. New Zealand did not elect to account for any of the Article 3.4 activities during the first commitment period.

1.1.3 The inventory

The Climate Change Convention covers emissions and removals of all anthropogenic greenhouse gases not controlled by the Montreal Protocol. *New Zealand's Greenhouse Gas Inventory* (the inventory) is the official annual report of these emissions and removals in New Zealand.

The methodologies, content and format of the inventory are prescribed by the IPCC (IPCC, 1996; 2000; 2003) and reporting guidelines agreed by the Conference of the Parties to the Climate Change Convention. The most recent reporting guidelines are FCCC/SBSTA/2006/9 (UNFCCC, 2006). A complete inventory submission requires two components: the national inventory report and the common reporting format tables. Inventories are subject to an annual three-stage international expert review process administered by the Climate Change Convention secretariat. The results of these reviews are available online (www.unfccc.int).

The inventory reports emissions and removals of the gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The indirect greenhouse gases, carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOCs) are also included. Only emissions and removals of the direct greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) are reported in total emissions under the Climate Change Convention and accounted for under the Kyoto Protocol. The gases are reported under six sectors: energy; industrial processes; solvent and other product use; agriculture; land use, land-use change and forestry (LULUCF); and waste.

1.1.4 Supplementary information required

Under Article 7.1 of the Kyoto Protocol, New Zealand is required to include supplementary information in its annual greenhouse gas inventory submission. The supplementary information is included in Part II of this report.

The supplementary information required includes:

- information on emissions and removals for each activity under Article 3.3 and for any elected activities under Article 3.4 (chapter 11)
- holdings and transactions of units transferred and acquired under Kyoto Protocol mechanisms (chapter 12)
- significant changes to a Party's national system for estimating emissions and removals (chapter 13) and to the Kyoto Protocol unit registry (chapter 14)
- information relating to the implementation of Article 3.14 on the minimisation of adverse impacts on non-Annex I Parties (chapter 15).

1.2 Institutional arrangements

1.2.1 Legal and procedural arrangements

The Climate Change Response Act 2002 (updated 1 January 2013) enables New Zealand to meet its international obligations under the Climate Change Convention and Kyoto Protocol. A Prime Ministerial directive for the administration of the Climate Change Response Act 2002 names the Ministry for the Environment as New Zealand's 'Inventory

Agency'. Part 3, section 32 of the Climate Change Response Act 2002 specifies the following functions and requirements:

1. The primary functions of the inventory agency, are to:
   a. estimate annually New Zealand's anthropogenic emissions by sources and removals by sinks, of greenhouse gases
   b. prepare the following reports for the purpose of discharging New Zealand's obligations:
      i. New Zealand's annual inventory report under Article 7.1 of the Protocol, including (but not limited to) the quantities of long-term certified emission reduction units and temporary certified emission reduction units that have expired or have been replaced, retired, or cancelled
      ii. New Zealand's national communication (or periodic report) under Article 7.2 of the Kyoto Protocol and Article 12 of the Climate Change Convention
      iii. New Zealand's report for the calculation of its initial assigned amount under Article 7.4 of the Kyoto Protocol, including its method of calculation.
2. In carrying out its functions, the inventory agency must:
   a. identify source categories
   b. collect data by means of:
      i. voluntary collection
      ii. collection from government agencies and other agencies that hold relevant information
      iii. collection in accordance with regulations made under this Part (if any)
   c. estimate the emissions and removals by sinks for each source category
   d. undertake assessments on uncertainties
   e. undertake procedures to verify the data
   f. retain information and documents to show how the estimates were determined.

Section 36 of the Climate Change Response Act 2002 provides for the authorisation of inspectors to collect information needed to estimate emissions or removals of greenhouse gases.

1.2.2 The national system

New Zealand is required under Article 5.1 of the Kyoto Protocol to have a national system in place for its greenhouse gas inventory. New Zealand provided a full description of the national system in its initial report under the Kyoto Protocol (Ministry for the Environment, 2006). Changes to the national system are documented in chapter 13 of this submission.

The Ministry for the Environment is New Zealand's single national entity for the greenhouse gas inventory, responsible for the overall development, compilation and submission of the inventory to the Climate Change Convention secretariat. The Ministry coordinates all of the government agencies and contractors involved in the inventory. The national inventory compiler is based at the Ministry for the Environment. Arrangements with other government agencies have evolved as resources and capacity have allowed and as a greater understanding of the reporting requirements has been attained.

The Ministry for the Environment calculates estimates of emissions for the solvent and other product use sector, waste sector, emissions and removals from the LULUCF sector and Article 3.3 activities under the Kyoto Protocol. Emissions of the non-CO_2 gases from the industrial processes sector are obtained through industry surveys by consultants contracted by the Ministry for the Environment. The various estimates for the industrial processes sector are compiled by the Ministry for the Environment.

The Ministry of Business, Innovation and Employment (the former Ministry of Economic Development) collects and compiles all emissions from the energy sector and CO_2 emissions from the industrial processes sector.

The Ministry for Primary Industries (the former Ministry of Agriculture and Forestry) compiles emissions from the agriculture sector. Estimates are underpinned by research and modelling undertaken at New Zealand's Crown research institutes and universities.

The Ministry for Primary Industries provided data from the *National Exotic Forest Description* and from the New Zealand Emissions Trading Scheme (NZ ETS) on planting, harvesting and deforestation to the Ministry for the Environment's Land Use and Carbon Analysis System (LUCAS) to assist in estimates for the LULUCF sector and Kyoto Protocol Article 3.3 activities.

The Reporting Governance Group provides leadership over the reporting, modelling and projections of greenhouse gas emissions and removals. Membership includes representation from the Ministry for the Environment, the Environmental Protection Authority, Ministry for Primary Industries and the Ministry of Business, Innovation and Employment. The key roles and expectations of the Reporting Governance Group include:

- guide, confer and approve inventory and projection improvements and assumptions (on the basis of advice from technical experts), planning and priorities, key messages, management of stakeholders and risks
- focus on delivery of reporting commitments to meet national and international requirements
- provide reporting leadership and guidance to analysts, modellers and technical specialists
- share information, provide feedback and resolve any differences between departments that impact on the delivery of the work programme
- monitor and report to the Climate Change Directors Group (a cross-agency group that oversees New Zealand's international and domestic climate change policy) on the 'big picture' of the reporting work programme, direction, progress in delivery and capability to deliver.

New Zealand's national statistical agency, Statistics New Zealand, provides many of the official statistics for the agriculture sector through regular agricultural censuses and surveys. Activity data on lime application and livestock slaughtering is also sourced from Statistics New Zealand. Population census data from Statistics New Zealand is used in the waste, and solvent and other product use sectors.

The Climate Change Response Act 2002 (updated 1 January 2013) establishes the requirement for a registry and a registrar. The Environmental Protection Authority is designated as the agency responsible for the implementation and operation of New Zealand's national registry under the Kyoto Protocol, the New Zealand Emission Unit Register. The registry is electronic and accessible via the internet (www.eur.govt.nz). Information on the annual holdings and transactions of transferred and acquired units under the Kyoto Protocol is provided in the standard electronic format tables accompanying this submission. Refer to chapter 12 for further information.

To provide for data security and recovery in the event of disaster for the national inventory files, a distributive strategy for storage is in place. This included storing the inventory files using different types of storage devices (network drives and physical devices) in different geographical locations. The changes to all files are backed up on a daily basis and the entire system is backed up on a weekly basis.

1.3 Inventory preparation processes

Consistent with the Climate Change Convention reporting guidelines, each inventory report is submitted 15 months after conclusion of the calendar year reported, allowing time for data to be collected and analysed. Over the period of October to January, sectoral data is calculated and entered into the Climate Change Convention common reporting format database, and then sectoral peer review and quality checking occur.

The national inventory compiler at the Ministry for the Environment calculates the inventory uncertainty, undertakes the key category assessment, conducts further quality checking and finalises the national inventory report. The inventory is reviewed internally at the Ministry for the Environment before being approved and submitted to the Climate Change Convention secretariat.

The inventory and all required data for the submission to the Climate Change Convention secretariat are stored at the Ministry for the Environment in a controlled file system. The published inventory is available from the websites of the Ministry for the Environment and the Climate Change Convention.

1.4 Methodologies and data sources used

The guiding documents in inventory preparation are the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1996), the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), the Climate Change Convention guidelines on reporting and review (UNFCCC, 2006) and the Kyoto Protocol guidelines on reporting and review (UNFCCC 2005a–k). The concepts contained in the goo8d practice guidance are implemented in stages, according to sector priorities and national circumstances.

The IPCC provides a number of different possible methodologies or variations for calculating a given emission or removal. In most cases, these possibilities represent calculations of the same form but the differences are in the level of detail at which the original calculations are carried out. The methodological guidance is provided in a tiered structure of calculations that describe and connect the various levels of detail at which estimates can be made depending on the importance of the source category, availability of data and other capabilities. The tiered structure ensures that estimates calculated at a very detailed level can be aggregated up to a common minimum level of detail for comparison with all other reporting countries:

a. Tier 1 methods apply IPCC default emission factors and use IPCC default models for emissions and/or removals calculations

b. Tier 2 methods apply country-specific emission factors and use IPCC default models for emissions and/or removals calculations

c. Tier 3 methods apply country-specific emission factors and use country-specific models for emissions and/or removals calculations.

Energy (chapter 3): Emissions from the energy sector are calculated using IPCC Tier 1 and 2 methods. Activity data is compiled from industry-supplied information by the Ministry of Business, Innovation and Employment. Where available, New Zealand-specific emission factors are used for CO_2 emission calculations. Applicable IPCC default factors are used for CO_2 and non-CO_2 emissions where New Zealand emission factors are not available.

Industrial processes, and solvent and other product use (chapters 4 and 5): Activity data and most of the CO_2 emissions are supplied directly to the Ministry of Business, Innovation and Employment by industry sources. The remaining CO_2 estimates are either sourced from the New Zealand Emission Unit Register or directly provided by the industry to the inventory agency. IPCC Tier 1 and 2 approaches and a combination of New Zealand-specific and IPCC default parameters are applied in the industrial processes sector for the CO_2 estimates. Activity data for the non-CO_2 gases is collected via an industry survey, and emissions are estimated by CRL Energy (2012). Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach, and SF_6 emissions from large users are estimated with the Tier 3a approach (IPCC, 2006a).

Agriculture (chapter 6): Livestock population data is obtained from Statistics New Zealand through the agricultural production census and surveys. A Tier 2 (model) approach is used to estimate CH_4 emissions from dairy cattle, non-dairy cattle, sheep and deer. This methodology uses New Zealand animal productivity data to estimate dry-matter intake and CH_4 production. The same dry-matter intake data is used to calculate N_2O emissions from animal excreta. A Tier 1 approach is used to calculate CH_4 and N_2O emissions from livestock species present in less significant numbers.

Land use, land-use change and forestry (chapters 7 and 11): New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating emissions and removals for the LULUCF sector under the Climate Change Convention and Article 3.3 activities under the Kyoto Protocol. A Tier 2 approach has been used to estimate biomass carbon in the pools with the most living biomass at steady state; natural forest, pre-1990 planted forest, post-1989 forest, perennial cropland and grassland with woody biomass. A Tier 1 approach is used for estimating biomass carbon in all other land-use categories. A Tier 1 modelling approach has also been used to estimate carbon changes in the mineral soil component of the soil organic matter pool and for organic soils.

New Zealand has established a data collection and modelling programme for the LULUCF sector called the Land Use and Carbon Analysis System (LUCAS). The LUCAS programme includes the:

- use of field plot measurements for natural and planted forests and airborne scanning LiDAR (Light Detection and Ranging) for planted forests (Stephens et al, 2007, 2008)
- use of allometric equations and models to estimate carbon stock and carbon-stock change in natural and planted forests respectively (Beets et al, 2009; Beets and Kimberley, 2011)
- wall-to-wall land-use mapping for 1990 and 2008 using satellite and aircraft remotely sensed imagery, with the additional information on post-1989 forest afforestation, and deforestation of planted forest used for estimating change

- development of databases and applications to store and manipulate all data associated with LULUCF activities.

Waste (chapter 8): Emissions from the waste sector are estimated using waste survey data combined with population data from Statistics New Zealand. Calculation of emissions from solid waste disposal uses the Tier 2 model from the IPCC 2006 guidelines. Methane and N_2O emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 1996). A combination of New Zealand-specific and IPCC default parameters are used for both the solid waste disposal and wastewater subcategories. There is no incineration of municipal waste in New Zealand. Emissions from incineration of medical, quarantine and hazardous wastes are estimated using the Tier 1 approach (IPCC, 2006b).

1.5 Key categories

1.5.1 Reporting under the Climate Change Convention

The IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000) identifies a key category as: "one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both". Key categories identified within the inventory are used to prioritise inventory improvements.

The key categories in the New Zealand inventory have been assessed using the Tier 1 level and trend methodologies from the IPCC good practice guidance (IPCC, 2000 and 2003). The methodologies identify sources of emissions and removals that sum to 95 per cent of the total level of emissions, and 95 per cent of the trend of the inventory in absolute terms.

In accordance with the *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), the key category analysis is performed once for the inventory excluding LULUCF categories and then repeated for the inventory including the LULUCF categories. Non-LULUCF categories that are identified as key in the first analysis but that do not appear as key when the LULUCF categories are included are still considered as key categories.

The key categories identified in the 2011 year are summarised in table 1.5.1. The major contributions to the level analysis including LULUCF (table 1.5.2(a)) were:

- CO_2 removals from conversion to forest land; a contribution of 23.9 per cent
- CH_4 emissions from dairy cattle enteric fermentation; a contribution of 9.1 per cent
- CO_2 emissions from forest land remaining forest land; a contribution of 8.3 per cent
- CH_4 emissions from sheep enteric fermentation; a contribution of 6.8 per cent.

The key categories that were identified as having the largest relative influence on the trend including LULUCF from 1990 to 2011, compared with the average change in net emissions from 1990 to 2011 (table 1.5.3(a)), were:

- CH_4 emissions from sheep enteric fermentation; contributed 18.8 per cent to the net emissions trend through a decrease

- CH_4 emissions from dairy cattle enteric fermentation; contributed 10.7 per cent to the net emissions trend through an increase
- CO_2 emissions from forest land remaining forest land; a contribution of 9.7 per cent
- CO_2 emissions from diesel oil road transportation; contributed 9.3 per cent to the net emissions trend through an increase.

Table 1.5.1 Summary of New Zealand's key categories for the 2011 level assessment and the trend assessment for 1990 to 2011 (including and excluding LULUCF activities)

Quantitative method used: IPCC Tier 1		
IPCC categories	**Gas**	**Criteria for identification**
Energy		
Transport - road transport - gasoline	CO_2	level, trend
Transport - road transport - diesel oil	CO_2	level, trend
Transport - road transport - gaseous fuels	CO_2	trend
Transport - civil aviation - jet kerosene	CO_2	level
Energy industries - public electricity and heat production - solid fuels	CO_2	level, trend
Energy industries - public electricity and heat production - gaseous fuels	CO_2	level, trend
Energy industries - Petroleum refining - liquid fuels	CO_2	level, trend
Energy industries - Petroleum refining - gaseous fuels	CO_2	trend
Energy industries - Manufacture of solid fuels and other energy industries - gaseous fuels	CO_2	trend
Manufacturing industries and construction - gaseous fuels	CO_2	level
Manufacturing industries and construction - liquid fuels	CO_2	level
Manufacturing industries and construction - solid fuels	CO_2	level, trend
Other sectors - liquid fuels	CO_2	level, trend
Other sectors - solid fuels	CO_2	level, trend
Other sectors - gaseous fuels	CO_2	level
Fugitive emissions - flaring combined	CO_2	level, trend
Fugitive emissions - geothermal	CO_2	level, trend
Fugitive emissions - natural gas	CH_4	trend
Industrial processes		
Mineral products - cement production	CO_2	level
Chemical industry - ammonia production	CO_2	qualitative
Metal production - iron and steel production	CO_2	level
Metal production - aluminium production	CO_2	level
Metal production - aluminium production	PFCs	trend
Consumption of halocarbons and SF_6 - refrigeration and air conditioning	HFCs & PFCs	level, trend
Agriculture		
Enteric fermentation - non dairy cattle	CH_4	level, trend
Enteric fermentation - dairy cattle	CH_4	level, trend
Enteric fermentation - sheep	CH_4	level, trend
Enteric fermentation - deer	CH_4	level
Enteric fermentation - other	CH_4	trend
Manure management	CH_4	level
Agricultural soils – pasture, range and paddock	N_2O	level, trend
Agricultural soils – indirect emissions	N_2O	level
Agricultural soils - direct emissions	N_2O	level, trend
LULUCF		
Forest land remaining forest land	CO_2	level, trend
Grassland remaining grassland	CO_2	level, trend
Conversion to forest land	CO_2	level, trend
Conversion to grassland	CO_2	level, trend
Conversion to cropland	CO_2	trend
Conversion to wetland	CO_2	trend
Waste		
Solid waste disposal on land	CH_4	level, trend
Waste-water handling	CH_4	level

Note: 'Enteric fermentation – other' refers to all enteric fermentation excluding enteric fermentation from dairy cattle, non-dairy cattle, sheep and deer.

Table 1.5.2 (a & b) 2011 level assessment for New Zealand's key category analysis including LULUCF (a) and excluding LULUCF (b)

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2011				
IPCC categories	**Gas**	**2011 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	27,227.0	23.9	23.9
Enteric fermentation – dairy cattle	CH_4	10,381.8	9.1	33.1
Forest land remaining forest land	CO_2	9,468.7	8.3	41.4
Enteric fermentation – sheep	CH_4	7,750.6	6.8	48.2
Transport – road transport – gasoline	CO_2	7,061.4	6.2	54.4
Agricultural soils – pasture, range and paddock	N_2O	5,705.4	5.0	59.4
Transport – road transport – diesel oil	CO_2	5,314.3	4.7	64.1
Enteric fermentation – non-dairy cattle	CH_4	4,860.6	4.3	68.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,622.1	3.2	71.6
Agricultural soils – indirect emissions	N_2O	2,578.4	2.3	73.8
Manufacturing industries and construction – gaseous fuels	CO_2	2,179.9	1.9	75.7
Grassland remaining grassland	CO_2	2,063.5	1.8	77.6
Other sectors – liquid fuels	CO_2	1,880.0	1.7	79.2
Agricultural soils – direct emissions	N_2O	1,874.8	1.6	80.9
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,798.3	1.6	82.4
Manufacturing industries and construction – solid fuels	CO_2	1,752.5	1.5	84.0
Metal production – iron and steel production	CO_2	1,690.8	1.5	85.5
Conversion to grassland	CO_2	1,650.0	1.5	86.9
Energy industries – public electricity and heat production – solid fuels	CO_2	1,489.7	1.3	88.2
Solid waste disposal on land	CH_4	1,331.1	1.2	89.4
Manufacturing industries and construction – liquid fuels	CO_2	1,034.4	0.9	90.3
Transport – civil aviation – jet kerosene	CO_2	971.6	0.9	91.2
Energy industries – petroleum refining – liquid fuels	CO_2	782.9	0.7	91.8
Fugitive emissions – flaring – combined	CO_2	780.6	0.7	92.5
Other sectors – gaseous fuels	CO_2	686.2	0.6	93.1
Manure management	CH_4	647.3	0.6	93.7
Fugitive emissions – geothermal	CO_2	626.8	0.6	94.3
Metal production – aluminium production	CO_2	571.2	0.5	94.8
Mineral products – cement production	CO_2	528.5	0.5	95.2

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2011				
IPCC categories	**Gas**	**2011 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation – dairy cattle	CH_4	10,381.8	14.3	14.3
Enteric fermentation – sheep	CH_4	7,750.6	10.6	24.9
Transport – road transport – gasoline	CO_2	7,061.4	9.7	34.6
Agricultural soils – pasture, range and paddock	N_2O	5,705.4	7.8	42.4
Transport – road transport – diesel oil	CO_2	5,314.3	7.3	49.7
Enteric fermentation – non-dairy cattle	CH_4	4,860.6	6.7	56.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,622.1	5.0	61.4
Agricultural soils – indirect emissions	N_2O	2,578.4	3.5	64.9
Manufacturing industries and construction – gaseous fuels	CO_2	2,179.9	3.0	67.9
Other sectors – liquid fuels	CO_2	1,880.0	2.6	70.5
Agricultural soils – direct emissions	N_2O	1,874.8	2.6	73.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,798.3	2.5	75.5
Manufacturing industries and construction – solid fuels	CO_2	1,752.5	2.4	77.9
Metal production – iron and steel production	CO_2	1,690.8	2.3	80.3
Energy industries – public electricity and heat production – solid fuels	CO_2	1,489.7	2.0	82.3
Solid waste disposal on land	CH_4	1,331.1	1.8	84.1
Manufacturing industries and construction – liquid fuels	CO_2	1,034.4	1.4	85.5
Transport – civil aviation – jet kerosene	CO_2	971.6	1.3	86.9
Energy industries – petroleum refining – liquid fuels	CO_2	782.9	1.1	88.0
Fugitive emissions – flaring – combined	CO_2	780.6	1.1	89.0
Other sectors – gaseous fuels	CO_2	686.2	0.9	90.0
Manure management	CH_4	647.3	0.9	90.9
Fugitive emissions – geothermal	CO_2	626.8	0.9	91.7
Metal production – aluminium production	CO_2	571.2	0.8	92.5
Mineral products – cement production	CO_2	528.5	0.7	93.2
Enteric fermentation – deer	CH_4	478.2	0.7	93.9
Wastewater handling	CH_4	471.7	0.6	94.5
Other sectors – solid fuels	CO_2	434.0	0.6	95.1

Table 1.5.3 1990–2011 trend assessment for New Zealand's key category analysis including LULUCF (a) and excluding LULUCF (b)

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2011 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,736.1	7,750.6	0.050	18.8	18.8
Enteric fermentation – dairy cattle	CH_4	4,976.5	10,381.8	0.028	10.7	29.5
Forest land remaining forest land	CO_2	4,540.3	9,468.7	0.026	9.7	39.3
Transport – road transport – diesel oil	CO_2	1,409.5	5,314.3	0.024	9.3	48.5
Conversion to forest land	CO_2	23,198.2	27,227.0	0.015	5.9	54.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,798.3	0.012	4.7	59.1
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	427.4	0.012	4.6	63.8
Enteric fermentation – non-dairy cattle	CH_4	4,983.8	4,860.6	0.010	3.9	67.6
Conversion to grassland	CO_2	201.5	1,650.0	0.010	3.7	71.3
Agricultural soils – direct emissions	N_2O	460.1	1,874.8	0.009	3.4	74.7
Agricultural soils – pasture, range and paddock	N_2O	5,372.5	5,705.4	0.008	2.9	77.6
Manufacturing industries and construction – solid fuels	CO_2	2,172.6	1,752.5	0.007	2.6	80.3
Energy industries – public electricity and heat production – solid fuels	CO_2	469.3	1,489.7	0.006	2.4	82.6
Metal production – aluminium production	PFCs	629.9	30.2	0.005	2.0	84.7
Grassland remaining grassland	CO_2	1,074.1	2,063.5	0.005	1.8	86.5
Solid waste disposal on land	CH_4	1,514.4	1,331.1	0.004	1.6	88.1
Fugitive emissions – flaring – combined	CO_2	228.9	780.6	0.003	1.3	89.3
Other sectors – liquid fuels	CO_2	1,757.9	1,880.0	0.002	0.9	90.3
Fugitive emissions – geothermal	CO_2	228.6	626.8	0.002	0.9	91.2
Enteric fermentation – other	CH_4	209.6	46.6	0.002	0.6	91.7
Other sectors – solid fuels	CO_2	512.1	434.0	0.001	0.6	92.3
Conversion to cropland	CO_2	214.8	70.5	0.001	0.5	92.8
Energy industries – petroleum refining – liquid fuels	CO_2	773.9	782.9	0.001	0.5	93.4
Fugitive emissions – natural gas	CH_4	438.1	359.9	0.001	0.5	93.9
Conversion to wetland	CO_2	167.3	20.9	0.001	0.5	94.4
Transport – road transport – gaseous fuels	CO_2	139.6	2.9	0.001	0.5	94.8
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3,622.1	0.001	0.4	95.3

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)						
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2011 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,736.1	7,750.6	0.074	23.2	23.2
Enteric fermentation – dairy cattle	CH_4	4,976.5	10,381.8	0.048	15.2	38.4
Transport – road transport – diesel oil	CO_2	1,409.5	5,314.3	0.040	12.7	51.0
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,798.3	0.020	6.3	57.4
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	427.4	0.019	5.9	63.3
Agricultural soils – direct emissions	N_2O	460.1	1,874.8	0.015	4.6	67.9
Enteric fermentation – non-dairy cattle	CH_4	4,983.8	4,860.6	0.014	4.3	72.2
Energy industries – public electricity and heat production - solid fuels	CO_2	469.3	1,489.7	0.010	3.2	75.4
Manufacturing industries and construction – solid fuels	CO_2	2,172.6	1,752.5	0.010	3.2	78.6
Agricultural soils – pasture, range and paddock	N_2O	5,372.5	5,705.4	0.010	3.0	81.6
Metal production – aluminium production	PFCs	629.9	30.2	0.008	2.6	84.2
Solid waste disposal on land	CH_4	1,514.4	1,331.1	0.006	1.8	86.1
Fugitive emissions – flaring – combined	CO_2	228.9	780.6	0.006	1.8	87.8
Fugitive emissions – geothermal	CO_2	228.6	626.8	0.004	1.2	89.1
Other sectors – liquid fuels	CO_2	1,757.9	1,880.0	0.003	0.9	90.0
Transport – road transport – gasoline	CO_2	5,582.2	7,061.4	0.003	0.9	90.9
Enteric fermentation – other	CH_4	209.6	46.6	0.002	0.7	91.6
Manufacturing industries and construction – gaseous fuels	CO_2	1,619.7	2,179.89	0.002	0.7	92.3
Other sectors – solid fuels	CO_2	512.1	434.0	0.002	0.7	93.0
Fugitive emissions – natural gas	CH_4	438.1	359.9	0.002	0.6	93.6
Transport – road transport – gaseous fuels	CO_2	139.6	2.9	0.002	0.6	94.2
Energy industries – petroleum refining – liquid fuels	CO_2	773.9	782.9	0.002	0.6	94.8
Energy industries – petroleum refining – gaseous fuels	CO_2	0.0	127.84	0.001	0.5	95.2

1.5.2 LULUCF activities under the Kyoto Protocol

The LULUCF categories identified as key (level assessment) under the Climate Change Convention in the 2011 year that correspond to the key categories for Article 3.3 activities under the Kyoto Protocol are shown in table 1.5.4.

Table 1.5.4 Key categories under the Kyoto Protocol and corresponding categories under the Climate Change Convention

Category as reported under the Climate Change Convention	Article 3.3 activities under the Kyoto Protocol
Conversion to forest land	Afforestation and reforestation
Conversion to grassland	Deforestation

1.6 Quality assurance and quality control

Quality assurance and quality control are an integral part of preparing New Zealand's annual inventory. The Ministry for the Environment developed a quality assurance and control plan in 2004, as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006), to formalise, document and archive the quality assurance and control procedures. Details of the quality-control and quality-assurance activities performed during the compilation of the 2013 inventory submission are discussed in sections 1.6.1 and 1.6.2 below. Examples of quality-control checks are provided in the Excel spreadsheets accompanying this submission.

1.6.1 Quality control

For this submission, the completion of the IPCC (2000) Tier 1 quality control check sheets for each sector was the responsibility of the leading agency. Sectoral Quality Control processes and procedures have been revised and thoroughly documented in the updated version of New Zealand's National Systems Guidelines. Wherever possible, human checks have been replaced by automated electronic checks covering 100 per cent of the data in each checked data file.

The national inventory complier was provided with common reporting format xml files for all sectors that passed all Tier 1 checks. The Tier 1 checks are based on the procedures suggested in the IPCC good practice guidance (IPCC, 2000). All key categories for the 2011 inventory year were checked.

All sector level data was entered into the common reporting format database by early February by the national inventory compiler. This deadline allowed time for the agencies leading each sector to complete their own quality-control activities. All sector contributions to the national inventory report, common reporting format tables and Tier 1 quality-control checks were signed off by the responsible agency by early February.

Data in the common reporting format database was also checked visually for anomalies, errors and omissions. The Ministry for the Environment uses the quality control checking procedures included in the database to ensure the data submitted to the Climate Change Convention secretariat is complete.

1.6.2 Quality assurance

New Zealand's quality-assurance system includes prioritisation of improvements, processes around accepting improvements into the inventory, communication across the distributed system and improving the expertise of key contributors to the inventory. Each of these quality-assurance aspects is explained in detail below.

A list of previous quality-assurance reviews, their major conclusions and follow-up actions is included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

The energy and agriculture activity data provided by Statistics New Zealand are official national statistics and, as such, are subject to rigorous quality-assurance and quality-control procedures.

Prioritisation of improvements

Priorities for inventory development are guided by the analysis of key categories (level and trend), uncertainty surrounding existing emission and removal estimates, and recommendations received from previous international reviews of New Zealand's inventory. The inventory improvement and quality-control and quality-assurance plans are updated annually to reflect current and future inventory development. The sector risk registers are useful in identifying potential improvements.

Chapter 10 (section 10.2.2) details the five stages of New Zealand's planned improvement process, from identifying the improvement to acceptance into the inventory.

Acceptance of improvements

The process of accepting any improvements into the inventory includes demonstrating that the improvement has been independently assessed if the resulting change is greater than the agreed threshold (0.5 per cent of total sector emissions and/or removals). Resulting recalculations need to be approved by the Reporting Governance Group.

In the agriculture sector, any improvements in method and/or parameters need the approval of the independent agricultural inventory advisory panel.

Independent assessment

Any change in a method or parameter that is greater than the agreed threshold needs to be reviewed by an independent expert and a 'Peer Review Change form' filled in. The change will only be included in the inventory if the expert concludes that the change is consistent with IPCC good practice.

Recalculation approval

All recalculations require the approval of the Reporting Governance Group. The recalculations need to be sufficiently explained in terms of improving one or more of the IPCC good practice principles. The recalculations and the explanations are recorded in tables for documentation and archiving purposes.

Independent agricultural inventory advisory panel

New Zealand has established an independent agricultural inventory advisory panel to assess whether proposed changes to the agriculture sector of New Zealand's national inventory are scientifically robust enough to be included into the inventory. Reports and/or papers on proposed changes must be peer reviewed before they are presented to the panel. The panel assesses if the proposed changes have been rigorously tested and if there is enough scientific evidence to support the change. The panel advises the Ministry for Primary Industries of its recommendations. Refer to section 6.1.1 for further details.

Expertise

The technical competence of key contributors to the inventory has continued to increase and with this comes the ability to provide effective quality assurance on the inventory before it is finalised for submission. One of the most effective ways that New Zealand experts improve their expertise is through participating in the Climate Change Convention inventory review process. During the reviews, experts can learn from each other and from the Party under review. New Zealand government officials who are qualified to review inventory reporting under the Climate Change Convention and the Kyoto Protocol include three lead reviewers, two energy reviewers, one industrial processes reviewer, two agricultural reviewers, four LULUCF reviewers and one waste reviewer. Whenever possible, these reviewers are independent of the compilation process of their respective area of expertise and are used as peer reviewers before the sector is finalised for the aggregate compilation by the national inventory compiler.

New Zealand has developed inventory system guidelines that document the tasks required for making an official submission starting from the submission of the previous year. The role of the agricultural and energy sector compilers is well documented within respective manuals. There is also documentation for compiling the industrial processes, LULUCF and waste sectors. These manuals are designed to help lower the risk of losing compiling knowledge.

1.6.3 Verification activities

Where relevant in a sector, verification activities are discussed under the appropriate section. Section 1.10 provides information about the verification that has become available for the inventory from the NZ ETS.

1.6.4 Treatment of confidentiality issues

Confidentiality issues largely apply to sources of emissions in the energy and industrial processes sectors. Confidential information is held by the Environmental Protection Authority, the Ministry for the Environment and the Ministry of Business, Innovation and Employment. Each agency has security procedures (e.g. restricted access to files on computers) to ensure this data is kept confidential.

1.6.5 Climate Change Convention annual inventory review

New Zealand's inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a, 2001b, 2001c, 2003). The inventory was subject to detailed in-country, centralised and desk review procedures. The inventories submitted for the years 2001 and 2003 were reviewed in a centralised review process. The 2006 inventory submission was reviewed as part of the Kyoto Protocol initial review (UNFCCC, 2007). This was an in-country review held from 19–24 February 2007. The 2007–2009 and 2011–2012 inventory submissions were reviewed during centralised reviews (UNFCCC, 2009; UNFCCC 2010; UNFCCC 2012 and UNFCCC (in press)). The 2010 inventory submission was subject to an in-country review in August–September 2010 (UNFCCC, 2011). The review report for the 2012 inventory submission was not fully completed at the time of finalising this 2013 submission. In all instances, the reviews were coordinated by the secretariat and were conducted by an international team of experts assembled from experts nominated by Parties to the Climate Change Convention Roster of Experts. Review reports are available from the Climate Change Convention website (www.unfccc.int).

New Zealand has consistently met the reporting requirements under the Climate Change Convention and Kyoto Protocol. The submission of the inventory to the Climate Change Convention secretariat has consistently met the required deadline under decision 15/CMP.1. The expert review report (UNFCCC, 2012) concluded that:

- *"New Zealand made its annual submission on 15April 2011. The annual submission contains the GHG inventory (comprising CRF tables and an NIR) and supplementary information under Article 7, paragraph 1, of the Kyoto Protocol (information on: activities under Article 3, paragraph 3, of the Kyoto Protocol, Kyoto Protocol units, changes to the national system and the national registry and minimization of adverse impacts in accordance with Article 3, paragraph 14, of the Kyoto Protocol). This is in line with decision 15/CMP.1".*
- *"The national system continued to perform its required functions".*
- *"The national registry continues to perform the functions set out in the annex to decision 13/CMP.1 and the annex to decision 5/CMP.1, and continues to adhere to the technical standards for data exchange between registry systems in accordance with relevant CMP decisions".*

New Zealand's consistency in meeting the reporting requirements allowed it to be one of the first four Parties to be eligible to participate in the Kyoto Protocol mechanisms for the first commitment period. New Zealand's registry, the official transactions and balance of New Zealand's Kyoto Protocol units, was operational on 1 January 2008, the first day of the first commitment period.

1.7 Inventory uncertainty

1.7.1 Reporting under the Climate Change Convention

Uncertainty estimates are an essential element of a complete greenhouse gas emissions and removals inventory. The purpose of uncertainty information is not to dispute the validity of the inventory estimates but to help prioritise efforts to improve the accuracy of inventories and guide decisions on methodological choice (IPCC, 2000). Inventories prepared in accordance with IPCC good practice guidance (IPCC, 2000 and 2003) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable emissions such as N_2O fluxes from soils and waterways.

In this submission, New Zealand included a Tier 1 uncertainty analysis of the aggregated figures as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory for the latest inventory year and the uncertainty in the overall inventory trend over time. LULUCF categories have been included using the absolute value of any removals of CO_2 (table A7.1.1). Table A7.1.2 calculates the uncertainty in emissions only (ie, excluding LULUCF removals).

In most instances, the uncertainty values are determined by analysis of emission factors or activity data using expert judgement from sectoral or industry experts, or by referring to uncertainty ranges provided in the IPCC guidelines. The uncertainty for CH_4 emissions from enteric fermentation was calculated by expressing the coefficient of variation according to the standard error of the methane yield. A Monte Carlo simulation has been used to determine uncertainty for N_2O from agricultural soils. For the 2011 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value.

Total emissions

Uncertainty in 2011

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is ±12.0 per cent. The high uncertainty in a given year is dominated by emissions of N_2O from agricultural soils (section 6.5), CH_4 from enteric fermentation (section 6.2) and N_2O from wastewater handling. These categories comprised ±10.3 per cent, ±5.2 per cent and ±3.0 per cent respectively of New Zealand's total emissions uncertainty in 2011. The uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems, for example, the uncertainty in cattle dry-matter intake and, hence, in estimates of CH_4 emissions per unit of dry-matter intake.

Uncertainty in the trend

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) in the trend from 1990 to 2011 is ±2.3 per cent. This is a slight decrease in the trend uncertainty compared with the value reported in the 2011 submission (±2.8 per cent) due to revised activity data uncertainties in the gaseous fuels category of the energy sector and the consumption of hydrofluorocarbons in the industrial processes sector.

Net emissions

Uncertainty in 2011

The calculated uncertainty for New Zealand's inventory including emissions and removals from the LULUCF sector in 2011 is ±15.3 per cent. Removals of CO_2 from forest land were a major contribution to the uncertainty for 2011 at ±12.1 per cent of New Zealand's net emissions.

In this submission, the overall uncertainty when emissions and removals from the LULUCF sector are included for the 2011 year has increased 1.1 per cent compared with the estimate provided for the 2010 year in the 2012 submission (±14.2 per cent). This increase is mainly due to updated uncertainty estimates for all categories within the LULUCF sector. The change is most noticeable in the forest land category given its large contribution to the LULUCF sector.

Uncertainty in the trend

When emissions and removals from the LULUCF sector are included, the overall uncertainty in the trend from 1990 to 2011 is ±8.6 per cent. This is an increase of 2.9 per cent from the uncertainty estimates in the trend compared with the 2012 submission. This change is also due to updated uncertainty estimates for all categories within the LULUCF sector.

1.7.2 LULUCF activities under the Kyoto Protocol

The combined uncertainty for emissions from afforestation and reforestation activities in 2011 was 17.8 per cent. The uncertainty introduced into net emissions from deforestation in 2011 was 2.9 per cent.

Please refer to section 11.3.1 for further information on the uncertainty analysis for Article 3.3 activities under the Kyoto Protocol and how this relates to the Climate Change Convention LULUCF uncertainty analysis.

1.8 Inventory completeness

1.8.1 Reporting under the Climate Change Convention

The New Zealand inventory for the period 1990–2011 is complete. In accordance with good practice guidance (IPCC, 2000), New Zealand has focused its resources for inventory development in the key categories.

A background MS Excel workbook is provided for agriculture and submitted with the inventory. The file is also available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

Other worksheets submitted are MS Excel workbooks for Tier 1 quality checks and for quality assurance.

1.8.2 LULUCF activities under the Kyoto Protocol

New Zealand has included all carbon pools for Article 3.3 activities under the Kyoto Protocol.

1.9 National registry

In January 2008, New Zealand's national registry was issued with New Zealand's assigned amount of 309,564,733 metric tonnes of carbon dioxide equivalent (CO_2-e).

At the beginning of the calendar year 2012, New Zealand's national registry held 306,248,485 assigned amount units, 530,346 emissions reduction units, 2,935,654 certified emission reduction units and 3,900,000 removal units held in the registry at the beginning of the 2012 calendar year (table 1 in table 12.2.2).

At the end of 2012, there were 306,041,662 assigned amount units, 16,153,534 emission reduction units, 8,680,399 certified emission reduction units and 9,050,000 removal units held in the New Zealand registry (table 4 in table 12.2.2). The removal units and majority of certified emission reduction units (approximately 4,400,000 units) were traded into New Zealand's national registry by private entities. These units will not be part of the Crown account unless surrendered under the NZ ETS.

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2012 (table 4 in table 12.2.2).

During January to December 2012, no Kyoto Protocol units were expired, replaced or cancelled.

1.10 New Zealand’s Emissions Trading Scheme

The NZ ETS is New Zealand’s principal policy response to mitigating climate change. The following sections explain how the domestic New Zealand Unit relates to international units and how the data collected for the NZ ETS has been used to verify CO_2 emissions in the industrial processes sector.

1.10.1 The New Zealand Unit

In 2008, New Zealand established the NZ ETS. The NZ ETS puts obligations on certain industries to account for the greenhouse gas emissions that result from their activities. The Climate Change Response Act 2002 states which sectors are mandatory participants in the NZ ETS – those that generate emissions and that have an obligation. The NZ ETS is based around a trade in units that represent a tonne of carbon dioxide equivalent. The primary unit of trade is the New Zealand Unit (NZU), which is the unit created and distributed by the New Zealand Government.

New Zealand Units (NZUs) are issued into the New Zealand Registry by the New Zealand Government. New Zealand decided to leverage off and extend its existing national registry to incorporate the requirements under the NZ ETS. Most significantly, this meant the issue of the NZUs in the national registry and creation of Crown holding accounts to hold these NZUs. These changes were made in the early part of 2009 and were reported in the 2010 inventory submission.

The Government allocates NZUs into the market by giving them to eligible individuals or firms in specific sectors, by awarding them to individuals or firms conducting approved removal activities (such as the establishment of forests) or by selling them. When sectors enter the NZ ETS, participants are required to record and report the greenhouse gas emissions for which they have obligations or the removals for which they can claim NZUs. Participants with obligations are also required to surrender NZUs to cover their emissions. The methods for estimating emissions are set out in regulations prescribed under the Climate Change Response Act 2002.

Trading NZUs for international units

NZUs can be traded within New Zealand. During a transition phase (July 2010 to December 2012), the forestry sector will be able to exchange NZUs for NZ AAUs through the New Zealand Emission Unit Registry for the purposes of transferring that NZ AAU to an overseas national registry. Under current settings, after the transition phase, all sectors will be able to convert NZUs to Kyoto units to trade overseas.

The process for the exchange of an NZU for an NZ AAU takes place as follows:

(a) on application from an account holder, the NZUs are transferred to the relevant Crown Holding Account

- an equivalent number of NZ AAUs are transferred from a New Zealand Initial Assigned Amount to the applicant

– those same NZ AAUs are transferred from the applicant's holding account to a holding account in an overseas national registry.

The commitment period reserve is protected by a cap. NZUs can be exchanged for NZ AAUs, unless only the commitment period reserve is left in the New Zealand Emission Unit Registry. When this cap has been reached, exchanges of NZUs for AAUs cannot occur.

1.10.2 Verification

For this submission, data collected for the NZ ETS was used to verify the inventory estimates for CO_2 emissions in the energy and industrial processes sector (see chapter 3 and sections 4.2.4 and 4.4.4 for further detail of the verification). When sectors enter the NZ ETS, participants are required to record and report the greenhouse gas emissions for which they have obligations or the removals for which they can claim NZUs. Participants with obligations are also required to surrender NZUs to cover their emissions annually. How participants estimate their emissions is set out in the regulations prescribed under the Climate Change Response Act 2002. The schedule for sectors entering the NZ ETS is detailed in table 1.10.1.

Some NZ ETS data is already used within the LULUCF sector. Information on deforestation reported under the NZ ETS is used for verifying the area of pre-1990 planted forest and deforestation for LULUCF reporting.

Table 1.10.1 Dates for sector entry into the New Zealand Emissions Trading Scheme

Sector	Voluntary reporting	Mandatory reporting	Full obligations
Forestry	–	–	1 January 2008
Transport fuels	–	1 January 2010	1 July 2010
Electricity production	–	1 January 2010	1 July 2010
Industrial processes	–	1 January 2010	1 July 2010
Synthetic gases	1 January 2011	1 January 2012	1 January 2013
Waste	1 January 2011	1 January 2012	1 January 2013
Agriculture	1 January 2011	1 January 2012	

1.11 Improvements introduced

This inventory includes improved estimates of emissions and removals compared with the 2011 inventory submission, resulting in a number of recalculations to the estimates. Recalculations of estimates reported in the previous inventory can be due to improvements in:

- activity data
- emission factors and/or other parameters
- methodology
- additional sources identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003)

- availability of activity data and emission factors for sources that were previously reported as NE (not estimated) because of insufficient data.

It is good practice to recalculate the whole time series from 1990 to the current inventory year to ensure a consistent time series. This means estimates of emissions in a given year may differ from emissions reported in the previous inventory submission. There may be exceptions to recalculating the entire time series and, where this has occurred, explanations are provided.

The largest improvements in the accuracy of the New Zealand greenhouse gas inventory since the 2012 submission were made in the LULUCF and energy sectors. Chapter 10 provides a summary of all recalculations made to the estimates.

Improvements made to the national system are included in chapter 13 and improvements made to New Zealand's national registry are included in chapter 14.

LULUCF – Forest land (sections 7.1.5 and 7.3.5)

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2012 submission are the result of (in decreasing order of magnitude):

- the activity data used to estimate harvesting emissions in pre-1990 planted forests being scaled by 17 per cent throughout the time series to account for differences in forest definitions used in the inventory and the source of the activity data
- the correction of an error detected in the calculation process when upgrading to the Forest Carbon Predictor, version 3 for last year's submission, which affected the implementation of the new post-1989 planted forest yield table
- continued improvements to the 1990 and 2008 land-use maps. Mapping data provided from the NZ ETS was integrated into the 1990 and 2008 maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- emissions being reported for controlled burning in forest land remaining forest land for the first time in the 2013 submission. Estimates are provided for the burning of post-harvest slash prior to restocking.

Energy – Emission factor for solid fuels (section 3.3.1)

The most significant recalculation for the energy sector was a review of carbon dioxide emission factors for solid fuels across the time series from 1990–2011. A comprehensive list of carbon content by coal mining is not currently available. However, a review of New Zealand's coal emission factors in preparation for the New Zealand Emissions Trading Scheme (CRL Energy Ltd, 2009) recommended re-weighting the current default emission factors to 2007 production rather than continue with those in the New Zealand Energy Information Handbook (Baines, 1993). A comparison of the original and updated emission factors can be found in table 3.3.1 of this submission. This has resulted in changes in emissions from solid fuel combustion across all sectors, including public electricity and heat production.

Chapter 1: References

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Chapter 2: Trends in greenhouse gas emissions

2.1 Emission trends for aggregated greenhouse gas emissions

2.1.1 National trends

Total (gross) emissions

Total emissions include those from the energy, industrial processes, solvent and other product use, agriculture and waste sectors, but do not include net removals from the land use, land-use change and forestry (LULUCF) sector. Reporting of total emissions excluding the LULUCF sector is consistent with the reporting requirements of the Climate Change Convention (UNFCCC, 2006).

1990–2011

In 1990, New Zealand's total greenhouse gas emissions were 59,643.1 Gg carbon dioxide equivalent (CO_2-e). In 2011, total greenhouse gas emissions had increased by 13,191.9 Gg CO_2-e (22.1 per cent) to 72,834.9 Gg CO_2-e (figure 2.1.1). Between 1990 and 2011, the average annual growth in total emissions was 1 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were dairy cattle enteric fermentation,[16] road transport, agricultural soils, and consumption of halocarbons and sulphur hexafluoride (SF_6).

2010–2011

Between 2010 and 2011, New Zealand's total greenhouse gas emissions increased by 987.2 Gg CO_2-e (1.4 per cent). The size of the overall increase is small because, although emissions from the industrial processes and agriculture sectors rose, there was a decrease in emissions from the energy sector.

The decrease in energy emissions is primarily due to a decrease in emissions from electricity generation. The main drivers that led to the decrease in emissions from electricity generation were:

- a reduction in national electricity demand in the wake of the Canterbury earthquake in February 2011
- an increase in the supply from wind generation following the commissioning of two new wind farms.

The continued increase in emissions from the consumption in hydrofluorocarbons (HFCs) was the main driver in the rise of emissions from industrial processes. Generally, the consumption of HFCs has been increasing since the mid-1990s when chlorofluorocarbons

[16] Methane emissions produced from ruminant livestock.

(CFCs) and hydrochlorofluorocarbons (HCFCs) began to be phased out under the Montreal Protocol. In New Zealand, the Ozone Layer Protection Act 1996 sets out a programme for phasing out the use of ozone-depleting substances by 2015. The unusually large increase in HFC emissions in 2011 is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

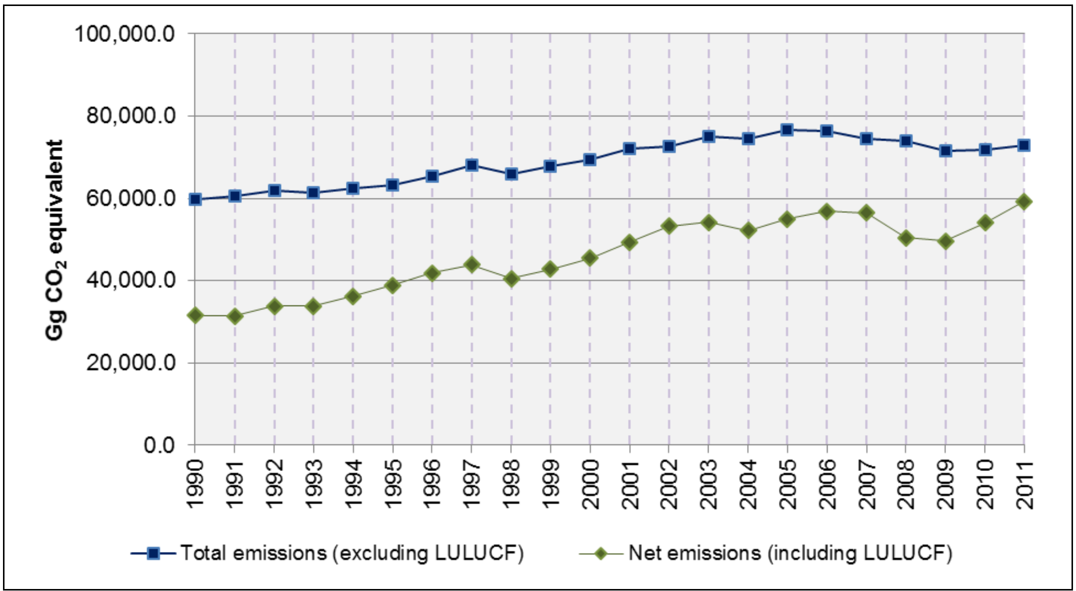
The continued increase in the national dairy cattle population led to the increase in agricultural emissions. The dairy industry is the main user of nitrogen fertiliser in New Zealand, therefore, with a favourable milk price there was an increase in volume of nitrogen fertiliser in 2011.

Net emissions – Climate Change Convention reporting

Net emissions include emissions from the energy, industrial processes, solvent and other product use, agriculture and waste sectors, together with emissions and removals from the LULUCF sector.

In 1990, New Zealand's net greenhouse gas emissions were 31,530.4 Gg CO_2-e. In 2011, net greenhouse gas emissions had increased by 27,764.4 Gg CO_2-e (88.1 per cent) to 59,294.7 Gg CO_2-e (figure 2.1.1). The four categories that contributed the most to the increase in net emissions between 1990 and 2011 were forest land remaining forest land, dairy enteric fermentation, road transport and grassland remaining grassland categories.

Figure 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2011



Accounting under the Kyoto Protocol

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time series of emissions reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 3.7 per cent lower than the 1990 level of 61,912.9 Gg CO_2-e, which was estimated in 2006 and used in the initial assigned amount calculation.

In 2011, net removals were 16,765.5 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section 2.5 for further detail). The accounting quantity for 2011 was 16,876.9 Gg CO_2-e. This is different from net removals because debits resulting from harvesting of afforested and reforested land during the first commitment period are limited to the level of credits received for that land.

2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers six direct greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and HFCs. Table 2.2.1 provides the change in each gas from 1990 to 2011. In 2011, CO_2 contributed the largest proportion of total emissions (figure 2.2.1), while in 1990, CO_2 and CH_4 contributed nearly equal proportions to total emissions (figure 2.2.2). The proportion of CH_4 has been decreasing over the time series while the proportion of CO_2 has been increasing. This trend reflects the increase in emissions from the energy sector (section 2.3) – nearly 90 per cent of New Zealand's CO_2 emissions come from the energy sector. Carbon dioxide was also the greenhouse gas that has had the strongest influence on the trend in total emissions between 1990 and 2011 (figures 2.2.3 and 2.2.4).

In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases are included in inventory reporting but are not included in the total emissions. These indirect gases include carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOCs).

Carbon dioxide

2011

Carbon dioxide contributed the largest proportion of total emissions in 2011 at 33,162.2 Gg (45.5 per cent). The largest sources of total CO_2 emissions are from road transport and electricity and heat production. In 2011, road transport contributed 12,404.8 Gg (37.4 per cent) to total CO_2 emissions, and public electricity and heat production contributed 5,112.9 Gg (15.4 per cent).

In 2011, net removals of CO_2 from the LULUCF sector (as reported under the Climate Change Convention) were 13,606.0 Gg. The forest land category is the biggest contributor to the sector, with net removals of 17,758.3 Gg CO_2 in 2011. Carbon dioxide removals from afforestation and reforestation activities (as accounted for under Article 3.3 of the Kyoto Protocol) were 18,445.8 Gg. The difference between the two estimates is largely due to the inclusion of pre-1990 forests within the LULUCF sector. While reporting under the Climate Change Convention includes pre-1990 forests, they are excluded from all but deforestation reporting under the Kyoto Protocol.

In 2011, CO_2 emissions from deforestation of all forests (3,700 hectares) contributed 1,674.6 Gg to net emissions. The deforestation was mainly for conversion into grassland, largely due to the relative profitability of pastoral farming, particularly dairy farming, compared with forestry.

1990–2011

Total CO_2 emissions have increased by 8,115.2 Gg (32.4 per cent) from the 1990 level of 25,047.1 Gg. The two largest sources of this growth were the increased emissions from road transport, and public electricity and heat production.

Between 1990 and 2011, net CO_2 removals from LULUCF have decreased by 14,572.5 Gg CO_2-e (51.8 per cent) from the 1990 level of –28,113 Gg CO_2-e. This decrease in net removals is largely the result of increased harvesting and deforestation since 1990.

2010–2011

Between 2010 and 2011, total CO_2 emissions decreased 241 Gg (0.7 per cent). The decrease in CO_2 emissions from energy sector is primarily due to a decrease in emissions from electricity generation. The main drivers that led to the decrease in emissions from electricity generation were:

- a reduction in national electricity demand in the wake of the February 2011 Canterbury earthquake
- an increase in the supply from wind generation following the commissioning of two new wind farms.

Between 2010 and 2011, net removals from the LULUCF sector decreased by 4,274.2 Gg CO_2-e (24 per cent). The main contributor to the change occurred within the forest land category as a greater proportion of forest land was harvested in 2011 compared with 2010 due to its age class profile. Emissions have also increased in the grassland category due to larger areas of forest land being converted to grassland in 2011 than in 2010.

Between 2010 and 2011, CO_2 emissions from the deforestation of all forests increased by 645.2 Gg (62.7 per cent) as there was a larger area deforested in 2011 than in 2010.

Methane

2011

Methane contributed 27,050.1 Gg CO_2-e (37.1 per cent) to total emissions in 2011. The principal source of CH_4 emissions is from enteric fermentation, particularly from the four major ruminant livestock populations of sheep, dairy cattle, non-dairy cattle and deer. In 2011, enteric fermentation CH_4 from all livestock contributed 23,517.7 Gg CO_2-e (86.9 per cent) to total CH_4 emissions.

1990–2011

In 2011, CH_4 emissions have increased by 1,399.8 Gg CO_2-e (5.5 per cent) from the 1990 level of 25,650.3 Gg CO_2-e. This is largely due to an increase in CH_4 emissions from enteric fermentation. While the decline in the population of sheep between 1990 and 2011 has led to a decrease in CH_4 of enteric fermentation from sheep by 3,985.6 Gg CO_2-e, the increase in the national dairy cattle herd over the same period has increased CH_4 from enteric fermentation from dairy cattle by 5,405.2 Gg CO_2-e.

2010–2011

Between 2010 and 2011, CH_4 emissions increased by 174.4 Gg CO_2-e (0.7 per cent) primarily due to the increase in emissions from dairy cattle enteric fermentation.

Nitrous oxide

2011

Nitrous oxide contributed 10,689.7 Gg CO_2-e (14.7 per cent) to total emissions in 2011. The largest source of N_2O emissions is from agricultural soils. In 2011, the agricultural soils category contributed 10,158.6 Gg CO_2-e (95.0 per cent) to New Zealand's total N_2O emissions.

1990–2011

In 2011, N_2O emissions increased by 2,389.1 Gg CO_2-e (28.8 per cent) from the 1990 level of 8,300.6 Gg CO_2-e. The growth in N_2O is from an increase in emissions from the use of nitrogen fertilisers in the agriculture sector and from an increase in emissions from animal excreta. There has been an almost six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2011 time series, which has resulted in an increase of direct N_2O emissions from synthetic fertiliser use from 260.4 Gg CO_2-e in 1990 to 1,581.0 Gg CO_2-e in 2011.

2010–2011

Between 2010 and 2011, emissions of nitrous oxide increased by 259.7 Gg CO_2-e (2.5 per cent). This was largely due to an increase in the amount of nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. The milk price was higher during 2011 compared with 2010 (Ministry for Primary Industries, 2012) and this increased the demand for nitrogen fertiliser in 2011.

Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride

Hydrofluorocarbons, PFCs and SF_6 contributed the remaining 1,932.9 Gg CO_2-e (2.7 per cent) to total emissions in 2011.

In 1990, no HFCs were used in New Zealand and, therefore, no percentage is shown in table 2.2.1. In 2011, 1,885.1 Gg CO_2-e of HFC emissions occurred. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol. In addition, an unusually large increase of HFC emissions in 2011 was due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

Emissions of PFCs have decreased by 599.7 Gg CO_2-e (95.2 per cent) from the 629.9 Gg CO_2-e in 1990 to 30.2 Gg CO_2-e in 2011. This decrease is the result of improvements in the aluminium smelting process.

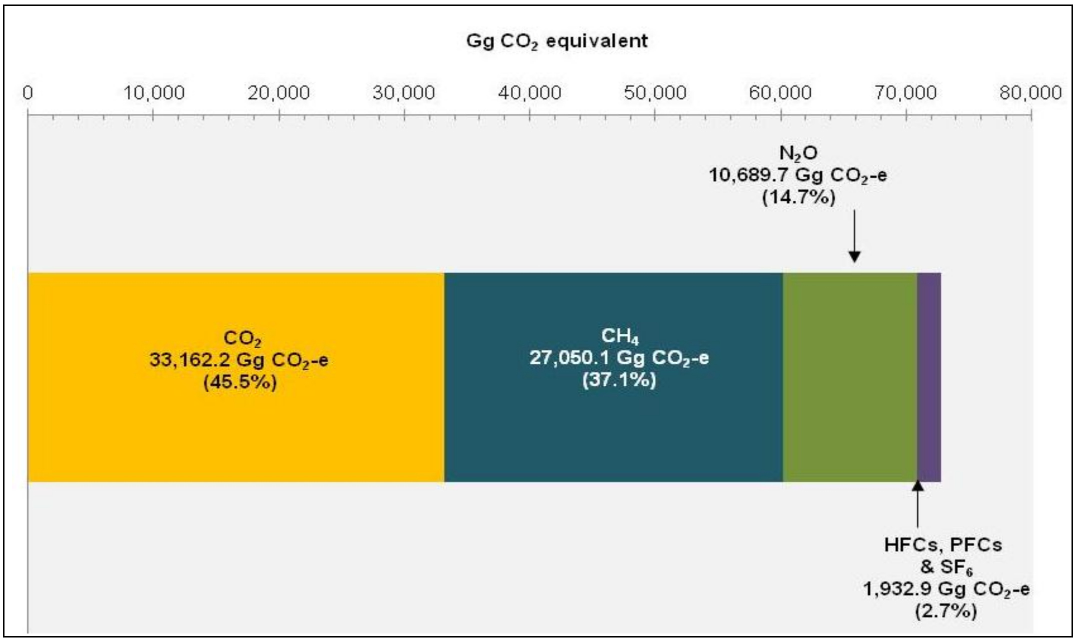
Emissions of SF_6 have increased by 2.4 Gg CO_2-e (15.9 per cent) from the 1990 level of 15.2 Gg CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

Table 2.2.1 New Zealand's total (gross) emissions by gas in 1990 and 2011

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2011	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	25,047.1	33,162.2	+8,115.2	+32.4
CH_4	25,650.3	27,050.1	+1,399.8	+5.5
N_2O	8,300.6	10,689.7	+2,389.1	+28.8
HFCs	NO	1,885.1	+1,885.1	NA
PFCs	629.9	30.2	–599.7	–95.2
SF_6	15.2	17.6	+2.4	+15.9
Total	**59,643.1**	**72,834.9**	**+13,191.9**	**+22.1**

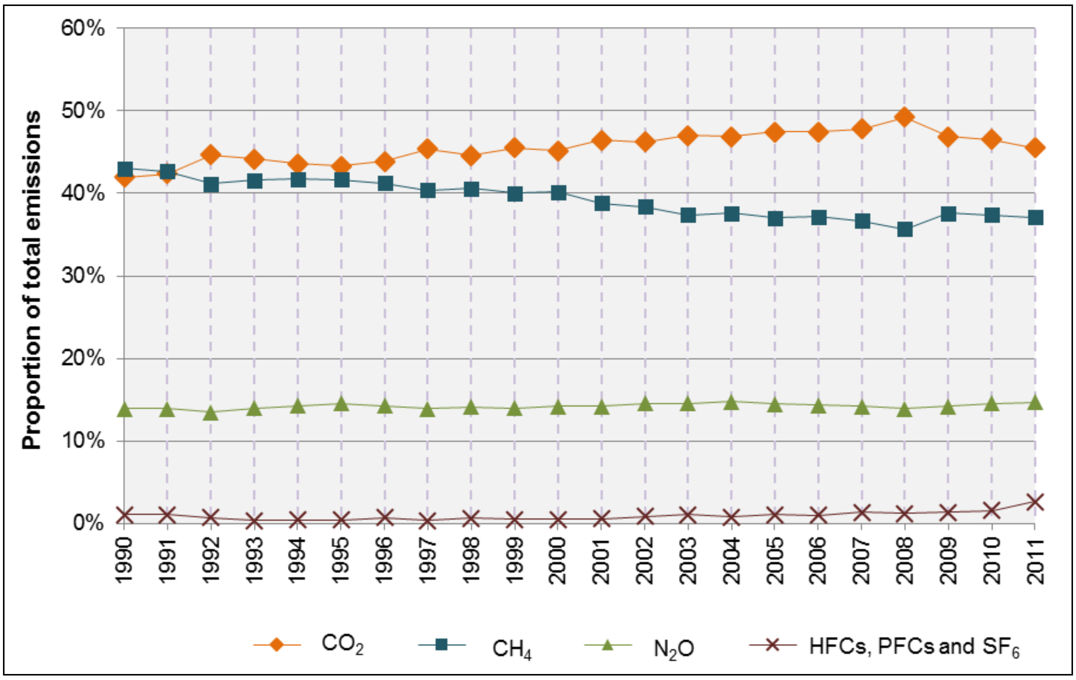
Note: Total emissions exclude net removals from the LULUCF sector. The per cent change for hydrofluorocarbons is not applicable (NA) as production of hydrofluorocarbons in 1990 was not occurring (NO). Columns may not total due to rounding.

Figure 2.2.1 New Zealand's total emissions by gas in 2011



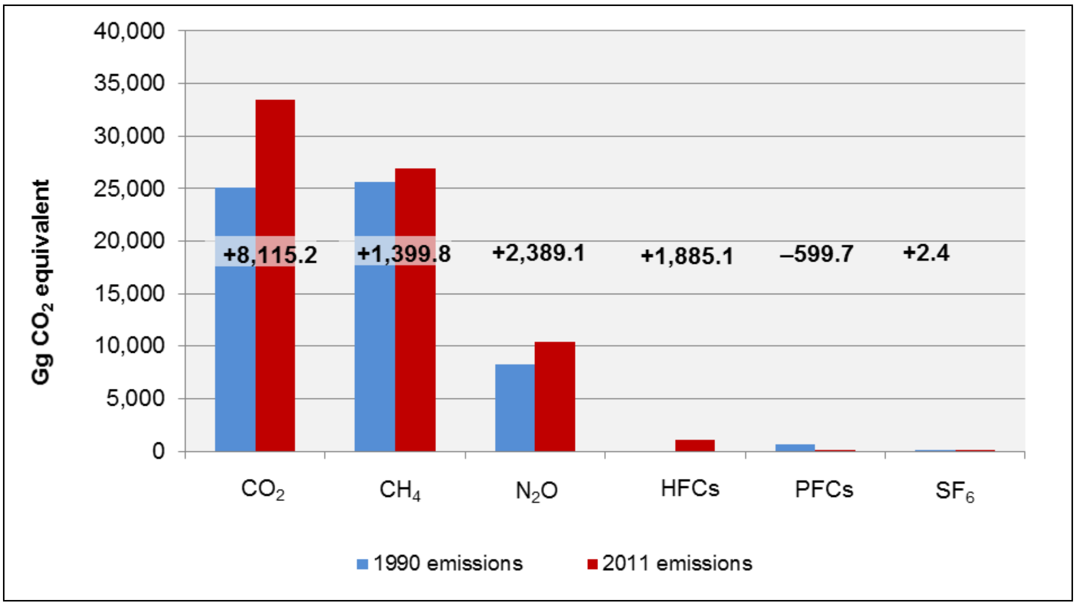
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.2 Proportion that gases contributed to New Zealand's total emissions from 1990 to 2011



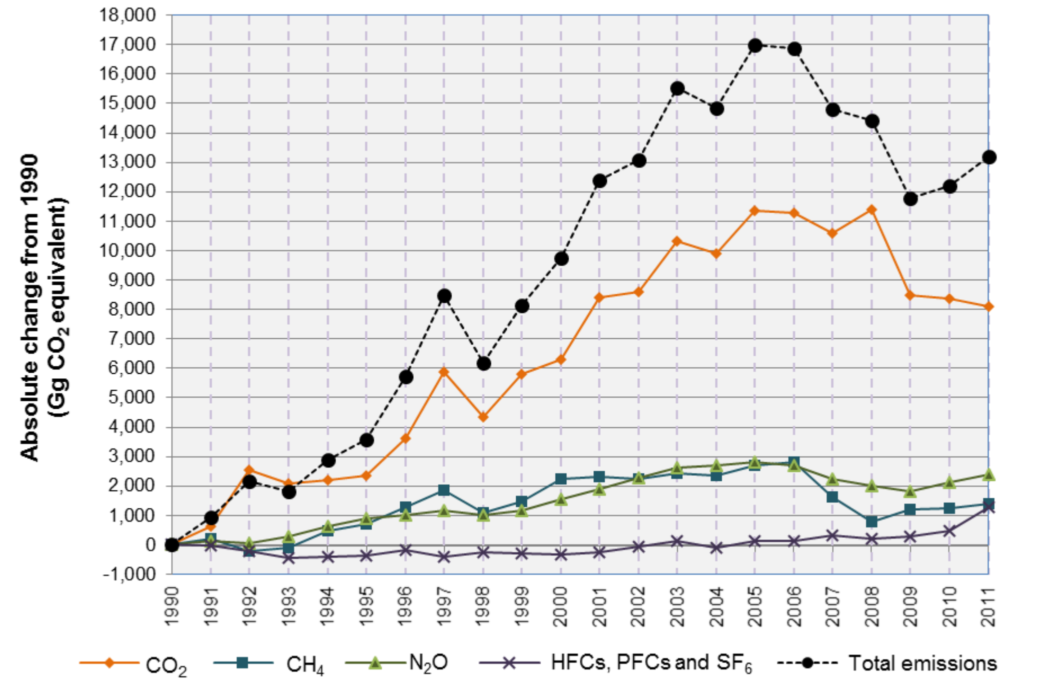
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.3 Change in New Zealand's total emissions by gas in 1990 and 2011



Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.4 Change from 1990 in New Zealand's total emissions by gas from 1990 to 2011



Note: Total emissions exclude net removals from the LULUCF sector.

2.3 Emission trends by source

Inventory reporting under the Climate Change Convention covers six sectors: energy, industrial processes, solvent and other product use, agriculture, LULUCF and waste. The agriculture sector contributed the largest proportion of total emissions in 2011 (table 2.3.1 and figure 2.3.1). The proportion of emissions from the agriculture sector has generally been decreasing since 1990, while the proportion of emissions from the energy sector increased (figure 2.3.2) until 2008. The proportion of the agriculture sector in total emissions from 2009 to 2011 showed a steady increase surpassing that of the energy sector due to good growing seasons and economic conditions for the dairy industry.

Energy (chapter 3)

2011

The energy sector was the source of 31,003.3 Gg CO_2-e (42.6 per cent) of total emissions in 2011. The largest sources of emissions in the energy sector were road transportation, contributing 12,569.8 Gg CO_2-e (40.5 per cent), and public electricity and heat production, contributing 5,127.9 Gg CO_2-e (16.5 per cent) to energy emissions.

1990–2011

In 2011, energy emissions had increased by 7,515.6 Gg CO_2-e (32.0 per cent) from the 1990 level of 23,487.7 Gg CO_2-e. This growth in emissions is primarily from road transportation, which increased by 5,162.8 Gg CO_2-e (69.7 per cent), and electricity generation and heat production, which increased by 1,655.9 Gg CO_2-e (47.7 per cent).

2010–2011

Between 2010 and 2011, emissions from the energy sector decreased by 314.1 Gg CO_2-e (1.0 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production. The main drivers that led to the decrease in emissions from electricity generation were:

- a reduction in national electricity demand in the wake of the February 2011 Canterbury earthquake
- an increase in the supply from wind generation following the commissioning of two new wind farms.

Industrial processes (chapter 4)

2011

In 2011, New Zealand's industrial processes sector produced 5,431.0 Gg CO_2-e, contributing 7.5 per cent of New Zealand's total greenhouse gas emissions. The largest source of industrial process emissions is the metal production category (CO_2 and perfluorocarbons (PFCs)), contributing 42.2 per cent of industrial process emissions in 2011.

1990–2011

Emissions from industrial processes in 2011 had increased by 2,038.1 Gg CO_2-e (60.1 per cent) above the 1990 level of 3,392.8 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of HFCs. Hydrofluorocarbon emissions have increased because of their use as substitutes for chlorofluorocarbons phased out under the Montreal Protocol.

2010–2011

Between 2010 and 2011, emissions from the industrial processes sector increased by 666.8 Gg CO_2-e (14.0 per cent). The main emission source that drove this increase was the consumption of HFCs. The unusually large increase in HFC emissions in 2011 is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

Solvent and other product use (chapter 5)

In 2011, the solvent and other product use sector was responsible for 27.9 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products use sector are negligible compared with other sectors.

Agriculture (chapter 6)

2011

The agriculture sector was the largest source of emissions in 2011, contributing 34,387.3 Gg CO_2-e (47.2 per cent) of total emissions. New Zealand has an unusual emissions profile amongst developed countries. In many other developed countries, agricultural emissions are typically around 12 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2011 were enteric fermentation from dairy cattle and sheep, and nitrous oxide emissions from agricultural soils.

1990–2011

In 2011, New Zealand's agricultural emissions increased by 3725.4 Gg CO_2-e (12.1 per cent) from the 1990 level of 30,661.9 Gg CO_2-e (figure 2.3.3). This increase is largely due to the increase in the enteric fermentation emissions from dairy cattle and nitrous oxide emissions from agriculture soils.

2010–2011

Between 2010 and 2011, emissions from the agriculture sector increased 665.0 Gg CO_2-e (2.0 per cent). The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a favourable milk price, there was an increase in both dairy cattle population and the sale and use of nitrogen fertiliser in 2011.

This increase in dairy cattle and fertiliser emissions outweighed emission reductions from decreases in the population of sheep, non-dairy cattle and deer. The increase in dairy cattle numbers and the reduction in non-dairy cattle, sheep and deer are primarily due to higher relative returns being achieved in the dairy sector.

LULUCF (chapter 7)

The following information on LULUCF summarises reporting under the Climate Change Convention. For information of Article 3.3 activities under the Kyoto Protocol see section 2.5.

2011

In 2011, net removals from the LULUCF sector under the Climate Change Convention were 13,540.2 Gg CO_2-e. The highest contribution to removals in 2011 was from land converted to forest land. In 2011, net removals contributed 27,221.3 Gg CO_2-e towards the total for the LULUCF sector.

The largest source of emissions in LULUCF is from forest land remaining forest land. In 2011, net emissions for forest land remaining forest land contributed 9,480.1 Gg CO_2-e to the sector total. This is largely due to the emissions from harvesting exceeding removals from growth of these forests during 2011.

1990–2011

Between 1990 and 2011, net removals from LULUCF decreased by 14,572.5 Gg CO_2-e (51.8 per cent) from the 1990 level of –28,112.7 Gg CO_2-e. This is largely the result of increased harvesting of plantation forests as a larger proportion of the estate reaches harvest age.

The fluctuations in net removals from LULUCF across the time series (figure 2.3.5) are influenced by harvesting and deforestation rates. Harvesting rates are driven by a number of factors particularly tree age and log prices. Deforestation rates are driven largely by the relative profitability of forestry compared with alternative land uses. The decrease in net removals between 2004 and 2007 was largely due to the increase in the planted forest deforestation that occurred leading up to 2008, before the introduction of the

New Zealand Emissions Trading Scheme.[17] The decrease in net removals since 2008 is due to the increasing harvesting that has been occurring in pre-1990 planted forests.

2010–2011

Between 2010 and 2011, net removals from LULUCF decreased by 4,274.2 Gg CO_2-e (24.0 per cent). This decrease in net removals is largely the result of an increase in harvesting of pre-1990 planted forest and increased new planting. New planting resulted in emissions due to a loss of biomass associated with the previous land use and a loss of soil carbon with the land-use change to forestry, outweighing removals by forest growth.

Waste (chapter 8)

The waste sector contributed 1,985.4 Gg CO_2-e (2.7 per cent) to total emissions in 2011. Emissions from the waste sector have decreased by 73.7 Gg CO_2-e (3.6 per cent) from the 1990 level of 2,059.1 Gg CO_2-e. This reduction occurred in the solid waste disposal on land category and is likely a result of initiatives to improve solid waste management practices.

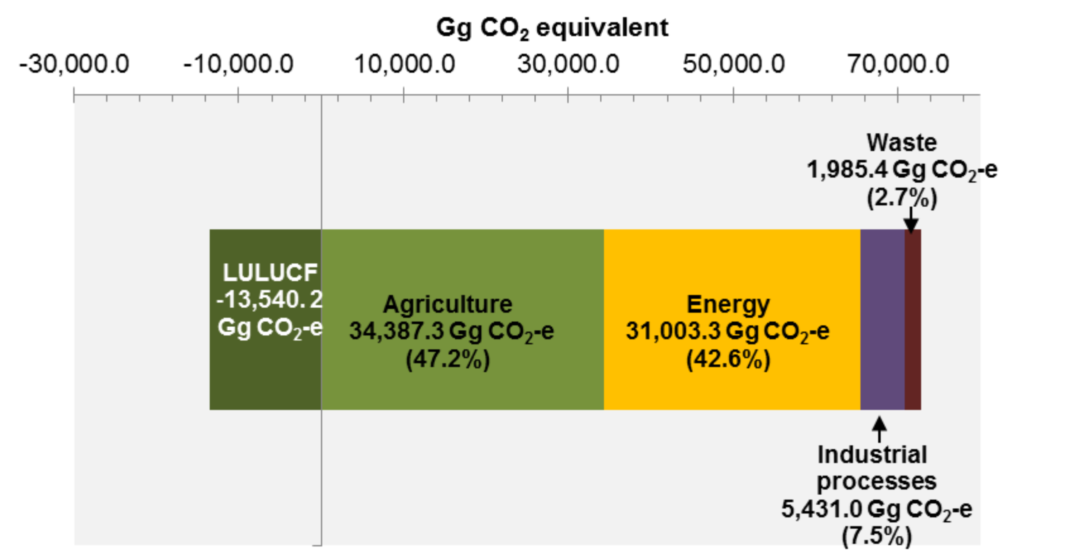
Table 2.3.1 New Zealand's emissions by sector in 1990 and 2011

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2011	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,487.7	31,003.3	+7,515.6	+32.0
Industrial processes	3,392.8	5,431.0	+2,038.1	+60.1
Solvent and other product use	41.5	27.9	–13.6	–32.8
Agriculture	30,661.9	34,387.3	+3,725.4	+12.1
Waste	2,059.1	1,985.4	–73.7	–3.6
Total (excluding LULUCF)	**59,643.1**	**72,834.9**	**+13,191.9**	**+22.1**
LULUCF	–28,112.7	–13,540.2	+14,572.5	+51.8
Net total (including LULUCF)	**31,530.4**	**59,294.7**	**+2,7764.4**	**+88.06**

Note: Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding.

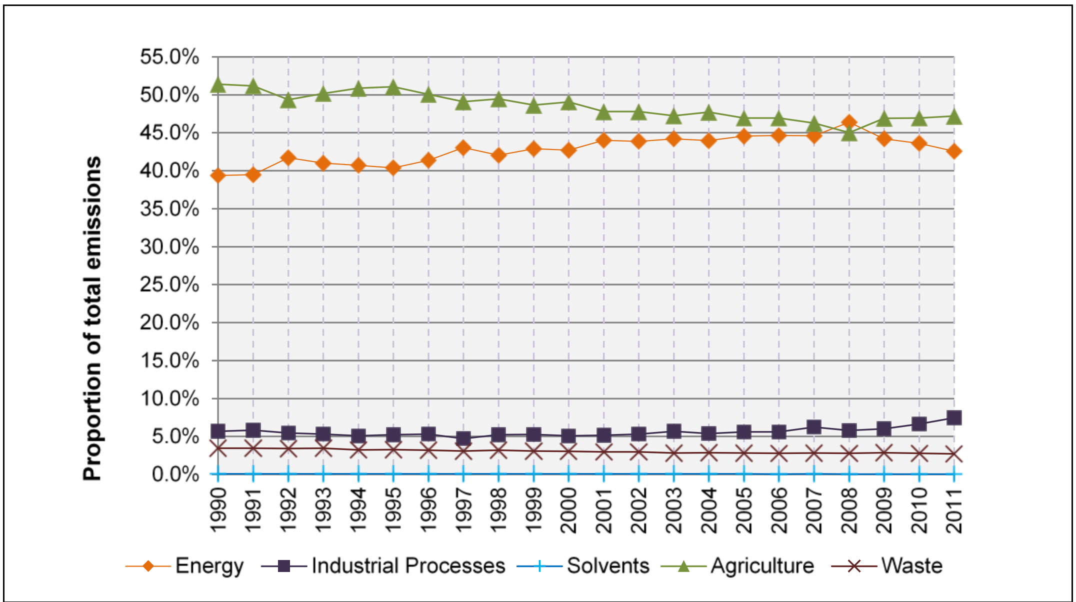
[17] The New Zealand Emissions Trading Scheme included the forestry sector as of 1 January 2008.

Figure 2.3.1 New Zealand's emissions by sector in 2011



Note: Emissions from the solvent and other product use sector are not represented in this figure. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7).

Figure 2.3.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2011



Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.3.3 Change in New Zealand's emissions by sector in 1990 and 2011

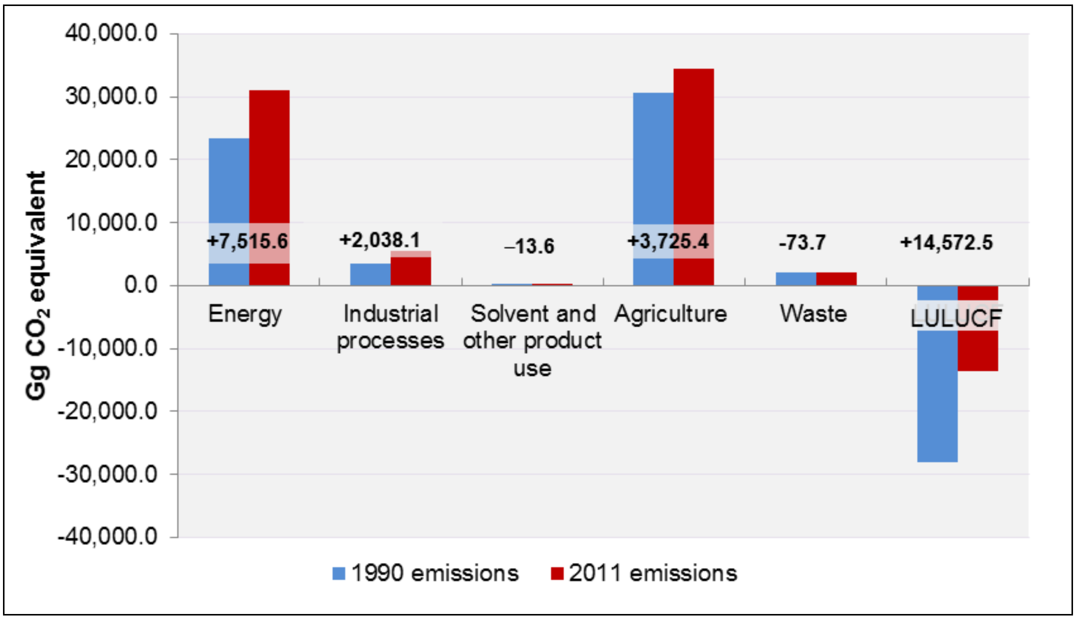
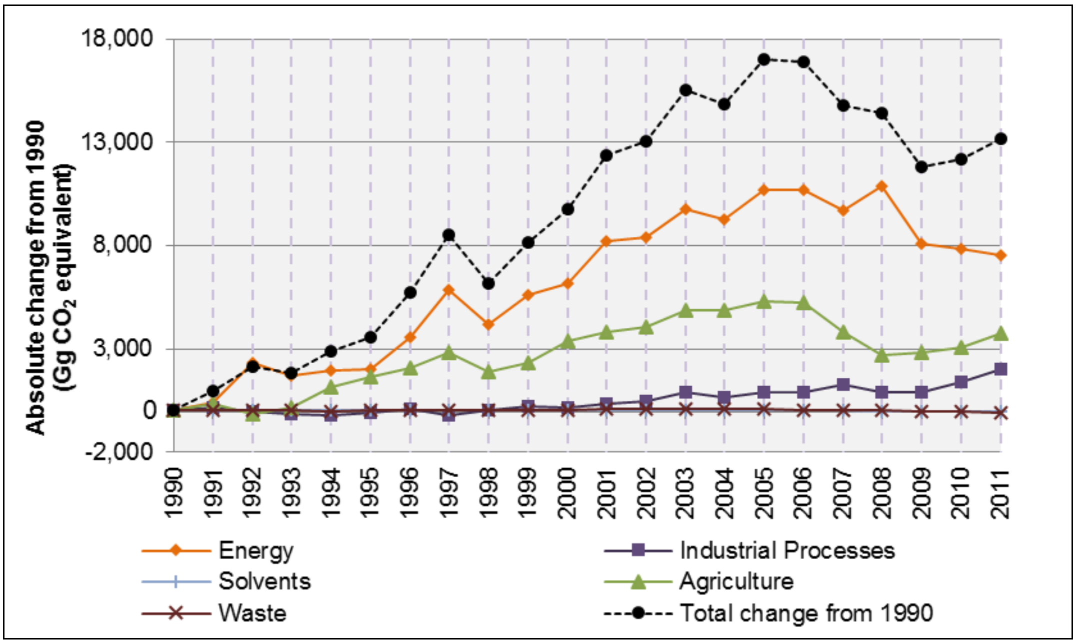
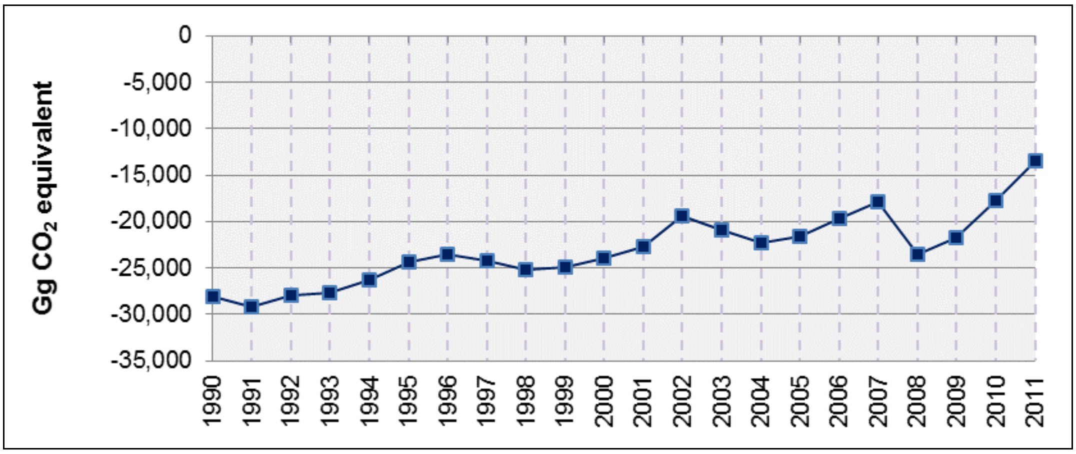


Figure 2.3.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2011



Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.3.5 Absolute change from 1990 in New Zealand's net removals from the LULUCF sector from 1990 to 2011 (UNFCCC reporting)



2.4 Emission trends for indirect greenhouse gases

The indirect greenhouse gas emissions SO_2, CO, NO_x and NMVOCs are also reported in the inventory. Emissions of these gases in 1990 and 2011 are shown in table 2.4.1. Consistent with Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases are not included in New Zealand's greenhouse gas emissions total.

Table 2.4.1 New Zealand's emissions of indirect greenhouse gases in 1990 and 2011

Indirect gas	Gg of gas(es) 1990	2011	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	99.5	151.1	+51.6	+51.9
CO	645.4	730.1	+84.8	+13.1
NMVOCs	135.3	175.8	+40.5	+29.9
SO_2	58.5	73.9	+15.5	+26.4
Total	**938.6**	**1,130.9**	**+192.3**	**+20.5**

Note: Columns may not total due to rounding.

Emissions of CO and NO_x are largely from the energy sector. The energy sector produced 88.7 per cent of total CO emissions in 2011. The largest single source of CO emissions was from the road transportation subcategory. Similarly, the energy sector was the largest source of NO_x emissions (98.0 per cent), with the road transportation subcategory dominating. Other sources of NO_x emissions were from the manufacturing industries and construction category and the energy industries category.

The energy sector was also the largest producer of NMVOCs, producing 72.6 per cent of NMVOC emissions in 2011. Emissions from road transportation comprised 58.6 per cent of total NMVOC emissions. Other major sources of NMVOCs were in the solvent and other product use sector (20.3 per cent) and the industrial processes sector (7.0 per cent).

In 2011, emissions of SO_2 from the energy sector comprised 84.4 per cent of total SO_2 emissions. The energy industries category contributed 11.7 per cent, manufacturing industries and construction category 38.2 per cent and the transport category 16.2 per cent of total SO_2 emissions. The industrial processes sector contributed 15.6 per cent of total SO_2 emissions. Aluminium production accounted for 9.7 per cent of SO_2 emissions.

2.5 Article 3.3 activities under the Kyoto Protocol

In 2011, net removals from land subject to afforestation, reforestation and deforestation (Article 3.3 activities under the Kyoto Protocol) were 16,765.5 Gg CO_2-e (table 2.5.1). This estimate includes:

- removals from the growth of post-1989 forest
- emissions from the conversion of land to post-1989 forest
- emissions from the harvesting of post-1989 forest
- emissions from the deforestation of all forest types
- emissions from lime application to deforested land
- emissions from biomass burning
- emissions from soil disturbance associated with land-use conversion to cropland.

New Zealand's afforestation, reforestation and deforestation estimates under Article 3.3 of the Kyoto Protocol do not include:

- removals from forests that existed as at 31 December 1989 (natural and pre-1990 planted forest)
- emissions from the liming of afforested and reforested land because this activity does not occur in New Zealand. The notation key NO (not occurring) is reported in the common reporting format tables for carbon emissions from lime application
- non-carbon dioxide emissions from controlled burning on deforested land because there is insufficient data to quantify the emissions from this activity. The notation key NE (not estimated) is reported in the common reporting format tables for controlled burning associated with deforestation
- emissions associated with nitrogen fertiliser use on afforested and reforested land because these are reported in the agriculture sector. The notation key IE (included elsewhere) is reported in the common reporting format tables for direct N_2O emissions from nitrogen fertilisation associated with afforestation and reforestation.

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2011 was 599,269 hectares. The net area is the total area of post-1989 forest (618,053 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (18,784 hectares). Net removals from this land in 2011 were 18,440.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2011 was 105,512 hectares. The area subject to deforestation in 2011 was 3,700 hectares. In

2011, deforestation emissions were 1,674.6 Gg CO_2-e, compared with 1,029.4 Gg CO_2-e in 2010 (a 62.7 per cent increase). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2011 as a result of deforestation since 1990. Lagged emissions include the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table 2.5.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2008–2011

Source	2008	2009	2010	2011
Afforestation/reforestation (AR)				
Net cumulative area since 1990 (ha)	580,765.01	583,964.82	588,768.97	599,269.00
Area in calendar year (ha)	1,900.00	4,300.00	6,000.00	12,000.00
Net removals from AR land not harvested in CP1 (Gg CO_2-e)	**–18,199.48**	**–18,293.56**	**–18,455.91**	**–18,551.52**
Emissions from AR land harvested in CP1 (Gg CO_2-e)	82.42	96.24	106.08	111.43
Net removals in calendar year (Gg CO_2-e)	**–18,117.06**	**–18,197.32**	**–18,349.83**	**–18,440.09**
Deforestation				
Net cumulative area since 1990 (ha)	95,937.27	99,195.93	101,811.91	105,511.91
Area in calendar year (ha)	3,467.00	3,259.00	2,616.00	3,700.00
Emissions in calendar year (Gg CO_2-e)	1,586.19	1,368.06	1,029.40	1,674.62
Total area subject to afforestation, reforestation and deforestation	**676,702.28**	**683,160.76**	**690,580.88**	**704,780.91**
Net removals (Gg CO_2-e)	**–16,530.87**	**–16,829.26**	**–17,320.43**	**–16,765.48**
Accounting quantity (Gg CO_2-e)	**–16,613.29**	**–16,925.50**	**–17,426.50**	**–16,876.91**

Note: The areas stated are as at 31 December. They are net areas, that is, areas of afforestation and reforestation that were deforested during the period are only included in the figures as deforestation. Afforestation/reforestation refers to new forest established since 1 January 1990. Deforestation includes deforestation of natural forest, pre-1990 planted forest and post-1989 forest. Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Columns may not total due to rounding.

Chapter 2: References

Ministry for Primary Industries. 2012. *Situation and Outlook for Primary Industries (SOPI)*. Wellington: Ministry for Primary Industries.

Ministry for the Environment. 2006. *New Zealand's Initial Report under the Kyoto Protocol: Facilitating the calculation of New Zealand's assigned amount and demonstrating New Zealand's capacity to account for its emissions and assigned amount in accordance with Article 7 paragraph 4 of the Kyoto Protocol*. Wellington: Ministry for the Environment.

UNFCCC. 2006. FCCC/SBSTA/2006/9. *Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (following incorporation of the provisions of decision 13/CP.9)*.

Chapter 3: Energy

3.1 Sector overview

The energy sector produced 31,003.3 Gg carbon dioxide equivalent (CO_2-e) emissions in 2011, representing 42.6 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector were 32.0 per cent (7,515.6 Gg CO_2-e) above the 1990 level of 23,487.7 Gg CO_2-e (figure 3.1.1). The sources contributing most to this increase were emissions from subcategory 1.AA.3.B road transportation, an increase of 5,162.8 Gg CO_2-e (69.7 per cent), and 1.AA.1.A public electricity and heat production subcategory, an increase of 1,655.9 Gg CO_2-e (47.7 per cent). Emissions from subcategory 1.AA.1.C manufacture of solid fuels and other energy industries subcategory have decreased by 1,289.9 Gg CO_2-e (75.0 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, emissions from the energy sector decreased by 314.1 Gg CO_2-e (1.0 per cent). This is primarily due to a 316.8 Gg CO_2-e (5.8 per cent) decrease in emissions from subcategory 1.AA.1.A public electricity and heat production as a result of:

- the February 2011 Canterbury earthquake:
  - a population reduction in the region resulted in a drop in regional residential energy demand, which was observed primarily in electricity and gasoline statistics
  - damage to infrastructure led to demolition or closure of much of the Christchurch central business district, resulting in reduced commercial electricity demand.
- a 20 per cent increase in generation from wind following the commissioning of two new wind farms in 2011. This had the effect of pushing the most expensive generation (thermal) off the dispatch list in any period when wind generates, resulting in a total net reduction in greenhouse gas emissions.

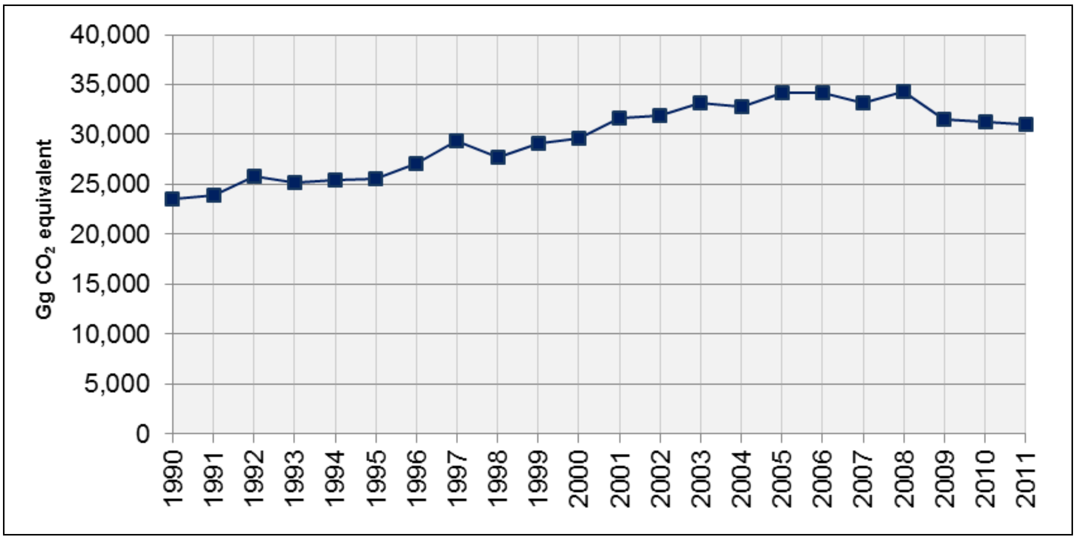
The effect of both of these factors on total generation is relatively small (around 1 per cent each). However, as the marginal generator is often a thermal unit, the effect on thermal generation can be significantly larger.

There was also a 222.2 Gg CO_2-e (8.7 per cent) decrease in sector 1.B fugitive emissions. This was primarily due to reduced activity in subcategory 1.B.1.A coal mining and handling as a result of:

- Pike River Mine being sealed in January 2011 due to explosions in November 2010
- nearby Spring Creek Mine suspending its coal production in November 2010 to May 2011 to accelerate work on a safety improvement programme (Solid Energy, 2011).

These decreases were partially offset by a 184 Gg CO_2-e (1.3 per cent) increase in emissions from sector 1.AA.3 transport.

Figure 3.1.1 New Zealand's energy sector emissions (1990–2011)



Energy flows

This inventory submission includes energy flow diagrams (annex 2, section A2.5). These diagrams provide a snapshot of the flow of various fuels from the suppliers to the end users within New Zealand for the 2011 calendar year.

Ministry nomenclature

In July 2012, the Ministry of Economic Development was merged with the Ministry of Science and Innovation, the Department of Labour and Department of Housing to become the Ministry of Business, Innovation and Employment. For the purposes of this submission, historical references will refer to the Ministry of Economic Development and current or ongoing references will refer to the Ministry of Business, Innovation and Employment.

3.2 Background information

3.2.1 Comparison of sectoral approach with reference approach

Greenhouse gas emissions from the energy sector are calculated using a detailed sectoral approach. This bottom-up approach is demand based; it involves processing energy data collected through various surveys. For verification, New Zealand has also applied a reference approach to estimate carbon dioxide (CO_2) emissions from fuel combustion for the time series 1990–2011.

The reference approach uses a country's energy supply data to calculate the CO_2 emissions from the combustion of fossil fuels using the apparent consumption equation. The apparent consumption in the reference approach is derived from production, import and export data. This information is included as a check for combustion-related emissions (IPCC, 2000) calculated from the sectoral approach.

The apparent consumption for primary fuels in the reference approach is obtained from 'calculated' energy-use figures (see annex 2, section A2.4). These are derived as a residual figure from an energy balance equation comprising production, imports, exports, stock change and international transport on the supply side according to Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996)

Apparent consumption = Production + Imports – Exports

– International bunkers – Stock change

Apparent consumption is then multiplied by a carbon emission factor to obtain an estimate of carbon emissions from combustion. The carbon content of fuel used for non-energy purposes, such as iron and steel or methanol production, is subtracted from this figure. The result is the reference approach estimate for carbon emissions, which is then multiplied by an oxidation factor and the molar mass ratio between carbon dioxide and carbon (44/12) to obtain an estimate of CO_2 emissions.

The majority of the CO_2 emission factors for the reference approach are New Zealand specific. Most emissions factors for liquid fuels are based on annual carbon content and the gross calorific value data provided by New Zealand's only oil refinery, the New Zealand Refining Company. Where this data is not available, an Intergovernmental Panel on Climate Change (IPCC, 1996) default is used. The natural gas emission factor is based on a production-derived, weighted average of emission factors from all gas production fields. The CO_2 emission factors for solid fuels have been updated for the 2013 submission following analysis to verify default emission factors used for the New Zealand Emissions Trading Scheme (NZ ETS). For more information on this improvement, see section 3.3.

The activity data used for the sectoral approach is referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by the Ministry of Business, Innovation and Employment. The differences between 'calculated' and 'observed' figures are reported as statistical differences in the energy balance tables contained in the *New Zealand Energy Data File* (Ministry of Economic Development, 2012).

In 2011, CO_2 emissions estimated in the reference approach were 0.7 per cent higher than those estimated in the sectoral approach. This is within the accepted tolerance threshold of 5 per cent difference between the two approaches. The fuel that showed the largest difference between the two approaches was solid fuels. Carbon dioxide emissions estimated in the reference approach for were 2.8 per cent higher than those estimated in the sectoral approach, largely due to statistical difference in national energy data.

For this submission, natural gas flared at gas and oil fields has been removed from the reference approach to improve the usefulness of the reference approach as a quality-check to the sectoral approach. For further explanation, see section 3.2.5.

In some years, large differences exist between the reference and sectoral approaches, particularly from the early 1990s to the year 2000. Much of this difference is due to the statistical differences found in the energy balance tables (Ministry of Economic Development, 2012) that are used as the basis for the reference and sectoral approach. Since 2000, the standard of national energy data has improved significantly due to increased resources and focus. In 2008, Statistics New Zealand delegated responsibility for the collection and analysis of national energy data to the Ministry of Economic Development. Prior to 2008, various energy statistics were collected by either Statistics New Zealand or the Ministry of Economic Development. The change resulted in a more consistent approach to energy data collection as one agency collected data across the supply chain.

Figure 3.2.1 Differences between sectoral and reference approaches (1990–2011)

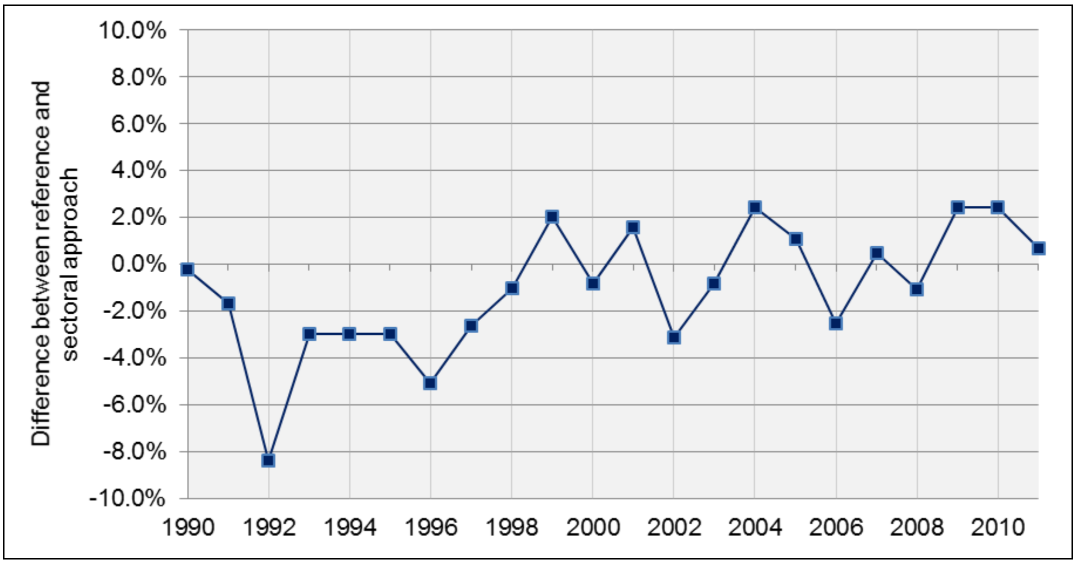


Table 3.2.1 Difference between reference and sectoral approaches 1990–2011

	Reference approach	Sectoral approach	Difference	
	Gg	Gg	Gg	%
1990	21,778.4	21,827.5	–49.0	–0.2
1991	21,857.4	22,232.2	–374.8	–1.7
1992	22,073.3	24,092.7	–2,019.4	–8.4
1993	22,840.3	23,543.5	–703.1	–3.0
1994	23,056.4	23,762.6	–706.3	–3.0
1995	23,129.8	23,838.8	–709.0	–3.0
1996	23,710.9	24,979.5	–1,268.6	–5.1
1997	26,517.3	27,234.5	–717.2	–2.6
1998	25,360.2	25,619.4	–259.2	–1.0
1999	27,537.4	26,985.5	551.9	2.0
2000	27,324.5	27,549.7	–225.2	–0.8
2001	29,986.4	29,525.3	461.1	1.6
2002	28,833.5	29,758.7	–925.1	–3.1
2003	31,009.6	31,262.2	–252.6	–0.8
2004	31,356.1	30,614.7	741.4	2.4
2005	32,312.5	31,967.6	344.9	1.1
2006	31,030.8	31,841.9	–811.1	–2.5
2007	31,077.9	30,936.9	140.9	0.5
2008	31,442.3	31,777.3	–335.0	–1.1
2009	29,503.7	28,801.6	702.1	2.4
2010	29,035.5	28,340.3	695.2	2.5
2011	28,441.7	28,254.6	187.1	0.7

3.2.2 International bunker fuels

The data on fuel use by international transportation comes from the *New Zealand Energy Data File* (Ministry of Economic Development, 2012). This report uses information from oil company monthly survey returns provided to the Ministry of Business, Innovation and Employment.

Data on fuel use by domestic transport is sourced from the quarterly *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development.

Consultation undertaken to review the method used to split international from domestic transport in civil aviation and navigation is covered in further detail in section 3.3.3.

3.2.3 Feedstock and non-energy use of fuels

For some industrial companies, the fuels supplied are used both as a fuel and as a feedstock. In these instances, emissions are calculated by taking the fraction of carbon stored or sequestered in the final product (this is based on industry production and chemical composition of the products) and subtracting this from the total fuel supplied. This difference is assumed to be the amount of carbon emitted as CO_2 and is reported in the common reporting format table 1.A(d).

In New Zealand, there are four main sources of stored carbon.

- Much of the carbon in natural gas used in methanol and synthetic petrol production is stored in the product and therefore has no associated emissions. The balance of the carbon is oxidised and results in CO_2 emissions reported in the associated sector. Due to confidentiality concerns raised by New Zealand's sole methanol producer, emissions from methanol production are reported in manufacturing industries and construction – chemicals, rather than in industrial processes. For more information, see section 3.3.2. Emissions from synthetic petrol production are reported under the manufacture of solid fuels and other energy industries subcategory. Synthetic petrol production in New Zealand ceased in 1997.
- Emissions from the use of natural gas used in urea production are reported under the industrial processes sector.
- Bitumen produced in New Zealand is not used as a fuel but rather used by the companies Fulton Hogan and Downer EDi Works in making roads (non-energy use). Bitumen therefore has no associated emissions.
- Coal used in steel production at New Zealand Steel is used as a reductant, which is part of an industrial process. Therefore, emissions from this coal are reported under the industrial processes sector rather than the energy sector.

3.2.4 Carbon dioxide capture from flue gases and subsequent carbon dioxide storage

There was no CO_2 capture from flue gases and subsequent CO_2 storage occurring in New Zealand between 1990 and 2011.

3.2.5 Country-specific issues

Reporting of the energy sector has few areas of divergence from the IPCC guidelines (IPCC, 1996 and IPCC, 2000). The differences that exist are listed below.

Reference approach – Solid fuels in iron and steel manufacture

As mentioned in section 3.2.3, some of the coal production activity data in the reference approach is used in steel production. Carbon dioxide emissions from this coal have been accounted for under the industrial processes sector in the sectoral approach as recommended by IPCC guidelines (IPCC, 2000), therefore, they are not included in table 1.AA Fuel combustion – Sectoral approach.

The associated carbon is not entirely stored in the end-product, however, so should not be subtracted from the apparent consumption in the reference approach according IPCC guidelines (IPCC, 1996). This creates inconsistent boundaries for table 1.AC Difference – Reference and the sectoral approach; emissions from coal use in iron and steel production appear in the reference approach but not in the sectoral approach.

To improve the utility of the quality check provided by the reference approach, the carbon in coal used in iron and steel production is therefore considered 'carbon stored' for the purposes of the reference approach only. Quantities of coal and carbon are reported in table 1.AD.10.

Reference approach – Natural gas flaring

As mentioned in section 3.2.1, New Zealand includes the carbon content of gas flared at gas fields and offshore oil rigs as carbon stored in the reference approach. The boundaries of the sectoral approach and the reference approach, as described in the IPCC guidelines (IPCC, 1996), seem inconsistent with respect to flared gas.

In the reference approach, table 1.AB, emissions from flared gas are not stored and so should not be subtracted from apparent consumption to obtain CO_2 emissions estimates. In the sectoral approach, emissions from flared gas are reported under the 1.B – fugitive emissions from fuels, so are not included in table 1.AA Fuel combustion. Table 1.AC, comparing the 1.AA and 1.AB, therefore, is comparing datasets with inconsistent boundaries; flared gas is included in the reference approach but excluded from the sectoral approach.

To make this comparison a more accurate quality check for New Zealand's circumstances, the carbon content of gas flared has therefore been included under carbon stored in table 1.AD.5 Feedstocks and non-energy use of fuels – Natural Gas.

Sectoral approach – Methanol production

The sector activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. As a result, subtraction of emissions is not needed to account for this carbon sequestration. Also, due to confidentiality concerns raised by New Zealand's sole methanol producer, emissions from methanol production are reported in 1.AA.2.C chemicals. For further explanation, see section 3.3.1.

3.2.6 Energy balance

The *New Zealand Energy Data File* (Ministry of Economic Development, 2012) is an annual publication from the Ministry of Economic Development. It covers energy statistics, including supply and demand by fuel types, energy balance tables, pricing information and international comparisons. An electronic copy of this report is available online at: www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-data-file. Annex 2, section A2.4 provides an overview of the 2011 energy supply and demand balance for New Zealand.

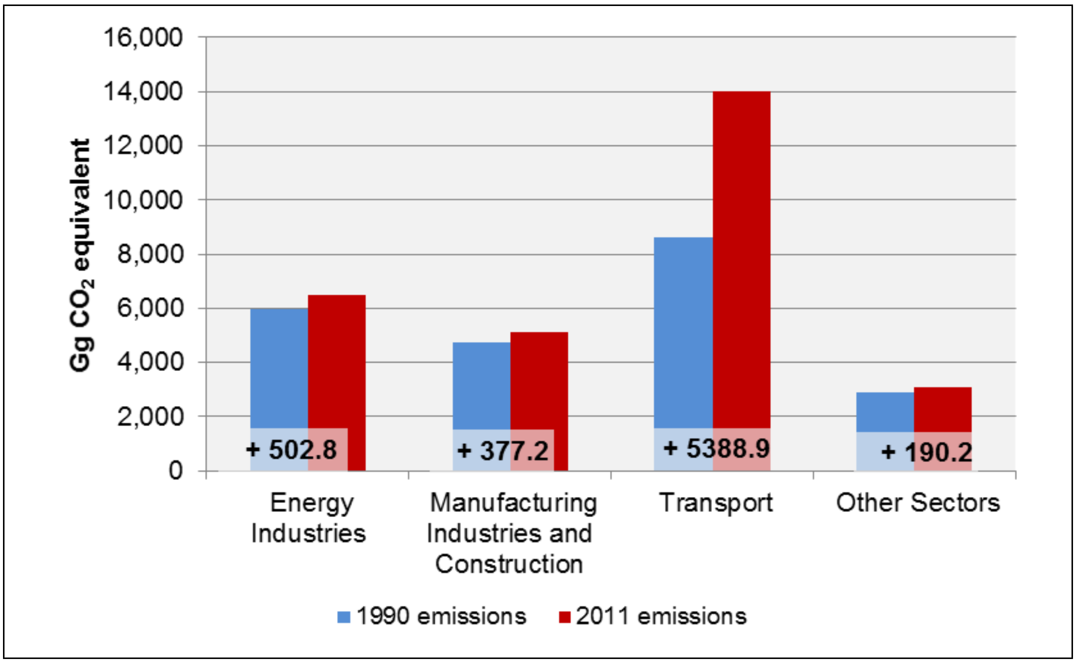
3.3 Fuel combustion (CRF 1A)

Description

The fuel combustion category reports all fuel combustion activities from 1.AA.1 energy industries, 1.AA.2 manufacturing industries and construction, 1.AA.3 transport and 1.AA.4 other sectors subcategories (figure 3.3.1). These subcategories use common activity data sources and emission factors. The common reporting format tables require energy emissions to be reported by subcategory. Apportioning energy activity data across subcategories is not as accurate as apportioning activity data by fuel type because of difficulties in allocating liquid fuel to the appropriate subcategories.

Information about methodologies, emission factors, uncertainty, and quality control and assurance relevant to each of the subcategories is discussed below.

Figure 3.3.1 Change in New Zealand's emissions from the fuel combustion categories (1990–2011)



Methodological issues

Energy emissions are compiled using the Ministry of Business, Innovation and Employment's energy statistics along with relevant New Zealand-specific emission factors. Unless otherwise noted in the relevant section, CO_2 emissions are calculated by multiplying a country-specific emission factor for the given fuel by the relevant activity data using an IPCC 1996 Tier 2 method. Non-CO_2 emissions are calculated using IPCC 1996 default emission factors unless otherwise noted.

Activity data

Liquid fuels

The primary source of liquid fuel consumption data is the *Delivery of Petroleum Fuels by Industry Survey*. The Ministry of Economic Development began conducting the survey in 2009. Before this, the survey was conducted by Statistics New Zealand. The quarterly survey includes liquid fuels sales data collected from the four major oil companies and an independent oil company. The purpose of the survey is to provide data on the amount of fuel delivered by all oil companies to end users and other distribution outlets. Each oil company in New Zealand supplies the Ministry of Business, Innovation and Employment with the volume of petroleum fuels delivered to resellers, industry, commercial and residential sectors.

The volume of petroleum fuels is currently collected in volume units (thousand litres). Prior to 2009, data was collected in metric tonnes. Year-specific calorific values are used for all liquid fuels reflecting changes in liquid fuel properties over time. Annual fuel property data is provided by New Zealand's sole refinery.

Emissions from fuel sold for use in international transport (eg, international bunker fuels) are reported separately as a memo item as required (IPCC, 1996).

A Ministry of Economic Development-commissioned survey in 2008 (see Ministry of Economic Development, 2008) found that there are 19 independent fuel distribution companies operating in New Zealand that resell fuel bought wholesale from the oil companies. It further found that this on-selling resulted in over-allocation of liquid fuel activity data to the transport sector. The study recommended starting an annual survey of deliveries of petrol and diesel to each sector by independent distributors. This data was then used to correctly allocate sales of liquid fuels by small resellers to the appropriate sector.

The *Annual Liquid Fuel Survey* was started in 2009 (for the 2008 calendar year) and found that the 19 independent fuel distribution companies delivered 18 per cent of New Zealand's total diesel consumption and 3 per cent of New Zealand's total petrol consumption. Using this data, each company's deliveries between 1990 and 2006 were estimated because no information was available for these years. The report *Delivering the Diesel – Liquid Fuel Deliveries in New Zealand 1990–2008* (see Ministry of Economic Development, 2010a) outlines in further detail the methodology employed to perform this calculation.

Figure 3.3.2 Reallocation of emissions from gasoline combustion due to *Annual Liquid Fuel Survey* – 2011

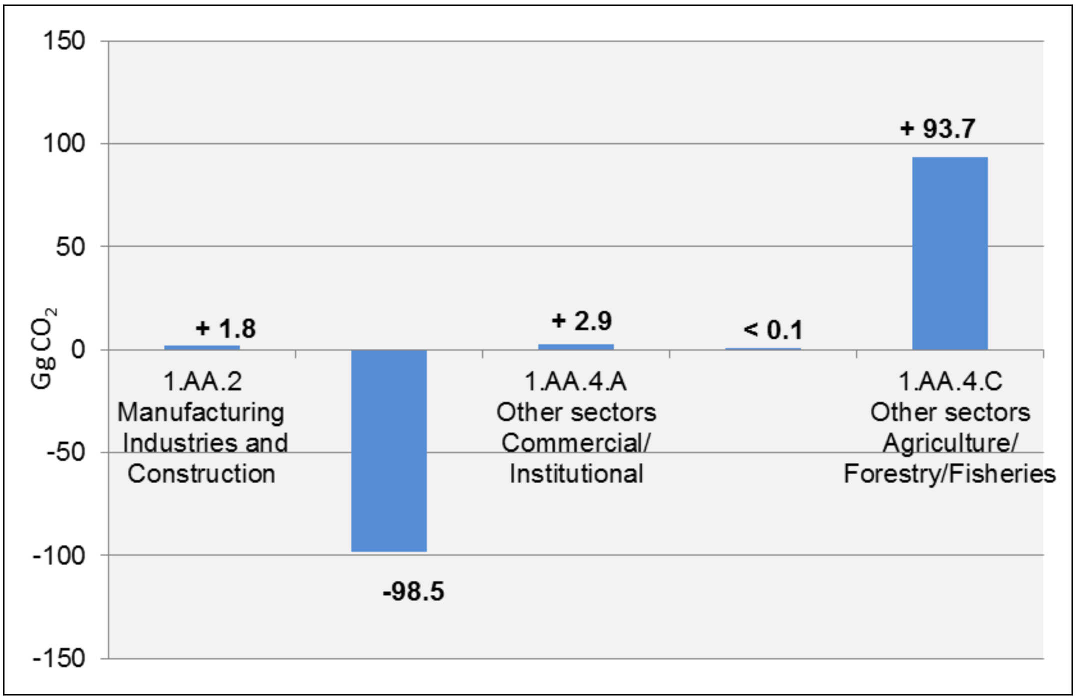
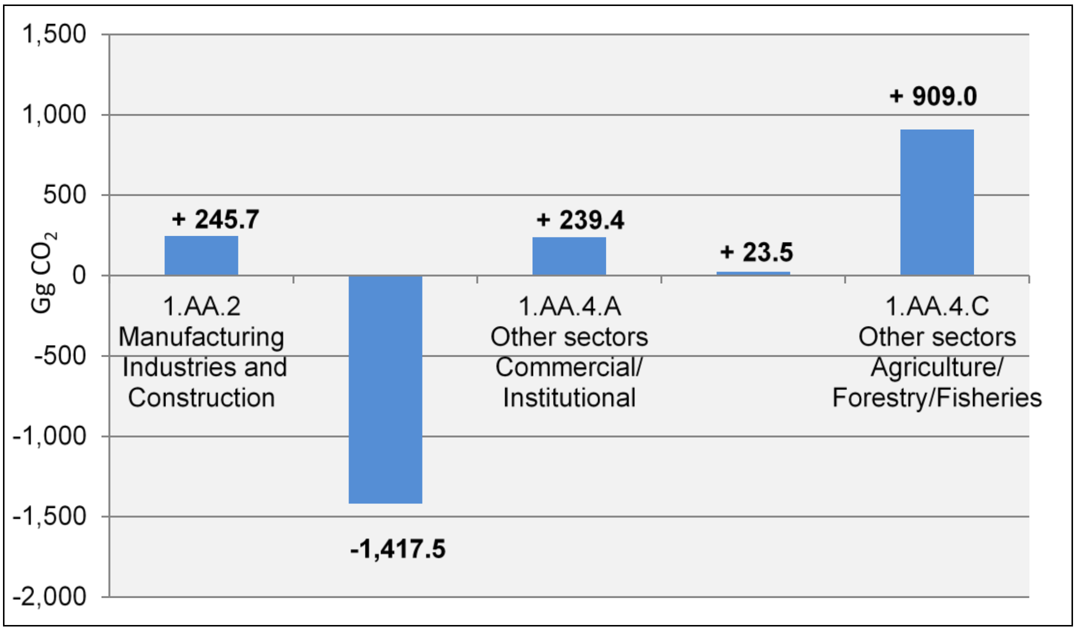


Figure 3.3.3 Reallocation of emissions from diesel combustion due to *Annual Liquid Fuel Survey* – 2011



Solid fuels

Since 2009, the Ministry of Economic Development has conducted the *New Zealand Quarterly Statistical Return of Coal Production and Sales*, previously conducted by Statistics New Zealand. The survey covers coal produced and sold by coal producers in New Zealand. The three grades of coal surveyed are bituminous, sub-bituminous and lignite.

The *Quarterly Statistical Return of Coal Production and Sales* splits coal sold into over 20 industries using the Australian and New Zealand Standard Industry Classification (2006). Prior to 2009, when Statistics New Zealand ran the survey, coal sold was attributed to seven sectors.

All solid fuel used in iron and steel manufacture is reported in the industrial processes sector to avoid double counting.

Gaseous fuels

The Ministry of Business, Innovation and Employment receives activity data on gaseous fuels from a variety of sources. Individual gas field operators provide information on the amount of gas extracted, vented, flared and own use at each gas field. Information on processed gas, including the Kapuni gas field, and information on gas transmission and distribution throughout New Zealand is also provided by the operator of the Kapuni Gas Treatment Plant and gas distribution network, Vector.

Large users of gas, including electricity generation companies, provide their activity data directly to the Ministry of Business, Innovation and Employment. Finally, the Ministry of Business, Innovation and Employment surveys retailers and wholesalers on a quarterly basis to obtain activity data from industrial, commercial and residential gas users.

In response to expert review team recommendations, this submission disaggregates all fuel combustion for electricity auto-production into the appropriate sector rather than in 1.AA.2.F manufacturing industries and construction – other non-specified as in previous submissions. This improvement has resulted in a reduction in unallocated industrial emissions and increases in both various manufacturing and construction sub-sectors. For further information see section 3.3.2.

Biomass

Activity data for the use of biomass comes from a number of different sources. Electricity and co-generation data is received by the Ministry of Business, Innovation and Employment from electricity generators. Commercial biomass data is provided by the Cogeneration Association of New Zealand. Residential biomass data is estimated based on census results and data from the Building Research Association of New Zealand (2002). Finally, industrial biomass data is based on the report *Heat Plant in New Zealand* (Bioenergy Association of New Zealand, 2008).

This submission disaggregates all fuel combustion for electricity auto-production into the appropriate sector rather than reporting it in 1.AA.2.F manufacturing industries and construction – other non-specified as in previous submissions. This improvement has resulted in a reduction in unallocated industrial emissions and increases in both various manufacturing and construction sub-sectors and the commercial–industrial sector. For further information see section 3.3.2.

Liquid biofuel activity data is based on information collected under the Petroleum or Engine Fuel Monitoring Levy as reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2012).

Electricity auto-production

In response to expert review team recommendations, this submission disaggregates all combustion for electricity auto-production into the appropriate sector rather than in

1.AA.2.F manufacturing industries and construction – other non-specified as in previous submissions. This improvement has resulted in a reduction in unallocated industrial emissions and increases in both various manufacturing and construction sub-sectors. For further information see section 3.3.2.

Emission factors

New Zealand emission factors are based on gross calorific values. A list of emission factors for CO_2, methane (CH_4) and nitrous oxide (N_2O) for all fuel types is listed in annex 2, tables A2.1 to A2.4. Explanations of the characteristics of liquid, solid and gaseous fuels and biomass used in New Zealand are described under each of the fuel sections below. Where a New Zealand-specific value is not available, New Zealand uses either the IPCC value that best reflects New Zealand conditions or the mid-point value from the IPCC range. All emission factors from the IPCC (1996) are converted from net calorific value to gross calorific value. New Zealand adopts the Organisation for Economic Co-operation and Development and International Energy Agency assumptions to make these conversions:

- gaseous fuels: *Gross Emission Factor = 0.90 x Net Emission Factor*
- liquid and solid fuels: *Gross Emission Factor = 0.95 x Net Emission Factor*.

Liquid fuels

Where possible, liquid fuel CO_2 emission factors for liquid fuels are calculated on an annual basis. Carbon dioxide emission factors are calculated from New Zealand Refining Company data on carbon content and calorific values. For non-CO_2 emissions, IPCC (1996) default values are used unless otherwise specified in the relevant section. Annex 2, section A2.1 includes further information on liquid fuels emission factors, including a time series of gross calorific values.

Solid fuels

Emission factors for solid fuels have been updated for this submission across the time series from 1990 to 2011. A comprehensive list of carbon content by coal mining is not currently available. However, a review of New Zealand's coal emission factors in preparation for the New Zealand Emissions Trading Scheme (CRL Energy Ltd, 2009) recommended reweighting the current default emission factors to 2007 production rather than continue with those in the *New Zealand Energy Information Handbook* (Baines, 1993). A comparison of the original and updated emission factors can be found in table 3.3.1.

Table 3.3.1 Gross carbon dioxide emission factors for solid fuels

Solid fuel type	2012 Submission (kt CO_2/PJ)	2013 Submission (kt CO_2/PJ)
Bituminous	88.8	89.13
Sub-bituminous	91.2	91.99
Lignite	95.2	93.11

Also for this submission, the emission factor used to calculate emissions from coal use in the public electricity and heat production sector has been weighted to reflect the combustion of imported coal. A time series of the effect of this weighting is included in annex 2 (table A2.2).

Gaseous fuels

New Zealand gaseous fuel emission factors are above the IPCC 2006 default range as New Zealand gas fields tend to have higher CO_2 content than most international gas fields. This is verified by regular gas composition analysis. Emission factors for 2011 from all fields, along with the production weighted average are included in annex 2 (section A2.3).

The gaseous fuels emission factor is the calculated weighted average for all of the gas production fields. The emission factor takes into account gas compositional data from all gas fields. This method provides increased accuracy as the decline in production from both Maui and Kapuni gas fields has been replaced by other new gas fields (for example, Pohoukura) coming on stream. This emission factor fluctuates slightly from year to year, mainly due to the relative production at different gas fields in a given year.

The Kapuni gas field has particularly high CO_2 content. Historically, this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated and the excess CO_2 removed at the Kapuni Gas Treatment Plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and untreated gas due to the difference in carbon content (refer to annex 2, table A2.1). Carbon dioxide removed from raw Kapuni gas then vented is reported under 1.B(2)c.2.3 denting and flaring – flaring – combined.

Biomass

The emission factors for wood combustion are calculated from the IPCC (1996) default emission factors. This assumes that the net calorific value is 5 per cent lower than the gross calorific value (IPCC, 1996). Carbon dioxide emissions from wood used for energy production are reported as a memo item and are not included in the estimate of New Zealand's total greenhouse gas emissions (IPCC, 1996). Carbon dioxide emission factors for liquid biofuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993) while CH_4 and N_2O emission factors are IPCC (2006) default emission factors.

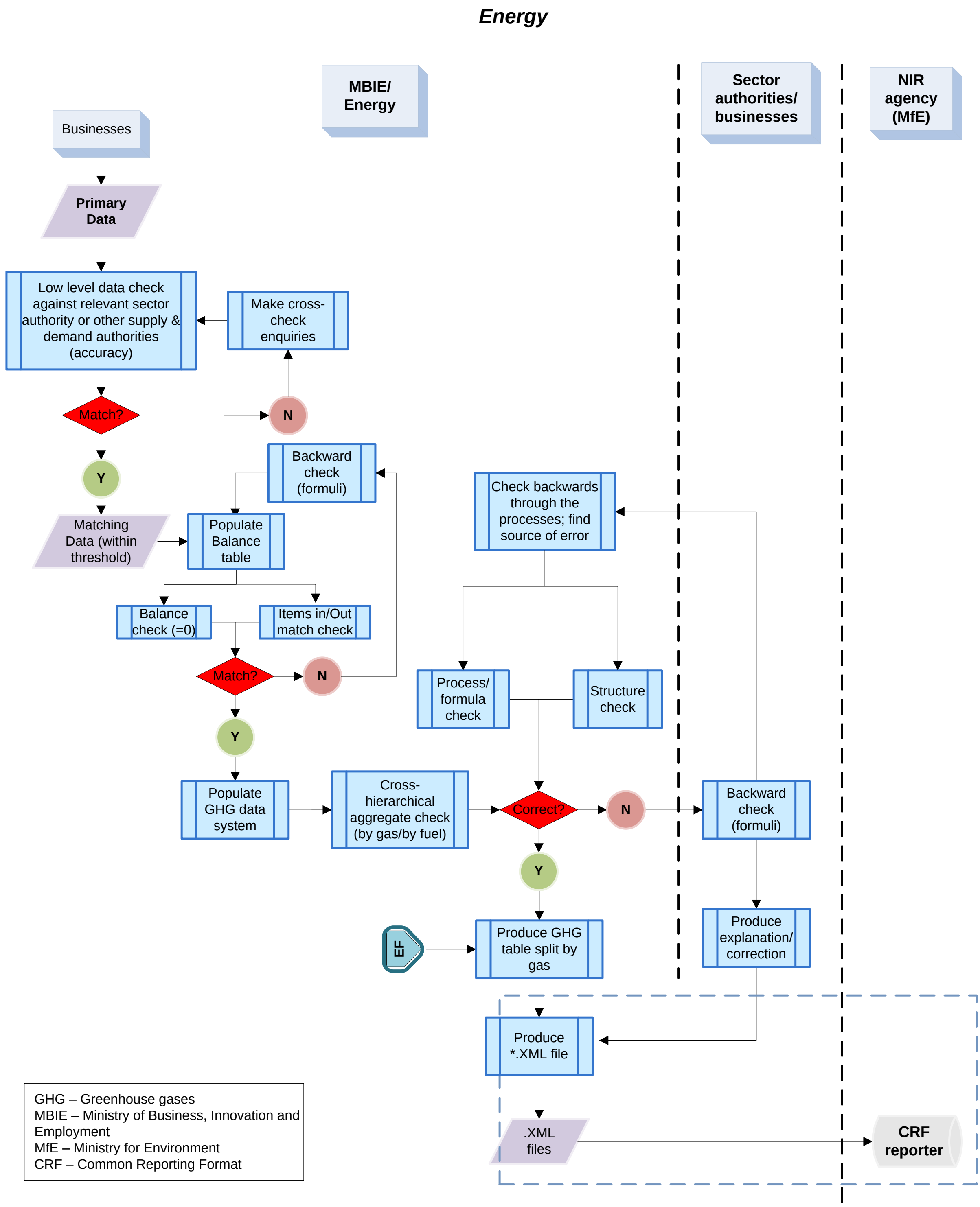
Sector-wide planned improvements

- All source-specific planned improvements will be discussed in their corresponding sections.
- The Ministry of Business, Innovation and Employment will continue to examine the use of more specific solid fuel CO_2 emission factors.

Sector-wide quality assurance/quality control (QA/QC)

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity, time-series consistency check on activity data and consistency checks on implied emission factors at the industry–plant level where possible.

Figure 3.3.4 Energy sector quality control process map



As discussed in section 3.1, the reference approach provides a good, high-level quality check for activity data. A significant deviation (greater than 5 per cent) indicates a likely issue.

Implied CO_2 emission factors for combustion of liquid, solid and gaseous fuels from this inventory were compared with those in the IPCC Emission Factor Database and converted to gross values for comparability with the New Zealand energy system.

The graphs below weight the upper, lower and middle IPCC 2006 emission factor ranges according to observed fuel consumption in New Zealand for the given year. For example, the IPCC range for high point for liquid fuels was calculated using the top of the IPCC 2006 emission factor range for each liquid fuel and observed New Zealand activity data for each liquid fuel.

The sum of all these emissions was then divided by the total observed liquid fuel combustion to obtain an implied emission factor weighted by New Zealand liquid fuel use. This was repeated for all fuel groups and years for the high, low and mid-points of the IPCC 2006 ranges.

With the exception of gaseous fuels (discussed above), each fuel type falls within the IPCC default range.

Figure 3.3.5 Carbon dioxide implied emission factor – Liquid fuel combustion (1990–2011)

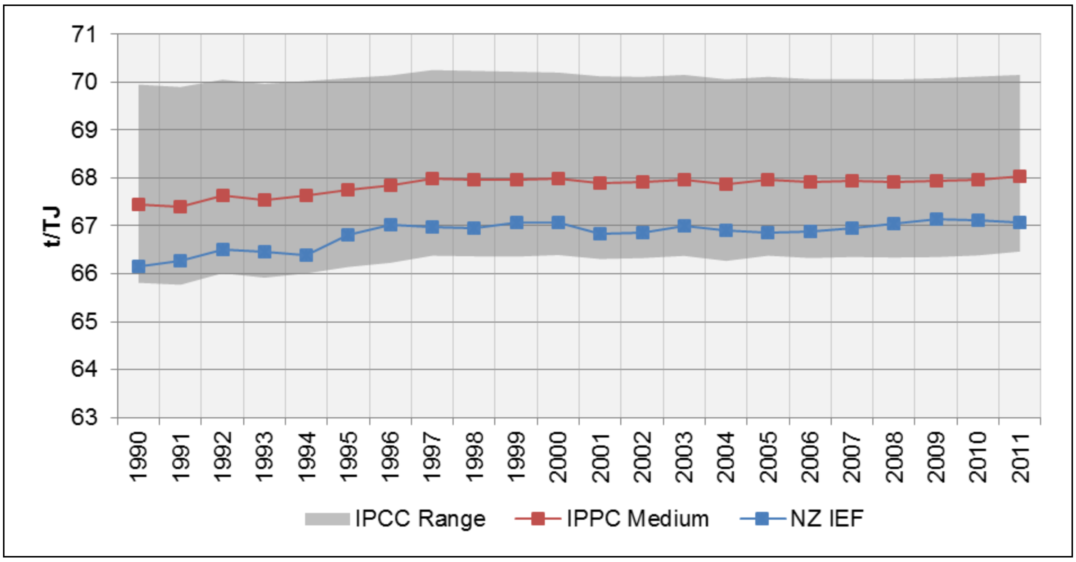


Figure 3.3.6 Carbon dioxide implied emission factor – Solid fuel combustion (1990–2011)

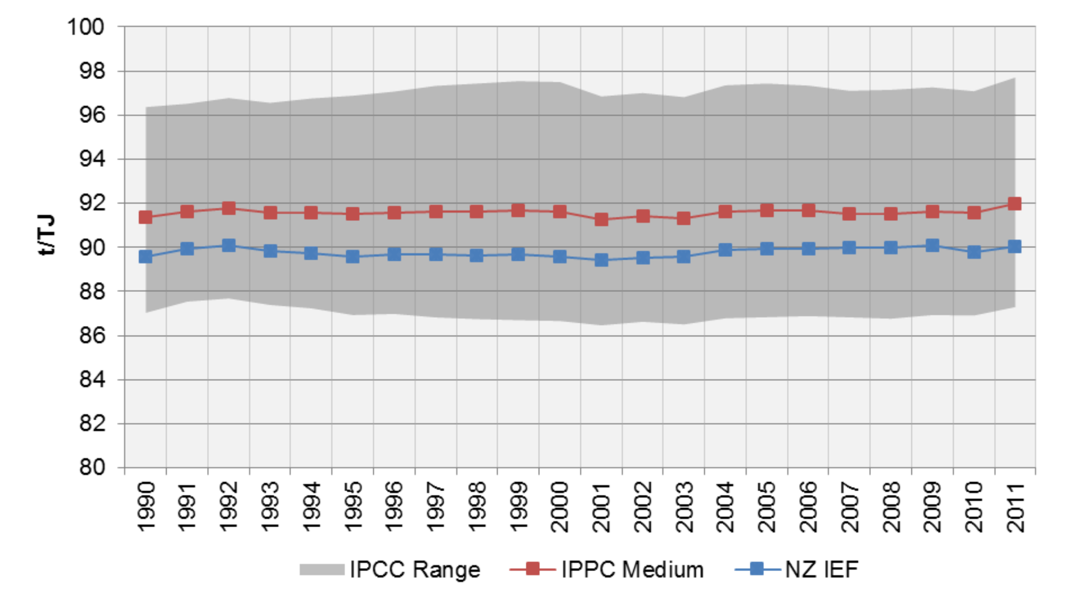
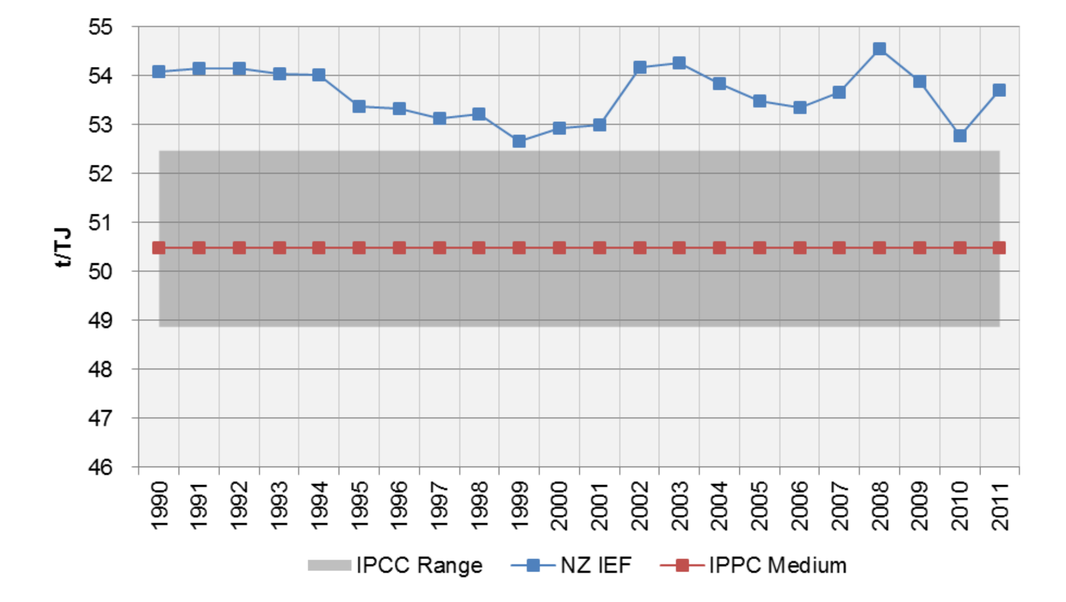


Figure 3.3.7 Carbon dioxide implied emission factor – Gaseous fuel combustion (1990–2011)



Note: As discussed in section under 'Emission factors' above, carbon dioxide emission factors for New Zealand gas fields are established through gas composition analysis and are known to be high by international standards.

New Zealand is currently working through improvements to the energy greenhouse gas system. When this process is complete an external review of the entire system will be commissioned.

Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies, depending on the type of greenhouse gas. The uncertainty of CO_2 emissions is relatively low. This is important as CO_2 emissions made up 95.5 per cent of carbon dioxide equivalent emissions from fuel combustion in New Zealand in 2011. By comparison, emissions of the non-carbon dioxide gases are much less certain, as emissions vary with combustion conditions. Uncertainties for CO_2, CH_4 and N_2O activity data and emission factors are supplied in table 3.3.2. Many of the non-carbon dioxide emission factors used by New Zealand are the IPCC default values. Further detailed information around uncertainties for each fuel type can be found in annex 2, sections A2.1, A2.2 and A2.3.

Table 3.3.2 Uncertainty for New Zealand's energy sector emission estimates

		Activity data uncertainty (%)	Emission factor uncertainty (%)
CO_2	Liquid Fuels	±0.05	±0.5
	Solid Fuels	±4.26	±3.5
	Gaseous Fuels	±3.68	±2.4
	Fugitive – Geothermal	±5.00	±5.0
	Fugitive – Venting/Flaring	±2.58	±2.4
	Fugitive – Oil Transport	±5.00	±50.0
	Fugitive – Transmission and Distribution	±2.58	±5.0
CH_4	Liquid Fuels	±0.05	±50.0
	Solid Fuels	±3.50	±50.0
	Gaseous Fuels	±3.68	±50.0
	Biomass	±5.00	±50.0
	Fugitive – Geothermal	±5.00	±5.0
	Fugitive – Venting/Flaring	±3.68	±50.0
	Fugitive – Coal Mining	±4.26	±50.0
	Fugitive – Transmission and Distribution	±3.68	±5.0
	Fugitive – Other Leakages	±5.00	±50.0
	Fugitive – Oil Transportation	±5.00	±50.0
N_2O	Liquid Fuels	±0.05	±50.0
	Solid Fuels	±4.26	±50.0
	Gaseous Fuels	±3.68	±50.0
	Biomass	±5.00	±50.0

New Zealand uses the percentage difference between annual calculated consumer energy from supply-side surveys and annual observed consumer energy from demand-side surveys for activity data uncertainty. As a result, activity data uncertainty can vary significantly from year to year.

3.3.1 Fuel combustion: Energy industries (CRF 1A1)

Description

This category includes combustion for public electricity and heat production, petroleum refining and the manufacture of solid fuels and other energy industries. The latter subcategory includes estimates for natural gas in oil and gas extraction and from natural gas in synthetic petrol production. The excess CO_2 removed from Kapuni gas at the

Kapuni Gas Treatment Plant has also been reported under the manufacture of solid fuels and other energy industries subcategory because of confidentiality concerns.

In 2011, emissions in category 1.AA.1 energy industries totalled 6,468.7 Gg carbon dioxide equivalent (CO_2-e) (20.9 per cent of energy sector emissions). Emissions from energy industries have increased by 502.8 Gg CO_2-e (8.4 per cent) since the 1990 level of 5,965.9 Gg CO_2-e. The category 1.AA.1.A public electricity and heat production subcategory accounted for 5,127.9 Gg CO_2-e (79.3 per cent) of the emissions from the energy industries category in 2011. This is an increase of 1,655.9 Gg CO_2-e (47.7 per cent) from the 1990 level of 3,472.0 Gg CO_2-e.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, there was a decrease of 316.8 Gg CO_2-e (5.8 per cent) in emissions from 1.AA.1.A public electricity and heat production. This was due to a combination of:

- the February 2011 Canterbury earthquake:
  - population reduction in the region resulted in a drop in regional residential energy demand, which was observed primarily in electricity and gasoline statistics
  - damage to infrastructure led to demolition or closure of much of the Christchurch central business district, resulting in reduced commercial electricity demand.
- a 20 per cent increase in generation from wind following the commissioning of two new wind farms in 2011. This had the effect of pushing the most expensive generation (thermal) off the dispatch list in any period when wind generates having a total net reduction in greenhouse gas emissions.

The effect of both of these factors on total generation is relatively small (around 1 per cent each). However, as the marginal generator is often a thermal unit, the effect on thermal generation can be significantly larger.

Key categories identified in the 2011 level assessment from the energy industry category include CO_2 emissions from:

- public electricity and heat production – solid fuels
- public electricity and heat production – gaseous fuels
- petroleum refining – liquid fuels.

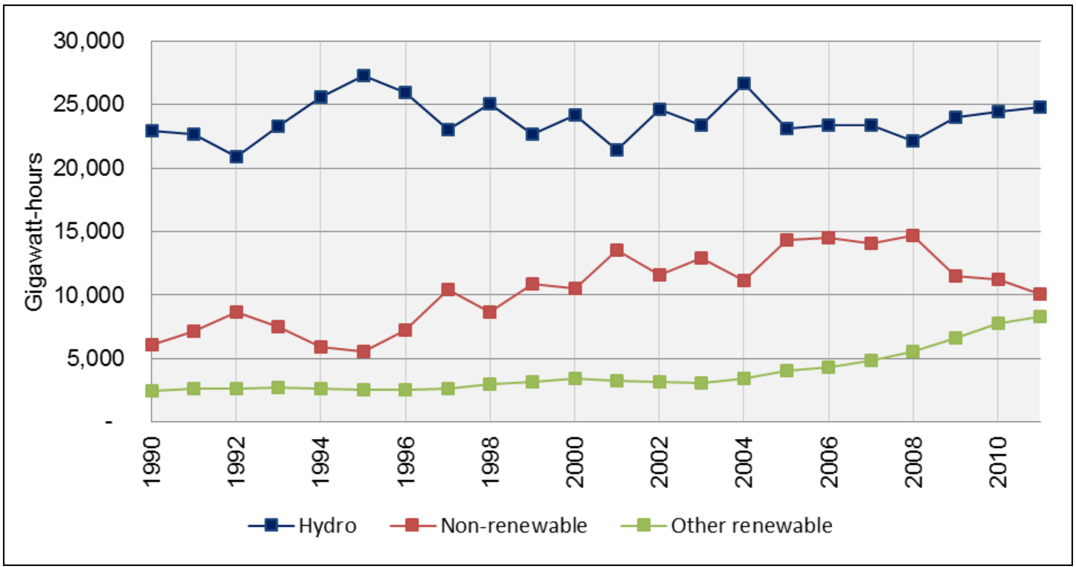
Key categories identified in the 2011 trend assessment from the energy industry category include CO_2 emissions from:

- public electricity and heat production – solid fuels
- public electricity and heat production – gaseous fuels
- petroleum refining – liquid fuels
- manufacture of solid fuels and other energy industries – gaseous fuels.

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2011 calendar year, hydro generation provided 58 per cent of New Zealand's electricity generation. A further 13 per cent came from geothermal, 5 per cent from wind and 1 per cent from biomass. The remaining 23 per cent was provided by fossil fuel thermal generation plants using gas, coal and oil (Ministry of Economic Development, 2012).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2011. These fluctuations can also be seen over the time series for New Zealand's total emissions. The fluctuations are influenced by the close inverse relationship between thermal and renewable generation (figure 3.3.8). In a dry year, where low rainfall affects the majority of New Zealand's hydroelectric lake levels, the shortfall is made up by thermal electricity generation. New Zealand's hydro resources have limited storage capacity, with around 10 per cent of New Zealand's annual demand of reservoir storage (Electricity Technical Advisory Group and the Ministry of Economic Development, 2009). Electricity generation in a 'normal' hydro year requires lower gas and coal use, while a 'dry' hydro year requires higher gas and coal use.

Figure 3.3.8 New Zealand's electricity generation by source (1990–2011)



Methodological issues

1.AA.1.C Manufacture of solid fuels and other energy industries

Methanex New Zealand produced synthetic petrol until 1997. A Tier 1 methodology was used to estimate emissions based on the annual weighted average gas emission factor.

Activity data

1.AA.1.A Public electricity and heat production

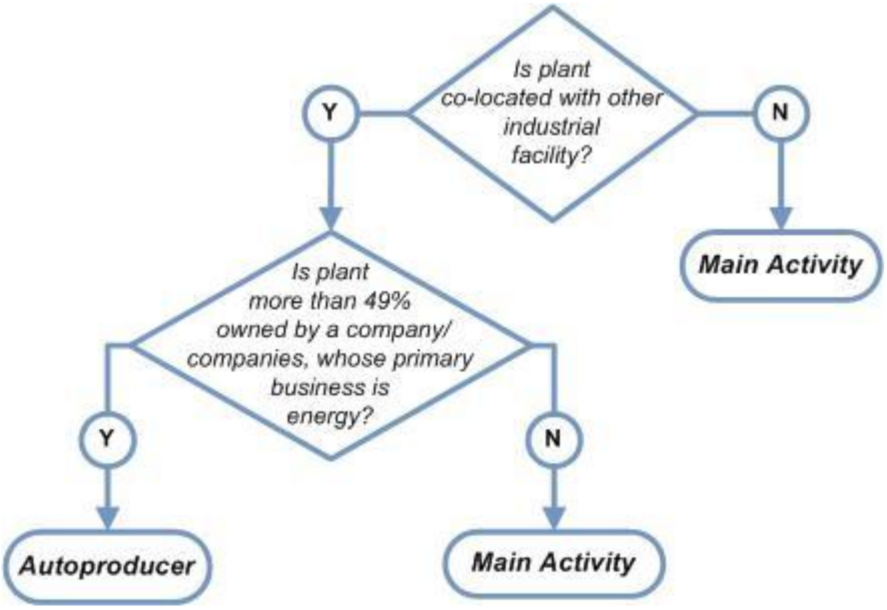
All thermal electricity generators provide figures for the amount of coal, gas and oil used for electricity generation to the Ministry of Business, Innovation and Employment. Greenhouse gas emissions from geothermal electricity generation are reported under 1.B.2.D.

Around 6 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (Ministry of Economic Development, 2012). Most of the major co-generation plants are attached to large industrial facilities that consume most of the electricity and heat generated.

There are six co-generation plants that fit the IPCC (1996) definition of public electricity and heat production and that produce electricity as their primary purpose. The emissions from these plants are included under the public electricity and heat production subcategory, while emissions from other co-generation plants are included within the manufacturing industries and construction category (section 3.3.2).

To establish a consistent approach to on-site generation, the national electricity system developed a decision-tree to guide the allocation of associated fuel consumption and identify whether the plant is a main activity electricity generator or an autoproducer (figure 3.3.9).

Figure 3.3.9 Decision tree to identify an autoproducer



1.AA.1.B Petroleum refining

The New Zealand Refinery Company provides annual activity data and emission factors for each type of fuel being consumed at the site. The fuel-type specific emission factors were adopted under the Government's Projects to Reduce Emissions in 2003 (Ministry for the Environment, 2009). As no data is available concerning non-carbon dioxide emissions from the refinery, the IPCC (1996) default emission factors for industrial boilers have been applied.

Refinery gas is obtained during the distillation of crude and production of oil products. As a result, emissions from its combustion are implicitly included under liquid fuels in the reference approach. To improve the validity of the reference approach as a quality check at a fuel level, these emissions are allocated to liquid fuels in both approaches. This change was implemented for the 2012 submission and is retained for this submission.

1.AA.1.C Manufacture of solid fuels and other energy industries

Activity data for the combustion of natural gas during oil and gas extraction are provided to the Ministry of Business, Innovation and Employment by each individual gas and/or oil field operator. Liquid fuels are also combusted during oil and gas extraction. The activity data for this is provided by the individual gas and/or oil field operator while the IPCC default for crude oil combustion is used.

Emission factors

Gaseous fuels

As mentioned in section 3.3, New Zealand's natural gas emission factor fluctuates from year to year, mainly due to the different mixture of gas fields that were used in that year. New Zealand gas fields also have higher carbon content than most international gas fields. This is particularly evident in the public electricity and heat production subcategory.

Uncertainties and time-series consistency

Uncertainties in emissions and activity data estimates for this category are relevant to the entire fuel combustion sector (refer to table 3.3.2).

Source-specific QA/QC and verification

In the preparation of this inventory, the fuel combustion category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and consistency checks on implied emission factors.

Source-specific recalculations

As discussed in section 3.3, emission factors for solid fuels have been updated for this submission. This has resulted in changes in emissions from solid fuel combustion across all sectors, including public electricity and heat production. In addition, this submission uses emission factors for solid fuel combustion for electricity generation that include the effect of imported coal use reported by the operator of the country's only primary producer coal-fired electricity generation.

The net effect is an increase in CO_2 emissions in the public electricity and heat production sector across the time series. A full time series of the emission factor for sub-bituminous coal used for electricity generation can be found in annex 2 (table A2.2).

3.3.2 Fuel combustion: Manufacturing industries and construction (CRF 1A2)

Description

This category comprises emissions from fossil fuels combusted in iron and steel, other non-ferrous metals, chemicals, pulp, paper and print, food processing, beverages and tobacco, and other uses. Emissions from co-generation plants that do not meet the definition of co-generation as provided in the revised 1996 IPCC guidelines (IPCC, 1996) are included in this category.

In 2011, emissions from 1.AA.2 manufacturing industries and construction subcategory accounted for 5,101.4 Gg CO_2-e (16.5 per cent) emissions from the energy sector. Emissions were 377.2 Gg CO_2-e (8.0 per cent) above the 1990 level of 4,724.2 Gg CO_2-e. A decline in methanol production in 2003–2004 caused a significant reduction in emissions from this category. Methanol production is the largest source of emissions in subcategory 1.AA.2.C chemicals.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, emissions from the manufacturing industries and construction sector decreased by 127.3 Gg CO_2-e (2.4 per cent). This is primarily due to a 186.9 Gg CO_2-e (10.7 per cent) decrease in emissions from solid fuels in the sector as a result of the reduced coal production discussed in section 3.1.

Key categories identified in the 2011 level assessment from the manufacturing industries and construction category include CO_2 emissions from:

- gaseous fuels
- liquid fuels
- solid fuels.

Key categories identified in the 2011 trend assessment from the manufacturing industries and construction category include CO_2 emissions from:

- solid fuels.

Methodological issues

To ensure there is no double counting of emissions, there are some instances where emissions from the use of solid fuels and gaseous fuels are excluded from this category as they are accounted for under the industrial processes sector. New Zealand Steel uses coal as a reductant in the steel-making process. In accordance with IPCC (1996) guidelines, the emissions from this are included in the industrial processes sector rather than the energy sector. There are a number of instances where natural gas is excluded from the manufacturing industries and construction subcategory as it is accounted for under industrial processes. This includes urea production, hydrogen production and some of the natural gas used by New Zealand Steel (New Zealand Steel separately reports its emissions from natural gas as part of the combustion process and natural gas as part of the chemical process).

Activity data

This inventory submission further disaggregates emissions previously reported in subcategory 1.AA.F manufacturing industries and construction – other non-specified into specific subcategories. This has resulted in the ‘other’ subcategory becoming much smaller.

Energy balance tables used in the *New Zealand Energy Data File* (Ministry of Economic Development, 2012) split out industrial uses of energy using the Australia New Zealand Standard Industrial Classification (ANZSIC) 2006. This was possible because of the collection of more detailed information from the various surveys used to compile the energy balance tables since 2009.

This has allowed a further disaggregation of the manufacturing industries and construction category and, therefore, greater transparency. Where actual survey data is not available at the required level, estimates of the energy use across these subcategories have been made to ensure time-series consistency. These are described in further detail below.

Solid fuels

The 2010 *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) disaggregated the 'industrial' category for coal. This was the first time this category has been disaggregated and applied from 2009. These percentage splits, based on 2009 data, were applied to activity data for the annual inventory submission across the whole time series (ie, back to 1990). Carbon dioxide, CH_4 and N_2O emissions have been split out using the same percentage splits. From 2009 onwards, surveys provide data at a more disaggregated level. As more disaggregated data becomes available, these splits will be reviewed and revised as necessary.

Table 3.3.3 Splits used for manufacturing industries and construction category – Solid fuels for 2009 calendar year

Manufacturing industries and construction subcategory	Bituminous coal (%)	Sub-bituminous coal (%)	Lignite coal (%)
1.AA.2.A Iron and steel	IE	NO	NO
1.AA.2.B Non-ferrous metals	NO	0.06	NO
1.AA.2.C Chemicals	NO	NO	NO
1.AA.2.D Pulp, paper and print	NO	6.82	2.41
1.AA.2.E Food processing, beverages and tobacco	10.89	72.17	95.10
1.AA.2.F Other – Mining and construction	0.21	1.15	0.45
1.AA.2.F Other – Textiles	NO	1.10	NO
1.AA.2.F Other – Non-metallic minerals	28.77	5.19	NO
1.AA.2.F Other – Mechanical/electrical equipment	NO	0.12	NO
1.AA.2.F Other – Non-specified	60.13	13.38	2.04

Note: IE = included elsewhere; NO = not occurring. Survey data indicates that coal combustion does not occur in these sectors. In the case of solid fuels used for iron and steel production, emissions are reported in the industrial processes sector. See 'Iron and Steel' explanation later in this section.

Solid biomass

The Bioenergy Association of New Zealand conducted a *2006 Heat Plant Survey of New Zealand* (Bioenergy Association of New Zealand, 2008) to gain information on heat plant (boiler) capacity and use in New Zealand. One area this survey examined was solid biomass use in New Zealand industrial companies (see table 3.3.4). The survey shows that most solid biomass in New Zealand is used by the wood processing industry. The industrial splits from the survey were used to separate out solid biomass activity data for the New Zealand greenhouse gas inventory. These splits were applied across the whole time series (ie, back to 1990) for activity data and CO_2, CH_4 and N_2O emissions.

Table 3.3.4 Splits used for manufacturing industries and construction category – Solid biomass for 2006

Manufacturing industries and construction subcategory	%
1.AA.2.A Iron and steel	NO
1.AA.2.B Non-ferrous metals	NO
1.AA.2.C Chemicals	NO
1.AA.2.D Pulp, paper and print	99.94
1.AA.2.E Food processing, beverages and tobacco	0.05
1.AA.2.F Other – Mining and construction	NO
1.AA.2.F Other – Textiles	NO

1.AA.2.F Other – Non-metallic minerals	NO
1.AA.2.F Other – Mechanical/electrical equipment	NO
1.AA.2.F Other – Non-specified	0.01

Note: NO = not occurring. Survey data indicates that solid biomass combustion does not occur in the sectors.

Gaseous biomass

During the 2012 centralised review, it was discovered that the national inventory was not capturing emissions from the combustion of biogas produced at the Tirau dairy processing facility. Cattle effluent is utilised to produce biogas that is used to raise heat for the milk processing facility, which is open from September through to December each year.

Biogas is not metered or analysed at the site, but estimates of flow rate and methane content were obtained from the facility manager for the 2011 reporting year. The Ministry of Business, Innovation and Employment then used these to calculate an estimate of the total energy content, which was then confirmed by the facility manager.

The facility has operated in the same fashion since its construction in the late 1980s, therefore this estimate was assumed to be valid across the time series.

Liquid fuels (diesel, gasoline and fuel oil)

As mentioned in section 3.3, New Zealand uses the *Annual Liquid Fuel Survey* to capture sales by small independent distributors. With this information, some liquid fuel demand that would otherwise be allocated to national transport is reallocated to the correct sectors' demand. In terms of energy sector emission estimates, emissions attributed to category 1.AA.3 transport decrease by around 20 per cent as a result of this reallocation and emissions attributed to other categories, such as 1.AA.4.C agriculture/forestry/fisheries increase significantly. For the effect on 2011 sector emissions, see figures 3.3.3 and 3.3.4.

Following Expert Review Team recommendations (2007 in-country review), New Zealand began to disaggregate liquid fuel combustion in 1.AA.2 Manufacturing industries and construction categories for the 2011 inventory. Diesel and gasoline consumption were disaggregated for the 2012 submission and the method has been extended to include fuel oil for this submission.

While data is not collected at this level of detail in energy surveys for liquid fuels, New Zealand has produced estimates based on Statistics New Zealand survey data. Statistics New Zealand conducted a *Manufacturing Energy Use Survey* (Statistics New Zealand, 2010), which assessed energy consumption and end use across manufacturing industries for the 2009 calendar year.

These splits, along with sub-sector gross domestic product (GDP) data from Statistics New Zealand for the period, were used to calculate implied energy intensities (petajoule (PJ) per unit GDP) for each sub-sector for diesel, gasoline and fuel oil. These intensities were then applied to Statistics New Zealand GDP data across the time series and scaled to match the fuel sales reported for all manufacturing industries and construction to estimate activity data for each sub-sector.

In past national energy surveys, consumption of liquid fuels in the mining sector was captured along with that in the forestry and logging sector as 'other primary industry'. Statistics New Zealand conducted an *Energy Use Survey of Primary Industries* in 2008 (Statistics New Zealand, 2008). In this inventory, this data was used to estimate the split of 'other primary industry' consumption into 'forestry and logging' and 'mining'. As a result, a significant shift of emissions from agriculture, forestry and fisheries to mining and construction can be seen across the time series in this inventory.

By disaggregating into sub-sectors, more accurate estimates of stationary versus mobile combustion for diesel were also able to be made, resulting in small changes to total emissions from manufacturing industries and construction.

Disaggregating the manufacturing industries and construction category for solid fuels, solid biomass, gasoline and diesel has led to the 'other – not specified' category (1.A.2.F) under manufacturing industries and construction decreasing significantly.

Figure 3.3.10 Splits used for manufacturing industries and construction category – Gasoline (1990–2011)

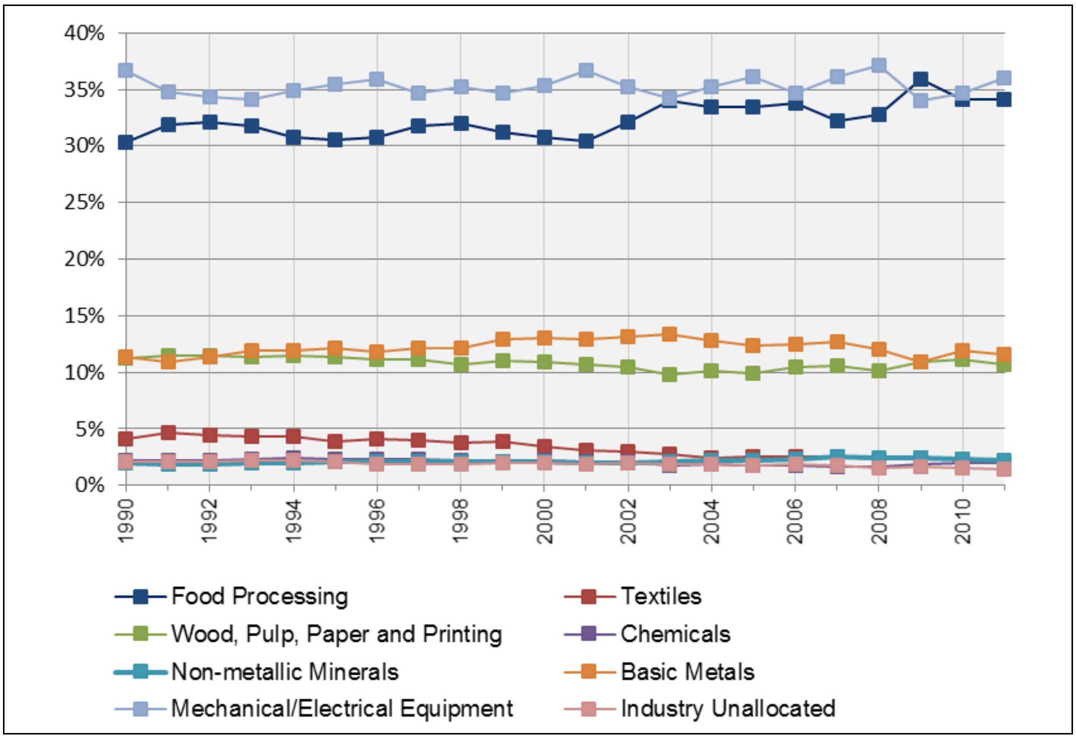


Figure 3.3.11 Splits used for manufacturing industries and construction category – Diesel (1990–2011)

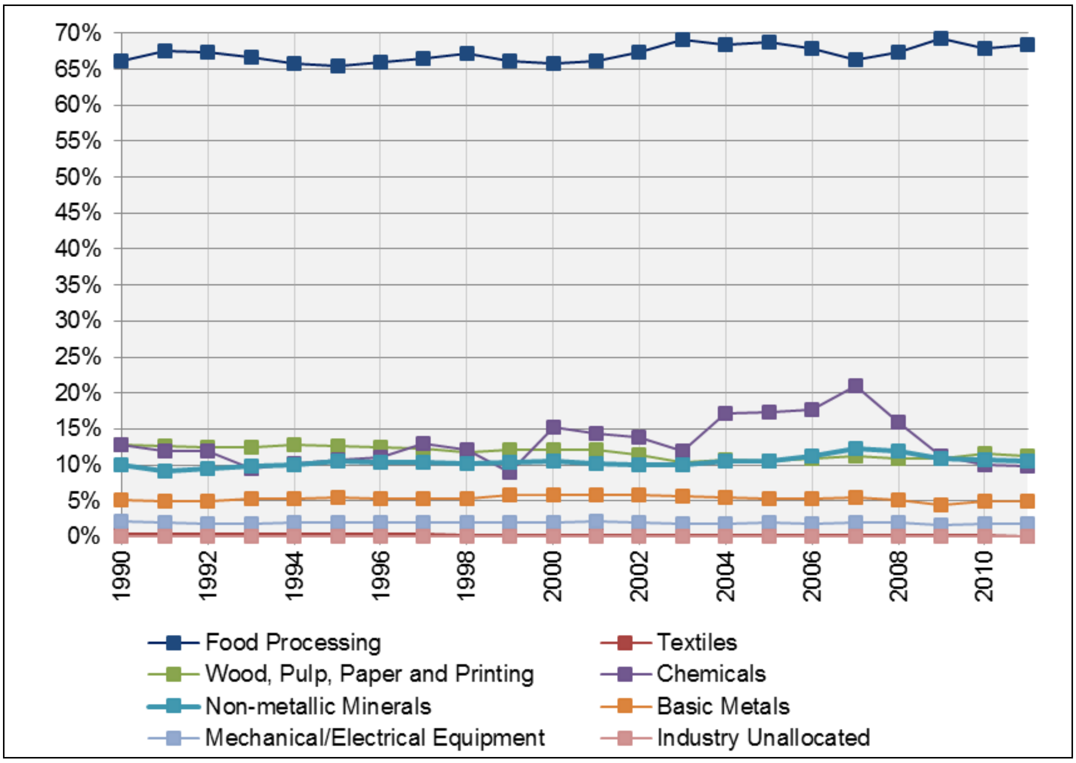
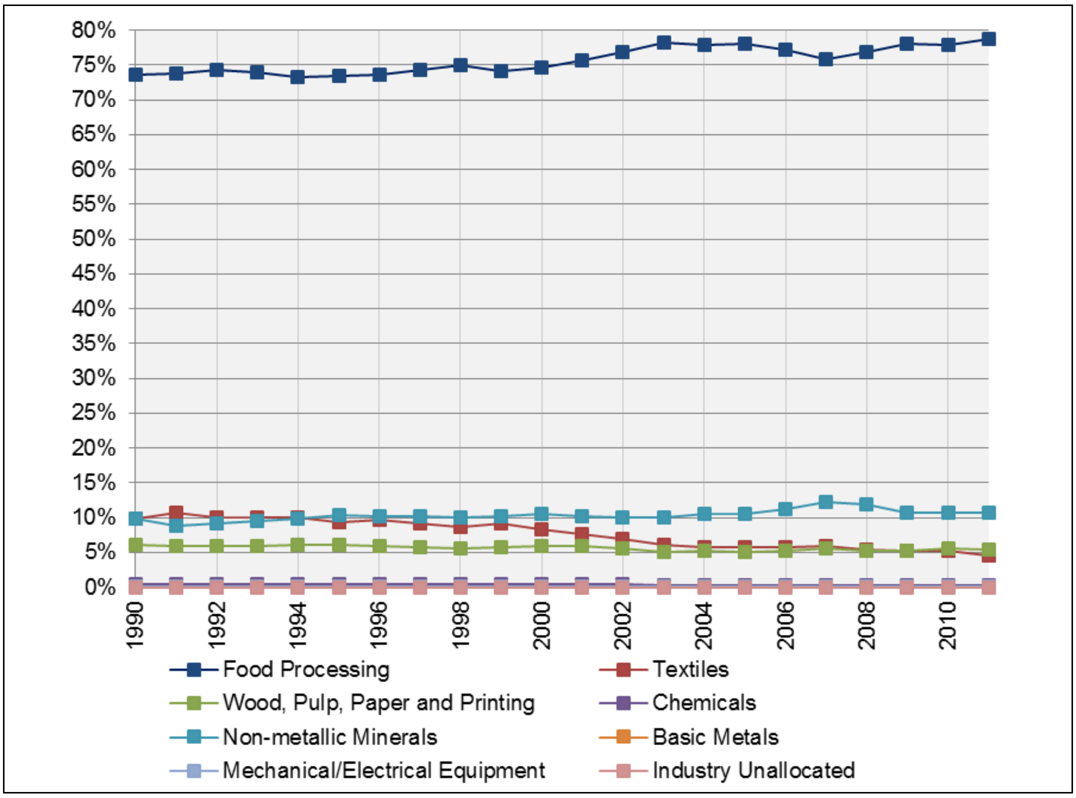


Figure 3.3.12 Splits used for manufacturing industries and construction category – Fuel oil (1990–2011)



Gaseous fuels

A considerable amount of cleansing of national energy data was undertaken in 2011. As result, several inconsistencies in sector reporting were found along with a considerable amount of missing data for natural gas consumption. Where necessary, new estimates were made using consumer data. Where no consumer data was available, sales data was used followed by estimates based on regression against sub-sector GDP.

Method used in order of preference based on available data:

- actual consumer data
- sales data
- regression against sector GDP.

1.AA.2.A Iron and steel

Activity data for coal used in iron and steel production is reported to the Ministry of Business, Innovation and Employment by New Zealand Steel. A considerable amount of coal is used in the production of iron. The majority of the coal is used in the direct reduction process to remove oxygen from ironsand. However, all emissions from the use of coal are included in the industrial processes sector because the primary purpose of the coal is to produce iron (IPCC, 2000). A small amount of gas is used in the production of iron and steel to provide energy for the process and is reported in the energy sector.

1.AA.2.C Chemicals

The chemicals subcategory includes estimates from the following sub-industries:

- industrial gases and synthetic resin
- organic industrial chemicals
- inorganic industrial chemicals, other chemical production, rubber and plastic products.

Emissions from methanol production would normally be reported in the industrial processes sector, as the emissions are from the chemical transformation of materials and not from the combustion of fuel (IPCC, 1996). However, due to confidentiality concerns raised by the owners of the plant, all emissions from methanol production in New Zealand are reported under Manufacturing industries and construction – Chemicals.

The activity data for methanol production is supplied directly by Methanex New Zealand. Until 2004, methanol was produced at two plants by Methanex New Zealand. In November 2004, production at the Motunui plant was halted and the plant reopened in late 2008. Methanex New Zealand exports the majority of this methanol.

However, Methanex is the sole methanol producer in New Zealand and considers its gas consumption to be commercially sensitive information. Also, New Zealand uses a Tier 2 (IPCC, 2000) approach to estimating emissions from methanol production that uses gas consumption at the plant and country- and field-specific emission factors to calculate potential emissions before deducting the carbon sequestered in the end product.

While methanol production data is publicly available in the Methanex's annual reports, gas consumption is not. However, the consumption could be easily calculated if emissions from methanol production were reported directly. As recommended by the 2012 expert review team, this issue is being considered by both the Ministry for the

Environment and Ministry of Business, Innovation and Employment to find a solution that is more satisfactory.

The major non-fuel related emissions from the methanol process are CH_4 and non-methane volatile organic compounds.

On-site electricity generation

As mentioned in section 3.3.1, on-site electricity generation is allocated to either public electricity and heat production or the sector in which the associated plant operates using the decision in figure 3.3.9.

Uncertainties and time-series consistency

Uncertainties in emission and activity data estimates are those relevant to the entire energy sector (annex 2, sections A.2.1, A2.2 and A2.3).

Source-specific QA/QC and verification

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and time-series consistency checks.

Source-specific recalculations

As mentioned under methodological issues, following Expert Review Team recommendations (2007 in-country review), New Zealand has continued to disaggregate liquid fuel consumption in the manufacturing industries and construction sector. For this submission, the method previously used to split diesel and gasoline combustion has been extended to fuel oil following new data becoming available from Statistics New Zealand.

The result has been a significant reduction in fuel combustion allocated to sub-sector 1.AA.2.F manufacturing industries and construction – other non-specified, and increases in several other sub-sectors of the same category, in particular 1.AA.2.E – Food processing, beverages and tobacco. For details on the share of unallocated industrial fuels given to each sub-sector, see figures 3.3.10, 3.3.11 and 3.3.12.

Fuel used in the electricity auto-production has been allocated to the appropriate sub-sector. Previously, these emissions were reported under sub-sector 1.AA.2.F manufacturing industries and construction – other non-specified. Reallocation occurred at the plant level using fuel consumption and electricity generation data supplied by operators for the purposes of national electricity statistics.

These recalculations have led to further reductions in emissions allocated to this sub-sector and increases in sub-sectors 1.AA.2.D – Pulp, paper and print, 1.AA.2.E – Food processing, beverages and tobacco and 1.AA.4.A Other sectors – Commercial/Institutional.

Source-specific planned improvements

New Zealand intends to continue working with Methanex, the country's sole methanol producer, to address confidentiality concerns. This may allow emissions associated with methanol production to be reported in the industrial processes sector, consistent IPCC guidelines and Expert Review Team recommendations.

3.3.3 Fuel combustion: Transport (CRF 1A3)

Description

This category includes emissions from fuels combusted during domestic transportation, such as civil aviation, road, rail and domestic marine transport. Emissions from international marine and aviation bunkers are reported as memo items and are not included in New Zealand's total emissions.

In 2011, category 1.AA.3 transport was responsible for 14,014.6 Gg CO_2-e (45.2 per cent of emissions from the energy sector), or 19.2 per cent of total emissions. Emissions increased 5,388.9 Gg CO_2-e (62.5 per cent) from the 8,625.7 Gg CO_2-e emitted in 1990. The transport emissions profile in 2011 was dominated by emissions from subcategory 1.AA.3.B road transportation. In 2011, road transport accounted for 12,569.9 Gg CO_2-e (89.7 per cent) of total transport emissions. This was an increase of 5,162.8 Gg CO_2-e (69.7 per cent) from the 1990 level of 7,407.1 Gg CO_2-e.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, emissions from transport increased by 184.8 Gg CO_2-e (1.3 per cent).

Key categories identified in the 2011 level assessment from the transport category include CO_2 emissions from:

- road transport – gasoline
- road transport – diesel oil
- civil aviation – jet kerosene.

Key categories identified in the 2011 trend assessment from the transport category include CO_2 emissions from:

- road transport – gasoline
- road transport – diesel oil
- road transport – gaseous fuels.

Methodological issues

1.AA.3.A Civil aviation

A Tier 1 approach (IPCC, 1996) that does not use landing and take-off cycles has been used to estimate emissions from the civil aviation subcategory. Given the uncertainty surrounding CH_4 and N_2O emission factors for landing and take-off cycles, a Tier 2 approach to estimating non-CO_2 emissions would not necessarily reduce uncertainty (IPCC, 2000).

1.AA.3.B Road transportation

The IPCC (2000) Tier 1 approach was used to calculate CO_2 emissions from road transportation using New Zealand-specific emission factors calculated using data provided by New Zealand's sole oil refinery for oil products and the weighted average emissions factor of New Zealand gas fields for compressed natural gas (CNG).

Since the 2012 submission, New Zealand has a Tier 2 (IPCC, 2000) methodology to estimate CH_4 and N_2O emissions from road transport. Data collected by New Zealand's Ministry of Transport provides comprehensive information on vehicle-kilometres-travelled by vehicle class and fuel type from 2001–2010. Prior to 2001, insufficient data was available; therefore, IPCC good practice guidance (2000) was used to guide the choice of splicing method to ensure time-series consistency and accuracy.

The current New Zealand vehicle fleet is split almost exactly evenly between:

- vehicles manufactured in New Zealand[18] or imported for sale as new vehicles
- vehicles produced and used in Japan and then imported into New Zealand.

This split has been relatively constant for the past six years.

For this reason, when estimating emissions from road transport, the New Zealand vehicle fleet (and associated CH_4 and N_2O emissions) is split into the 'New Vehicle Fleet' and 'Used Vehicle Fleet' (based upon the vehicles' year of manufacture rather than when they are first added to the New Zealand fleet).

New vehicles were allocated an appropriate vehicle class from the COPERT 4 model (European Environment Agency, 2007) and used Japanese vehicles were allocated emission factors as per categories from the Japanese Ministry of Environment. These emission factors are broken down by:

- vehicle type
- fuel type
- vehicle weight class
- year of manufacture.

Due to the presence of expensive catalysts, many used vehicles imported into New Zealand had their catalytic converters removed before being exported from Japan. The Ministry of Transport undertook several testing studies to determine the proportion of catalytic converters that are removed in Japan prior to export.

Information on non-CO_2 emission factors can be found in annex 2, table A2.7.

Vehicle-kilometres-travelled were sourced from national six-monthly warrant of fitness inspections. These were further split into travel type (urban, rural, highway, motorway) using New Zealand's Road Assessment and Maintenance Management system.

To further split the 'urban' travel type into cold and hot starts, a New Zealand household travel survey called the *New Zealand Travel Survey* (Ministry of Transport, 2010) is used. The *New Zealand Travel Survey* provides detailed trip-by-trip information on travel type. This is used to establish the percentage of light vehicle urban travel that was cold and hot starts.

The Ministry of Economic Development and Ministry for the Environment met with the Australian inventory reporting team in July 2011 in order to conduct a review of proposed

[18] New Zealand only manufactures a small number of buses and heavy trucks now.

methodologies for calculating emissions of CH_4 and N_2O emissions associated with road transport. New Zealand's Tier 2 approach for road transport was presented, resulting in a recommendation from the Australian team that the new methodology be adopted for the 2012 submission and that New Zealand attempt to use the IPCC good practice guidance (IPCC, 2000) to choose an appropriate splicing method.

Figures 3.3.13 and 3.3.14 show a comparison of the previously used Tier 1 method with the method for estimation of non-CO_2 emissions from gasoline combustion with the Tier 2 method used in this submissions.

Figure 3.3.13 Methane emissions from road transport from 2001 to 2011 – Gasoline

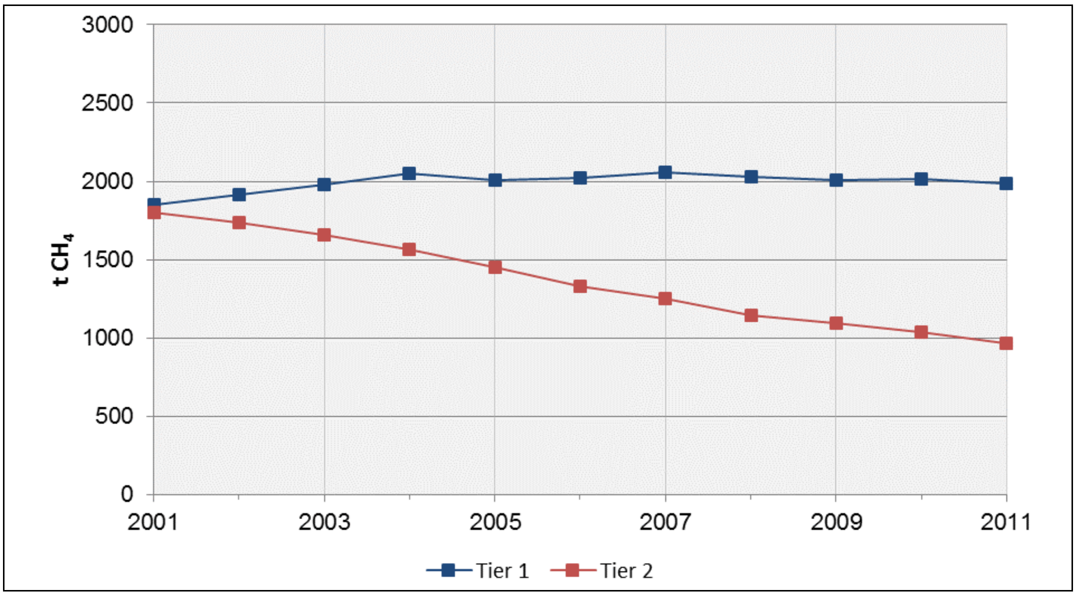
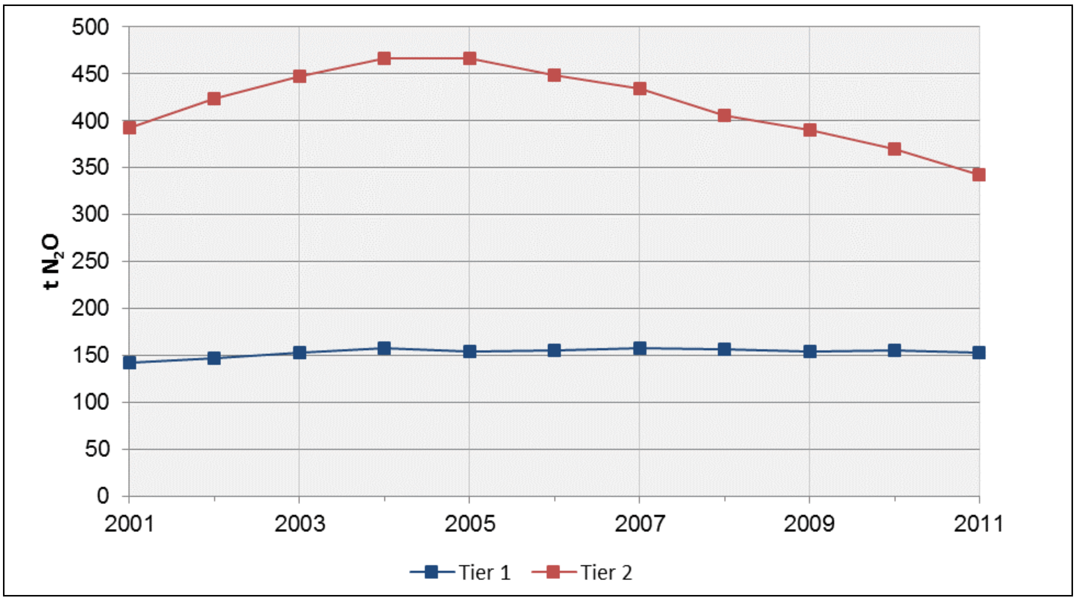


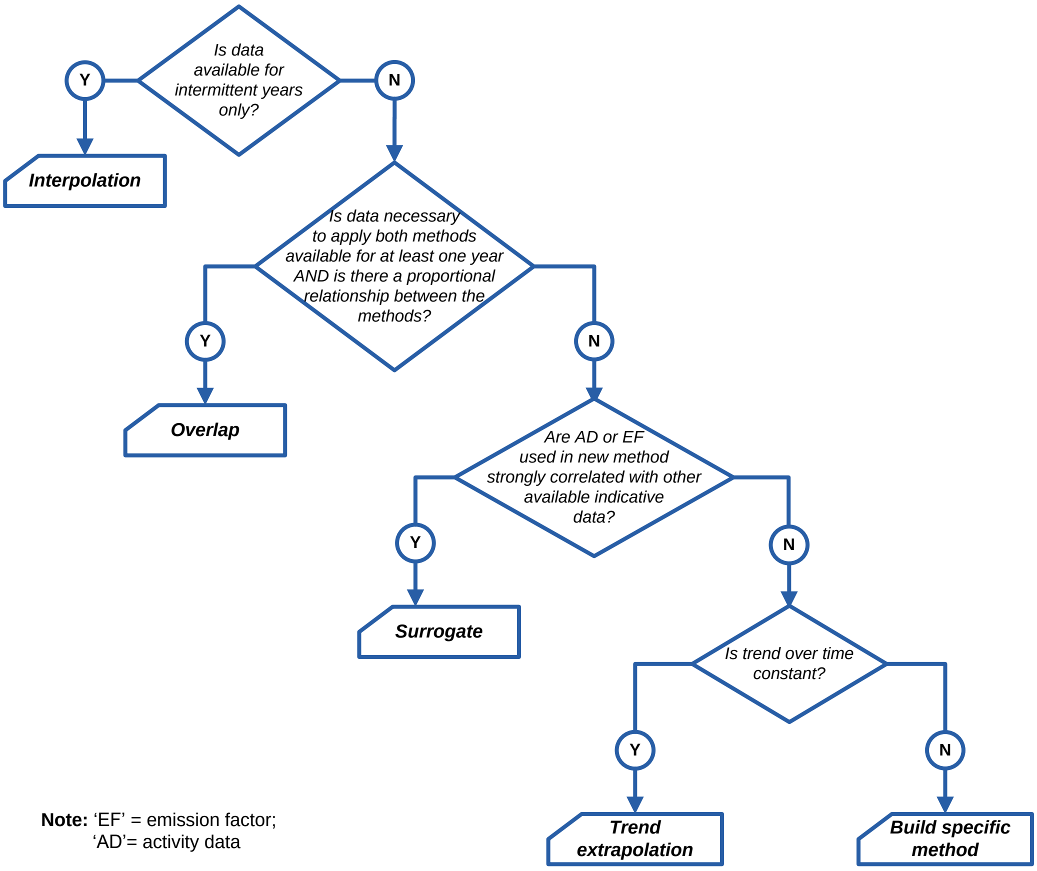
Figure 3.3.14 Nitrous oxide emissions from road transport from 2001 to 2011 – Gasoline



Time-series consistency

The data available for applying the Tier 2 methodology between 1990 and 2000 were insufficient, therefore, combining the methods to form a complete time series (splicing) was necessary. To establish the most appropriate splicing method the following process for analysis the relationship between the Tier 1 and Tier 2 methods was used (see figure 3.3.15). The process was developed on a basis of the IPCC Good Practice Guidance (IPCC, 2000).

Figure 3.3.15 Splicing method decision tree for gasoline emissions



For all fuels, interpolation was considered inappropriate due to the size of the block of unavailable data and the lack of data earlier than the missing block (1990–2000).

For emission estimates from diesel and liquefied petroleum gas (LPG), the relationship between Tier 1 and Tier 2 appears nearly constant for both N_2O and CH_4 from 2001 until 2004. As a result, the overlap method was used (IPCC, 2000), with:

$$y_t = x_t \left(\sum_{i=m}^{n} y_i \Big/ \sum_{i=m}^{n} x_i \right)$$

Where:

- y_t is the recalculated emission estimate computed using the overlap method
- x_t is the estimate developed using the previous method
- y_i and x_i are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years m through n.

However, for gasoline vehicles, the ratio Tier 2/Tier 1 appears to change approximately linearly with time. While surrogates for Ministry of Transport data were available (fuel consumption), their use resulted in a step-change that is likely not representative of road transport emissions for the period. While the trend in emissions was not consistent over time, the trend of the Tier 2/Tier 1 ratio emission estimates showed a strong linear relationship with time. As a result, a hybrid method of overlap and trend extrapolation was chosen with:

$$y_t = (at + b)x_t$$

Where:

- *t* is the year for which a new estimate is required
- *a* is the slope of the line achieved by regressing Tier 2/Tier 1 for the overlap period
- *b* is the intercept of the line achieved by regressing Tier 2/Tier 1 for the overlap period
- x_t is the estimate for year *t* using the previous methodology.

In the case of CH_4, the relationship is decreasing over the entire overlap period (2001–2010), as would be expected with the increasing uptake of emissions control technology. This relationship was extrapolated back to the beginning of the time series to derive a factor by which to multiply the Tier 1 estimate for a given year.

The Tier 2–Tier 1 relationship in N_2O emissions appears to increase in time until 2005 when it begins to decrease. This is consistent with international experience because N_2O emissions increased with the uptake of early emission control technologies followed by a peak and subsequent decline as newer technologies entered the fleet. As the earlier part of the overlap is likely to be a better estimate of the relationship prior, this trend was extrapolated back to 1990 to derive a factor by which to multiply the Tier 1 estimate for a given year.

A quality check was necessary to confirm that extrapolation of this trend over such a long period did not result in a New Zealand-implied emission factor diverging significantly from international observation. An international average implied emission factor was calculated using the IPCC Emissions Factor database (IPCC, 2012). For the purposes of this calculation, all countries using default emission factors – including New Zealand – were removed from the calculation.

Figures 3.3.16 and 3.3.17 indicate that the implied emission factor resulting from the new methodology and splicing is consistent with those observed internationally across the time series. The agreement is poorer for N_2O emissions due to the more complicated effect of changing technology and the lack of data at key stages in technology update.

International estimates show a peak in implied emission factors for N_2O between the mid-1990s and the early 2000s. This peak is consistent with the tendency of first generation emissions control technology to reduce particulate and CH_4 emissions but increase N_2O emissions. In later years, as more advanced emissions control technologies enter the fleet, N_2O emission factors decline.

First generation emission control technology could be damaged by leaded petrol. Lead was removed from all gasoline in New Zealand in 1996, therefore, it is likely that N_2O emission factors were flat for the early 1990s and began to increase sometime shortly after this. However, as data for this period is not available, the trend from 2001 to 2004 was extrapolated back to 1990. This is a conservative approach that is likely to over-estimate rather than underestimate N_2O emissions.

Figure 3.3.16 Nitrous oxide implied emission factors from 1990 to 2010 – Gasoline road transport

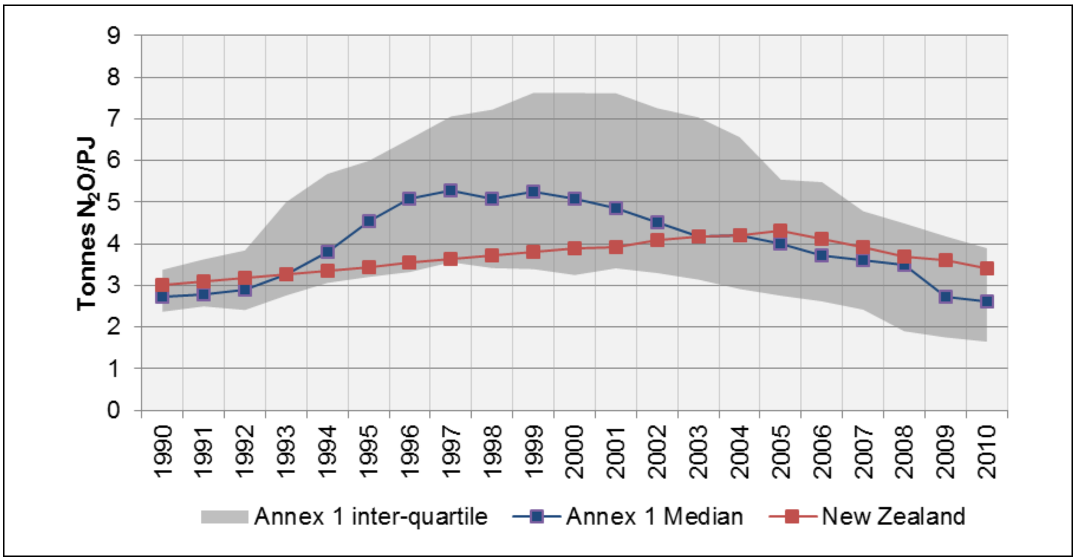
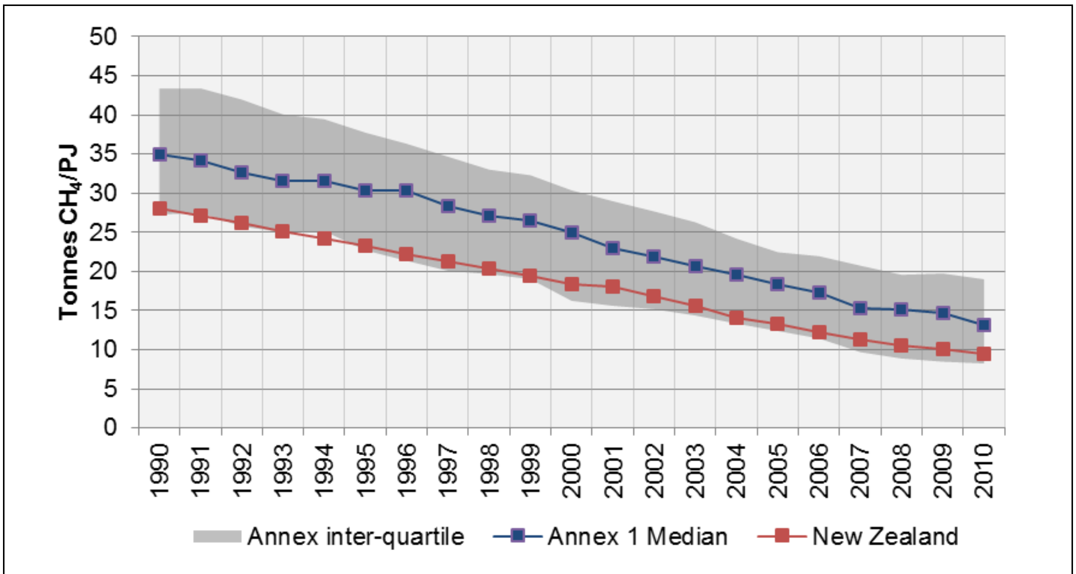


Figure 3.3.17 Methane implied emission factors from 1990 to 2010 – Gasoline road transport



Dual-fuel vehicles

Vehicle-kilometres-travelled data collected by the Ministry of Transport allocates vehicles using dual fuels (LPG-gasoline and compressed natural gas-gasoline) to the gasoline category. Historically, non-CO_2 emission factors have been lower for LPG than those for petrol. Analysis undertaken to remove activity data from petrol to be allocated to LPG resulted in a slight decrease in overall emissions. As a result, the reallocation was not made due to a desire to be conservative when applying methods that would lead to net emission reductions.

The amount of natural gas used in vehicles on New Zealand roads was significantly larger in 1990 than it was in 2010, when almost all natural gas in road transport was used in buses. For the purposes of time-series consistency, the new methodology was considered incomparable with the previous methodology due to fundamental differences in the type of activity that the two methods represent. The CH_4 emission factors (t CH_4/PJ) from a purpose-built natural gas (CNG) bus are known to be significantly lower than those from a light passenger vehicle built to run on petrol then converted to use natural gas.

To ensure that emissions were not underestimated, an estimate of the energy used in CNG buses was made. The remaining natural gas was then assumed to be combusted in converted light passenger vehicles, and an IPCC default emission factor was used to estimate the associated emissions.

Blended biofuels

Small volumes of bio-gasoline and biodiesel are sold blended with mineral oil products and combusted in the New Zealand road transport sector. To ensure that liquid biofuel combustion is considered in the inventory, the energy split was calculated (ie, gasoline as share of combined gasoline and bio-gasoline or mineral diesel as share of mineral diesel and biodiesel). The new estimate was then multiplied by this factor to account for gasoline and diesel not combusted. The emissions from the combustion of biofuels were then estimated using a Tier 1 methodology, as in previous inventories.

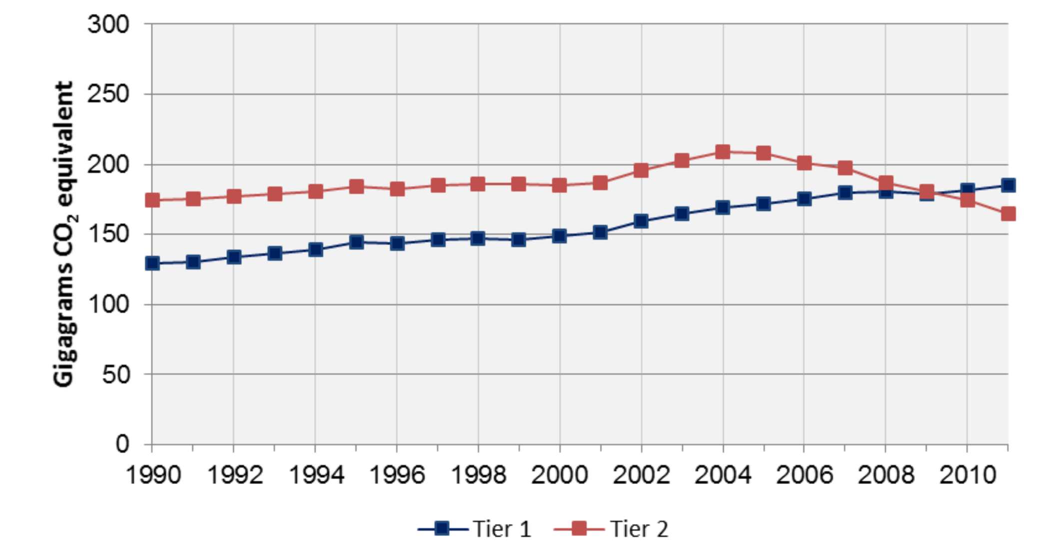
Overall effect of moving to Tier 2 methodology

The Tier 2 methodology indicated that New Zealand had been underestimating emissions of N_2O and overestimating emissions of CH_4 from 1990 to 2009. The combined result was an underestimation of CO_2-equivalent emissions from road transport for the period.

The result is consistent with the known effect of older catalytic converters to decrease CH_4 emissions while increasing emissions of N_2O relative to those observed from vehicles without emission controls.

As more advanced emissions control technologies entered the fleet, the difference between N_2O estimates from the Tier 2 methodology and Tier 1 methodology reduced while the differences between the CH_4 emissions continued to increase. From 2010, the combined CO_2-equivalent emissions from N_2O and CH_4 in road transport is lower under the Tier 2 methodology than under the previous Tier 1 methodology, reflecting continued improvements in emission control technology entering the fleet.

Figure 3.3.18 Total methane and nitrous oxide road transport emissions from 1990 to 2011



1.AA.3.C Railways

Emissions from the railways subcategory (including both liquid and solid fuels) were estimated using a Tier 1 approach (IPCC, 2000).

1.AA.3.D Navigation (domestic marine transport)

Emissions from the navigation subcategory in New Zealand were estimated using a Tier 1 approach (IPCC, 1996).

Activity data

1.AA.3.A Civil aviation

The Ministry of Business, Innovation and Employment (former Ministry of Economic Development) currently collects aviation fuels used for international and domestic aviation through the *Delivery of Petroleum Fuels by Industry Survey*. The respondents of this survey are New Zealand's five main oil companies, namely BP, Z Energy (formerly Shell), ExxonMobil, Chevron and Gull (Gull participates only in petrol and diesel sales).

The distinction between domestic and international flights is based on refuelling at the domestic and international terminals of New Zealand airports. The allocation of aviation fuels between domestic and international segments has previously been raised by the international greenhouse inventory reviewers. The latest centralised review stated:

> *The National Inventory Report (NIR) reports that the allocation of fuel consumption between domestic and international air transport is based on refuelling at the domestic and international terminals of New Zealand's airports. Currently splitting the domestic and international components of fuels used for international flights with a domestic segment was not considered; however, the number of international flights with a domestic segment is considered to be negligible. The Expert Review Team (ERT) notes that in 2006, New Zealand began consultations with the airlines to clarify the situation and improve the relevant Activity Data (AD), and is currently working on a methodology that will allow for better international and domestic fuel use allocation. New Zealand is encouraged to adopt the new approach and report the outcome in its 2010 submissions.*

After consultations with different parties, the Ministry of Business, Innovation and Employment believes that our current data collection methodology is sufficient and robust enough to ensure all the domestic aviation fuels are reported accordingly and do not result in missing or misallocation of domestic fuel use. Further information on the methodology used is given below.

In the *Delivery of Petroleum Fuels by Industry Survey*, the oil companies report quantities of different fuels (jet A1, aviation gasoline and kerosene amongst others) used for the purposes of international and domestic transport. The companies allocate the fuel to international or domestic transport based on whether or not they charge Goods and Services Tax (GST) on the fuel sold – GST is not charged when the destination of a flight is outside of New Zealand.

Some international flights from New Zealand contain a domestic leg, for example, Christchurch–Auckland–Tokyo. Industry practice is to refuel at both points with sufficient fuel to reach the next destination so that the domestic leg will be coded appropriately. By this logic, fuel used for the domestic leg will attract GST and therefore be coded as domestic, and the international leg, which does not attract GST, will be coded as international.

Although this is a supply-side approach, the Ministry of Business, Innovation and Employment believes the split of international and domestic transport to be accurate because BP, Z, ExxonMobil and Chevron control 100 per cent of the aviation fuels market in New Zealand.

1.AA.3.B Road transport

Activity data for the road transport sector is provided by the Ministry of Transport's six monthly fleet data and the Ministry of Business, Innovation and Employment's national energy statistics. For more information on the use of vehicle fleet data for estimating non-CO_2 emissions, see methodological issues above.

Activity data on the consumption of fuel by the transport sector was sourced from the *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development. Liquefied petroleum gas and compressed natural gas consumption figures are reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2012).

As mentioned in section 3.3, this inventory continues to use the results of the *Annual Liquid Fuel Survey* that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. These independent resellers account for approximately 18 per cent of national diesel sales and 3 per cent of national gasoline sales.

As a result of resale data captured by the *Annual Liquid Fuel Survey*, emissions that would otherwise be reported in subcategory 1.AA.3.B road transportation are allocated to the correct (sub-) category. See figure 3.3.3 and 3.3.4 for details.

For time-series consistency, these reallocations are also made from 1990–2008, prior to the collection of data on the resale of liquid fuel by small, independent distributors.

The diesel activity data for road transport subcategory is assumed to be the diesel reported for domestic transport, less that reported by KiwiRail in 1.AA.3.C railways and 1.AA.3.D navigation, discussed below.

1.AA.3.C Railways

Activity data for fuel used in this subcategory is obtained directly from KiwiRail, operators of national rail services. This also includes diesel sold to the metropolitan service operated by Veolia in Auckland.

1.AA.3.D Navigation (domestic marine transport)

Fuel oil activity data on fuel use by domestic transport is sourced from the quarterly *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development. Monthly oil statistics (MOS) provide monthly marine diesel supply figures that are added to automotive diesel consumption data provided by KiwiRail, operators of diesel ferries, to obtain total diesel consumption in the navigation sector. New Zealand-specific emission factors have been used to estimate CO_2 emissions and, because of insufficient data, the IPCC 1996 default emission factors have been used to estimate CH_4 and N_2O emissions.

Fuel sales to domestic navigation and international marine bunkers are reported separately in national energy data surveys. The companies allocate the fuel to international or domestic transport based on whether or not they charge Goods and Services Tax (GST) on the fuel sold – GST is not charged when the destination of a voyage is outside of New Zealand.

Uncertainties and time-series consistency

Uncertainties in emission estimates from the transport category are relevant to the entire fuel combustion sector (table 3.3.2).

Source-specific QA/QC and verification

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and time-series consistency checks.

Comparison of international implied emission factors across the time series (1990–2009), and those resulting from the new Tier 2 methodology for CH_4 and N_2O emissions from road transport, were made using the IPCC Locator Tool (version 3.4).

Source-specific recalculations

The small amount of solid fuel use reported as sales to the transport sector was moved from rail transport to water-borne navigation, following the discovery that the fuel is used entirely by a single steamer operating in the South Island.

A review of LPG consumption data in 2012 revealed that some of the LPG combustion previously allocated to 1.AA.3.B road transport was actually sold to 1.AA.4.A other sectors – residential. Revisions were made across the time series from 1990 to 2010 to reflect this new information.

Source-specific planned improvements

There are no planned improvements currently in this sector.

3.3.4 Fuel combustion: Other sectors (CRF 1A4)

Description

The category 1.AA.4 other sectors comprises emissions from fuels combusted in the commercial and institutional, residential, and agriculture, forestry and fisheries subcategories.

In 2011, fuel combustion of the other sectors category accounted for 3,085.5 Gg CO_2-e (10.0 per cent of the emissions from the energy sector). This is an increase of 190.2 Gg CO_2-e (6.6 per cent) from the 1990 value of 2,895.3 Gg CO_2-e.

Emissions from subcategory 1.AA.4.A commercial/institutional were 839.7 Gg CO_2-e (27.2 per cent) of the other sectors category in 2011. This is a decrease of 60.6 Gg CO_2-e (6.7 per cent) from the 1990 level of 900.3 Gg CO_2-e.

Emissions from subcategory 1.AA.4.B residential were 620.3 Gg CO_2-e (20.1 per cent) of the other sectors category in 2011. This is a decrease of 151.2 Gg CO_2-e (19.6 per cent) from the 1990 level of 771.4 Gg CO_2-e.

Emissions from subcategory 1.AA.4.C agriculture, forestry and fisheries subcategory were 1,625.5 Gg CO_2-e (52.7 per cent) of the other sectors category in 2011. This is an increase of 402.0 Gg CO_2-e (32.9 per cent) from the 1990 level of 1,223.6 Gg CO_2-e.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, emissions from 1.AA.4 other sectors increased by 156.2 Gg CO_2-e (5.3 per cent).

Key categories identified in the 2011 level assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- gaseous fuels
- solid fuels.

Key categories identified in the 2011 trend assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- solid fuels.

Methodological issues

There are no notable methodological issues in this category.

Activity data

Liquid fuels

As mentioned in section 3.3, this inventory continues to use the results of the *Annual Liquid Fuel Survey* that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. These independent resellers account for approximately 18 per cent of national diesel sales and 3 per cent of national gasoline sales.

As a result of resale data captured by the *Annual Liquid Fuel Survey*, emissions that would otherwise be reported in subcategory 1.AA.3.B road transportation are allocated to the correct (sub) category. See figure 3.3.2 and 3.3.4 for details.

For time-series consistency, these reallocations are also made from 1990–2008, prior to the collection of data on the resale of liquid fuel by small, independent distributors.

As mentioned in the section 3.3.2, historical national energy sales surveys captured fuel use by mining operations under ‘other primary industry’. For consistency with IPCC (1996) guidelines, the 2012 inventory submission uses the Statistics New Zealand *Energy Use Survey: Primary Energy 2008* (Statistics New Zealand, 2008) to estimate the split of historical other primary industry between forestry and logging and mining.

Table 3.3.5 Split of ‘other primary industry’

	Petrol (%)	Diesel (%)	Fuel oil (%)
Forestry and logging	85.9	27.2	51.4
Mining	14.1	72.8	48.6

Solid fuels

On-selling of coal reported as sold to the commercial sector was found in 2010. As a result, some activity previously reported in the commercial sector has been reallocated to the agriculture sector. This behaviour is assumed to continue across the time series of 1990–2011.

Solid biomass

New Zealand estimates residential combustion of biomass using household number estimates from Statistics New Zealand along with five-yearly census figures estimating the percentage of households using biomass for heating. Interpolation is used to estimate shares for intermediate years.

The energy content of biomass burnt in each household that uses biomass for heat was estimated by the study *Energy Use in New Zealand Households* (Building Research Association of New Zealand, 2002).

Gaseous fuels

A considerable amount of cleansing of energy data was undertaken in 2011. As result, several inconsistencies in sector reporting were found along with a considerable amount of missing data for natural gas consumption.

Where necessary, new estimates were made using consumer data. Where no consumer data was available, sales data was used followed by estimates based on regression against sub-sector GDP.

The method used in order of preference, based on available data was:

- actual consumer data
- sales data
- regression against sub-sector GDP.

Uncertainties and time-series consistency

Uncertainties in emission estimates for data from other sectors are relevant to the entire energy sector (table 3.3.2).

Source-specific QA/QC and verification

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and consistency checks of implied emission factors.

Source-specific recalculations

As mentioned in the methodological issues section, recalculations have occurred across the time series due to the inclusion of mining in the manufacturing industries and constructions sector and data-cleansing of gas activity data across the time series for all sectors.

Some sales of coal previously reported as commercial were found to be resold to the manufacturing industries and construction, agriculture, forestry and fisheries and residential sectors. For time-series consistency, this split was applied to historical activity data resulting in reallocations from commercial to manufacturing industries and construction.

A review of LPG consumption data in 2012 revealed that some of the LPG combustion previously allocated to 1.AA.3.B road transport was actually sold to 1.AA.4.A other sectors – residential. Revisions were made across the time series from 1990 to 2010 to reflect this new information.

Source-specific planned improvements

There are no current planned improvements for this specific category.

3.4 Fugitive emissions from fuels (CRF 1B)

Fugitive emissions arise from the production, processing, transmission, storage and use of fossil fuels, and from non-productive combustion. This category comprises two subcategories: solid fuels and oil and natural gas.

In 2011, fugitive emissions from fuels accounted for 2,333.1 Gg CO_2-e (7.5 per cent) of emissions from the energy sector. This is an increase of 1,056.1 Gg CO_2-e (82.8 per cent) from the 1990 level of 1,276.6 Gg CO_2-e.

Changes in emissions between 2010 and 2011

Between 2010 and 2011, fugitive emissions from fuels emissions decreased by 222.2 Gg CO_2-e (8.7 per cent). This was primarily the result of decreased activity in subcategory 1.AA.1.A coal mining and handling due to:

- Pike River Mine being sealed in January 2011 due to explosions in November 2010
- nearby Spring Creek Mine suspending its coal production in November 2010 to May 2011 to accelerate work on a safety improvement programme (Solid Energy New Zealand Ltd, 2011).

Key categories identified in the 2011 level assessment from fugitive emissions include CO_2 emissions from:

- flaring combined
- geothermal electricity generation.

Key categories identified in the 2011 trend assessment from fugitive emissions include CO_2 emissions from:

- flaring combined
- geothermal electricity generation.

No key categories were identified in the 2011 level assessment from fugitive emissions that include CH_4 emissions.

Key categories identified in the 2011 trend assessment from fugitive emissions include CH_4 emissions from:

- natural gas.

3.4.1 Fugitive emissions from fuels: Solid fuels (CRF 1B1)

Description

In 2011, fugitive emissions from the solid fuels subcategory produced 390.7 Gg CO_2-e (16.7 per cent) of emissions from the fugitive emissions category. This is an increase of 116.2 Gg CO_2-e (42.3 per cent) from the 274.5 Gg CO_2-e reported in 1990.

Between 2010 and 2011, fugitive emissions from solid fuels decreased by 161.6 Gg CO_2-e (29.3 per cent) as a result of decreased production from underground mines. Pike River Mine was sealed in January 2011, following an explosion in November 2010. Also, production at Spring Creek Mine was suspended from November 2010 until May 2011 as safety upgrades were implemented (Solid Energy New Zealand Ltd, 2011). As a result, 2011 production from underground mines in New Zealand was 32.1 per cent lower than in 2010, leading to a similar reduction in fugitive emissions in the subcategory.

New Zealand's fugitive emissions from the solid fuels subcategory are a by-product of coal-mining operations. Methane is created during coal formation. The amount of CH_4 released during coal mining is dependent on the coal grade and the depth of the coal seam. In 2011, 81.9 per cent of the CH_4 from coal mining came from underground mining. This includes the emissions from post-underground mining activities such as coal processing, transportation and use. In 2011, New Zealand coal production was 4.9 million tonnes, a 7.2 per cent decrease from the 2010 production level of 5.3 million tonnes.

At the end of 2011, there was no known flaring of CH_4 at coalmines in New Zealand, and CH_4 captured for industrial use is negligible. Pilot schemes of both coal seam gas and underground coal gasification began in 2012. Data on these schemes will be collected and reported in the 2014 submission.

Methodological issues

The underground mining subcategory dominates fugitive emissions from coal mining. The New Zealand-specific emission factor for underground mining of sub-bituminous coal is used to calculate CH_4 emissions (Beamish and Vance, 1992). Emission factors for the other subcategories, for example, surface mining, are sourced from the IPCC (1996) guidelines.

Activity data

Activity data for this subcategory is collected from the Ministry of Business, Innovation and Employment's coal production survey. This survey gathers quarterly data on coal production by mine-type (underground/surface) and rank (coking/bituminous/sub-bituminous/lignite).

Uncertainties and time-series consistency

Uncertainties in fugitive emissions are relevant to the entire energy sector (table 3.3.2).

Source-specific QA/QC and verification

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and consistency checks of implied emission factors.

Source-specific recalculations

Historical coal production data has been revised due to revisions in data provided by companies. This has resulted in minor revisions in activity data and corresponding emissions for some years.

Source-specific planned improvements

There are no current planned improvements for this specific category.

3.4.2 Fugitive emissions from fuels: Oil and natural gas (CRF 1B2)

Description

In 2011, fugitive emissions from the oil and natural gas subcategory contributed 1,942.4 Gg CO_2-e (83.3 per cent) to emissions from the fugitive emissions category. This is an increase of 940.3 Gg CO_2-e (93.8 per cent) from 1,002.1 Gg CO_2-e in 1990.

The main source of emissions from the production and processing of natural gas is the Kapuni Gas Treatment Plant. Emissions from the Kapuni Gas Treatment Plant are not technically due to flaring and are included under this category because of data confidentiality concerns. The plant removes CO_2 from a portion of the Kapuni gas (a high CO_2 gas when untreated) before it enters the national transmission network.

The large increase in CO_2 emissions from the Kapuni Gas Treatment Plant between 2003 and 2004 and between 2004 and 2005 is related to the drop in methanol production. Carbon dioxide previously sequestered during this separation process is now released as fugitive emissions from venting at the Kapuni Gas Treatment Plant.

Carbon dioxide is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95 to 99 per cent, leaving some fugitive emissions as a result of incomplete combustion.

Fugitive emissions also occur in transmission and distribution within the gas transmission pipeline system. However, these emissions are relatively minor in comparison with those from venting and flaring.

The oil and natural gas subcategory also includes estimates for emissions from geothermal operations. While some of the energy from geothermal fields is transformed into electricity, emissions from geothermal electricity generation are reported in the fugitive emissions category because they are not the result of fuel combustion, unlike the emissions reported under the energy industries category. Geothermal sites, where there is no use of geothermal steam for energy production, have been excluded from the inventory.

In 2011, emissions from geothermal operations were 737.0 Gg CO_2-e, an increase of 462.4 Gg CO_2-e (164.4 per cent) since the 1990 level of 274.6 Gg CO_2-e.

Between 2010 and 2011, emissions from geothermal have decreased by 2.5 per cent.

Methodological issues

1.B.2.A.3 Oil transport

Fugitive emissions from the oil transport subcategory are calculated using an IPCC Tier 1 approach (IPCC, 1996).

1.B.2.A.4 Oil refining and storage

Fugitive emissions from the oil refining and storage subcategory are calculated using an IPCC Tier 1 approach (IPCC, 1996).

Ozone precursors and sulphur dioxide from oil refining

New Zealand has only one oil refinery that has a hydrocracker rather than a catalytic cracker. There are, therefore, no emissions from fluid catalytic cracking but there are from sulphur recovery plants and storage and handling.

1.B.2.B.5 Natural gas other leakage

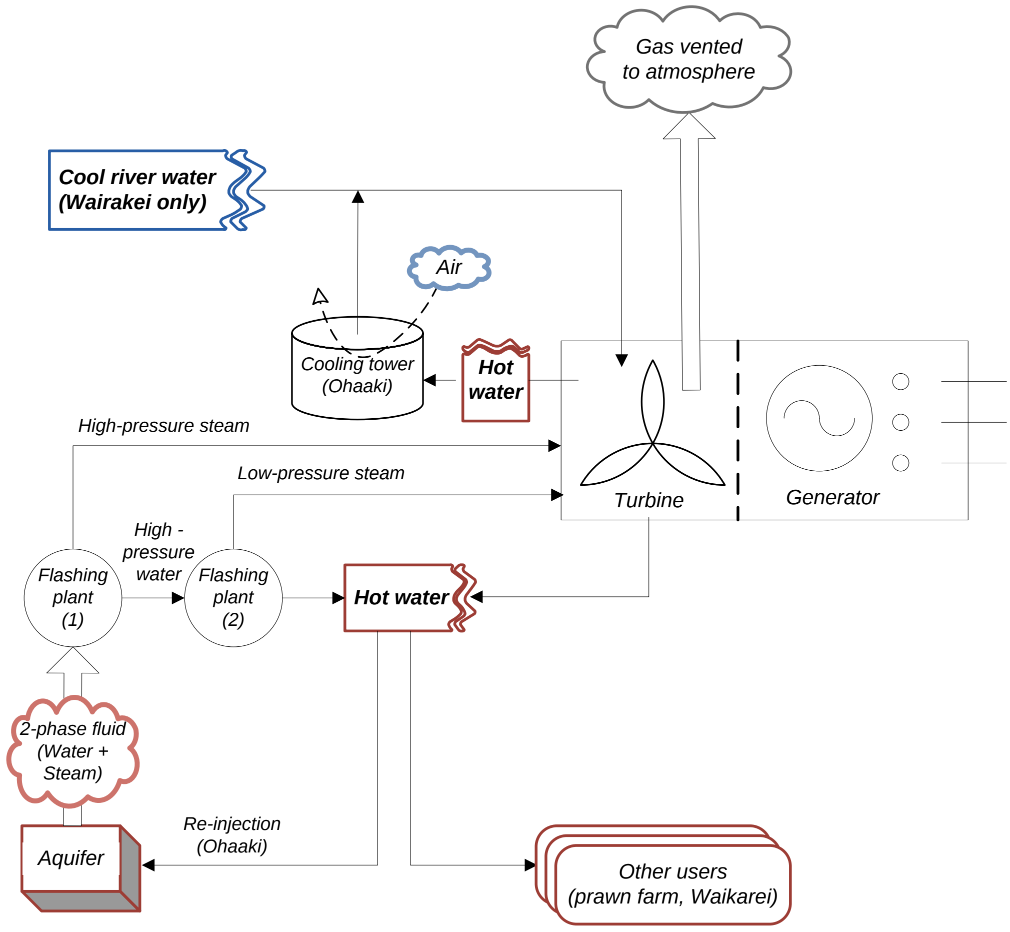
Emissions for other leakages of natural gas are estimated using a Tier 1 method. Methane emissions are estimated for leakages at both 'industrial plants and power stations' and 'residential and commercial sectors'.

1.B.2.D Geothermal

When geothermal fluid is discharged, some CO_2 and small amounts of CH_4 are also released. The largest proportion is CO_2 with smaller amounts of CH_4. The emissions released during electricity generation using geothermal fluid are reported in this inventory. Figure 3.4.1 below shows a schematic diagram of a typical New Zealand geothermal flash power station.

Estimates of CO_2 and CH_4 emissions for the geothermal subcategory are obtained directly from the geothermal power companies. There are currently 12 geothermal power stations – most of these are owned by two major power companies. Two examples of methodologies used to estimate emissions by these companies are explained below.

Figure 3.4.1 Schematic diagram of the use of geothermal fluid for electricity generation – as at Wairakei and Ohaaki geothermal stations (New Zealand Institute of Chemistry, 1998)



Emissions from geothermal have increased greatly in recent years. These increases are driven by an increase in geothermal emissions related to electricity generation, particularly with the new 100 megawatt Kawerau geothermal plant being online since late 2008 and Nga Awa Purua and Tauhara plant being online since 2010.

The Climate Change Response Act 2002 creates obligations for people carrying out certain activities in the schedules of the Act to report greenhouse gas emissions as part of the NZ ETS. The Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 and Climate Change (Liquid Fossil Fuel) Amendment Regulations 2009 set out the data collection requirements and methods for participants in those sectors to calculate their emissions, including prescribed default emissions factors (DEFs).

The Climate Change (Unique Emissions Factors) Regulations 2009 outline requirements for participants in certain sectors to calculate and apply for approval to use a unique emissions factor (UEF) in place of a DEF to calculate and report on emissions. Sectors that are eligible to apply for a UEF are a class of:

- liquid fossil fuel
- coal
- natural gas – CH_4 and N_2O
- geothermal fluid
- used oil, waste oil, used tyres or waste.

The 2010 year was the first calendar year in which operators could apply for UEFs. The Ministry of Economic Development received five applications relating to the use of UEF of geothermal fluid for the 2010 calendar year. These five approved UEFs were then adopted by the greenhouse gas inventory after careful assessment of the materiality impact and time-series consistency.

As 2010 was the introduction year, the Ministry of Economic Development made a judgement that the UEF would apply only to years for which sufficient data is available, that is, from 2010 onward. This submission continues with this approach. From 1990 to 2009, emissions are calculated using field-specific DEFs. Emissions for 2010 and 2011 are calculated using UEFs where available and field-specific default emission factors otherwise.

When several years of UEF data is available for comparison, the 1990–2009 emissions factors for each affected field will be reviewed.

Geothermal methodology for Company A

At Company A, quarterly gas sampling analysis is conducted to measure the amount of carbon dioxide and methane in the steam. Gas samples are collected at the inlet to the electricity generation station and at the extraction process when gas is dissolved in the condensate (waste water).

The concentration of carbon dioxide (eg, 0.612 per cent) and methane (eg, 0.0029 per cent) by weight of discharged steam is then calculated by carrying out a mass balance:

'Gas discharged to atmosphere' = 'Gas to electricity generation station' – 'Gas dissolved in condensate'

Company A also collects information on the average steam flow (tonnes of steam per hour) to the electricity generation station. This average steam flow is based on an annual average (eg, 582.3 tonnes of steam per hour).

Therefore, to work out carbon dioxide emissions discharged to atmosphere:

Average discharge per hour is calculated as:

$$582.3\ \frac{tonnes\ of\ steam}{hour}\ x\ \frac{0.612\ CO_2}{100}\ by\ weight\ of\ steam\ = 3.565\ \frac{tonnes\ of\ CO_2}{hour}$$

And the total discharge per year is:

$$3.565\ \frac{tonnes\ of\ CO_2}{hour}\ x8760\ \frac{hours}{year} = 31{,}230 \text{ tonnes of carbon dioxide.}$$

Using the same metholodogy above will yield 149 tonnes of methane. The overall emission for Company A is therefore 34,359 tonnes of carbon dioxide equivalent emissions.

Geothermal methodology for Company B

At Company B, spot measurements of both carbon dioxide and methane concentrations are taken at the inlet steam when the power stations are operating normally. The net megawatt-hours of electricity generated that day are then used to calculate the emission factor. This implied emission factor is then multiplied by the annual amount of electricity generated to work out the annual emissions for each power station.

Activity data

Venting and flaring from oil and gas production

Data on the amount of carbon dioxide released through flaring was supplied directly by the gas field. Vector Ltd, operator of the Kapuni Gas Treatment Plant, supplies estimates of CO_2 released during the processing of the natural gas.

New Zealand is currently working to improve the data on the split between natural gas flaring and venting. Current gas surveys request that gas field operators report venting and flaring separately, but data has been of poor quality and sporadic. Disaggregation will continue to be addressed in later inventories.

1.B.2.B.3 Gas transmission and 1.B.2.B.4 Gas distribution

Carbon dioxide and CH_4 emissions from gas leakage mainly occur from low-pressure distribution pipelines rather than from high-pressure transmission pipelines. Emissions from transmission and distribution are reported separately.

Emissions from the high-pressure transmission system were provided by Vector Ltd, the system and technical operator. In consultation with the Gas Association of New Zealand, the Ministry of Business, Innovation and Employment estimates that 3.5 per cent of the gas entering the low-pressure distribution system is unaccounted for, and half of this (1.75 per cent) is lost through leakage. The other half is unaccounted for because of metering errors and theft. Consequently, activity data from the low-pressure distribution system is based on 1.75 per cent of the gas entering the distribution system, and CO_2 and CH_4 emissions are based on gas composition data.

1.B.2.A.3 Oil transport

The activity data is New Zealand's total production of crude oil reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2012). The CO_2 emission factor is the IPCC (2000) default for oil transport using tanker trucks and rail cars, while the CH_4 emission factor is the mid-point of the IPCC (1996) default value range.

1.B.2.A.4 Oil refining and storage

Activity data is based on oil intake at New Zealand's single oil refinery. The CH_4 emission factor for oil refining is the same as that for oil transport. The emission factor for oil storage is 0.14 tonnes of CH_4/PJ, a New Zealand-specific emission factor. The combined emissions factor for oil refining and storage is 0.885 tonnes of CH_4/PJ.

1.B.2.B.5 Natural gas other leakage

Activity data for leakages at industrial plants and power stations is taken from the total natural gas used for industrial and electricity generation use. The emission factor used is the mid-point of the 1996 IPCC default for 'leakage at industrial plants and power stations'.

Activity data for leakages in residential and commercial sectors is taken from the total natural gas used for residential and commercial purposes. The emission factor used is the mid-point of the 1996 IPCC default for 'leakage in the residential and commercial sectors'.

Emission factors

1.B.2.A.3 Oil transport

The CO_2 emission factor is the IPCC (2000) default for oil transport using tanker trucks and rail cars, while the CH_4 emission factor is the mid-point of the IPCC (1996) default value range.

1.B.2.A.4 Oil refining and storage

The emission factor for oil storage is 0.14 tonnes of CH_4/PJ, a New Zealand-specific emission factor. The combined emissions factor for oil refining and storage is 0.885 tonnes of CH_4/PJ.

Ozone precursors and sulphur dioxide from oil refining

All the emission factors used to calculate these emissions are IPCC default values.

1.B.2.B.5 Natural gas other leakage

The emission factor used is the mid-point of the 1996 IPCC default for 'leakage at industrial plants and power stations'.

The emission factor used is the mid-point of the 1996 IPCC default for 'leakage in the residential and commercial sectors'.

Uncertainties and time-series consistency

The time series of data from the various geothermal fields varies in completeness. Some fields were not commissioned until after 1990 and hence do not have records back to 1990.

Source-specific QA/QC and verification

In the preparation of this inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular controls sums throughout systems to verify system integrity and consistency checks of implied emission factors.

Source-specific recalculations

A small error in the calculation of gas consumed at industrial plant and power stations was corrected in table 1.B.2.B.5.1.

Source-specific planned improvements

New Zealand will continue to look at methods to reliably separate natural gas venting and flaring across the time series. Also, as the dataset of verified unique emission factors for individual geothermal fields and coal mines obtained from the NZ ETS grow, New Zealand will consider methods of incorporating this data to improve the accuracy of estimates.

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Chapter 4: Industrial processes

4.1 Sector overview

In 2011, New Zealand's industrial processes sector produced 5,431.0 Gg of carbon dioxide equivalent (CO_2-e), contributing 7.5 per cent of New Zealand's total greenhouse gas emissions. The largest source of industrial process emissions is the metal production category (carbon dioxide (CO_2) and perfluorocarbons (PFCs)), contributing 42.2 per cent of sector emissions in 2011.

Emissions from industrial processes in 2011 had increased by 2,038.1 Gg CO_2-e (60.1 per cent) above the 1990 level of 3,392.8 Gg CO_2-e (figure 4.1.1). This increase has largely been driven by emissions from the consumption of halocarbons and sulphur hexafluoride (SF_6) category, with an increase in these emissions of 1,890.4 Gg CO_2-e (figure 4.1.2).

Figure 4.1.1 New Zealand's industrial processes sector emissions from 1990 to 2011

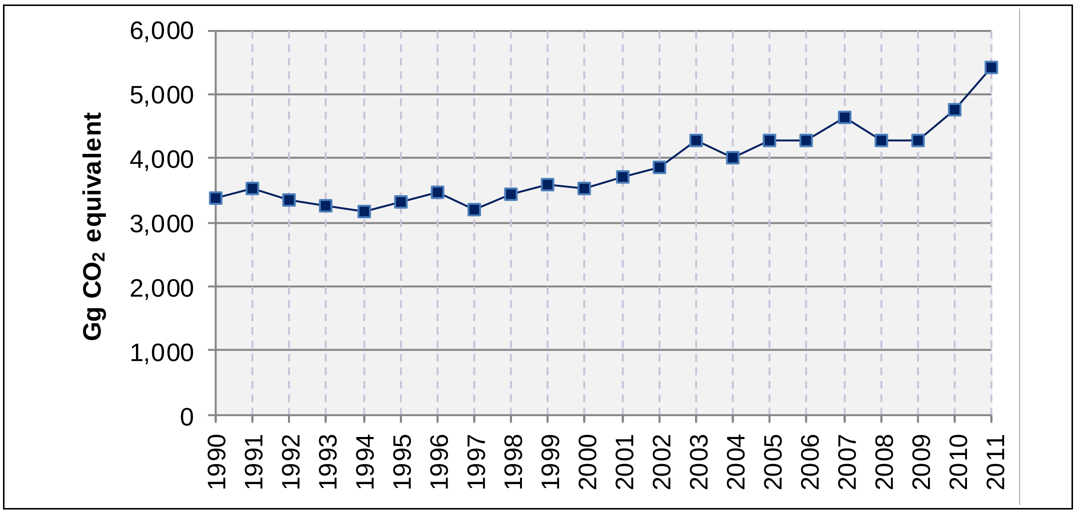
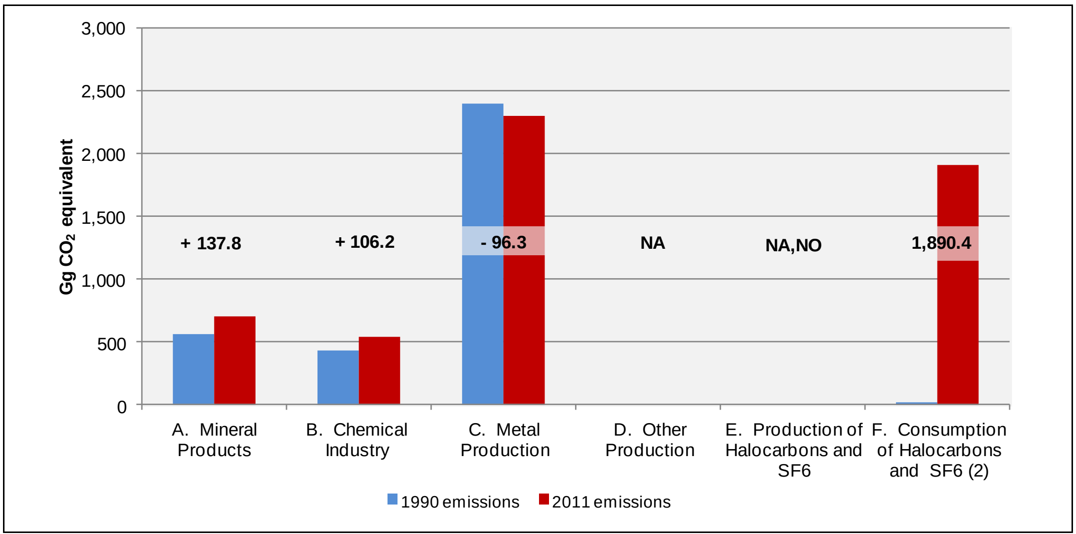


Figure 4.1.2 Change in New Zealand's industrial processes sector emissions from 1990 to 2011



Note: Other production and the production of halocarbons and sulphur hexafluoride (SF_6) is not occurring (NO) within New Zealand. The per cent change for the consumption of halocarbons and SF_6 is not applicable (NA) because, within New Zealand, there was no consumption of hydrofluorocarbons in 1990.

The emissions reported in the industrial processes sector are from the chemical transformation of materials from one substance to another and from the consumption of halocarbons and SF_6. Although fuel is also often combusted in the manufacturing process, emissions arising from combustion are reported in the energy sector. Carbon dioxide emissions related to energy production, for example, refining crude oil and the production of synthetic petrol from natural gas, are also reported within the energy sector.

New Zealand has a relatively small number of industrial plants emitting non-energy related greenhouse gases from industrial processes. However, there are six industrial processes in New Zealand that emit significant quantities of CO_2. These are the:

- production of steel
- oxidation of anodes in aluminium production
- calcination of limestone for use in cement production
- calcination of limestone for lime production
- production of ammonia for use in the production of urea
- production of hydrogen.

Changes in emissions since 2010

Since 2010, emissions from the industrial processes sector increased by 666.8 Gg CO_2-e (14.0 per cent). The main emission source that drove this increase was the consumption of hydrofluorocarbons (HFCs). Emissions from the consumption of HFCs increased by 807.4 Gg CO_2-e (74.9 per cent) since 2010. This large increase in HFC emissions is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

4.1.1 Methodological issues

Emissions of CO_2 from industrial processes are compiled by the Ministry of Business, Innovation and Employment (former Ministry of Economic Development) from information collected through industry surveys and through New Zealand Emissions Trading Scheme (NZ ETS) emissions returns submitted by a number of individual companies.

Most of the activity data for the non-CO_2 gases is collated by an external consultant. Emissions of HFCs, PFCs, and some SF_6 applications, are estimated using the Intergovernmental Panel on Climate Change (IPCC) Tier 1 and Tier 2 approaches (IPCC, 2006). Sulphur hexafluoride emissions from large users are assessed via the Tier 3a approach (IPCC, 2000).

Between 1990 and 2011, the only known methane (CH_4) emissions from the industrial processes sector came from methanol production. For confidentiality reasons, CH_4 emissions from methanol production are reported under the energy sector (section 3.3.2).

4.1.2 Uncertainties

The uncertainties for CO_2 and non-CO_2 emissions are discussed under each category. The uncertainty surrounding estimates of non-CO_2 emissions is greater than for CO_2 emissions and varies depending on the particular gas and category.

4.1.3 Verification

For this submission, the inventory agency verified CO_2 emissions reported in the 'iron and steel production' category for the 2011 year with information provided by participants under the NZ ETS. Results of the verification are discussed under the relevant sections below.

4.2 Mineral products (CRF 2A)

4.2.1 Description

In 2011, the mineral products category accounted for 699.7 Gg CO_2 (12.9 per cent) of total emissions from the industrial processes sector. Emissions in this category have increased by 137.8 Gg CO_2 (24.5 per cent) from the 1990 level of 561.9 Gg CO_2. There are no known emissions of CH_4 or nitrous oxide (N_2O) from the mineral products category. The emissions from the combustion of coal, used to provide heat for the calcination process, are reported in the energy sector.

In New Zealand, the emissions from mineral products include emissions from the production of cement, lime and glass and from the use of soda ash and limestone. In 2011, cement production accounted for 528.5 Gg CO_2 (75.5 per cent) of emissions from the mineral products category. In the same year, lime production accounted for 119.0 Gg CO_2 (17.0 per cent), limestone use 44.5 Gg CO_2 (6.4 per cent) and soda ash use 7.7 Gg CO_2 (1.1 per cent).

This category also includes the reporting of the indirect emissions from asphalt roofing and road paving with asphalt.

Key categories identified in the 2011 level assessment from the minerals category include only CO_2 emissions from cement production. There were no sources identified in the 1990–2011 trend assessment as key categories from the minerals category.

4.2.2 Methodological issues

Use of NZ ETS data

The Environmental Protection Authority administers annual NZ ETS emissions returns from participants. Major companies (eg, cement producers, lime producers and glass producers) have been obliged to submit annual emissions returns since 2010. Under section 149 of the Climate Change Response Act 2002, the inventory agency (Ministry for the Environment) can request information from the Environmental Protection Authority for the purpose of compiling emissions statistics for New Zealand's annual greenhouse gas inventory.

Therefore, the production data and/or emissions data provided by the cement producers, lime producers and glass producers through their NZ ETS returns have been used in this inventory to calculate emissions from their respective categories for the 2010 and 2011 calendar years. Methodologies for these categories are detailed individually below.

The NZ ETS will remain the main source of emissions data for these categories for future inventory submissions.

Cement production

In 2011, there were two cement production companies operating in New Zealand, Holcim New Zealand Ltd and Golden Bay Cement Ltd. Both companies produce general purpose and Portland cement. Holcim New Zealand Ltd also produces general, blended cement. From 1995 to 1998 inclusive, another smaller cement company, Lee Cement Ltd, was also operating.

Due to commercial sensitivity, individual company estimates have remained confidential and the data has been indexed as shown in figure 4.2.1. Consequently, only total process emissions are reported and the implied emission factors are not included in the common reporting format tables.

Carbon dioxide is emitted during the production of clinker, an intermediate product of cement production. Clinker is formed when limestone is calcined (heated) within kilns to produce lime and CO_2. The emissions from the combustion of fuel to heat the kilns are reported in the energy sector.

Methodology

Estimates of CO_2 emissions from cement production are calculated by the companies using the Cement CO_2 Protocol (World Business Council for Sustainable Development, 2005). The amount of clinker produced by each cement plant is multiplied by a plant-specific clinker emission factor. The emission factors are based on the calcium oxide (CaO) and magnesium oxide (MgO) content of the clinker produced. The inclusion of MgO in the emission factors means they are slightly higher than the IPCC (2000) default of 0.51 tonnes of CO_2 per tonne of clinker. This method is consistent with the IPCC (2000) Tier 2 method.

Historically, the cement companies supplied their emissions data to the Ministry of Business, Innovation and Employment during an annual survey. However, since 2010, both cement production companies are required to report their emissions from the production of clinker under the NZ ETS.

Until 2010, the Ministry of Business, Innovation and Employment required Holcim New Zealand Ltd to submit its CO_2 emissions from raw meal converted to clinker. Following discussions with Holcim New Zealand Ltd in 2010, it was decided to not use its cement-kiln dust data as it could not be verified. Therefore, the IPCC (2000) default cement-kiln dust correction factor, 1.02, is applied to Holcim New Zealand Ltd's CO_2 emissions calculation of emissions from raw meal converted to clinker from 1990 to 2009 to obtain its final process CO_2 emissions. For 2010 and 2011, the formula used by Holcim New Zealand Ltd to calculate emissions under the NZ ETS already includes a cement-kiln dust correction factor. Therefore, for 2010 and 2011, the IPCC (2000) default cement kiln-dust correction factor is not applied to Holcim New Zealand Ltd's emissions calculations to maintain consistency in the time series.

Cement-kiln dust is a mix of calcined and uncalcined raw materials and clinker. Golden Bay Cement Ltd has not included a correction factor as it operates a dry process with no cement-kiln dust lost to the system.

Trends

Figure 4.2.1 shows the trends in New Zealand clinker and cement production, imported clinker and the implied emission factor for clinker and cement for the 1990–2011 time series. In general, the figure shows clinker and cement production increasing over the time series 1990–2011. However, cement production has increased at a faster rate than clinker production as significant volumes of clinker were imported between 2001 and 2005 as New Zealand production had reached capacity (figure 4.2.1).

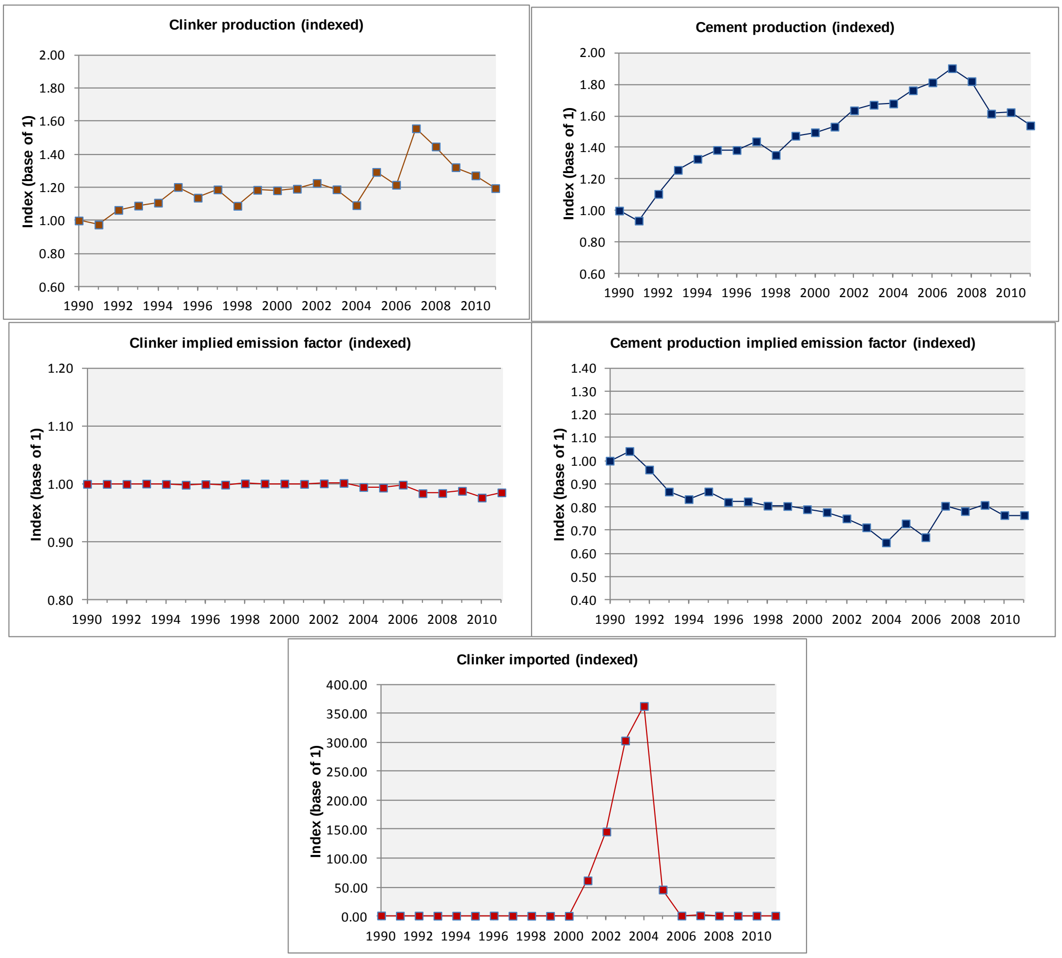
The cement implied emission factor decreased between 2000 and 2006 with the increasing use of imported clinker. Meanwhile, the implied emission factor for clinker remained relatively unchanged. In September 2006, Golden Bay Cement completed an expansion of its Northland facility, resulting in an increase in clinker production between 2006 and 2007. The increase in domestic production also reduced the demand for imported clinker, which led to the cement implied emission factor to return to pre-2002 levels.

A change in national standards for cement production in 1995, permitting mineral additions to cement of up to 5 per cent by weight (Cement and Concrete Association of New Zealand, 1995), has also resulted in less CO_2 emissions per tonne of cement produced. An amendment to this New Zealand cement standard was made in 2010 to allow further mineral additions to cement of up to 10 per cent by weight. The increase in clinker production from 2006 to 2007 is due to one of New Zealand's cement companies running at full production in 2007.

Sulphur dioxide

Sulphur dioxide (SO_2) is emitted in small quantities from the cement-making process. The amount of SO_2 is determined by the sulphur content of the limestone (while the SO_2 emissions from the fuel's sulphur content are considered to be energy sector emissions). Seventy-five per cent to 95 per cent of the SO_2 will be absorbed by the alkaline clinker product (IPCC, 1996). The emission factor for SO_2 used by New Zealand is calculated using information from a sulphur mass-balance study on one company's dry-kiln process. The mass-balance study enabled the proportion of sulphur, originating in the fuel and the sulphur in the raw clinker material as sodium and potassium salts, to be determined. The average emission factor was calculated as 0.64 kilograms of SO_2 per tonne of clinker and was weighted to take into account the relative activity of the two cement companies (CRL Energy, 2006a). This submission continues to use this emission factor as it is still considered to accurately reflect the New Zealand situation.

Figure 4.2.1 New Zealand's cement production data including clinker production, clinker imports, and cement and clinker-implied emission factors (indexed) from 1990–2011



Lime production

There are three companies (McDonalds Ltd, Websters Hydrated Lime Ltd and Perrys Group Ltd) producing lime (commonly known as burnt lime) in New Zealand. It is assumed that all three companies produce high-calcium hydrated lime.

Emissions from lime production occur when the limestone ($CaCO_3$) is heated within the kilns to produce CaO and CO_2. The emissions from the combustion of fuel are reported within the energy sector.

Methodology

Lime production data has historically been supplied to the Ministry of Business, Innovation and Employment by the lime production companies through an annual survey.

In the annual survey, each of the three lime companies was required to provide the amount of burnt lime produced during a calendar year. However, since 2010, all three lime production companies are required to report their emissions for the production of burnt lime under the NZ ETS. For this reason, the production of burnt lime data used to calculate emissions for 2010 and 2011 is the data supplied by the companies through their NZ ETS returns.

Emissions are calculated using the IPCC (2000) Tier 1 method by multiplying the burnt lime production data by the IPCC (2000) default emission factor of 0.75. In alignment with good practice, an impurity correction factor of 0.97 is applied for the whole time series assuming all three companies are producing hydrated lime.

With the introduction of the NZ ETS, all three lime companies have reported their emissions since 2010. The inventory agency is currently investigating the emissions associated with burnt lime production to validate the historical dataset. It is anticipated that progress on this investigation will be reported in future inventory submissions as more NZ ETS data becomes available.

Sulphur dioxide

The SO_2 emissions from lime production vary, depending on the processing technology and the input materials. An average emission factor for SO_2 was calculated in 2005 as 0.5 kilograms of SO_2 per tonne of lime. The emission factor was weighted to take SO_2 measurements at the various lime plants into account (CRL Energy, 2006a). This submission has continued to use the 2005 emission factor.

Glass production

There are two glass manufacturers in New Zealand, O-I New Zealand and Tasman Insulation New Zealand Ltd. All CO_2 emissions arising from glass production in New Zealand come from limestone and soda ash use. Emissions from the limestone used in the production of glass are reported under ‘Limestone and Dolomite Use’ and emissions from soda ash use from glass production are reported under ‘Soda Ash Production and Use’, as recommended by the 2011 expert review team (UNFCCC, 2012).

The activity data is considered confidential by both companies and, consequently, the activity data for glass production is not provided in the common reporting format tables.

Non-methane volatile organic compounds (NMVOCs) may be emitted from the manufacture of glass, and the IPCC (1996) suggests a default emissions factor of 4.5 kilograms of NMVOC per tonne of glass output. It has been assumed that the IPCC default emission factor for NMVOCs was based on total glass production that includes recycled glass input.

Sulphur dioxide (SO_2) is emitted from the sodium sulphate decomposition from glass production by O-I New Zealand. The emissions are assumed to be in proportion to non-cullet glass output in 2005. For 2005, the emissions were assumed to have a pure anhydrous mole ratio of 450 kilograms of SO_2 per tonne of sodium sulphate.

Oxides of nitrogen and carbon dioxide (CO) emissions are assumed to be associated with fuel use and are reported under the energy sector.

Limestone and dolomite use

In New Zealand, small amounts of limestone are used in the production of iron and steel by New Zealand Steel Ltd and in the production of glass by O-I New Zealand and Tasman Insulation New Zealand Ltd.

The majority of limestone quarried in New Zealand is calcined to produce lime or cement. Emissions from the use of limestone for these activities are reported under the lime and cement production categories as specified in the IPCC guidelines (IPCC, 1996). Ground limestone used in the liming of agricultural soils is reported in the land use, land-use change and forestry sector.

Iron and steel production

In the iron production process, New Zealand Steel Ltd blends the coal with limestone to achieve the required primary concentrate specifications. New Zealand has separated emissions arising from limestone, coke and electrodes used in the iron- and steel-making process from the remaining process CO_2 emissions and reported these emissions under the limestone and dolomite use subcategory (2.A.3). This data provided by New Zealand Steel Ltd could not be disaggregated any further (ie, reporting only limestone emissions from iron and steel production under 2.A.3). Emissions from limestone/coke/electrode use make up approximately 2 per cent of total iron and steel process emissions.

Glass production – O-I New Zealand

The inventory agency has been working with O-I New Zealand to improve the accuracy of the limestone use time series, particularly for the years of the first commitment period. Emissions from limestone use and soda ash use for 2010 and 2011 are available from the company's NZ ETS returns. O-I New Zealand also provided production data for the years 2008–2011. However, there is insufficient data to estimate a time series of limestone use using the two years for which there is both production data and limestone use data from the NZ ETS. Consequently, the NZ ETS data has been used for 2010 and 2011, and the 2010 NZ ETS limestone emissions estimate has been held constant over the rest of the time series. The inventory agency will continue to work with O-I New Zealand to improve the accuracy and consistency of this time series for future submissions as more NZ ETS data becomes available.

Glass production – Tasman Insulation New Zealand Ltd

Tasman Insulation New Zealand Ltd operates two production plants; one in Auckland and one in Christchurch. Emissions from limestone used in glass wool production by Tasman Insulation New Zealand Ltd have been provided to the inventory agency directly by the company for this inventory submission for the first time. These emissions have been calculated by multiplying the quantity of pure calcium carbonate used (calculated with plant-specific correction factors) by the NZ ETS emissions factor of 0.4397 tonnes of CO_2 per tonne of limestone used (the chemical ratio of CO_2 contained in limestone).

Data on limestone use at the Auckland plant was provided with very high confidence for 1990–2009, as this data has originated from actual measurements. For the Christchurch plant, data was provided with very high confidence for 2007–2009 (based on actual measurements). For 1997–2006, data has been provided with average-to-low confidence, as this data has been calculated based on the assumed limestone ratio in known finished goods. For 1990–1996, data was provided with low confidence as this data has been calculated based on the assumed limestone ratio in estimated finished goods.

The data used for 2010 and 2011 is the tonnage of pure calcium carbonate as submitted by the company for its NZ ETS returns.

Soda ash production and use

In New Zealand, small amounts of soda ash are used in the glass production process by O-I New Zealand and Tasman Insulation New Zealand Ltd and in aluminium production by Rio Tinto Alcan Ltd (under New Zealand Aluminium Smelter Limited - NZAS). There is no soda ash production in New Zealand.

Glass production – O-I New Zealand

A survey of the industrial processes sector estimated CO_2 emissions resulting from the use of imported soda ash in glass production in 2005 (CRL Energy, 2006a). The glass manufacturer, O-I New Zealand, provided information on the amount of imported soda ash used in 2005.

The manufacturer also provided approximate proportions of recycled glass to new glass production over the previous 10 years. This enabled CO_2 emissions from soda ash to be estimated from 1996 to 2005, as the amount of soda ash used is in fixed proportion to the production of new (rather than recycled) glass. Linear extrapolation was used to estimate activity data from 1990 to 1995. Updated activity data for 2006 to 2009 was provided by the glass manufacturer through an external consultant.

The IPCC (2000) default emission factor of 415 kilograms of CO_2 per tonne of soda ash was applied to the soda ash activity data to calculate the CO_2 emissions until 2009. Soda ash use emissions estimates submitted by O-I New Zealand for its NZ ETS returns have been used for 2010 and 2011.

The inventory agency will continue to work with O-I New Zealand to improve the accuracy and consistency of this time series for future submissions as more NZ ETS data becomes available.

Glass production – Tasman Insulation New Zealand Ltd

Emissions from soda ash used in glass wool production by Tasman Insulation New Zealand Ltd have been provided to the inventory agency directly by the company for the first time for this submission. These emissions have been calculated by multiplying the quantity of pure sodium carbonate used (raw weight of material used multiplied by the fraction 0.992 to account for the purity of the soda ash, as provided by the company in correspondence with the inventory agency) by the NZ ETS emissions factor 0.4152 tonnes of CO_2 per tonne of soda ash used (the chemical ratio of CO_2 contained in soda ash).

Data from the Auckland plant was provided with very high confidence for 1990–2009, as this data has originated from actual measurements. For the Christchurch plant, data was provided with very high confidence for 2007–2011 (based on actual measurements). For 1997–2006, data has been provided with average to low confidence, as this data has been calculated based on the assumed soda ash ratio in known finished goods. For 1990–1996, data was provided with low confidence as this data has been calculated based on the assumed soda ash ratio in estimated finished goods.

The data used for 2010 and 2011 is the tonnage of pure sodium carbonate as submitted by the company for its NZ ETS returns.

Aluminium production

In the process of producing aluminium, NZAS adds soda ash to the reduction cells to maintain the electrolyte chemical composition. This results in CO_2 emissions as a by-product. NZAS has assumed that all of the carbon content of the soda ash is released as CO_2. The emissions are estimated using the Tier 3 International Aluminium Institute (2006) method (equation 7).

Asphalt roofing

There is one company manufacturing asphalt roofing in New Zealand, Bitumen Supply Ltd. There are no known direct greenhouse gas emissions from asphalt roofing but there are indirect emissions. Default emission factors of 0.05 kilograms of NMVOCs per tonne of product and 0.0095 kilograms of CO per tonne of product respectively were used to calculate NMVOC and CO emissions (IPCC, 1996). A survey of indirect greenhouse gases was last conducted for the 2005 calendar year. In the absence of updated data, activity data for 2005 has been used for 2006–2011.

Road paving with asphalt

There are three main bitumen production companies operating within New Zealand. Data on bitumen production and emission rates is provided by these companies. Estimates of national consumption of bitumen for road paving are confirmed by the New Zealand Bitumen Contractors' Association.

As with asphalt roofing, there are no known direct greenhouse gas emissions from road paving but there are indirect emissions.

In New Zealand, solvents are rarely added to asphalt. This means asphalt paving is not considered a significant source of indirect emissions. New Zealand uses a wet 'cut-back' bitumen method rather than bitumen emulsions, which are common in other countries.

The revised 1996 IPCC guidelines (IPCC, 1996) make no reference to cut-back bitumen but do provide default emission factors for the low rates of SO_2, oxides of nitrogen (NOx), CO and NMVOC emissions that arise from an asphalt plant. The IPCC default road-surface emissions factor of 320 kilograms of NMVOC per tonne of asphalt paved is not considered applicable to New Zealand. There is no possibility of this level of NMVOC emissions because the bitumen content of asphalt in New Zealand is only 6 per cent.

For the 2002 inventory submission, the New Zealand Bitumen Contractors' Association provided a method for calculating total NMVOC emissions from the use of solvents in the roading industry (Box 4.1). The industrial processes survey for the 2005 calendar year (CRL Energy, 2006a) showed that the fraction by weight of bitumen used to produce chip-seal has been changing as methods of laying bitumen have improved. From 1990 to 2001, the fraction by weight of bitumen used to produce chip-seal was 0.80 (and the remaining 20 per cent was for asphalt production with insignificant emissions). From 2002 to 2003, it was 0.65 and, from 2004, the fraction was 0.60. The NMVOC emissions were updated to reflect this changing fraction.

In the absence of updated data, activity data for 2005 was extrapolated for 2006–2011.

Box 4.1 New Zealand's calculation of NMVOC emissions from road-paving asphalt

NMVOC emitted = A x B x C x D
where:

A = the amount of bitumen used for road paving

B = the fraction by weight of bitumen used to produce chip-seal (originally 0.80)

C = solvent added to the bitumen as a fraction of the bitumen (0.04)

D = the fraction of solvent emitted (0.75).

4.2.3 Uncertainties and time-series consistency

The IPCC (2000) default uncertainties for CO_2 emission factors have been applied to cement and lime production (table 4.2.1). The IPCC (2006) default uncertainty has been applied to glass production.

An uncertainty of ±1 per cent has been applied to the activity data for cement. The range of ±1 to ±2 per cent is provided in IPCC (2000). As the data was provided directly from the companies to the Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) until 2010 and to the NZ ETS for 2010–2011, the lower end of the range has been selected. The IPCC (2000) defaults for the plant-level data for the CaO content of the clinker (±1 per cent uncertainty) and for clinker kiln dust (±5 per cent uncertainty) have been applied.

The uncertainty for lime production takes into account the IPCC (2000) guidance that the uncertainty for activity data is likely to be much higher than for the emission factors because there is typically non-marketed lime that is not included in the estimates. The IPCC (2000) default of ±100 per cent for activity data uncertainty has been applied. The IPCC (2000) ±2 per cent uncertainty for the emission factor for lime has been applied. This high percentage of uncertainty has been applied although New Zealand has only three lime production companies that supply annual returns to the NZ ETS. The uncertainty estimates for this category may be revised after the completion of planned improvement activities for lime production (see section 4.2.6).

Uncertainties in non-CO_2 emission factors (table 4.2.1) have been assessed by a contractor from questionnaires and correspondence with industry sources (CRL Energy, 2006a).

Table 4.2.1 Uncertainty in New Zealand's emissions from the mineral products category

Mineral product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Cement – CaO content of the clinker	±1	±1 (CO_2)
Cement – clinker kiln dust	±1	± 5(CO_2)
Cement	±1	±40 (SO_2)
Lime	±100	±2 (CO_2)
		±80 (SO_2)
Asphalt roofing	±30 (±50 for 1990–2000)	±40 (NMVOC and SO_2)
Road paving with asphalt	±10	±15 (chip-seal fraction and solvent emission fraction) to ±25 (solvent dilution)
Glass	±5	±5 (CO_2)
		±50 (NMVOC)
		±10 (SO_2)

4.2.4 Source-specific quality assurance/quality control (QA/QC) and verification

In 2011, CO_2 emissions from cement production were a key category (2011 level assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks. The estimates for a non-key category, the soda ash use category, were also subject to IPCC Tier 1 quality checks. The outcome of these checks resulted in minor transcription corrections and improvements to the transparency of internal documentation for calculating soda ash use emissions.

4.2.5 Source-specific recalculations

The largest improvement for the mineral products category has been to, where applicable, use data provided by companies in their emissions returns to the NZ ETS for 2010 and 2011. This enhances yearly domestic reporting consistency for both the industry and the inventory agency.

Cement production

For 2010 and 2011, the formula used by Holcim New Zealand Ltd to calculate its emissions under the NZ ETS already includes a cement-kiln dust correction factor. For this reason, the IPCC (2000) default cement kiln-dust correction factor is not applied to Holcim New Zealand Ltd's emissions calculations for 2010 and 2011. In the last submission, a cement-correction factor had been applied twice for the time series. The slight overestimation of cement emissions for 2010 mentioned in the last inventory submission has therefore been rectified. This has resulted in an improvement in the accuracy of the cement production time series.

Lime production

Lime production data prior to 2010 for one of the lime producers has been revised for consistency with data submitted to the NZ ETS for 2010 and 2011. Production figures supplied to the Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) for 1990 to 2009 were the total mass of burnt lime produced, including small amounts of impurities from the raw limestone. Production figures submitted to the NZ ETS are the mass of pure CaO in the product only.

For time-series consistency, a purity correction factor has been applied to the company's raw production data for the years prior to the NZ ETS production data becoming the activity data source. This is based on correspondence between the company and the Ministry of Business, Innovation and Employment, stating that the lime producer assumed 96 per cent pure limestone, with the contaminants assumed to remain in the burnt lime produced. Burnt lime has therefore been multiplied by 100 per cent minus the share of impurities by mass in the burnt lime produced to obtain the burnt lime mass to compare the company's implied emission factors with NZ ETS data. This has resulted in an improvement in the accuracy of the lime production time series.

Limestone and dolomite use

The transparency and accuracy of reported emission estimates from limestone use have been improved. In the previous submission, the 2010 estimated emissions were held constant over the time series because the quantity of pure uncalcined limestone used by each company was only available for the 2010 year through the NZ ETS.

For the first time for this submission, Tasman Insulation New Zealand Ltd provided detailed data on the quantity of limestone used in the production of wool glass at its two production plants in Auckland and Christchurch for the whole time series.

Soda ash production and use

The transparency and accuracy of reported emission estimates from soda ash use has been improved.

Tasman Insulation New Zealand Ltd provided detailed data on the quantity of soda ash used in the production of wool glass at its two production plants in Auckland and Christchurch for the first time for this inventory submission.

The NZ ETS data on soda ash used by O-I New Zealand has been used for 2010 and 2011. This improvement in accuracy has led to a rectification of the 2010 value, which had been held constant from 2009, in the 2012 inventory submission.

4.2.6 Source-specific planned improvements

The inventory agency will continue to work closely with glass producers and New Zealand Steel to further improve the accuracy, consistency and transparency of emissions estimations for future submissions.

The inventory agency is currently investigating the emissions associated with burnt lime production to validate the historical dataset. It is anticipated that progress on this investigation will be reported in future inventory submissions as more NZ ETS data becomes available.

4.3 Chemical industry (CRF 2B)

4.3.1 Description

The chemical industry category reports emissions from the production of chemicals. The major chemical processes occurring in New Zealand that fall into this category are the production of ammonia and urea, methanol, hydrogen, superphosphate fertiliser and formaldehyde. There is no production of nitric acid, adipic acid, carbide, carbon black, ethylene, dichloroethylene, styrene, coke or caprolactam in New Zealand.

In 2011, emissions from the chemical industry category comprised 536.4 Gg CO_2-e (9.9 per cent) of total emissions from the industrial processes sector. Emissions have increased by 106.2 Gg CO_2-e (24.7 per cent) from the 1990 level of 430.2 Gg CO_2-e. In 2011, CO_2 emissions from ammonia production accounted for 283.2 Gg CO_2-e (52.8 per cent) of emissions in the chemical industry category. Hydrogen production contributed the remaining 253.2 Gg CO_2-e (47.2 per cent) of emissions from the chemical industry in 2011.

A key category identified in the 2011 qualitative assessment from the chemical industry category was CO_2 emissions from ammonia production.

4.3.2 Methodological issues

Ammonia and urea

Ammonia is manufactured in New Zealand by the catalytic steam reforming of natural gas. Liquid ammonia and CO_2 are reacted together to produce urea. The total amount of natural gas supplied to the plant is provided to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) by Ballance Agri-Nutrients Ltd, which operates the only ammonia–urea production plant in New Zealand.

It is assumed that the carbon in urea is eventually released after it is applied to the land (IPCC, 1996). Emissions of CO_2 are calculated by multiplying the quantities of gas (from different gas fields) by their respective emission factors. The proportion of gas from each of these fields used in ammonia production changes on an annual basis. This explains the fluctuation in the CO_2 implied emission factor over the 1990–2011 time series.

Double counting with the energy sector is prevented by reporting all CO_2 emissions arising from ammonia production as industrial processes emissions.

Non-carbon dioxide emissions are considered by industry experts to arise from fuel combustion rather than from the process of making ammonia and are therefore reported in the energy sector.

Methanol

Emissions from methanol production would normally be reported in the industrial processes sector as the emissions are from the chemical transformation of materials and not from the combustion of fuel. However, due to confidentiality concerns (there is only one methanol producer in New Zealand), both CO_2 and non-CO_2 from methanol production have been reported under the energy subcategory, manufacturing industries and construction (section 3.3.2) for all years. This means there are no emissions reported under methanol production in the industrial processes sector.

Hydrogen

Emissions of CO_2 from hydrogen production are supplied directly to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) by the two production companies. The majority of hydrogen produced in New Zealand is made by the New Zealand Refining Company as a feedstock at the Marsden Point refinery. Another company, Degussa Peroxide Ltd, produces a small amount of hydrogen that is converted to hydrogen peroxide. The hydrogen is produced from CH_4 and steam. Carbon dioxide is a by-product of the reaction and is vented to the atmosphere. Company-specific emission factors are used to determine the CO_2 emissions from the production of hydrogen. In 2011, the implied emission factor for the sum of both companies was 6.1 tonnes of CO_2 per tonne of hydrogen produced.

Formaldehyde

Formaldehyde is produced at five plants (owned by two different companies) in New Zealand. Non-methane volatile organic compound emissions are calculated from company-supplied activity data and a New Zealand-specific emission factor of 1.5 kilograms of NMVOC per tonne of product (CRL Energy, 2006a). Emissions of CO and CH_4 are not reported under this subcategory as these emissions relate to fuel combustion and are consequently reported in the energy sector.

Fertiliser

The production of sulphuric acid during the manufacture of superphosphate fertiliser produces indirect emissions of SO_2. In New Zealand, there are two companies, Ballance Agri-Nutrients Ltd and Ravensdown, producing superphosphate. Each company owns two production plants. Three plants produce sulphuric acid. One plant imports the sulphuric acid.

Activity data supplied in 2005 has been used for 2006–2011. Plant-specific emission factors used in previous years were applied to the 2011 data. No reference is made to superphosphate production in the IPCC guidelines (IPCC, 1996). For sulphuric acid, the IPCC guidelines recommend a default emission factor of 17.5 kilograms of SO_2 (range of 1 to 25) per tonne of sulphuric acid. However, New Zealand industry experts have recommended that this is a factor of 2 to 10 times too high for the New Zealand industry. Consequently, emission estimates are based on emission factors supplied by industry. In 2011, the combined implied emission factor is 1.5 kilograms of SO_2 per tonne of sulphuric acid.

4.3.3 Uncertainties and time-series consistency

The uncertainties in ammonia activity data and for the CO_2 emission factor are assessed using the IPCC (2006) defaults as no default uncertainties are provided in IPCC (1996) and (2000).

While there are no IPCC defaults for methanol production, there is only one plant in New Zealand that provides data to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment)the Ministry of Business, Innovation and Employment. The same default as applied to ammonia production (±2 per cent) has been applied to the activity data for methanol production.

Uncertainties in non-CO_2 emissions are assessed from questionnaires and correspondence with industry sources (CRL Energy, 2006a). These are documented in table 4.3.1.

Table 4.3.1 Uncertainty in New Zealand's non-CO_2 emissions from the chemical industry category

Chemical industry	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Ammonia/urea	±2	±6 (CO_2)
Formaldehyde	±2	±50 (NMVOCs)
Methanol	±2	±50 (NO_x and CO)
		±30 (NMVOCs)
		±80 (CH_4)
Fertiliser	±10 sulphuric acid	±15 sulphuric acid
	±10 superphosphate	±25 to ±60 superphosphate (varies per plant)

4.3.4 Source-specific QA/QC and verification

In the preparation of this inventory, the data for emissions from ammonia production (as a key category) underwent IPCC Tier 1 quality checks. The main result of this check has been to improve the transparency of the calculation within internal documentation.

4.3.5 Source-specific recalculations

Ammonia and urea

New Zealand gas is distributed via the Maui and Vector transmission pipelines. These pipelines take gas from various gas fields and transport it to major industrial facilities and to smaller consumers via distribution networks. The New Zealand gas emission factor for gas delivered via the Maui pipeline is calculated as an annual production-weighted average of the emission factors of each contributing gas field. Emission factors for individual gas fields are reported by the operating companies based on gas composition analysis. An emission factor for the Kowhai gas field was not available for the 2012 inventory submission but has been included in the weighted average for this submission. Kowhai is a small gas field (approximately 3 per cent of New Zealand net production) that reached full-production in 2010, so the emission factor for distributed gas in 2010 has been revised to reflect updated data. As a result, the total emissions from ammonia and urea production have been revised for 2010 as the facility uses pipeline gas as its primary feedstock. This has improved the accuracy of the ammonia and urea time series.

4.3.6 Source-specific planned improvements

The inventory agency has acknowledged past comments from expert review teams (eg, in 2009 and 2010) around emissions from the production of methanol, and where these emissions are reported. New Zealand plans to work closely with the industry to attempt to improve transparency in this sector for future submissions.

4.4 Metal production (CRF 2C)

4.4.1 Description

The metal production category reports CO_2 emissions from the production of iron and steel, ferroalloys, aluminium and magnesium. The major metal production activities occurring in New Zealand are the production of steel (from ironsand and scrap steel) and aluminium. A small amount of SF_6 was used in a magnesium foundry until 1998. New Zealand has no production of coke, sinter or ferroalloys.

In 2011, emissions from the metal production category were 2,292.2 Gg CO_2-e, 42.2 per cent of emissions from the industrial processes sector. Emissions from this category decreased 96.3 Gg CO_2-e (4.0 per cent) from the 1990 level of 2,388.5 Gg CO_2-e.

Carbon dioxide emissions accounted for 98.7 per cent of emissions in this category, with another 1.3 per cent from PFCs. In 2011, the level of CO_2 emissions had increased by 503.4 Gg CO_2 (28.6 per cent) above the 1990 level.

Perfluorocarbon emissions have decreased from the 629.9 Gg CO_2-e in 1990 to 30.2 Gg CO_2-e in 2011, a decrease of 599.7 Gg CO_2-e (95.2 per cent). This decrease is due to improvements made by the aluminium smelter. These improvements are discussed further in the following section.

In 2011, emissions from iron and steel contributed 1,690.8 Gg CO_2-e (73.8 per cent) and aluminium production contributed 601.4 Gg CO_2-e (26.2 per cent) to the metal production category.

Key categories identified in the 2011 level assessment from the metal production category include CO_2 emissions from:

- iron and steel production
- aluminium production.

Key categories identified in the 1990–2011 trend assessment from the metal production category include PFC emissions from aluminium.

4.4.2 Methodological issues

Iron and steel

There are two steel producers in New Zealand. New Zealand Steel Ltd produces iron using the ‘alternative iron-making’ process from titanomagnetite ironsand (Ure, 2000). The iron is then processed into steel. Pacific Steel operates an electric arc furnace to process scrap metal into steel.

The production data from the two steel producers is provided to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) but is confidential and is reported as such in the common reporting format tables.

The non-CO_2 emission factors for the indirect greenhouse gases (CO, SO_2 and NO_x) for both steel plants are based on measurements in conjunction with mass balance (for SO_2) and technical reviews (CRL Energy, 2006a).

New Zealand Steel Ltd

The majority of the CO_2 emissions from the iron and steel subcategory are produced through the production of iron from titanomagnetite ironsand. The CO_2 emissions arise from the use of coal as a reducing agent and the consumption of other carbon-bearing materials such as electrodes. There is no carbon contained in the ironsand used by New Zealand Steel Ltd (table 4.4.1).

Table 4.4.1 Typical analysis from New Zealand Steel Ltd of the primary concentrate (provided by New Zealand Steel Ltd)

Element	Result (%)
Fe_3O_4	81.4
TiO_2	7.9
Al_2O_3	3.7
MgO	2.9
SiO_2	2.3
MnO	0.6
CaO	0.5
V_2O_3	0.5
Zn	0.1
Na_2O	0.1
Cr	0.0
P	0.0
K_2O	0.0
Cu	0.0
Sum	100.0

Sub-bituminous coal and limestone in the multi-hearth furnaces are heated and dried together with the ironsand. This iron mixture is then fed into the reduction kilns, where it is converted to 80 per cent metallic iron. Melters then convert this into molten iron. The iron, at a temperature of around 1,480°C, is transferred to the Vanadium Recovery Unit, where vanadium-rich slag is recovered for export and further processing into a steel strengthening additive. The molten pig iron is then converted to steel in a Klockner Oxygen Blown Maxhutte oxygen steel-making furnace. Further refining occurs at the ladle treatment station, where ferroalloys are added to bring the steel composition up to its required specification. The molten steel from the ladle treatment station is then transferred to the continuous caster, where it is cast into slabs.

The IPCC (2000) Tier 2 approach is used for calculating CO_2 emissions from the iron and steel plant operated by New Zealand Steel Ltd. Emissions from pig iron and steel production are not estimated separately as all of the pig iron is transformed into steel. A plant-specific emission factor of 0.0937 tonnes of CO_2 per gigajoule is applied to the sub-bituminous coal used as a reducing agent. The following equation shows how the estimates are derived: CO_2 emissions = mass of reducing agent × EF reducing agent – mass C in finished steel.

Care has been taken not to double-count coal use for iron and steel making. The coal used in the iron-making process at New Zealand Steel Ltd acts both as a reductant and an energy source. However, all of the coal is first fed into the reduction kilns and, consequently, all CO_2 emissions associated with coal use are reported in the industrial processes sector, regardless of the end use (IPCC, 2000). Following the calculation of CO_2, to ensure there is no double counting between the energy and industrial processes sectors, New Zealand Steel Ltd provides plant-specific analysis of the proportions of coal and natural gas that contribute to the chemical transformation and to the combustion.

Carbon dioxide emissions arising from limestone, coke and electrodes used in the iron- and steel-making process are reported under the limestone and dolomite use subcategory (CRF 2.A.3) because the data on limestone could not be separated from those on coke and electrodes. These emissions are reported in section 4.2.2.

Pacific Steel

Emissions from Pacific Steel production of steel arise from the combustion of the carbon charge to the electric arc furnace. Each of the carbon-containing charges inputted into the electric arc furnace is weighed, and each charge is multiplied by its carbon content (see table 4.4.2). The average carbon content (0.20 per cent by mass) in the finished product is then subtracted from the total carbon charge to obtain the carbon emitted. The result is multiplied by the molar mass ratio of CO_2 to CO to obtain the CO_2 emissions.

Table 4.4.2 Carbon content of carbon-containing charges inputted into the electric arc furnace (provided by Pacific Steel)

Charge	Carbon content (%)
20'' electrode	98.00
12'' electrode	98.00
Scrap metal	0.59
Lime	12.00
Mag-Carb	30.00
Diajetta	99.90
Recarburiser	98.00

Reported emissions exclude the minor carbon component of the additives that are subsequently added to the ladle, as the emissions are generally a contaminant of the vanadium, manganese or silicon additives. These additives are excluded because they are considered negligible and are contained in the final steel product.

Due to limited process data at Pacific Steel, emissions between 1990 and 1999 are calculated using the average of the implied emission factors for 2000–2008 based on production volume. Emissions from 2000 onwards are reported using the IPCC (2000) Tier 2 method. Pacific Steel provides this data directly to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment).

Aluminium

Aluminium production is a source for CO_2 and PFC emissions. There is one aluminium smelter in New Zealand, Rio Tinto Alcan Ltd (under NZAS). The smelter produces aluminium from raw material using the centre worked prebaked technology.

Carbon dioxide is emitted during the oxidation of the carbon anodes. The PFCs are emitted from the cells during anode effects. An anode effect occurs when the aluminium oxide concentration in the reduction cell electrolyte is low. The emissions from combustion of various fuels used in the aluminium production process, such as heavy fuel oil, liquefied petroleum gas, petrol and diesel, are included in the energy sector. The indirect emissions are reported at the end of this section.

Estimates of CO_2 and PFC emissions were supplied by NZAS to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) until 2010. For 2011, the CO_2 and PFC emissions have been sourced from the company's NZ ETS returns.

The NZ ETS will remain the main source of emissions data for this category for future submissions.

Carbon dioxide

NZAS calculates the process CO_2 emissions using the International Aluminium Institute (2006) Tier 3 method (equations 1 to 3), which is the equivalent to the IPCC (2006) Tier 3 method. This method breaks the prebake anode process into three stages: baked anode consumption, pitch volatiles consumption and packing coke consumption.

NZAS adds soda ash to the reduction cells to maintain the electrolyte chemical composition. This results in CO_2 emissions as a by-product. These emissions are reported under the 'soda production and use' subcategory.

Perfluorocarbons

The PFC emissions from aluminium smelting are calculated using the IPCC–International Aluminium Institute (2006) Tier 2 methodology summarised below:

Perfluorocarbon emissions (t CO_2-e) = hot metal production (t) × slope factor × anode effect duration (min/cell-day) × global warming potential.

The smelter captures every anode effect, both count and duration, through its process-control software. All monitoring data is logged and stored electronically to provide the anode effect minutes per cell day value. This is then multiplied by the tonnes of hot metal, the slope factor and the global warming potential to provide an estimate of tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) emissions. The slope values of

0.143 for CF_4 and 0.0173 for C_2F_6 are applied because they are specific to the centre worked prebaked technology and are sourced from the International Aluminium Institute (2006). The global warming potentials of CF_4 and C_2F_6 are 6500 and 9200 respectively.

Anode effect durations were not recorded in 1990, 1991 and 1992. Consequently, the Tier 1 method (IPCC, 2000) has been applied, with the following defaults: 0.31 kilograms of CF_4 per tonne of aluminium and 0.04 kilograms of C_2F_6 per tonne of aluminium. The estimates for 1991 are based on the reduction cell operating conditions being similar to those in 1990.

To derive the value for 1992, the Tier 2 (International Aluminium Institute, 2006) method has been applied using the mid-point value for the extrapolated anode effect duration from the 1991 Tier 1 default PFC emission rate and the 1993 anode effect duration. The reported estimate for 1992 is considered to better reflect PFC emissions than the IPCC default value.

The smelter advises that there are no plans to directly measure PFC emissions. A smelter-specific long-term relationship between measured emissions and operating parameters is not likely to be established in the near future.

Trends

As figure 4.4.1 indicates, the implied emission factors for emissions from aluminium production have fluctuated over the time series. These fluctuations are identified and explained in table 4.4.3.

Figure 4.4.1 New Zealand's implied emission factors for aluminium production from 1990 to 2011

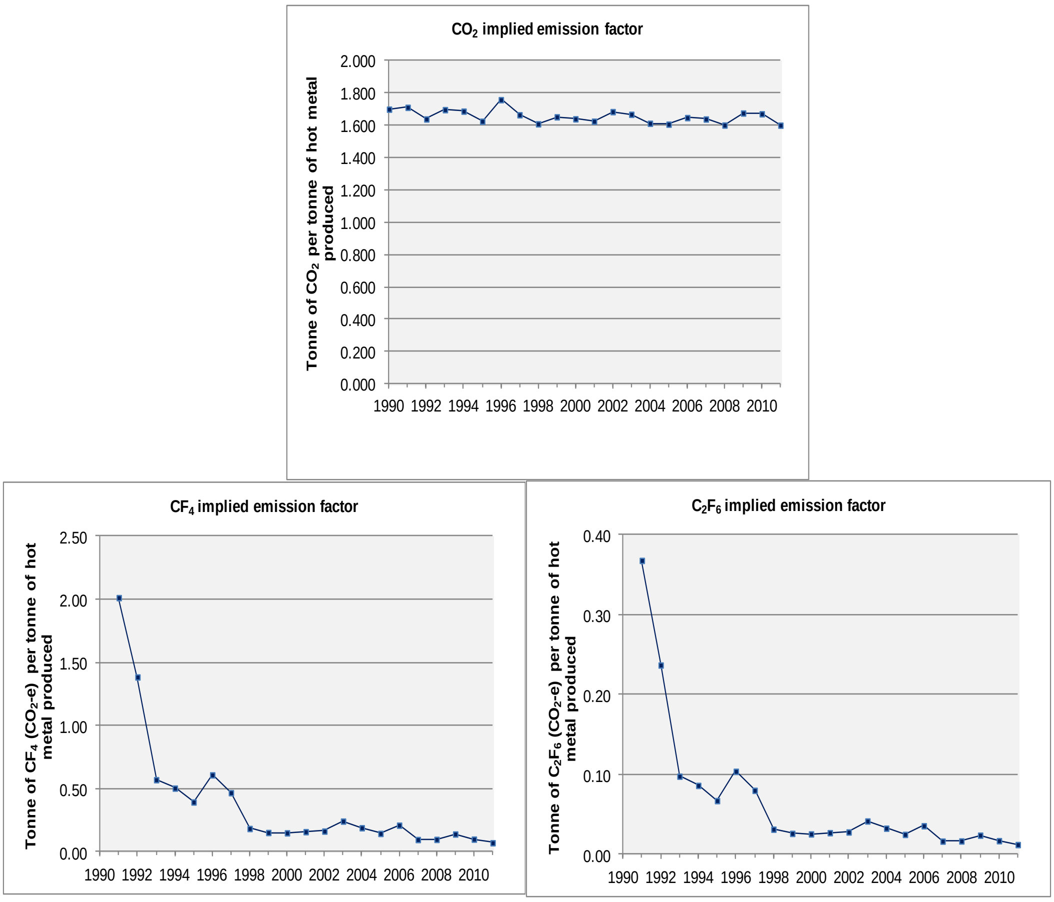


Table 4.4.3 Explanation of variations in New Zealand's aluminium emissions

Variation in emissions	Reason for variation
Increase in CO_2 and PFC emissions in 1996	Commissioning of the Line 4 cells
Decrease in CO_2 emissions in 1995	Good anode performance compared with 1994 and 1996
Decrease in CO_2 emissions in 1998	Good anode performance
Decrease in CO_2 emissions in 2001, 2003 and 2006	Fewer cells operating from reduced aluminium production due to reduced electricity supply
	Good anode performance contributed in 2001
Increase in CO_2 emissions in 1996	All cells operating, including introduction of additional cells
	Increasing aluminium production rate from the cells
Decrease in PFC emissions in 1995	Reduced anode frequencies
	The implementation of the change control strategy to all reduction cells
	Repairs made to cells exerting higher frequencies
PFC emissions remained high in 1997	Instability over the whole plant as the operating parameters were tuned for the material coming from the newly commissioned dry scrubbing equipment (removes the fluoride and particulate from the main stack discharge)
Decrease in PFC emissions in 1998	Cell operating parameter control from the introduction of modified software. This software has improved the detection of an anode effect onset and will initiate actions to prevent the anode effect from occurring
PFCs remain relatively static in 2001, 2003 and 2006	Increased emissions from restarting the cells

Indirect emissions

Aluminium production also produces indirect emissions. The most significant are CO emissions from the anode preparation. There is also a small amount of CO emitted during the electrolysis reaction in the cells. For estimates of indirect greenhouse gases, plant-specific emission factors were used for CO and SO_2. Sulphur dioxide emissions are calculated from the input sulphur levels and direct monitoring. An industry supplied value of 110 kilograms of CO per tonne of product was based on measurements and comparison with Australian CO emission factors. The IPCC (1996) default emission factor was used for NO_x emissions.

Other metal production

Small amounts of SF_6 were used as a cover gas in a magnesium foundry to prevent oxidation of molten magnesium from 1990–1999. The company has since changed to zinc technology so SF_6 is no longer used and emitted.

The only other metals produced in New Zealand are gold and silver. Companies operating in New Zealand confirm they do not emit indirect gases (NO_x, CO and SO_2), with one using the Cyanisorb recovery process to ensure everything is kept under negative pressure to ensure no gas escapes to the atmosphere. Gold and silver production processes are listed in IPCC (1996) as sources of non-CO_2 emissions. However, no details or emission factors are provided and no published information on emission factors has been identified. Consequently, no estimation of emissions from this source has been included.

4.4.3 Uncertainties and time-series consistency

The IPCC (2000) default assessment for uncertainty in activity data has been applied as ±5 per cent for both iron and steel and aluminium. A ±7 per cent uncertainty for the emission factors for iron and steel production include ±5 per cent uncertainty for the carbon content of the steel (IPCC, 2000) and ±5 per cent for the reducing agent. The IPCC (2006) default uncertainty of ±2 per cent has been applied to CO_2 emission factors from aluminium production.

Uncertainties in non-CO_2 emissions were assessed by the contractor from questionnaires and correspondence with industry sources (CRL Energy, 2006a). These are documented in table 4.4.4.

Table 4.4.4 Uncertainty in New Zealand's emissions from the metal production category

Metal product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Iron and steel	±5	±7 (CO_2)
		±20–30 (CO)
		±70 (NO_x)
Aluminium	±5	±2 (CO_2)
		±30 (PFCs)[1]
		±5 (SO_2)
		±40 (CO)
		±50 (NO_x)

[1] There is no independent means of assessing the calculations of PFC emissions from the smelter. Given the broad range of possible emission factors indicated in the IPCC (2000) table 3.10, and in the absence of measurement data and precision measures, the total uncertainty is assessed to be ±30 per cent (CRL Energy, 2006b).

4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from iron and steel production and aluminium production (2011 level assessment), and PFC emissions from aluminium production (trend assessment) underwent IPCC Tier 1 quality checks. There were no significant findings from these checks.

Verification with the NZ ETS

New Zealand followed a Tier 2 quality assurance and quality control (QA/QC) check for the iron and steel production category. Reported estimates of CO_2 emissions from this category were verified with data provided by the two steel producers under the NZ ETS for the 2010 and 2011 calendar year.

The verification process concluded there that were no significant discrepancies between the datasets for emissions from Pacific Steel Ltd.

The emission estimates from New Zealand Steel Ltd for the national inventory apply the mass-balance approach. In contrast, the method for calculating steel emissions under the NZ ETS uses the total amount of raw materials and the stoichiometry of each of the raw materials to calculate the final emissions.

The verification process has enabled the inventory agency to discover that the national inventory may be potentially underestimating emissions from New Zealand Steel Ltd in two subcategories.

First, it has been discovered that New Zealand Steel Ltd reports emissions from uncalcined dolomite under the NZ ETS, whereas these emissions may not be captured in the national inventory.

Additionally, New Zealand Steel Ltd reports emissions from carbon-containing inputs under the NZ ETS. Once methodological differences are accounted for, it has been assumed that the emissions from carbon-containing inputs should be comparable with the emissions from limestone, coke and electrodes as reported by the company to Ministry of Economic Development (currently the Ministry of Business, Innovation and Employment) for the compilation of the national inventory using the mass-balance approach (see section 4.2.2). However, the comparison between data submitted by the company under the NZ ETS and data submitted for the purposes of compiling the national inventory reveal a discrepancy for 2010 and 2011, and that the national inventory may be underestimating emissions from this category.

The inventory agency is actively monitoring these apparent discrepancies and working closely with New Zealand Steel Ltd to work through the differences in reporting methodologies. The inventory agency is expecting to resolve these discrepancies in future inventory submissions.

4.4.5 Source-specific recalculations

Iron and steel production

An error was corrected in the data provided by New Zealand Steel Ltd, which affects emission estimates for 2009 and 2010. This error was contained in the company's internal data system, and corrected by the company for this inventory submission. This improves the accuracy of the Iron and Steel production time series.

4.4.6 Source-specific planned improvements

The inventory agency is actively monitoring the apparent discrepancies explained in section 4.4.4 and is working closely with New Zealand Steel Ltd to improve the consistency, transparency and accuracy of the time series for this category for future submissions.

4.5 Other production (CRF 2D)

4.5.1 Description

The other production category includes emissions from the production of pulp and paper, and food and drink. In 2011, emissions from this category totalled 7.8 Gg NMVOC. This was an increase of 1.9 Gg NMVOC from the 1990 level of 5.9 Gg NMVOC.

Other production was not identified as a key category in either the level assessment or the trend assessment.

4.5.2 Methodological issues

All CO_2 emissions from this category are those from fuel combustion and, consequently, these are reported in the energy sector.

Pulp and paper

There are a variety of pulping processes in New Zealand. These include:

- chemical (Kraft)
- chemical thermomechanical
- thermomechanical
- mechanical.

Pulp production in New Zealand is evenly split between mechanical pulp production and chemical production. Estimates of emissions from the chemical pulping process are calculated from production figures obtained from the Ministry for Primary Industries. Emission estimates from all chemical pulping processes have been calculated from the industry-supplied emission factors for the Kraft process. In the absence of better information, the NMVOC emission factor applied to the chemical pulping processes is also applied to the thermomechanical pulp processes (CRL Energy, 2006a). Emissions of CO and NO_x from these processes are related to fuel combustion and not reported under industrial processes and are therefore reported within the energy sector.

Food and drink

Emissions of NMVOCs are produced during the fermentation of cereals and fruits in the manufacturing of alcoholic beverages. These emissions are also produced during all processes in the food chain that follow after the slaughtering of animals or harvesting of crops. Estimates of indirect greenhouse gas emissions for the period 1990–2005 have been calculated using New Zealand production figures from Statistics New Zealand and relevant industry groups with default IPCC emission factors (IPCC, 1996). No New Zealand-specific emission factors could be identified. Subsequent NMVOC estimates from food and drink have been estimated using linear extrapolation, as no industry survey was conducted.

4.5.3 Uncertainties and time-series consistency

Uncertainties in non-CO_2 emissions were assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy, 2006a). These are documented in table 4.5.1.

Table 4.5.1 Uncertainty in New Zealand's non-CO_2 emissions from the other production category

Product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Pulp and paper	±5	±50 (chemical pulp)
		±70 (thermal pulp)
Food – alcoholic beverages	±5 (beer)	±80 (beer and wine)
	±20 (wine)	±40 (spirits)
	±40 (spirits)	
Food – food production	±5–20 (varies with food type)	±80 (IPCC factors)

4.5.4 Source-specific QA/QC and verification

Other production was not a key category and no specific quality-assurance or quality-control activities were performed.

4.5.5 Source-specific recalculations

There were no recalculations for this category.

4.5.6 Source-specific planned improvements

There are no planned improvements for this category.

4.6 Production of halocarbons and SF_6 (CRF 2E)

New Zealand does not manufacture halocarbons and SF_6. Emissions from consumption are reported under section 4.7.

4.7 Consumption of halocarbons and SF_6 (CRF 2F)

4.7.1 Description

In 2011, emissions from the consumption of HFCs and PFCs totalled 1,885.1 Gg CO_2-e, 34.7 per cent of emissions from the industrial processes sector. This is an increase of 807.2 Gg CO_2-e (74.9 per cent) from the 2010 level of 1,077.9 Gg CO_2-e. There was no consumption of HFCs or PFCs in 1990. The first consumption of HFCs in New Zealand was reported in 1992 and the first consumption of PFCs in 1995.

Emissions from the consumption of HFCs and PFCs from refrigeration and air conditioning were identified as a key category in the 2011 level assessment and in the trend assessment.

Hydrofluorocarbons and PFCs are used in a wide range of equipment and products from refrigeration systems to aerosols. No HFCs or PFCs are manufactured within New Zealand. Perfluorocarbons are produced from the aluminium-smelting process (as discussed in section 4.4.2).

The use of synthetic gases, especially HFCs, has increased since the mid-1990s when chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) began to be phased out under the Montreal Protocol. In New Zealand, the Ozone Layer Protection Act 1996 sets out a programme for phasing out the use of ozone-depleting substances by 2015.

According to the 1996 IPCC guidelines, emissions of HFCs and PFCs are separated into seven subcategories:

- aerosols
- solvents
- foam
- mobile air conditioning
- stationary refrigeration and air conditioning
- fire protection
- other.

In 2011, SF_6 emissions were 17.6 Gg CO_2-e. This is an increase of 5.3 Gg CO_2-e (42.8 per cent) from the 1990 level of 12.3 Gg CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

The emissions inventory for SF_6 is broken down into two subcategories: electrical equipment and other. In New Zealand, the main electricity distribution company accounts for 70 per cent of total SF_6 used in electrical equipment.

4.7.2 Methodological issues

Hydrofluorocarbons and perfluorocarbons

Activity data on the bulk imports and end use of HFCs and PFCs in New Zealand was collected through an annual survey of HFC and PFC importers and distributors. This data has been used to estimate the proportion of bulk chemicals used in each sub-source category. The total quantity of bulk chemical HFCs imported each year was compared with import data supplied by Statistics New Zealand. Imports of HFCs in products, and bulk imports of PFCs and SF_6, are more difficult to determine as import tariff codes are not specific enough to identify these chemicals.

New Zealand uses the IPCC Tier 2 approach to calculate emissions from the consumption of HFCs and PFCs (IPCC, 2000). The Tier 2 approach accounts for the time lag between consumption and emissions of the chemicals. A summary of the methodologies and emission factors used in emission estimates is included in table 4.7.1.

Potential emissions for HFCs and PFCs are included for completeness as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006). Potential emissions for HFCs and PFCs have been calculated using the IPCC (2000) approach (previously called Tier 1). Incomplete data is available on imports into New Zealand of HFC and PFC gases contained in equipment. Models have been developed to provide a complete data set (CRL Energy, 2012a).

Table 4.7.1 New Zealand's halocarbon and SF_6 calculation methods and emission factors

HFC source	Calculation method	Emission factor
Aerosols	IPCC (2006) equation 7.6	IPCC default factor of 50 per cent of the initial charge per year (but 100 per cent for metered dose inhalers)
Foam	IPCC (2006)	IPCC default factor of 10 per cent initial charge in first year and 4.5 per cent annual loss of initial charge over an assumed 20-year lifetime
Mobile air conditioning	IPCC (2000) equation 3.44	Top-down approach First fill: 0.5 per cent
Stationary refrigeration/ air conditioning	IPCC (2006) equation 7.9	Not applicable
Fire protection	IPCC (2006)	Top-down approach using an annual emission rate of 1.5 per cent
SF_6 source	**Calculation method**	**Emission factor**
Electrical equipment	IPCC (2000) equation 3.17	Tier 3 approach based on overall consumption and disposal. Company-specific emission factors measured annually and averaging 1 per cent for the main utility (representing 70 per cent of total holdings) and an equipment manufacturer This was supplemented by data from other utilities and users using the IPCC default emission factor of 2 per cent (Tier 2a approach)
Other applications	IPCC (2000) equation 3.22	No emission factor required as 100 per cent is emitted within two years

Aerosols and metered dose inhalers

New Zealand reports HFC-134a emissions from metered dose inhalers and other aerosols separately. The significant increase in emissions over the time series from both aerosols and metered dose inhalers can be attributed to HFC-134a being used as a substitute propellant for HCFCs and CFCs, as discussed in section 4.7.1.

Aerosols

Emissions from aerosols contributed 23.8 Gg CO_2-e in 2011, an increase of 22.2 Gg CO_2-e from the 1996 level of 1.6 Gg CO_2-e. Aerosols were not widely used in New Zealand until 1994, and therefore emissions from aerosols are estimated from 1996. The initial charge is expected to be emitted within the first two years of sale.

Activity data on aerosol usage was provided by Arandee Ltd, the only New Zealand aerosol manufacturer using HFCs, and the Aerosol Association of Australia/ New Zealand. Arandee Ltd also provided activity data on annual HFC use, domestic and export sales, and product loading emission rates.

Due to insufficient information at a sub-application level, a Tier 1a method (IPCC, 2006) is used to calculate HFC-134a emissions from aerosol use in New Zealand. This is a mass-balance approach, based on import and sales data. The approach accounts for the lag from time of sale to time of use.

Metered dose inhalers

In 2011, emissions from metered dose inhalers contributed 61.2 Gg CO_2-e, an increase of 60.7 Gg CO_2-e from the 1995 level of 0.5 Gg CO_2-e. The consumption of HFCs in metered dose inhalers is not known to have occurred in New Zealand before 1995.

Data on the total number of doses contained in metered dose inhalers used from 1999 to 2011 is provided by Pharmac, New Zealand's government pharmaceutical purchasing agency. The weighted average quantity of propellant per dose is calculated from information supplied by industry. Activity data from 1995 to 1998 is based on expert opinion (CRL Energy, 2012a).

A Tier 2a method has been applied to metered dose inhalers. The default emission factor of 50 per cent of the initial charge per year (IPCC, 2006) is applied to the sales of aerosols and metered dose inhalers.

Solvents

A survey of distributors of solvent products and solvent recycling firms did not identify any use of HFCs or PFCs as solvents in New Zealand (CRL Energy, 2012a).

Foam

In New Zealand, emissions from closed-cell foam (hard foam) only are known to have occurred between 2000 and 2011. In 2011, emissions from the use of HFCs in hard foam blowing were 0.2 Gg CO_2-e, an increase of 0.1 Gg CO_2-e from the 2000 level of 0.1 Gg CO_2-e.

For 2010 and 2011, use of the mixture HFC227ea/365mfc has been confirmed by one company.

The HFC-245fa/365mfc mixture is known to have only been used in New Zealand in foam blowing from 2004 to 2011. These emissions are estimated to have increased from 0.1 tonnes in 2004 to 1.8 tonnes in 2011. However, a global warming potential for this mixture has not been adopted by the UNFCCC for current reporting. This mixture is reported in the common reporting format tables 'information on additional greenhouse gases', as recommended by the in-country review team (UNFCCC, 2007).

For 2011, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2012a). Fisher and Paykel provided information to estimate emissions from a minority of imported refrigeration equipment containing HFCs in its insulation foam. It is unlikely that any HFC is used for insulation foam in exported equipment. However, there is insufficient information to be certain of this.

The IPCC (2006) Tier 1b method is used to calculate emissions from foam blowing. The recommended default emission factor of 10 per cent of the initial charge in the first year, and a 4.5 per cent annual loss of the initial charge over an assumed 20-year lifetime, is applied.

Stationary refrigeration and air conditioning

Emissions from the use of HFCs and PFCs in stationary refrigeration and air conditioning were 1,631.8 Gg CO_2-e in 2011. This is an increase of 1,630.5 Gg CO_2-e from the 1992 level of 1.3 Gg CO_2-e. In 2011, stationary refrigeration and air conditioning made up

85.8 per cent of the emissions from the halocarbon and SF_6 consumption category. In 1992, only HFC-134a was used, while in 2011, HFCs -32, -23, -152a, -134a, -125, -143a and PFCs -218 (C_3F_8) and -116 (C_2F_6) were consumed. There was no use of HFCs and PFCs before 1992.

The increase in emissions from 1992 to 2011 is due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs in refrigeration and air-conditioning equipment (section 4.7.1).

Emissions from the use of HFCs and PFCs in stationary refrigeration and air conditioning increased from 853.6 Gg CO_2-e in 2010 to 1,631.8 Gg CO_2-e in 2011. This large increase in calculated emissions is mainly due to one supplier changing its buying behaviour and importing a very high amount of HFC-134a in 2011 compared with previous years.

New Zealand uses the top-down IPCC (2006) Tier 2b approach (Box 4.2) and New Zealand-specific data to obtain actual emissions from stationary refrigeration and air conditioning. This approach is equivalent to the IPCC (2000) Tier 2 top-down approach. Table 4.7.2 provides a summary of results for the time series 1990–2011. Table 4.7.3 provides a breakdown of the annual sales of new refrigerant in New Zealand for 1990–2011. Table 4.7.4 provides a breakdown of the total charge of new equipment sold in New Zealand.

Box 4.2 Equation 7.9 (IPCC, 2006)

Emissions = (annual sales of new refrigerant) – (total charge of new equipment) + (original total charge of retiring equipment) – (amount of intentional destruction)

Table 4.7.2 HFC and PFC emissions from stationary refrigeration in New Zealand (CRL Energy, 2012a)

Year	Annual sales of new refrigerant[1] (tonnes)	Total charge of new equipment sold in NZ (tonnes)	Emissions from retiring NZ equipment (tonnes)	Amount of intentional destruction (tonnes)	Emissions (tonnes)
1990	0.0	0.0	0.0	0	0.0
1991	0.0	0.0	0.0	0	0.0
1992	1.2	0.2	0.0	0	1.0
1993	2.8	0.8	0.0	0	2.0
1994	49.5	10.0	0.0	0	39.5
1995	111.5	24.1	0.0	0	87.4
1996	173.2	41.6	0.0	0	131.7
1997	73.2	44.3	0.0	0	28.9
1998	226.1	58.9	0.0	0	167.1
1999	207.7	70.9	0.0	0	136.9
2000	201.8	79.0	0.0	0	122.8
2001	209.2	79.8	0.0	0	129.4
2002	246.2	62.5	0.0	0	183.7
2003	310.8	73.2	0.1	0	237.7
2004	220.9	100.3	1.0	0	121.6
2005	370.3	161.9	2.9	0	211.3
2006	390.3	197.1	6.5	0	199.7

Year	Annual sales of new refrigerant[1] (tonnes)	Total charge of new equipment sold in NZ (tonnes)	Emissions from retiring NZ equipment (tonnes)	Amount of intentional destruction (tonnes)	Emissions (tonnes)
2007	509.1	238.5	10.5	0	281.1
2008	471.7	267.5	16.1	0	220.2
2009	470.2	250.4	22.5	0	242.3
2010	578.4	255.4	29.9	0	353.0
2011	1,084.0	244.2	45.9	0	885.7

[1] Annual sales of new refrigerant include chemicals imported in bulk and in equipment (minus exports).

Table 4.7.3 Annual sales of new refrigerant in New Zealand (CRL Energy, 2012a)

Year	Domestically manufactured chemical (tonnes)	Imported bulk chemical (tonnes)	Exported bulk chemical (tonnes)	Chemical in imported equipment (tonnes)	Chemical in exported equipment (tonnes)	Annual sales (tonnes)
1990	0	0.0	0	0.0	0.0	0.0
1991	0	0.0	0	0.0	0.0	0.0
1992	0	2.0	0	0.0	0.8	1.2
1993	0	6.0	0	0.1	3.2	2.8
1994	0	55.1	0	1.7	7.3	49.5
1995	0	123.1	0	6.0	17.6	111.5
1996	0	180.9	0	10.7	18.4	173.2
1997	0	90.6	0	11.7	29.1	73.2
1998	0	234.2	0	11.5	19.6	226.1
1999	0	211.9	0.1	16.5	20.5	207.7
2000	0	207.0	0.4	17.8	22.7	201.8
2001	0	216.5	0.8	17.7	24.3	209.2
2002	0	248.3	0.9	23.2	24.4	246.2
2003	0	305.9	2.4	34.3	27.1	310.8
2004	0	230.8	6.0	55.0	58.9	220.9
2005	0	302.9	6.5	110.9	37.0	370.3
2006	0	285.8	6.7	142.7	31.6	390.3
2007	0	377.1	12.1	192.7	48.6	509.1
2008	0	339.2	13.3	210.0	64.4	471.7
2009	0	355.6	16.6	195.8	64.5	470.2
2010	0	499.2	24.8	188.8	84.8	578.4
2011	0	981.2	23.6	207.4	80.9	1,084.0

Table 4.7.4 Total charge of new equipment sold in New Zealand (CRL Energy, 2012a)

Year	Chemical to charge domestically manufactured + imported equipment[1] (tonnes)	Chemical contained in factory-charged imported equipment (tonnes)	Total charge of new equipment sold in NZ (tonnes)
1990	0.0	0.0	0.0
1991	0.0	0.0	0.0
1992	0.2	0.0	0.2
1993	0.8	0.1	0.8

Year	Chemical to charge domestically manufactured + imported equipment[1] (tonnes)	Chemical contained in factory-charged imported equipment (tonnes)	Total charge of new equipment sold in NZ (tonnes)
1994	8.4	1.7	10.0
1995	18.1	6.0	24.1
1996	30.9	10.7	41.6
1997	32.6	11.7	44.3
1998	47.5	11.5	58.9
1999	54.4	16.5	70.9
2000	61.2	17.8	79.0
2001	62.1	17.7	79.8
2002	39.3	23.2	62.5
2003	38.9	34.3	73.2
2004	45.3	55.0	100.3
2005	51.0	110.9	161.9
2006	54.4	142.7	197.1
2007	45.8	192.7	238.5
2008	57.5	210.0	267.5
2009	54.6	195.8	250.4
2010	66.6	188.8	255.4
2011	36.9	207.4	244.2

[1] It is not possible to differentiate between the chemical to charge domestically manufactured and imported non-factory-charged equipment.

To estimate HFCs and PFCs emissions, all refrigeration equipment is split into two groups: factory-charged equipment and all other equipment that is charged with refrigerant on site. This is because some information is available on the quantities of factory-charged imported refrigeration and air-conditioning equipment and on the amount of bulk HFC refrigerant used in that equipment.

The amount of new refrigerant used to charge all other equipment (charged on site after assembly) is assumed to be the amount of HFC refrigerant sold each year minus that used to manufacture factory-charged equipment and that used to top up all non-factory-charged equipment.

Factory-charged equipment consists of all equipment charged in factories (both in New Zealand and overseas), including all household refrigerators and freezers and all factory-charged, self-contained refrigerated equipment used in the retail food and beverage industry. All household air conditioners and most medium-sized commercial air conditioners are also factory charged, although some extra refrigerant may be added by the installer for piping.

It is estimated there are about 2.2 refrigerators and freezers per household in New Zealand. This calculation includes schools, factories, offices and hotels (Roke, pers. comm., Fisher and Paykel). Imported appliances account for around half of new sales each year, with the remainder manufactured locally. New Zealand also exports a significant number of factory-charged refrigerators and freezers.

Commercial refrigeration includes central rack systems used in supermarkets, self-contained refrigeration equipment, chillers used for commercial building air-conditioning and process-cooling applications, rooftop air conditioners, transport refrigeration systems and cool stores. In many instances, these types of systems are assembled and charged on site, although most imported units may already be pre-charged. Self-contained commercial equipment is pre-charged and includes some frozen food display cases, reach-in refrigerators and freezers, beverage merchandisers and vending machines.

The report on HFC and PFC emissions in New Zealand (CRL Energy, 2012a) provides detailed information on the assumptions that have been used to build models of refrigerant consumption and banks for the domestic and commercial refrigeration categories, dairy farms, industrial and commercial cool stores, transport refrigeration and stationary air conditioning.

Mobile air conditioning

In 2011, HFC-134a emissions from mobile air conditioning were 166.5 Gg CO_2-e, an increase of 165.2 Gg CO_2-e from the 1994 level of 1.3 Gg CO_2-e. Emissions from mobile air conditioning made up 8.8 per cent of total emissions from the halocarbon and SF_6 consumption category in 2011. There was no use of HFCs as refrigerants for mobile air conditioning in New Zealand before 1994. The increase since 1994 can largely be attributed to pre-installed air-conditioning units in a large number of second-hand vehicles imported from Japan, as well as reflecting the global trend of increasing use of air conditioning in new vehicles.

The automotive industry has used HFC-134a as the refrigerant for mobile air conditioning in new vehicles since 1994. HFC-134a is imported into New Zealand for use in the mobile air-conditioning industry through bulk chemical importers and distributors and within the air-conditioning systems of imported vehicles. Industry sources report that air-conditioning systems were retrofitted (with ‘aftermarket’ units) to new trucks and buses and to second-hand cars (mainly around 2000). Refrigerated transport is included in the stationary refrigeration and air-conditioning subcategory.

New Zealand has used the IPCC (2000) Tier 2b method, mass-balance approach (Box 4.3). This approach does not require emission factors (except for the minor first-fill component) as it is based on chemical sales and not equipment leak rates. Table 4.7.5 provides a summary of results for the time series 1994–2011.

Box 4.3 Equation 3.44 (IPCC, 2000)

Emissions = first-fill emissions + operation emissions + disposal emissions – intentional destruction

Table 4.7.5 HFC-134a emissions from mobile air conditioning in New Zealand (CRL Energy, 2012a)

Year	First-fill emissions	Operation emissions	Disposal emissions	Intentional destruction	Annual emissions of HFC-134a
1990	0.000	1.0	0.0	0	1.0
1991	0.003	2.6	0.3	0	2.9
1992	0.016	2.7	0.9	0	3.6
1993	0.012	5.4	2.9	0	8.3
1994	0.008	8.8	2.7	0	11.5
1995	0.005	13.4	3.0	0	16.4
1996	0.005	17.7	5.0	0	22.6

Year	First-fill emissions	Operation emissions	Disposal emissions	Intentional destruction	Annual emissions of HFC-134a
1997	0.007	23.6	7.4	0	31.0
1998	0.010	30.1	10.2	0	40.3
1999	0.015	37.4	11.4	0	48.8
2000	0.003	47.6	14.8	0	62.4
2001	0.001	55.7	21.5	0	77.2
2002	0.001	61.1	29.1	0	90.2
2003	0.001	66.7	35.0	0	101.8
2004	0.002	59.6	40.2	0	99.8
2005	0.001	72.2	41.8	0	114.0
2006	0.001	75.4	42.2	0	117.6
2007	0.001	77.8	50.3	0	128.1
2008	0.000	1.0	0.0	0	1.0
2009	0.003	2.6	0.3	0	2.9
2010	0.016	2.7	0.9	0	3.6
2011	0.012	5.4	2.9	0	8.3

First-fill emissions are calculated from vehicle fleet numbers provided by Statistics New Zealand and the New Zealand Transport Registry Centre. Assumptions are made on the percentage of mobile air-conditioning installations. Operation and disposal data are obtained from a survey of the industry and data from the New Zealand Transport Agency.

Detailed information on the assumptions that have been used in the calculation of emissions from mobile air conditioning can be found in the report on HFC emissions in New Zealand (CRL Energy, 2012a).

Fire protection

In 2011, HFC-227ea emissions from fire protection were 1.5 Gg CO_2-e, an increase of 1.5 Gg CO_2-e from the 1994 level of 0.1 Gg CO_2-e. There was no use of HFCs in fire protection systems before 1994 in New Zealand. The increase was due to HFCs used as substitutes to halons in portable and fixed fire protection equipment.

Within the New Zealand fire protection industry, the two main supply companies are identified as using relatively small amounts of HFC-227ea. The systems installed have very low leak rates, with most emissions occurring during routine servicing and accidental discharges.

A simplified version of the Tier 2b method, mass-balance approach (IPCC, 2006) has been used to estimate emissions. A New Zealand-specific annual emission rate of 1.5 per cent has been applied to the total amount of HFC installed. This rate is based on industry experience. Due to limited data, it has been assumed that HFC from any retirements was totally recovered for use in other systems.

Electrical equipment

In 2011, SF_6 emissions from electrical equipment were 14.8 Gg CO_2-e, an increase of 5.3 Gg CO_2-e from the 1990 level of 9.5 Gg CO_2-e.

The high dielectric strength of SF_6 makes it an effective insulant in electrical equipment. It is also very effective as an arc-extinguishing agent, preventing dangerous over-voltages once a current has been interrupted.

Actual emissions are calculated using the IPCC (2000) Tier 3a approach for the utility responsible for 70 per cent of the total SF_6 held in electrical switchgear equipment. This data is supplemented by data from other utilities. The additional data enables a Tier 2a approach to be taken for the rest of the industry (CRL Energy, 2012a).

Activity and emissions data is provided by the two importers of SF_6 and New Zealand's main users of SF_6, the electricity transmission, generation and distribution companies (CRL Energy, 2012a).

The IPCC (2000) Tier 1 method (equation 3.18) is used to calculate potential emissions of SF_6 (including estimates for SF_6 other applications). This is based on total annual imports of SF_6 into New Zealand. Potential SF_6 emissions are usually two-to-three times greater than actual emissions in a given year. However, in 2005, potential emissions were less than actual emissions because there was less SF_6 imported, compared with previous years. Import data from 2006 to 2011 shows potential SF_6 emissions are again greater than actual emissions.

Other SF_6 applications

Emissions from other SF_6 applications in 1990 and 2011 were 2.9 Gg CO_2-e. In New Zealand, other applications include medical uses for eye surgery, tracer gas studies, magnesium casting, plumbing services, tyre manufacture and industrial machinery equipment. A Tier 2 method (IPCC, 2006) is applied and a 50 per cent emission factor is used as it is assumed to be emitted over two years.

Activity data for 2005 to 2011 was provided by one main supplier for eye surgery, scientific use, plumbing, tyre manufacture and industry. Scientific use was also discussed with the National Institute of Water and Atmospheric Research, AgResearch and GNS Science.

For the first time, very small amounts of SF_6 were identified as having been imported for many years in single-use containers (30ml for a specialised type of eye surgery). Applying some uncertain assumptions to the quantity of SF_6 contained in these containers, the total imported annual quantity is estimated to be about 0.4kg. This accounts for a very small proportion of the annual 30kg that is assumed to be supplied for medical purposes.

4.7.3 Uncertainties and time-series consistency

The uncertainty in estimates of actual emissions from the use of HFCs and PFCs varied with each application and is described in table 4.7.6. For most sources, a quantitative assessment is provided for activity data and other calculation components from expert opinion. These components are then combined for a statistical calculation of uncertainty.

Table 4.7.6 New Zealand's uncertainties in the consumption of HFCs and SF_6 (CRL Energy, 2012a)

HFC source	Uncertainty estimates (%)
Aerosols	Combined uncertainty ±61
Metered dose inhalers	Combined uncertainty ±10
Solvents	Not occurring
Foam	Combined uncertainty ±50
Stationary refrigeration/air conditioning	Combined uncertainty ±13
Mobile air conditioning	Combined uncertainty ±34
Fire protection	Combined uncertainty ±32
SF_6 source	**Uncertainty estimates (%)**
Electrical equipment	Combined uncertainty ±20
Other applications	±60

4.7.4 Source-specific QA/QC and verification

In the preparation of this inventory, the data for the consumption of HFCs and SF_6 underwent Tier 1 quality checks. During data collection and calculation, activity data provided by industry was verified against national totals where possible and unreturned questionnaires and anomalous data were followed up and verified to ensure a complete and accurate record of activity data.

4.7.5 Source-specific recalculations

Stationary refrigeration and air-conditioning equipment

The largest improvement for this submission in the estimation of emissions from stationary refrigeration and air conditioning was that CRL Energy incorporated the results of a review of HFC refrigerant charges in imported refrigeration and air-conditioning goods (CRL Energy, 2012b). This review was undertaken as part of the development of Synthetic Greenhouse Gas regulations amendments under the Climate Change Response Act 2002 (as part of the latest NZ ETS review in 2012). These new regulations will come into force in 2013. Incorporating these results will ensure that assumptions made for the inventory treatment of the refrigeration and air-conditioning sectors are consistent with the average refrigerant charges chosen for the synthetic greenhouse gas levies that will be applied to imported goods in place of NZ ETS liabilities from July 2013.

A mistake was corrected for the 2010 stationary refrigeration and air-conditioning equipment emissions calculation where the assessed HFC-134a amount used to replace mobile air conditioning operational emissions was for 2009 rather than 2010. The effect was to over-estimate HFC-134a emissions for 2010 by 3,800 tonnes CO_2-e. This mistake has been corrected in this inventory.

A mistake was corrected for the 2008 to 2010 stationary refrigeration and air-conditioning equipment emissions calculation of the assessed HFC-134a amount retired from dehumidifiers. The effect was to underestimate HFC-134a emissions by 65 tonnes CO_2-e, 180 tonnes CO_2-e and 350 tonnes CO_2-e respectively. This mistake has been corrected in this inventory.

Bulk chemical exports for 2010 were increased by 3.1 tonnes of R404A to account for the revelation by a manufacturer and installer of remote cabinets and coolstores that they had exported 3.1 tonnes of R404A in 2010 and again in 2011. The effect was to reduce 2010 emissions of HFC-125, HFC-134a and HFC-143a by 3,900 tonnes CO_2-e, 130 tonnes CO_2-e and 6,100 tonnes CO_2-e respectively.

Household refrigeration

The review of HFC refrigerant charges in imported household refrigerators and freezers (CRL Energy, 2012b) showed that there were generally lower charges in Fisher and Paykel's equipment than in imported brands. Therefore, the average charges to be used for the synthetic greenhouse gas levy have been applied to historical figures for the inventory, while the Fisher and Paykel specific charge values have been retained for its equipment manufactured for export and local sale.

A small improvement in methodology for the household refrigeration sector has also been achieved by comparing Statistics New Zealand export numbers with the detailed sales breakdowns supplied by Fisher and Paykel for the years ended March 2006 and 2007. This comparison showed there were mis-classifications for some categories but that the impact on calculated total refrigerant exported was minor. The method used to estimate total refrigerant filled in exported equipment for 1994 to 2004 has, however, been improved for this inventory by placing greater weight on the pro rata calculation from Fisher and Paykel total HFC amounts rather than on export statistics.

Commercial refrigeration

Another important improvement in accuracy has been achieved as a detailed breakdown of commercial refrigeration units was made available. This has led to a more consistent way of managing the highly variable numbers for the three commercial refrigeration import categories (refrigerating equipment, freezing and refrigerating/freezing equipment, and other refrigerating equipment). This breakdown enabled CRL Energy to include the 'other commercial refrigeration' import category in calculations of the HFC refrigerant bank quantity.

The inclusion of this category, combined with the amendment of average refrigerant charges, has led to an improvement in the accuracy and completeness of the refrigerant bank estimates for R134a and R404A. This in turn has improved the accuracy of the retirement emissions estimates for HFC-125, HFC-134a and HFC-143a over the commercial refrigeration emissions time series.

Air conditioning

Improvements in the accuracy of the air conditioning model arose from the review of HFC refrigerant charges in imported air conditioning goods. The review showed that some of the charges used for some ranges of kilowatt cooling capacity were too low, and showed that the assumption that Temperzone's use of a 1kg holding charge for units of cooling capacity above 27kW was typical for all larger equipment was incorrect.

Additionally, the Energy Efficiency and Conservation Authority (EECA) made available detailed sales, imports and exports records (preserving company confidentiality) for its Minimum Energy Performance Standards reporting for the years ended March 2011 and March 2012. This data contradicted previous assumptions about the imports and exports of single phase and three phase air-conditioning units.

Another assumption shown to be untrue by the data provided by EECA was that any air-conditioning exports by companies other than Temperzone were negligible. The data showed that these companies exported about 2,300 imported units in 2010 and 1,900 units in 2011. These two annual data points have enabled CRL Energy to make assumptions about distinguishing manufactured air-conditioning exports from other air-conditioning exports in its calculations from 2003 onwards.

The EECA summary data also suggested that the assumption that all of Temperzone's purchased refrigerant not included in exported equipment was used to fill equipment for local sales was incorrect. A more realistic set of figures has been developed for Temperzone's manufacturing for local sales from 2007, so the refrigerant not accounted for is treated as an emission by the mass-balance emissions method.

The combined effect of these assumption changes was a minor increase in the 2010 air-conditioning retirement emissions for HFC-32 and HFC-125 (78 tonnes CO_2-e and 360 tonnes CO_2-e respectively). The effect on the HFC refrigerant bank (and consequently on future retirement emissions) is, however, much greater, with a 100 tonnes increase in mainly R410A for 2010.

Early equipment retirement from the Canterbury earthquake and demolitions

The calculated estimate of the impact of the February 2011 Canterbury earthquake and demolitions on early equipment retirement was 8.2 tonnes in addition to the 38.4 tonnes of assessed HFC emissions (not tonnes CO_2-e) from the normal stationary refrigeration and air-conditioning retirement models in 2011. This was composed of 0.7 tonnes from the household refrigeration sector, 1.0 tonnes from commercial refrigeration (including just one small supermarket system) and 6.5 tonnes from the air-conditioning sector. A very small proportion of this may have happened during the September 2010 earthquake, and a high proportion of the building demolitions have occurred during 2012. Nevertheless, they are all treated as 2011 emissions because it would not be practical to determine the proportion of demolished systems that remained intact after the February earthquake and subsequent after-shocks.

Mobile air conditioning

A mistake was corrected where the 2010 retirement emissions calculated from 2010 deregistrations failed to include vehicles first registered in 2010 and deregistered in the same year. The effect was to underestimate mobile air-conditioning retirement emissions of HFC-134a by 130 tonnes CO_2-e for the 2010 reporting year. This mistake has been corrected in this inventory submission.

Electrical equipment

Improved information on new and retired equipment for several lines companies has had a small impact on the calculation of actual emissions for 2008, 2009 and 2010 (11kg, 23kg and 13kg higher respectively compared with the previous study) and much smaller amounts in previous years.

A minor mistake was corrected where 75kg of new capacity should have been added to Electricity Ashburton's holdings the last time it reported in 2008. This mistake was carried over from 2008 to the 2009 and 2010 inventories. The impact of this was to slightly under-estimate emissions in 2008, 2009 and 2010. This mistake has been corrected in this inventory.

4.7.6 Source-specific planned improvements

There are no planned improvements for this category.

4.8 Other (CRF 2G)

4.8.1 Description

Panel products

Particleboard and medium-density fibreboard activity data is obtained from the Ministry for Primary Industries. The NMVOC emission factors for particleboard and medium-density fibreboard are derived from two major manufacturers (CRL Energy, 2006a). An assumption was made that the industry-supplied NMVOC emission factors are applicable to all particleboard and fibreboard production in New Zealand. There is no information in the IPCC guidelines (1996) for this category.

Estimates of NMVOC emissions from panel products in 2011 were 1.2 Gg. This is an increase of 0.4 Gg over the 1990 level of 0.8 Gg.

The other production category was not identified as a key category in either the 2011 level assessment or the trend assessment.

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Chapter 5: Solvent and other product use

5.1 Sector overview

In 2011, New Zealand's solvent and other product use sector produced 27.9 Gg of carbon dioxide equivalent (CO_2-e), contributing 0.04 per cent of New Zealand's total greenhouse gas emissions.

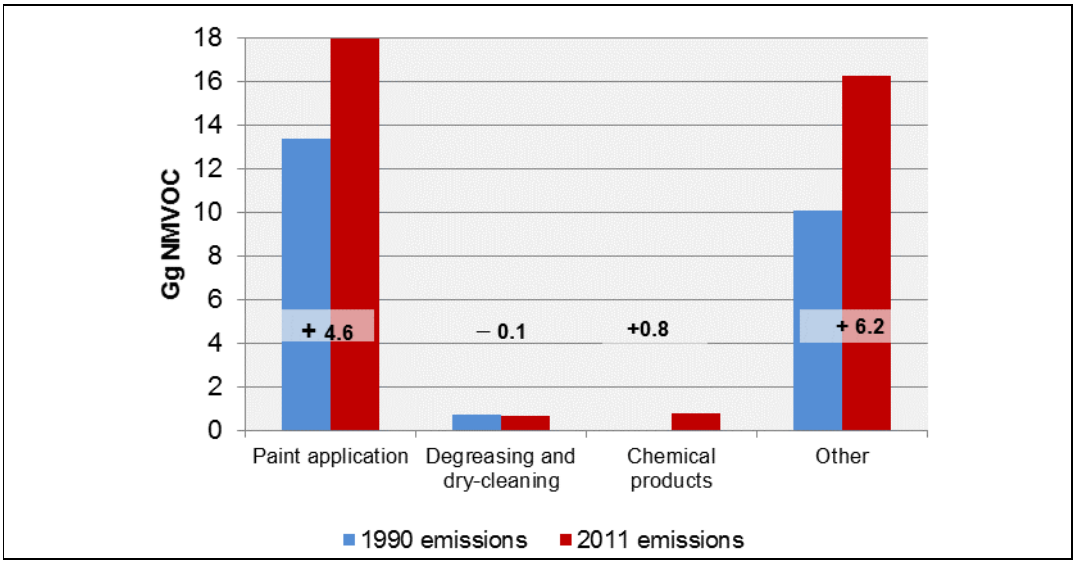
The only direct greenhouse gas reported in this category is nitrous oxide (N_2O) emissions from anaesthesia and other uses. In 2011, N_2O emissions from anaesthesia and other uses totalled 27.9 Gg CO_2-e. This was a decrease of 13.6 Gg CO_2-e (32.8 per cent) from the 1990 level of 41.5 Gg CO_2-e.

This sector also includes emissions from chemical cleaning substances used in dry-cleaning, printing, metal degreasing and from the use of paints, lacquers, thinners and related materials. The emissions arise from the evaporation of the volatile chemicals when solvent-based products are exposed to air.

In 2011, non-methane volatile organic compound (NMVOC) emissions from the solvent and other product use sector were 35.8 Gg, or 20.3 per cent of total NMVOC emissions. This was an increase of 11.5 Gg (47.4 per cent) from the 1990 level of 24.3 Gg of NMVOCs. The categories dominating the sector are NMVOC emissions from paint application and other domestic and commercial-use subcategories (figure 5.1.1).

The solvent and other product use sector was not identified as a key category in either the 2011 level assessment or the trend assessment.

Figure 5.1.1 Change in New Zealand's emissions of NMVOC from the solvent and other product use sector from 1990 to 2011



Note: The percent change for chemical products is not applicable (NA) as there is no activity data available for 1990.

5.1.1 Description

Ethanol and methanol are the only solvents produced in New Zealand, and the majority of both products are exported. All other solvents are imported, including some ethanol and methanol (for quality and price reasons).

5.1.2 Methodological issues

Detailed methodologies for emissions from the solvent and other product use sector are not provided in the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996). Two basic approaches for estimating emissions – consumption and production-based estimates – are documented. The IPCC guidelines note that, for many applications of solvents, the end uses are too small scale, diverse and dispersed to be tracked directly. Therefore, emission estimates are generally based on total consumption and an assumption that, once these products are sold to end users, they are applied and emissions are produced relatively rapidly. For most surface coating and general solvent use, this approach is recommended. The New Zealand inventory estimates solvent emissions with a consumption-based approach. Activity data is obtained by an industry survey (CRL Energy, 2006) and extrapolated for the 2006 to 2011 calendar years.

Emission factors are developed based on the likely final release of NMVOCs to the atmosphere per unit of product consumed. The emission factors are applied to sales data for the specific solvent or paint products. The subcategories of solvents and other products specified in the common reporting format are detailed below.

Nitrous oxide used for anaesthesia

The sole importer of bulk N_2O into New Zealand provided activity data for the 2011 calendar year (CRL Energy, 2012). As the importer supplies its competitor with its requirements, the emission estimate represents full coverage of N_2O use for New Zealand. Most of the N_2O is used for anaesthesia and the production of Entonox (a half-and-half mixture of nitrous oxide and oxygen for pain relief). There is a very small amount used in motor sports and scientific analysis.

Paint application

Activity and emissions data for 2006 to 2011 were extrapolated from the 2005 survey data (CRL Energy, 2006). Consumption and emissions from paints and thinners were based on information from Nelson (1992) and the Auckland Regional Council (1997). Additional activity data for 1993 to 1996 was provided by the New Zealand Paint Manufacturers' Association.

Degreasing and dry-cleaning

Dry-cleaning activity and emission data were extrapolated from 2005 activity data (CRL Energy, 2006) for the 2006 to 2011 calendar years. Most dry-cleaners in New Zealand use perchloroethylene and a small number use white spirits. Trichloroethylene has never been used in dry-cleaning but it is used in degreasing, for example, in the leather manufacturing industry. In general, solvent losses from the dry-cleaning industry have reduced substantially as closed-circuit machines and refrigerated recovery units are increasingly used. Consumption of perchloroethylene and trichloroethylene are assumed to equal the volume of imports. Import data was supplied by Statistics New Zealand.

Chemical products (manufacturing and processing)

The solvents tetrabutyl urea and alkyl benzene are used in the production of hydrogen peroxide. Emissions of NMVOCs were provided by Degussa Peroxide Ltd. The hydrogen peroxide plant has an online, continuous, activated-carbon solvent recovery system. Solvent losses were recorded annually as the difference between input solvent and solvent collected for incineration.

Losses of ethanol (and other minor components such as methanol, acetaldehyde and ethyl acetate) were monitored in the three ethanol plants in New Zealand. Using these values, an emission factor for NMVOCs of 6 grams per litre was calculated. Ethanol used for alcoholic beverage production has been reported under food and drink production in the industrial processes sector.

Due to data availability, data has remained unchanged since 2005.

Other – printing ink use

There is one major printing ink company in New Zealand with approximately 50 per cent of the solvent ink market share. The company provided a breakdown of the type of ink used. Approximately 50 per cent of inks used are oil inks (paste inks) containing high boiling temperature oils. These are evaporated off during heat setting, but the volatiles are generally treated in a solvent burner that minimises emissions. The remaining 50 per cent of inks are liquid, and 60 per cent of these are solvent inks (the remaining 40 per cent are water-based).

Due to data availability, data has remained unchanged since 2005.

Other – aerosols

Approximately 25 million aerosol units are sold in New Zealand each year. The average propellant charge is 84 grams and 95 per cent are hydrocarbon-based.

Other – domestic and commercial use

This category includes NMVOC emissions from domestic and commercial solvent use in the following areas: household products, toiletries, rubbing compounds, windshield washing fluids, adhesives, polishes and waxes, space deodorants, and laundry detergents and treatments. Emissions for this category are based on a per capita emission factor. The emission factor used is 2.54 kilograms NMVOC/capita/year (United States EPA, 1985). It is assumed that the emissions rate per capita derived by the United States Environmental Protection Agency is applicable to the average product use in New Zealand (CRL Energy, 2006). Population data is sourced from Statistics New Zealand.

5.1.3 Uncertainties and time-series consistency

Estimates of uncertainty are based on information provided by industry in the questionnaires and discussions with respondents (CRL Energy, 2006). The overall uncertainties are shown in table 5.1.1.

Table 5.1.1 New Zealand's uncertainties in the solvent and other product use sector (CRL Energy, 2006)

HFC source	Combined uncertainty estimates (%)
Paint application	±40
Degreasing/dry-cleaning	±30
Chemical products	±20
Printing	±50
Aerosols	±20
Domestic/commercial use	±60
Anaesthesia (N_2O)	±10

5.1.4 Source-specific recalculations

There were no recalculations for this sector.

5.1.5 Source-specific planned improvements

There are no planned improvements for this sector. There are large uncertainties; however, the emission levels from the solvent and other products sector are negligible compared with other sectors. In accordance with good practice, New Zealand will continue to focus its inventory development on key source categories (IPCC, 2000).

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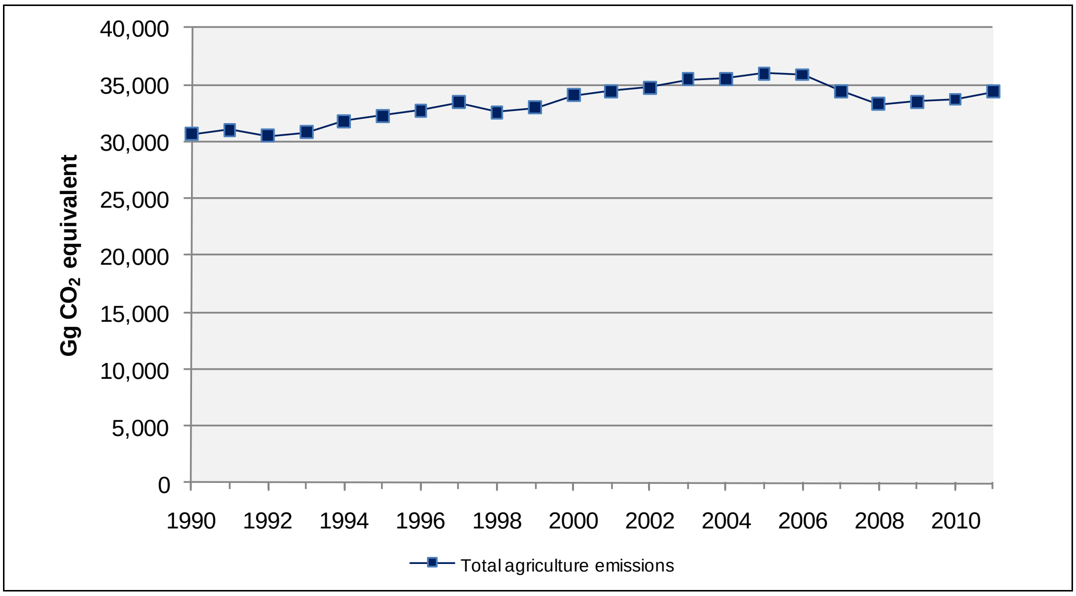
Chapter 6: Agriculture

6.1 Sector overview

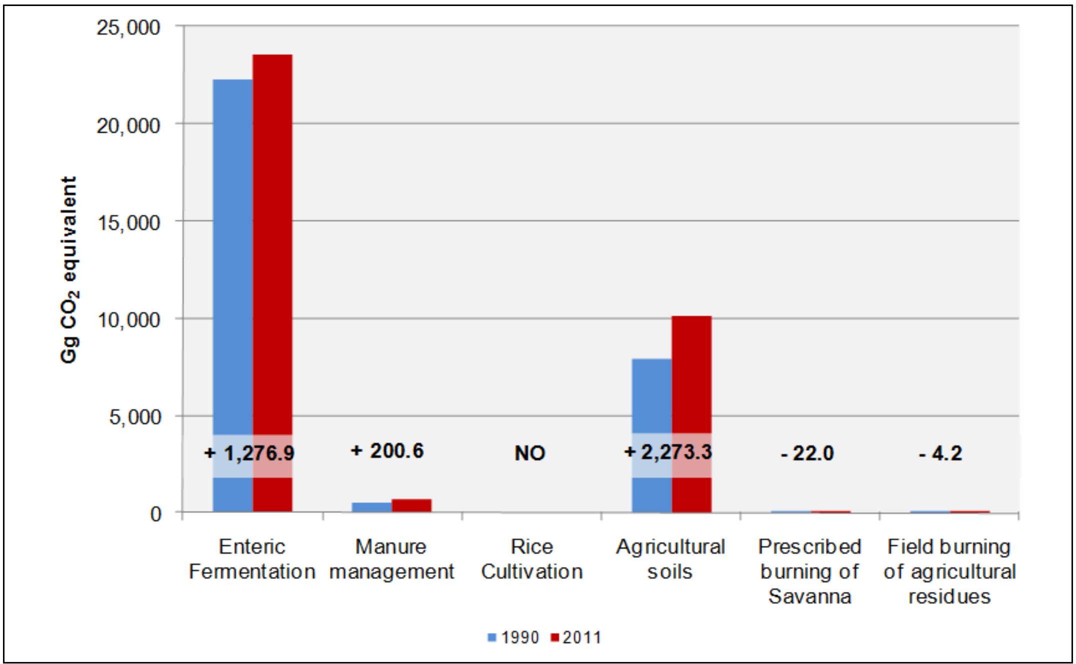
In 2011, the agriculture sector contributed 34,387.3 Gg carbon dioxide equivalent emissions (Gg CO_2-e) (47.2 per cent) to New Zealand's total greenhouse gas emissions. Emissions in this sector have increased by 3,725.4 Gg CO_2-e (12.1 per cent) from the 1990 level of 30,661.9 Gg CO_2-e (figure 6.1.1). The increase since 1990 is primarily due to a 1,276.9 Gg CO_2-e (5.7 per cent) increase in methane (CH_4) emissions from the enteric fermentation category and a 2,274.1 Gg CO_2-e (28.8 per cent) increase in nitrous oxide (N_2O) emissions from the agricultural soils category (figure 6.1.2).

Figure 6.1.1 New Zealand agriculture sector emissions from 1990 to 2011



In 2011, CH_4 emissions from enteric fermentation were 68.4 per cent (23,517.7 Gg CO_2-e) of agricultural emissions and 32.3 per cent of New Zealand's total emissions. Nitrous oxide emissions from the agricultural soils category were 29.5 per cent (10,158.6 Gg CO_2-e) of agricultural emissions and 13.9 per cent of New Zealand's total emissions.

Figure 6.1.2 Change in New Zealand's emissions from the agriculture sector from 1990 to 2011



Note: Rice cultivation does not occur (NO) in New Zealand.

Agriculture is a major component of the New Zealand economy, and agricultural products comprise 58 per cent of the total value of merchandise exports (http://www.mpi.govt.nz/news-resources/publications.aspx?title=Primary%%2020Industries%20production%20and%20trade). This is facilitated by the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the use of year-round extensive outdoor grazing systems and a reliance on nitrogen fixation by legumes rather than nitrogen fertiliser as the nitrogen source.

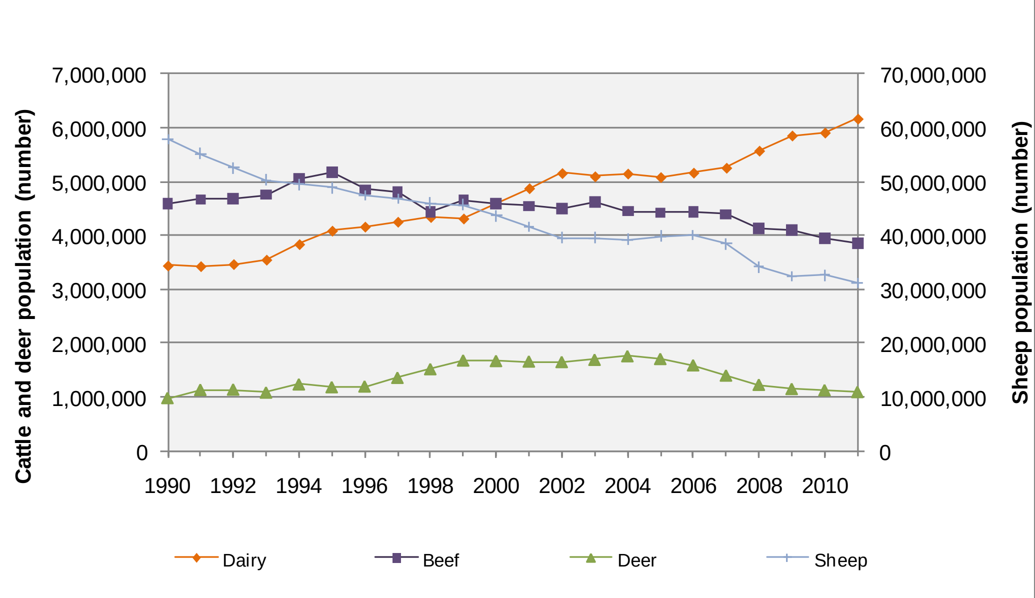
Dairy cattle, beef cattle, sheep and deer are grazed outside all year round. This means that New Zealand, like Australia, has a much lower proportion of agricultural emissions from manure management compared with other Annex 1 Parties, as intensive housing of major livestock is not practised in New Zealand. For further information of New Zealand's favourable agricultural growing conditions see chapters 1 and 2 (Executive summary and National Circumstances) of New Zealand's fifth national communication (www.mfe.govt.nz/publications/ climate/nz-fifth-national-communication/page3.html).

These chapters provide evidence of New Zealand's climate conditions, rainfall and temperature by region and season and, therefore, why there are no regions in New Zealand that need to house cattle, sheep and deer at any time of the year.

6.1.1 Trends in the agriculture sector

Since 1990, there have been changes in the proportions of the main livestock species farmed in New Zealand as the profitability of dairy products has become relatively higher compared with sheep and beef products. Pastoral land used for dairy has increased and pastoral land used for sheep and to a lesser extent beef has decreased (figure 6.1.3). Since 1990, there has also been more forestry on areas that were previously sheep pasture.

Figure 6.1.3 Population of New Zealand's major ruminant livestock from 1990 to 2011 – as at 30 June



Source: Provisional Agriculture Production Statistics 2012 (Statistics New Zealand)

There was a gradual increase in the implied emission factors per head for dairy cattle and beef cattle that reflects the increased levels of productivity (milk and meat yield per head) achieved by New Zealand farmers between 1990 and 2011. Increases in animal liveweight and performance (milk yield and liveweight gain per animal) require increased feed intake by the animal to meet higher energy demands. Increased feed intake results in increased CH_4 emissions per animal. In 2008, there was a nationwide drought that affected livestock numbers and productivity, resulting in lower livestock emissions. The implied emission factors have started to increase again now seasonal growing conditions have improved.

The land area used for horticulture has increased since 1990 and the types of produce grown have changed. There is now less cultivated land area for barley, wheat and fruit but more for grapes (for wine production) and vegetable production than in 1990. There has also been a net increase in land planted in forestry, reducing the land available for agricultural production.

Changes in emissions between 2010 and 2011

Total agricultural emissions in 2011 were 665.0 Gg CO_2-e (2.0 per cent) higher than the 2010 level, which is attributable to the favourable growing weather and the good grass growth. There was an increase in emissions due to increases in the population of dairy cattle (259,051 or 4.4 per cent) and volume of nitrogen fertiliser (27,303 tonnes or 7.6 per cent). This increase in dairy and fertiliser emissions outweighed emission reductions from decreases in the population of sheep (1,430,283 or 4.4 per cent), non-dairy cattle (102,106 or 2.6 per cent) and deer (34,162 or 3.0 per cent). The increase in dairy cattle numbers and the reduction in non-dairy cattle, sheep and deer are primarily due to higher relative returns being achieved in the dairy sector. The dairy industry is the main user of nitrogen fertiliser in New Zealand. The milk price was higher during 2011 compared with 2010 (Ministry of Agriculture and Forestry, 2011) and this increased the sale and use of nitrogen fertiliser.

6.1.2 Key categories in agriculture

Full details of New Zealand's key category analysis are presented in section 1.5. Key agriculture sector categories identified in the 2011 level assessment include:

- Methane from enteric fermentation of dairy cattle.
- Methane from enteric fermentation of non dairy cattle
- Methane from enteric fermentation of sheep.
- Methane from enteric fermentation of deer
- Methane from manure management.
- Nitrous oxide from agricultural soils, pasture, range, and paddock.
- Nitrous oxide from agricultural soils, indirect emissions.
- Nitrous oxide from agricultural soils, direct emissions.

Key agriculture sector categories identified in the 2011 trend assessment include:

- Methane from enteric fermentation of dairy cattle.
- Methane from enteric fermentation of non dairy cattle
- Methane from enteric fermentation of sheep.
- Methane from enteric fermentation of other.
- Nitrous oxide from agricultural soils, pasture, range, and paddock.
- Nitrous oxide from agricultural soils, direct emissions.

6.1.3 Methodological issues for the agriculture sector

New Zealand Tier 2 model for determining energy requirements for key livestock categories

Methane from enteric fermentation and manure management, and N_2O from nitrogen excretion from the four largest categories in the New Zealand ruminant population (dairy cattle, beef cattle, sheep and deer), are calculated using New Zealand's Tier 2 method (Clark et al, 2003). This method uses a detailed livestock population characterisation and livestock productivity data to calculate energy requirements and feed intake. From the calculated feed intake, annual calculations of enteric CH_4 and N_2O emissions are derived.

New Zealand uses a different characterisation for dairy and beef cattle compared with that recommended in the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines, the IPCC good practice guidelines and the 2006 IPCC good practice guidance. In the New Zealand inventory, dairy cattle encompass all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls.

All other cattle in New Zealand tend to be used for the breeding of animals that are slaughtered for meat consumption. These animals are characterised as beef animals. These include non-dairy breeding lactating cows used for breeding slaughter animals from calves, dry cows, bulls and all slaughter classes. The full characterisation list for both of these animal populations can be found in the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz/news-resources/statistics-forecasting/international-trade.aspx).

Activity data

Population data from Statistics New Zealand's annual Agricultural Production Survey and census (annex 3.1), and productivity data from New Zealand Dairy Statistics, Beef and Lamb New Zealand and slaughter statistics collected by the Ministry for Primary Industries are all used by the model to estimate greenhouse gas emissions. Most of this data is collected on a June year-end basis but the inventory is calculated on a calendar year. New Zealand uses a June year for animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. The models developed to estimate agricultural emissions work on a monthly time step, beginning on 1 July of one year and ending on 30 June of the next year. To calculate emissions for a single calendar year (January–December), calculated emission data from the last six months of a July–June year is combined with the first six months' emissions of the next July–June year. This is carried out so that New Zealand's emissions inventory is on a calendar year basis comparable with many countries.

Major species

Livestock population data

The detailed livestock population characterisation for each livestock type is subdivided in the population models. These population models estimate species subcategory population changes throughout the year on the monthly time step required by the inventory model, and have been developed by using industry knowledge and assumptions as detailed in Clark (2008b). The populations within a year are adjusted on a monthly basis to account for births, deaths and transfers between age groups. This is necessary because the numbers present at one point in time may not accurately reflect the numbers present at other times of the year. For example, the majority of lambs are born and slaughtered between August and May and, therefore, do not appear in the June census or survey data. Details of the subcategories for dairy cattle, beef cattle, sheep and deer are reported in the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Dairy livestock numbers are calculated on a regional basis and, therefore, regional dairy population numbers are used to take into account regional differences in production (Clark, 2008a).

Statistics New Zealand collects population data on a territorial authority basis. Territorial authorities are the lowest local political division in New Zealand. Territorial authorities are then aggregated up to regional council boundaries by Statistics New Zealand. In 1993, the regional council boundaries changed. Therefore, dairy population data for 1990–1993 were collected from Statistics New Zealand at a territorial authority level and then aggregated up to the regional council boundaries currently used. From 1993, Statistics New Zealand supplied livestock population data at the required regional council aggregation and, therefore, no manipulations of data were required.

Livestock productivity data

Productivity data comes from Livestock Improvement Corporation Ltd (LIC, 2011), Beef and Lamb New Zealand and slaughter statistics collected by the Ministry for Primary Industries. To ensure consistency, the same data sources are used each year.

The slaughter weights of all livestock exported from New Zealand are collected by the Ministry for Primary Industries from all slaughter plants in New Zealand. This information is used as a surrogate for changes in animal liveweight over time. Other information, such as the liveweight of dairy cattle and breeding bulls, is collected at irregular intervals from small survey populations, or is not available. Where limitations occur, expert opinion and extrapolation from existing data are used.

Livestock productivity and performance data are summarised in the time-series tables in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate/). The data includes average estimated liveweights, milk yields and milk composition of dairy cows, average liveweights of beef cattle (beef cows, heifers, bulls and steers), average liveweights of sheep (ewes and lambs) and average estimated liveweights of deer (breeding and growing hinds and stags).

The inventory model was developed to conform to the revised 1996 IPCC guidelines and the IPCC good practice guidance and is constantly under improvement. To ensure consistency, a single livestock population characterisation and feed-intake estimate is used to estimate CH_4 emissions for the enteric fermentation category, CH_4 and N_2O emissions for the manure management category and N_2O emissions for the pasture, range and paddock manure subcategory.

Dairy cattle: Data on milk production is provided by the Livestock Improvement Corporation, a dairy-farmer-owned company providing services to the dairy, beef and deer industries. This data includes the amount of milk processed through New Zealand dairy factories largely for export and milk for the domestic market.

Productivity data (milk yield and composition) are collected by the Livestock Improvement Corporation at the same territorial authority level as the population data is collected by Statistics New Zealand. Ministry for Primary Industries officials then aggregate this data up into the regional council boundaries used for the population data. Before 2004, not all productivity data required could be collected from the Livestock Improvement Corporation at a territorial authority level. Therefore, some extrapolations of data were required to obtain the required values. For example, from 1993–2003 annual milk yield per cow was determined by the following equation:

$$Litres\ milk\ per\ cow = \frac{Average\ kg\ milk\ fat\ per\ cow \times 100}{per\ cent\ milk\ fat}$$

From 2004, annual milk yields per animal have been obtained by dividing the total milk produced by the total number of milking dairy cows and heifers. For all years, lactation length is assumed to be 280 days. In 1992, no productivity data was available at a territorial authority level and, therefore, trends were fitted to data from 1990–2008 to estimate data.

Average liveweight data for dairy cows is obtained by taking into account the proportion of each breed in the national herd and its age structure based on data from the Livestock Improvement Corporation. Dairy cow liveweights are only available from the Livestock Improvement Corporation from 1996 onwards for six large livestock improvement regions, each comprising several regional councils. As there are 16 regional council regions, some regions have the same liveweight data as other regions. Due to the lack of liveweight data before 1996, liveweights prior to 1996 were estimated using the trend in liveweights from 1996 to 2008, together with data on the breed composition of the national herd.

Growing dairy replacement animals (calves) at birth are assumed to be 9 per cent of the weight of the average cow and reach 90 per cent of the weight of the average adult cow at calving (Clark et al, 2003). Growth between birth and calving (at two years of age) is divided into two periods: birth to weaning and weaning to calving. Higher growth rates are applied between birth and weaning, when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

No data is available on the liveweights and performance of breeding bulls, which can range from small Jerseys through to larger European beef breeds. It is assumed, based on expert opinion and taking into account industry data (Clark et al, 2003), that the average mature weight at 01 January is 500 kilograms and that they are growing at 0.5 kilograms per day. This gives an average weight (at the mid-point of the year) of 592 kilograms.

This is almost 25 per cent higher than the average weight of a breeding dairy cow but it is realistic given that some of the bulls will be of a heavier breed (eg, Friesian and some beef breeds). Total emissions are not highly sensitive to these assumed values because breeding bulls make only a small contribution to total animal numbers, for example, breeding dairy bulls contribute less than 0.1 per cent of emissions from the dairy sector.

Beef cattle: The principal source of information for estimating productivity for beef cattle is livestock slaughter statistics provided by the Ministry for Primary Industries. All growing beef animals are assumed to be slaughtered at two years of age, and the average weight at slaughter for the three subcategories (heifers, steers and bulls) is estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 per cent of an adult cow weight for heifers and 10 per cent of an adult cow weight for steers and bulls (Clark et al, 2003). As with dairy cattle, growth rates of all growing animals are divided into two periods: birth to weaning and weaning to slaughter. Higher growth rates are applied before weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

The carcass weights obtained from the Ministry for Primary Industries slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows. Therefore, a number of assumptions[19] are made to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow is assumed and is consumed by beef calves.

Sheep: Livestock slaughter statistics from the Ministry for Primary Industries are used to estimate the liveweights of adult sheep and lambs, assuming killing-out[20] percentages of 40 per cent for ewes and 45 per cent for lambs (Thomson et al, 2010). Lamb liveweights at birth are assumed to be 9 per cent of the adult ewe weight, with all lambs assumed to be born on 11 September (Thomson et al, 2010). Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size when subsequently mated at age 20 months. Adult wethers are assumed to be the same weight as adult breeding females. No within-year pattern of liveweight change is assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 per cent more than adult ewes (Clark et al, 2003). Wool growth (greasy fleece growth) is assumed to be 5 kilograms per annum in mature

19 The number of beef breeding cows was assumed to be 17 per cent of the total beef breeding cow herd and other adult cows slaughtered were assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 42 per cent. The total weight of dairy cattle slaughtered was calculated (carcass weight × number slaughtered) and then deducted from the national total carcass weight of slaughtered adult cows. This figure was then divided by the number of beef cows slaughtered to obtain an estimate of the carcass weight of adult beef cows. Liveweights were calculated assuming a killing-out percentage of 42.6 per cent (Thomson et al, 2010).

20 Percentage of carcass weight in relation to liveweight.

sheep (ewes, rams and wethers) and 2.5 kilograms per annum in growing sheep and lambs. Beef and Lamb New Zealand, the industry body representing the beef cattle and sheep industry, provides estimates of the total wool production from 1990 to 2011 from which the individual fleece weight is estimated.

Deer: Liveweights of growing hinds and stags are estimated from Ministry for Primary Industries slaughter statistics, assuming a killing-out percentage of 55 per cent. A fawn birth weight of 9 per cent of the adult female weight and a common birth date of mid-November are assumed. Liveweights of breeding stags and hinds are based on published data that have liveweights changing every year by the same percentage change recorded in the slaughter statistics for growing hinds and stags above the 1990 base. It is assumed there is no pattern of liveweight change within any given year. The lactation assumptions are 204 litres over 120 days, an average daily lactation yield of 1.7 litres per day (Suttie, 2012).

Dry-matter intake calculation

Dry-matter intake (DMI) for the major livestock classes (dairy cattle, beef cattle, sheep and deer) and sub-classes of animals (breeding and growing) is estimated by calculating the energy required to meet the levels of animal performance (metabolisable energy (ME)) and dividing this by the energy concentration of the diet consumed. For dairy cattle, beef cattle and sheep, energy requirements are calculated using algorithms developed in Australia (CSIRO, 2007). These algorithms are chosen because they specifically include methods to estimate the energy requirements of grazing animals, the feeding method used in New Zealand. This method estimates a maintenance requirement (a function of liveweight, the amount of energy expended on the grazing process) and production energy requirement needed for a given level of productivity (eg, milk yield and liveweight gain), physiological state (eg, pregnant or lactating) and the stage of maturity of the animal. All calculations are performed on a monthly basis. The equation below is the general equation from the Australian feeding standards. This has been adjusted to suit New Zealand conditions and the term ECOLD (additional energy expenditure in cold stress by animals in below lower critical temperature) has been removed as it was found not to apply to New Zealand conditions.

$$\mathbf{ME_m(MJ\ ME/d)} = \frac{K \times S \times M \times (0.28W^{0.75} \times \exp(-0.03A)}{km} + 0.1MEp + \frac{EGRAZE}{km}$$

Where:

ME_m	=	metabolisable energy
K	=	1.0 for sheep and 1.4 for cattle
S	=	1.0 for females and castrates or 1.15 for entire males
M	=	1 for animals except milk-fed animals. This factor has been removed in the New Zealand calculations and adjustment for milk-fed animals is carried out through a milk adjustment factor detailed later
W	=	liveweight (kg)
A	=	age in years, with a maximum value of 6
K_m	=	(net efficiency of use of ME for maintenance) $0.02 \times ME + 0.5$ where ME is the metabolisable energy (MJ ME per kg dry matter) of pasture that has a gross energy content of 18.4 MJ per kg dry matter
MEp	=	the amount of dietary ME being used directly for production (MJ ME/d). $0.1ME_p$ accounts for the accepted effect of feed intake level on the maintenance metabolism of ruminants (CSIRO, 2007)

EGRAZE = additional energy expenditure of grazing compared with similar housed animals (MJ ME/d).

The algorithms take into account animal liveweight and production requirements based on the rate of liveweight gain, sex, milk yield and physiological state. Total energy requirements for deer are the sum of the energy required for maintenance, milk production, conception/gestation, liveweight gain and velvet production.

For detailed methodology and examples of activity data see the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Monthly diet energy concentrations

A single data set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer are used for all years in the time series. This is because there is no comprehensive published data available that allows the estimation of a time series dating back to 1990. The data used are derived from research trial data and publications, and supplemented with actual data from farm surveys on commercial cattle and sheep farms.

Other minor livestock categories

For goats, horses, swine, poultry and alpaca, the revised 1996 IPCC guidelines Tier 1 methodology is used with a combination of default and country-specific emission factors. The country-specific emission factors are detailed in the relevant sections.

The populations of goats, horses and swine are reported using the animal census (or survey) data from Statistics New Zealand. The population of alpacas is provided by the Alpaca Association New Zealand (AANZ), where available, and supplemented by adjusted data from Statistics New Zealand (Henderson and Cameron, 2010).

During 2012 it was determined there are small herds of buffalo and donkeys in New Zealand. Statistics New Zealand, advised that, in 2011, there were 192 buffalo and 141 donkeys. Mules and asses are not farmed commercially in New Zealand and are not used as beasts of burden in New Zealand. A small donkey population supports breeding for pets and children’s rides at parks. A constant population of 141 donkeys has been included in the inventory under mules and asses.

Buffalo were brought into New Zealand around 2007 as a trial (approximately 60 head), and, since then, the herd has averaged around 200. The buffalo are used for milking to produce mozzarella cheese for the restaurant industry, and given the highly specialised nature of the product the herd size is not expected to increase. The buffalo farm has been reporting its livestock within the dairy herd so the notation key included elsewhere (IE) is used for buffalo.

Statistics New Zealand provides estimates of average annual broiler flock sizes using industry data on the numbers of broilers processed every year since 1990, mortality rates and days alive. Statistics New Zealand also obtains estimates of the number of layers and other poultry (eg, ducks, turkeys and breeder) from the animal census (or survey).

The average annual flock size is determined by the following equation:

Average annual flock size = (days alive)/365 × Annual numbers of bird processed/(1- rate of mortality).

6.1.4 Recalculations

Agriculture emissions research

Two parallel national inter-institutional expert groups, New Zealand Methanet and New Zealand NzOnet, have been running for 10 years. The groups were formed to identify the key strategic directions of research into the CH_4 and N_2O inventory and mitigation, and to develop a collaborative approach to improve the certainty of CH_4 and N_2O emission data. These expert groups are supported through the Ministry for Primary Industries. The improved uncertainty analysis and the implementation of the Tier 2 approach for livestock are a consequence of the research identified and conducted by the expert groups.

The Pastoral Greenhouse Gas Research Consortium has been established to carry out research, primarily into mitigation technologies and management practices for ruminants but also on improving on-farm inventories. The consortium is funded from both public and private sector sources.

New Zealand has also set up the New Zealand Agricultural Greenhouse Gas Research Centre, comprising eight of New Zealand's research providers including the Pastoral Greenhouse Gas Research Consortium. The aim of the Centre is to contribute to the agricultural greenhouse gas mitigation strategy through research programmes and international collaboration. It also seeks to enhance New Zealand's research capability and infrastructure in this area. Funding is made available through the Primary Growth Partnership funded by the New Zealand Government. The results of research by the Centre will also feed into improving the national inventory.

Recalculation and improvement approval process in the agriculture sector

The process for developing improvements and agreeing methodology changes in the agriculture inventory are shown in the flow chart figure 6.1.4.

The New Zealand Methanet and New Zealand NzOnet networks meet regularly during the year and present their research findings. When research projects are sufficiently developed they are assessed by the leaders of each network to choose those projects considered suitably developed to be included in the agriculture inventory. The research is contracted to address specific questions related to gaps in our knowledge or where current parameters are reviewed and tested. The draft research reports are reviewed by an external independent expert with knowledge in the field. The final report must include the reviewer's comments and the author's consideration of the comments.

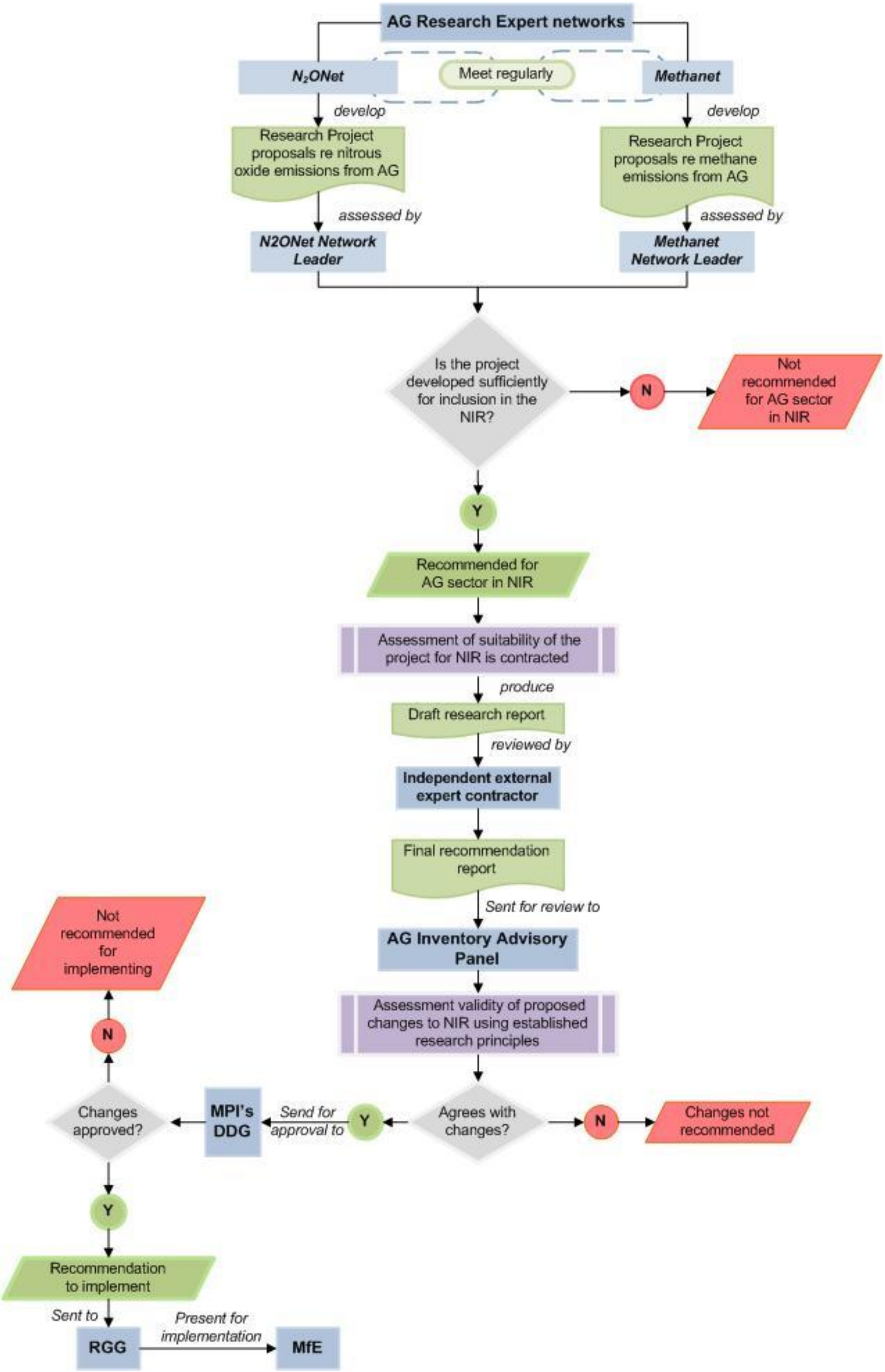
A briefing and the final report are sent to the Agriculture Inventory Advisory Panel (the Panel) to review proposed changes. The Panel, formed in 2009, comprises representatives from the Ministry for Primary Industries, the Ministry for the Environment and science representatives from the Royal Society of New Zealand, New Zealand Methanet and New Zealand NzOnet expert advisory groups. The Panel is independent of policy and industry influences and has been formed to give advice on whether changes to New Zealand's agricultural section of the national inventory are scientifically justified. The Panel assesses if the proposed changes have been appropriately researched, using recognised scientific principals, and if there is sufficient scientific evidence to support the change(s). The 2012 meeting of the Panel was held on 13 November 2012 where a range of changes for deer were recommended for inclusion into the agricultural greenhouse gas inventory for the 2013 submission. The briefs, reports and minutes of the Panel meeting have been placed on the Ministry for Primary Industries website: www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory-panel.

The Reporting Governance Group is chaired by the Ministry for the Environment and leads the reporting, modelling and projections of greenhouse gas emissions and removals across government. Membership includes managers from the Ministry for the Environment, Ministry for Primary Industries, Environmental Protection Authority and the Ministry of Business, Innovation and Employment. During the course of the year, recalculations being considered by all sectors are proposed to the Reporting Governance Group. Further details of the Reporting Governance Group are provided in section 1.2.2.

Once changes are agreed by the Panel they are sent to the Deputy Director-General of the Ministry for Primary Industries for consideration. The Deputy Director-General then recommends which changes should be presented to the Ministry for the Environment for implementation to the annual inventory materials.

The changes recommended by the Panel are detailed in the relevant recalculation and methodology sections of the national inventory report.

Figure 6.1.4: Agriculture sectoral approval process for recalculations and improvements



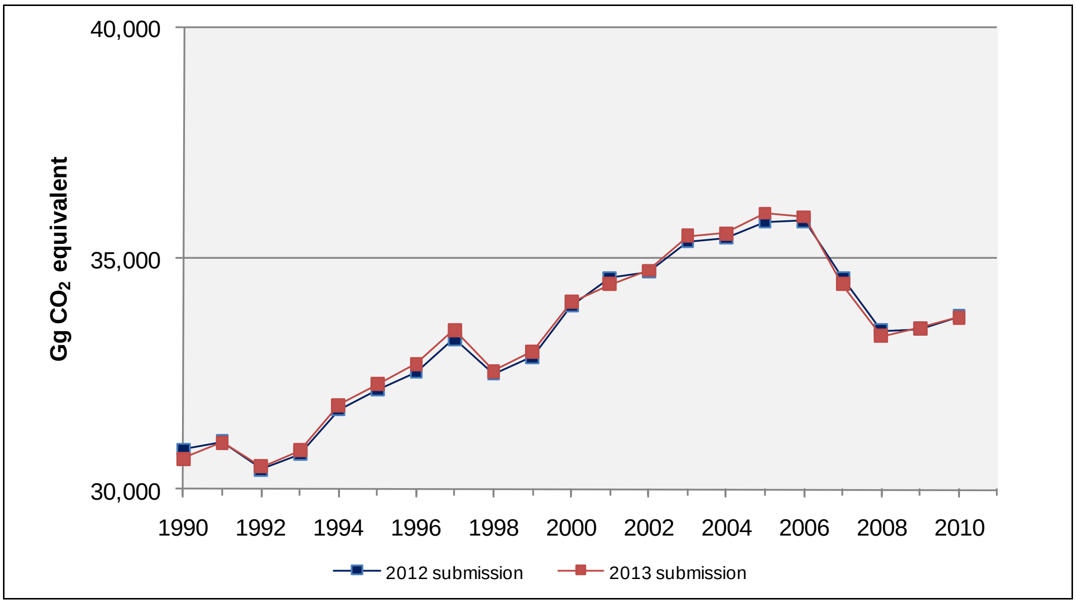
Note: AG = agriculture; DDG – Deputy Director-General; MfE = Ministry for Environment; MPI = Ministry for Primary Industries; NIR = national inventory report; N_2O – nitrous oxide; RGG = Reporting Governance Group (for the NIR).

Recalculations approved for the 2013 Inventory submission in the agriculture sector

For the 2013 annual submission, recalculations were made for the dairy, beef and sheep population models agreed by the 2011 Agriculture Inventory Advisory Panel but not implemented until the 2013 annual submission. Changes were also made to the parameters for the productivity and energy equations for deer agreed during the 2012 Panel. The recalculation for these activities will result in recalculations in enteric fermentation, manure management and agriculture soils. These are discussed in further detail in the relevant sector recalculation sections 6.2.5 (enteric fermentation), 6.3.5 (manure management), 6.5.5 (agricultural soils) and 6.7.5 (field burning of agricultural soils). A summary of recalculations is provided in section 10.1.4.

The improvements made in the agriculture sector have resulted in a 0.6 per cent (193.3 Gg CO_2-e) decrease in agricultural emissions in 1990, and a 0.1 per cent (26.1 Gg CO_2-e) decrease in agricultural emissions in 2010. The improvements that made the largest change in emissions in the agriculture sector are the changes to the Tier 2 model used to estimate emissions from dairy, beef, sheep and deer. Figure 6.1.5 shows a comparison of emission estimates for 1990 to 2010 from the 2012 submission with this submission.

Figure 6.1.5 Effect of recalculations on New Zealand's agriculture sector from 1990 to 2010



6.1.5 Quality assurance and quality control (QA/QC)

The compilation of the agriculture greenhouse gas inventory is performed by the team responsible for primary industries (agriculture, forestry and fishing) data collation. The team's role includes liaising with Statistics New Zealand and forecasting primary industries activity and performance. This arrangement provides for a good understanding and quantitative judgement of activity data and agriculture performance. The connection with Statistics New Zealand ensures that the statistical collection work keeps pace with the changes in the primary industries sector and provides for the tracking of possible new activities and management practices in the primary industries sector. There are also strong connections with secondary data sources such as Beef and Lamb New Zealand, the Livestock Improvement Corporation and the Fertiliser Association of New Zealand.

The draft national inventory report is reviewed by Ministry for Primary Industries policy teams with expertise in climate change policy, climate change science, livestock and cropping policy. This ensures that activity trends and emissions trends are reviewed at a high level and that the results from the national inventory are used to inform domestic climate change policy.

The agriculture inventory experts meet regularly at the Ministry for the Environment with the team responsible for coordinating the annual inventory submission. The Ministry for the Environment monitors Ministry for Primary Industries progress in implementing recommendations from previous expert review reports and on meeting timelines during the year.

The Ministry for the Environment also manages an internal guidance document 'New Zealand's National Inventory System Guidelines for compiling New Zealand's Greenhouse Gas Inventory'. This document provides domestic guidelines for sector leaders to follow, including the decisions under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and the application of these decisions within the Kyoto Protocol. The document also includes New Zealand's QA/QC plan followed by all Sector Leads.

The Ministry for Primary Industries participates in the annual inventory debrief coordinated by the Ministry for the Environment to ensure the national inventory compiler and each sector lead understands what is working well and where improvements could be made.

During the compilation of the 2013 submission, an external audit firm (Deloitte) with specialist skills in QA and QC management, was engaged to advance and improve our QA/QC processes. The results will be reported in the 2014 submission. New Zealand will use this feedback to update and improve the QA/QC methodology. The recommended improvements resulting from the review will be prioritised and implemented in future submissions.

The scope of the Deloitte review includes:

- a review of the existing QA/QC tools including: analytical testing of results, sample testing calculations against stated methodology, reviewing the reconciliation of outputs from the previous Delphi-based model with the current model and sample testing formulae for consistency across different time periods
- a review of the QA/QC process including assessing: controls, the QA/QC plan and procedures, observing data input processes and calculation processes, and making recommendations for potential process improvements.
- a review of record-keeping and archiving processes.

A process of quality control checks is mandated in the internal compilation process and is provided below.

Activity data

- New activity data is cross-checked for accuracy and completeness by someone not involved in the data input and primary compilation.

- New data on activity and year-to-year time variance is reviewed by commodity analysts and economic modellers to ensure the data is consistent and reflects the domestic situation.
- Where practical, key historical data is re-checked concurrently with updating the latest data.
- Records of data inputs and checks are recorded in a data check table. The data check table is included with the managerial sign-off materials before delivery to Ministry for the Environment.

Emissions

- Implied emissions factors are checked over time (1990 to most recent year) and against previous submissions. Any anomalies are investigated.
- Key category emissions are compared against Tier 1 default methodologies and against similar Parties, particularly Australia. A challenge for New Zealand is the lack of countries with similar agricultural circumstances and management practices. For example, New Zealand's Tier 2 livestock are all outdoors on pasture in all seasons.
- Total emissions and key activity data from the common reporting format (CRF) are checked for accuracy against total emissions and activity in the workbooks. Sub-sector totals are also checked. All checks are to a high level of precision.
- Emissions results are compared with other emissions estimates from other tools including farm level reporting tools such as the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003) and with the reporting required under the New Zealand Emissions Trading Scheme.

Recalculations

- Recalculations are agreed with the Ministry for the Environment and the Reporting Governance Group every year before the inventory compilation commences.
- Recalculations are compared with previous submissions and, as far as possible, changes in emissions are explained and confirmed by the changes in method or activity data.
- Anomalous results from recalculations are checked and, if necessary, corrected.
- The agriculture inventory compiler completes recalculation forms, signs the forms and forwards them to Ministry for the Environment.

Periodic reviews

- Periodic reviews are done on different aspects of the inventory. In recent years, the population models and animal productivity parameters have been reviewed (eg, Thomson et al, 2010). During 2013 the nitrogen retention rates in liveweight gains, milk protein and fibre will be reviewed.
- During the 2012 submission new crops were included for the first time and a new complex methodology was implemented. For the 2013 submission, Plant and Food Research, which has expertise in this area, has been hired to review the workbooks, check the formulae and model parameters.

Model improvements

- The original model for calculating Tier 2 emissions in the agriculture sector dates back to 2003. It had been developed using computer language Delphi, which is not in common use. During 2011 and 2012 the model for calculating Tier 2 emissions was converted from Delphi to Excel VBA. The advantage of Excel VBA language is that it is more widely understood and available. During the conversion, any noted errors in formulas and processes were documented. Once the conversion was complete, a parallel run of the data between the new and the original model could be done to test the data integrity.
- The results obtained from running the same data set between the Delphi-based model and the Excel VBA based model as part of the model testing were used for the reconciliation and validation process during development. Deloitte reviewed the results of the reconciliation process undertaken by the model developer as a part of its 2012/2013 review of the QA/QC practices for the agriculture sector. Detailed testing of the underlying formulae or VBA code was outside of the scope of this review.

Error checking and reporting

- Errors confirmed during the year are recorded, and the national inventory compiler is notified. The factors contributing to the error (if any) are assessed.
- As part of a review of QA/QC procedures by Deloitte, a sample of workbooks will be tested with proprietary diagnostic tools to test formulae consistency across time periods.
- An issues register was maintained throughout the QA/QC review process that includes a description of agreed actions to resolve each issue.
- A risk register is kept up to date and is used to prioritise key sources of risk to the agriculture inventory compilation and results.
- The agriculture chapter of the National Inventory Report and the data exported to the Common Reporting Format reporter are signed off by the compiler, persons involved in data checking and the manager responsible for the staff.

Documentation

- Internal working instructions are maintained to allow for staff movements.
- Workbooks and calculation sheets are kept on an electronic archiving and management system, enabling wider team access to all workbooks.
- Hyperlinks between check sheets, sign off documents and workbooks are used to link relevant files on the document management system.

Training and development

- Staff involved with the compilation of the agriculture greenhouse gas inventory are encouraged to complete the UNFCCC and Kyoto Protocol national system training and participate in expert review teams to develop review experience and learn from what other countries are doing.

6.1.6 Planned improvements

Short-term improvements include:

- a review of research specific to New Zealand of indirect emissions of N_2O from leaching and run-off (EF_5)
- nitrogen retention rates in liveweight gain, milk protein and fibre for Tier 2 livestock
- the effect of slope on N_2O emissions from excreta (beef, sheep and deer) deposited on grazed hill country
- a review of the robustness of existing New Zealand spatial data and information on pasture quality and nitrogen content to support further regional disaggregation of the inventory; if the data and information are not sufficiently robust the project will make recommendations for further research
- a review of the treatment of uncertainty.

Longer term trials are also being done to improve the estimates of:

- the relationship between DMI and CH_4 emissions from enteric fermentation for sheep and lactating cattle
- the direct N_2O emissions factor (EF_1) and ammonium emissions for urea nitrogen fertiliser and dairy shed effluent under a range and combination of treatments with nitrogen inhibitors including Urease
- methane emissions from anaerobic dairy effluent ponds.

These specific planned improvements are discussed in further detail in the relevant sector recalculation sections 6.2.6 (enteric fermentation (CRF 4A)), 6.3.6 (Manure management CRF 4B) and 6.5.6 (Agricultural soils CRF 4D).

As at 22 March 2013 New Zealand’s North Island and parts of the South Island have been declared to be in drought. At the time of the national inventory being finalised there are indications that some field trials will be affected and temporarily suspended until normal weather patterns return. This may delay some of the planned improvements.

6.2 Enteric fermentation (CRF 4A)

6.2.1 Description

Methane is a by-product of digestion in ruminants, for example, cattle and some non-ruminant animals, such as swine and horses. Within the agriculture sector, ruminants are the largest source of CH_4. The amount of CH_4 released depends on the quantity of feed consumed, which is determined by the type, age and weight of the animal, animal production, feed quality and the energy expenditure of the animal.

Methane emissions from the dairy cattle and sheep enteric fermentation category were identified as the largest key categories for New Zealand in the 2010 level assessment. Methane emissions from sheep enteric fermentation and dairy cattle enteric fermentation were also assessed as key categories for trend assessment. In accordance with IPCC good practice guidance (IPCC, 2000), the methodology for estimating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

In 2011, enteric fermentation contributed 23,517.7 Gg CO_2-e. This represented 32.3 per cent of New Zealand's total CO_2-e emissions and 68.4 per cent of agricultural emissions. Dairy and beef cattle contributed 15,242.4 Gg CO_2-e (64.8 per cent) of emissions from the enteric fermentation category, and sheep contributed 7,750.6 Gg CO_2-e (33.0 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2011 were 1,275.1 Gg CO_2-e (5.7 per cent) above the 1990 level of 22,240.8 Gg CO_2-e.

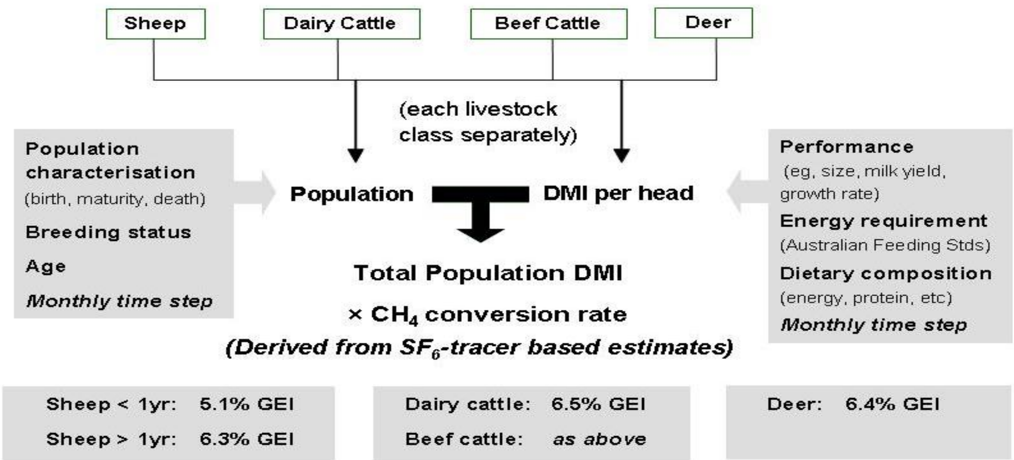
Since 1990, there have been changes in the relative sources of emissions within the enteric fermentation category. The largest increase came from emissions from dairy cattle. In 2011, dairy cattle were responsible for 10,381.8 Gg CO_2-e, an increase of 5,405.3 Gg CO_2-e (108.5 per cent) from the 1990 level of 4,976.5 Gg CO_2-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations, such as goats, horses and swine. In 2011, emissions from sheep were 7,750.6 Gg CO_2-e, a decrease of 3985.6 Gg CO_2-e (34.0 per cent) from the 1990 level of 11,736.1 Gg CO_2-e.

6.2.2 Methodological issues

Emissions from cattle, sheep and deer

Using the DMI per head and population data calculated by New Zealand's Tier 2 inventory model (section 6.1.3), the total amount of CH_4 emitted is calculated using CH_4 emissions per unit of feed intake (figure 6.2.1).

Figure 6.2.1 Schematic diagram of how New Zealand's emissions from enteric fermentation are calculated



Note: GEI is the gross energy intake and DMI is the dry-matter intake.

The equation for the total production of methane (kilogram CH_4 per head) is:

$$M = (DMI \times CH_4 \text{ conversion rate}/1{,}000).$$

Where: M = methane from enteric fermentation (kg CH_4 per head)

DMI = dry-matter intake (kg DM per head)

CH_4 conversion rate values are detailed in table 6.2.1 (g CH_4 per kg DMI).

Methane emissions per unit of feed intake (CH_4 conversion factor)

There are a number of published algorithms and models[21] of ruminant digestion for estimating CH_4 emissions per unit of feed intake. The data requirements of the digestion models make them difficult to use in generalised national inventories and none of the methods have high predictive power when compared against empirical experimental data. Additionally, the relationships in the models have been mainly derived from animals fed indoors on diets unlike those consumed by New Zealand's grazing ruminants.

Since 1996, New Zealand scientists have been measuring CH_4 emissions from grazing cattle and sheep using the sulphur hexafluoride (SF_6) tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data-sets in the world of CH_4 emissions determined using the SF_6 technique on grazing ruminants. To obtain New Zealand-specific values, published and unpublished data on CH_4 emissions from New Zealand were collated and average values for CH_4 emissions from different categories of livestock were obtained. Sufficient data was available to obtain values for adult dairy cattle, sheep more than one year of age and growing sheep (less than one year of age). This data is presented in table 6.2.1 together with the IPCC default values for per cent gross energy (GE) used to produce CH_4 (IPCC, 2000). The New Zealand values fall within the IPCC range and are applied in this submission. Table 6.2.2 shows a time series of CH_4 implied emission factors for dairy cattle, beef cattle, sheep and deer.

Table 6.2.1 Methane emissions from New Zealand measurements and IPCC default values

	Adult dairy cattle	Adult sheep	Sheep < 1 year
New Zealand data (g CH_4/kg DMI)	21.6	20.9	16.8
New Zealand data (%GE)	6.5	6.3	5.1
IPCC (2000) default values (%GE)	6 ±0.5	6 ±0.5	5 ±0.5

The adult dairy cattle value is assumed to apply to all dairy and beef cattle, irrespective of age, and the adult ewe value is applied to all sheep more than one year of age. An average of the adult cow and adult ewe value (21.25 grams CH_4/kg DMI) is assumed to apply to all deer (Clark et al, 2003). In very young animals receiving a milk diet, no CH_4 is assumed to arise from the milk proportion of the diet. Not all classes of livestock are covered in the New Zealand data-set and assumptions are made for these additional classes.

Table 6.2.2 New Zealand's implied emission factors for enteric fermentation from 1990 to 2011

Year	Dairy cattle (kg CH_4 per animal per annum)	Beef cattle (kg CH_4 per animal per annum)	Sheep (kg CH_4 per animal per annum)	Deer (kg CH_4 per animal per annum)
1990	68.9	51.7	9.7	16.3
1991	72.4	53.0	9.9	16.8
1992	72.3	53.7	9.9	17.5
1993	73.8	54.9	10.1	17.8
1994	71.9	55.7	10.2	17.5
1995	71.9	54.8	10.1	18.2
1996	74.4	56.7	10.5	18.6
1997	74.9	57.6	10.9	18.8
1998	72.4	57.6	10.9	19.0
1999	74.7	56.1	10.9	19.1

[21] For example, Blaxter and Clapperton (1965); Moe and Tyrrel (1975); Baldwin et al (1988); Djikstra et al (1992) and Benchaar et al (2001) – all cited in Clark et al (2003).

Year	Dairy cattle (kg CH_4 per animal per annum)	Beef cattle (kg CH_4 per animal per annum)	Sheep (kg CH_4 per animal per annum)	Deer (kg CH_4 per animal per annum)
2000	76.3	58.1	11.4	19.5
2001	76.9	59.0	11.3	19.4
2002	76.3	58.9	11.5	19.4
2003	79.2	58.7	11.5	19.5
2004	77.6	59.8	11.8	19.8
2005	78.6	60.5	12.0	20.2
2006	78.3	61.6	11.7	20.4
2007	77.0	59.8	11.3	20.4
2008	76.5	59.1	11.5	20.7
2009	76.7	59.5	11.9	20.8
2010	78.7	59.5	11.5	20.8
2011	80.1	60.2	11.9	20.9

Emissions from other minor livestock categories

A Tier 1 approach is adopted for the minor livestock categories of goats, horses, swine and alpaca using either IPCC default emission factors (horses and alpaca) or New Zealand country-specific emission factors (goats and swine). These minor species comprised less than 0.2 per cent of total enteric CH_4 emissions in 2011.

Livestock population data

The populations of goats, horses, pigs and alpacas are reported using statistical data as reported in section 6.1.3.

Livestock emissions data

Goats: New Zealand uses a country-specific emission factor for enteric fermentation of 7.4 kilograms CH_4/head for 1990 and 8.5 kilograms CH_4/head for 2009 based on the differing population characteristics for those two years (Lassey, 2011). From 1990 to 2009, the population declined from 1,062,900 goats to 82,229 goats. Most of the decline in the herd was in the non-milking goat population. Therefore, for the intermediate years between 1990 and 2009 and for 2010 to 2011, the emission factor was interpolated based on the assumption that the dairy goat population has remained in a near constant state over time, while the rest of the goat population has declined.

Horses: In the absence of data to develop New Zealand emissions' factors, the IPCC 1996 default value (18 kilograms CH_4/head/year) was used to determine emissions from enteric fermentation from horses.

Swine: New Zealand uses a country-specific emission factor of 1.08 Kg CH_4/head/year (Hill, 2012). This is based on the lower Gross Energy value of feed fed to swine in New Zealand.

Alpacas*:* In the absence of further work carried out on alpacas in New Zealand, the 2006 IPCC guidelines default value (8 kilograms CH_4/head/year) has been used to estimate emissions from this category, but this default value is yet to be approved as a country-specific value.

Mules and asses*:* The IPCC default value from the revised 1996 IPCC guidelines was used (10 kilograms CH_4/head/year).

6.2.3 Uncertainties and time-series consistency

Livestock numbers

Many of the calculations in this sector require livestock numbers. Both census and survey data are used. Surveys occur each year between each census. Detailed information from Statistics New Zealand on the census and survey methods is included in annex 3.1.

Methane emissions from enteric fermentation

In the 2003 inventory submission, the CH_4 emissions data from domestic livestock in 1990 and 2001 was subjected to Monte Carlo analysis using the software package @RISK to determine the uncertainty of the annual estimate (Clark et al, 2003). In subsequent submissions, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value.

In 2009, the Ministry for Primary Industries commissioned a report that recalculated the uncertainty of the enteric fermentation CH_4 emissions for sheep and cattle (Kelliher et al, 2009). Since the Monte Carlo analysis carried out in 2003, there has been significant research in New Zealand on measuring enteric CH_4 emissions from sheep and cattle. The initial analysis expressed the coefficient of variation (CV) according to the standard deviation of the CH_4 yield. The report (Kelliher et al, 2009) investigated calculating the uncertainty by expressing the CV according to the standard deviation of the CH_4 yield. Further research conducted since 2003, has based this uncertainty analysis on a larger sample. The current analysis was restricted to one diet type; grass–legume pasture, the predominant diet of sheep and cattle in New Zealand. The new overall uncertainty of the enteric CH_4 emissions inventory, expressed as a 95 per cent confidence interval, is ±16 per cent (Kelliher et al, 2009), see table 6.2.3.

Table 6.2.3 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990 and 2011, estimated using the 95 per cent confidence interval of the mean of ±16 per cent

Year	Enteric CH_4 emissions (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	1,059.2	889.7	1,228.6
2011	1,119.9	940.7	1,299.1

Note: The CH_4 emissions used in the Monte Carlo analysis exclude those from swine, horses, goats, mules and asses, and alpaca.

Uncertainty in the annual CH_4 estimate is dominated by variance in the measurements of the 'methane per unit of intake' factor. For the measurements used to determine this factor, the CV (standard deviation as a percentage of the mean), the standard error was the standard deviation divided by the number of records raised to a power of 0.5 and is equal to 0.03. This uncertainty is predominantly due to natural variation from one animal to the next. Uncertainties in the estimates of energy requirements, herbage quality and population data are much smaller (0.005–0.05).

6.2.4 Source-specific QA/QC control and verification

In 2010, CH_4 from enteric fermentation was identified as a key category (level and trend assessment). In the preparation for this inventory, the data for this category underwent Tier 1 and Tier 2 quality checks.

Methane emission rates measured for 20 dairy cows and scaled up to a herd have been corroborated using micrometeorological techniques. Laubach and Kelliher (2004) used the integrated horizontal flux technique and the flux gradient technique to measure CH_4 flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up animal emissions. The emissions from the cows measured by integrated horizontal flux and averaged over three campaigns were 329 (±153) grams CH_4/day/cow compared with 365 (±61) grams CH_4/day/cow for the scaled-up measurements reported by Waghorn et al (2002; 2003) using the SF_6 technique. Methane emissions from lactating dairy cows have also been measured using the New Zealand SF_6 tracer method and respiration chamber techniques (Grainger et al, 2007). Total CH_4 emissions were similar, 322 and 331 grams CH_4/day/cow, when measured using calorimeter chambers or the SF_6 tracer technique respectively.

Table 6.2.4 shows a comparison of the New Zealand-specific 2010 implied emission factor for enteric fermentation with the IPCC Oceania default and the Australian and United Kingdom implied emission factors for dairy, beef cattle and sheep (IPCC 1996; IPCC 2000; UNFCCC 2011a; UNFCCC 2011b). All calculations in this model are based on the revised 1996 IPCC guidelines, the IPCC good practice guidance and IPCC good practice guidance for LULUCF and the 2006 IPCC guidelines.

New Zealand has a slightly higher implied emission factor for dairy than the IPCC Oceania default, due to the higher productivity of the livestock compared with the Oceania average. The converse is true when comparing the implied emission factor with Australia and the United Kingdom. New Zealand livestock have a predominant diet of good quality grass–legume pasture with a higher digestibility than the Oceania value, which is based on Australia and reported in table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996). This would result in a lower implied emission factor compared with Australia and the United Kingdom. Also, in New Zealand's Tier 2 inventory model, dairy cattle encompass all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls. By taking the emissions from these animals into account, the implied emission factor will be lower than if only mature milking cows had been taken into account.

New Zealand's emission factor for sheep is higher than the IPCC default, and higher than Australia's and the United Kingdom. New Zealand takes into account lambs when determining actual CH_4 emissions but not when estimating the implied emission factor. Therefore, a higher implied emission factor is calculated than when the lamb population is also taken into account. Other countries report an implied emission factor including lambs.

Table 6.2.4 Comparison of IPCC default emission factors and country-specific implied emission factors for methane from enteric fermentation for dairy cattle, beef cattle and sheep

	Dairy cattle (kg CH_4/head/year)	Beef cattle (kg CH_4/head/year)	Sheep[22] (kg CH_4/head/year)
IPCC (2006) Oceania default value	68	53	8
Australian-specific IEF 2010 value	115	72	7

[22] All values except for New Zealand include lambs in the implied emission factor calculation.

United Kingdom-specific IEF 2010 value	111	43	5
New Zealand-specific 2010 value[23]	79	60	11

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 22 February 2013.

Note: IEF = implied emission factor.

For beef cattle, the implied emission factor is similar to the IPCC 2006 default. Differences such as feed type and quality, which animals are characterised as non-dairy, breed and so on will, however, influence the implied emission factor.

Overall, IPCC default values and values from some countries for CH_4 emissions from cattle are also determined from relationships based on analyses of the higher-quality feeds, for example, grain diets, typically found in the United States of America's temperate agricultural system (IPCC, 1996). New Zealand CH_4 emissions from cattle have been based on algorithms related to a grass–legume pasture diet and will therefore produce different values.

6.2.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2012), Livestock Improvement Corporation statistics (2012)).

Enhancements to New Zealand's Tier 2 inventory model have resulted in recalculations of dairy, non-dairy, sheep and deer, including some recoding of the Tier 2 model into Visual Basic. The recoding is improving the usability of the model as well as increasing its transparency and accuracy.

The population model for livestock in the Tier 2 model uses assumptions on livestock birthdates, slaughter and culling to determine a monthly population profile. The population model assumptions for sheep and cattle have been revised following the work by Muir and Thomson (2010). These improvements were approved at the end of 2011 but were not fully implemented in the Tier 2 inventory model in time for the 2012 submission. The report by Muir and Thompson (2010) and the briefing to the Panel recommending changes are available on the Ministry for Primary Industries webpage: www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory-panel.

The deer population model assumptions, productivity and energy equations have been reviewed and revised following research completed and reported by Suttie (2012) and Bown et al (2012). These improvements were approved and recommended during the 2012 Panel meeting.

As noted in section 6.1.3, a small population of donkeys has been estimated for New Zealand and included under Mules and Asses, increasing enteric fermentation CH_4 emissions by 0.03 Gg CO_2-e in all years 1990 to 2011.

[23] As reported in New Zealand's Greenhouse Gas Inventory 1990–2010 (Ministry for the Environment, 2012).

6.2.6 Source-specific planned improvements

Further work into improving the values of the pasture metabolisable energy concentration, digestibility and nitrogen content used in the Tier 2 inventory model is being investigated.

A three-year project to estimate the relationship between DMI and CH_4 emissions in lactating cattle is due to start early 2013. The field study will use the the New Zealand Ruminant Methane Measurement Centre's purpose-built calorimeter chambers to measure the relationship between enteric fermentation emissions and DMI. As part of the study, milk yields and nitrogen sampling of the feed will be conducted. The results will be used to improve the estimates of CH_4 and nitrous emissions from dairy cattle.

6.3 Manure management (CRF 4B)

6.3.1 Description

In 2011, emissions from the manure management category comprised 682.9 Gg CO_2-e (2.0 per cent) of emissions from the agriculture sector. Emissions from manure management had increased by 200.6 Gg CO_2-e (41.6 per cent) from the 1990 level of 482.3 Gg CO_2-e.

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce CH_4. The amount of CH_4 emissions is related to the amount of manure produced and the amount that decomposes anaerobically. Methane from manure management was identified as a key category for New Zealand in the 2010 level assessment (excluding land use, land-use change and forestry (LULUCF)).

The manure management category also includes N_2O emissions related to manure handling before the manure is added to the soil. The amount of N_2O emissions depends on the system of waste management and the duration of storage. With New Zealand's extensive use of all-year-round grazing systems, this category contributed a relatively small amount of N_2O (35.7 Gg CO_2-e) in 2011. In comparison, N_2O emissions from the agricultural soils category totalled 10,158.6 Gg CO_2-e in 2011.

In New Zealand, only dairy cows have their excreta stored in anaerobic lagoon waste systems (Ledgard and Brier, 2004) and then it is only a fraction (5 per cent) of the total dairy effluent produced. The remaining 95 per cent of excreta from dairy cattle is deposited directly onto pasture. These fractions relate to the proportion of time dairy cattle spend on pasture compared with the time they spend in the milking shed. Other livestock species (sheep, beef cattle, goats, deer, alpaca and horses) graze outdoors all year and deposit all of their faecal material (dung and urine) directly onto pastures. This distribution is consistent with the revised 1996 IPCC guidelines (IPCC, 1996) for the Oceania region. New Zealand scientists and Ministry for Primary Industries officials consider the default distributions are applicable to New Zealand farming practices for the ruminant animals listed. Estimates of the proportions of different waste management systems for swine and poultry broilers in the manure management systems have been provided by Hill (2012) and Fick et al (2011) respectively. Table 6.3.1 shows the current distribution of livestock waste into different animal waste management systems in New Zealand. Emissions from the pasture, range and paddock, and daily spread animal management systems are reported under the agricultural soils category.

Table 6.3.1 Distribution of livestock waste across animal waste management systems in New Zealand

Livestock	Anaerobic lagoon (%)	Daily spread[24] (%)	Pasture, range and paddock[25] (%)	Solid storage and dry-lot (%)	Other (%)
Non-dairy cattle	–	–	100	–	–
Dairy cattle	5	–	95	–	–
Sheep	–	–	100	–	–
Deer	–	–	100	–	–
Goats	–	–	100	–	–
Horses	–	–	100	–	–
Swine[26]	21	26	9	42	2
Poultry – Broilers[27]	0	–	4.9	0	95.1
Poultry – Layers[27]	–	–	5.8	–	94.2
Poultry – Other[28]	–	–	3	–	97
Alpaca	–	–	100	–	–
Mules and asses	–	–	100	–	–

6.3.2 Methodological issues

Methane from cattle, sheep and deer

A Tier 2 approach, which is consistent with the revised 1996 IPCC guidelines and the IPCC good practice guidance, is used to calculate CH_4 emissions from ruminant animal wastes from cattle, sheep and deer in New Zealand. The Tier 2 approach is based on the methods recommended by Saggar et al (2003).

The approach relies on (1) an estimation of the total quantity of faecal material produced; (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons; and (3) the development of New Zealand-specific emission factors for the quantity of CH_4 produced per unit of faecal dry matter deposited directly onto pastures and that stored in anaerobic lagoons.

Faecal dry-matter output is calculated monthly for each species' subcategory from the follow equation:

$$FDM = DMI \times (1\text{-}DMD)$$

Where:

FDM = faecal dry-matter output

DMI = dry-matter intake

DMD = dry-matter digestibility.

These feed intake and dry-matter digestibility estimates are the same as are used in the enteric CH_4 and N_2O estimates. Tier 2 model calculations are based on animal performance (section 6.1.1). Table 6.3.2 summarises the key New Zealand-specific variables in the calculation of CH_4 from manure management, including the proportion of

24 Reported under 'agricultural soils' under direct soil emissions from agricultural fields.

25 Reported under 'agricultural soils' under direct soil emissions from animal production.

26 Hill (2011).

27 Fick et al (2011) and pers. comm.; 2010 estimates shown.

28 IPCC (1996) default waste management proportions for Oceania.

this faecal matter deposited on pasture and anaerobic lagoons and the country-specific CH_4 yields determined from each.

Table 6.3.2 Derivation of methane emissions from manure management in New Zealand

Animal species	Proportion of faecal material deposited on pasture (%)	CH_4 from animal waste on pastures (g CH_4/kg faecal dry matter)	Proportion of faecal material stored in anaerobic lagoons (%)	Water dilution rate (litres water/kg faecal dry matter)	Average depth of a lagoon (metres)	CH_4 from anaerobic lagoon (g CH_4/m^2/ year)
Dairy cattle	0.95	0.98[29]	0.05	90[30]	4.6[31]	3.27[32]
Beef cattle	1.0	0.98[33]	0.0	–	–	–
Sheep	1.0	0.69[34]	0.0	–	–	–
Deer	1.0	0.92[35]	0.0	–	–	–

Using the above values, CH_4 from pasture is therefore determined using the following equation:

$$M = (FDM \times MMS) \times Ym$$

Where: M = methane from manure management
FDM = faecal dry-matter output
MMS = proportion of faecal material deposited on pasture
Ym = country-specific methane yield (g CH_4 per year).

And for anaerobic lagoons, the following equation is used:

$$M = (FDM \times MMS) \times W/1000/d \times Ym$$

Where: M = methane from manure management
MMS = proportion of faecal material deposited on pasture
W = water dilution rate (litres per kg faecal dry matter)
d = average depth of a lagoon (m)
Ym = methane yield (g CH_4 per m^2 per year).

Dairy cattle

Faecal material deposited directly onto pastures: Consistent with the N_2O inventory, 95 per cent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004). The quantity of CH_4 produced per unit of faecal dry matter is 0.98 grams CH_4/kg. This value is obtained from New Zealand studies on dairy cows and ranged from approximately 0.92 to 1.04 g CH_4/kg (Saggar et al, 2003; Sherlock et al, 2003).

29 Sherlock et al (2003) and Saggar et al (2003).
30 Heatley (2001).
31 McGrath and Mason (2004).
32 McGrath and Mason (2004).
33 Sherlock et al (2003) and Saggar et al (2003).
34 Carran et al (2003).
35 Average of sheep and cattle values. See text for details.

Faecal material stored in anaerobic lagoons: Five per cent of faecal material arising from dairy cows is assumed to be stored in anaerobic lagoons. The current method assumes that all faeces deposited in lagoons are diluted with 90 L of water per kg of dung dry matter (Heatley, 2001). This gives the total volume of effluent stored. Annual CH_4 emissions are estimated using the data of McGrath and Mason (2004). McGrath and Mason (2004) calculated specific emissions values of 0.33–6.21 kg CH_4/m^2/year from anaerobic lagoons in New Zealand. The mean value of 3.27 CH_4/m^2/year of this range is assumed in the New Zealand Tier 2 calculations.

Beef cattle, sheep and deer

Beef cattle, sheep and deer are not housed in New Zealand, and all faecal material is deposited directly onto pastures.

No specific studies have been conducted in New Zealand on CH_4 emissions from beef cattle faeces, and values obtained from dairy cattle studies (0.98 grams CH_4/kg) are used (Saggar et al, 2003; Sherlock et al, 2003).

The quantity of CH_4 produced per unit of sheep faecal dry matter is 0.69 grams CH_4/kg. This value is obtained from a New Zealand study on sheep and ranged from 0.340 to 1.288 over six sample periods (Carran et al, 2003).

There are no New Zealand studies on CH_4 emissions from deer manure, and values obtained from sheep and cattle are used. The quantity of CH_4 produced per unit of faecal dry matter is assumed to be 0.92 grams CH_4/kg. This value is the average value obtained from all New Zealand studies on sheep (Carran et al, 2003) and dairy cattle (Saggar et al, 2003; Sherlock et al, 2003).

Methane from other minor livestock categories

Goats and horses: New Zealand-specific emission factors are not available for CH_4 emissions from manure management for goats and horses. These are minor livestock categories in New Zealand, and IPCC 1996 default emission factors (goats 0.18 kilograms CH_4/head/year and horses 2.1 kilograms CH_4/head/year) are used to calculate emissions. All faecal material from goats and horses is deposited directly onto pastures.

Swine: New Zealand uses a country-specific emission factor of 5.94 kg CH_4/head/ year (Hill, 2012) for estimating emissions from swine manure management. This is based on New Zealand-specific proportions of swine faeces in manure management systems.

Poultry: Methane emissions from poultry manure management use New Zealand-specific emission factor values. These are based on New Zealand-specific volatile solids and proportions of poultry faeces in each manure management system for each production category. The poultry population has been disaggregated into three different categories and the values for each are: broiler birds – 0.022 kilograms CH_4/head/year; layer hens – 0.016 kg CH_4/head/year; and other – 0.117 kilograms CH_4/head/year. The value for other (turkeys, ducks and so on) is the IPCC default, as further work is being carried out on this category. Until country-specific information is available for these categories the IPCC default value will continue to be used.

Alpaca: There is no IPCC default value available for CH_4 emissions from manure management for alpacas. Therefore, this was calculated by assuming a default CH_4 emission from manure management value for alpacas for all years that is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions per total sheep population). The alpaca emission factor is not indexed to sheep over time because there is no data to support the kind of productivity increases that have been seen in sheep.

Mules and asses*:* The IPCC default value from the revised 1996 IPCC guidelines was used (1.14 kilograms CH_4/head/year).

Nitrous oxide from cattle, sheep and deer

This subcategory reports N_2O emissions from the anaerobic lagoon, solid storage, dry-lot and other animal waste management systems. Emissions from the pasture, range and paddock, and daily spread animal waste management systems are reported in the agricultural soils category.

The calculations for the quantity of nitrogen in each animal waste management system are based on the nitrogen excreted (N_{ex}) per head per year multiplied by the livestock population, the allocation of animals to animal waste management systems (table 6.3.1) and an N_2O emission factor for each animal waste management system.

The N_{ex} values are calculated from the nitrogen intake less the nitrogen retained in animal products. Nitrogen intake is determined from feed intake and the nitrogen content of the feed. Feed intake and animal productivity values are the same as used in the Tier 2 model for determining DMI (Clark et al, 2003; section 6.1.1). The nitrogen content of feed is estimated from a review of over 6,000 pasture samples of dairy and sheep and beef systems (Ledgard et al, 2003).

The nitrogen content of product is derived from industry data. For lactating cattle, the nitrogen content of milk is derived from the protein content of milk (nitrogen = protein/6.25) published annually by the Livestock Improvement Corporation. The nitrogen content of sheep meat and wool and beef, and the nitrogen retained in deer velvet, are taken from New Zealand-based research.

Table 6.3.3 shows N_{ex} values increasing over time, reflecting the increases in animal productivity in New Zealand since 1990. For full details of how N_{ex} is derived for each species see the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz).

Table 6.3.3 N_{ex} values for New Zealand's main livestock classes from 1990 to 2011

Year	Dairy N (kg/head/year)	Non-dairy cattle N (kg/head/year)	Sheep N (kg/head/year)	Deer N (kg/head/year)
1990	103.6	66.6	13.2	24.8
1991	108.1	68.4	13.7	25.4
1992	108.1	69.3	13.7	26.4
1993	110.0	70.9	13.9	26.7
1994	107.3	72.0	14.0	26.1
1995	107.4	70.9	13.9	27.1
1996	110.6	73.6	14.4	27.7
1997	111.2	74.9	15.0	28.0
1998	108.1	74.7	15.0	28.2
1999	111.0	72.7	15.0	28.4
2000	112.6	75.1	15.6	28.9
2001	113.3	76.4	15.5	28.8
2002	112.5	76.1	15.7	28.7
2003	116.7	75.7	15.8	28.7

2004	114.7	77.2	16.1	29.0
2005	115.8	78.3	16.4	29.3
2006	115.0	79.7	16.1	29.3
2007	113.3	77.2	15.6	29.0
2008	112.3	76.2	15.8	29.0
2009	112.7	76.9	16.3	29.0
2010	115.5	76.9	15.8	28.9
2011	116.8	77.8	16.2	29.1

Nitrous oxide from other minor livestock categories

Goats: New Zealand uses country-specific N_{ex} values rates for goats to estimate N_2O emissions of 10.6 kilograms N/head/year for 1990 and 12.1 kilograms N/head/year for 2009 based on the differing population characteristics for those two years (Lassey, 2011). As explained in section 6.2.2, for enteric fermentation, for the intermediate years between 1990 and 2009 and for later years, the excretion rate was interpolated based on assumptions that the dairy goat population has remained in a near constant state over time, while the rest of the goat population has declined.

Horses: New Zealand-specific N_{ex} values are not available for horses. Horses are in the minor livestock category in New Zealand, and the 1996 IPCC default emission factor (25.0 kilograms N/head/year) is used to calculate emissions (IPCC, 1996).

Swine: Nitrous oxide from manure management of swine is estimated using a New Zealand-specific N_{ex} value of 10.8 kilograms N/head/year (Hill, 2012) in 2010. This is based on the weighted average of the animal distribution of animal weights by swine subcategory. Estimates of N_{ex} for all other years back to 1990 are indexed to the average pig kill weights for each year.

Poultry: New Zealand-specific and IPCC default N_{ex} values are used for poultry (Fick et al, 2011). These are the country-specific values of 0.39 kilograms N/head/year for broiler birds and 0.42 kilograms N/head/year for layer hens. The default value of 0.60 kilograms N/head/year for ducks and turkeys is retained. These values are used for all years.

Alpaca: There is no IPCC default value available for N_{ex} for alpacas. Therefore, this was calculated by assuming a default N_{ex} value for alpacas for all years that is equal to the per-head value of the average sheep in 1990 (ie, total sheep emissions per total sheep population). The alpaca emission factor is not indexed to sheep over time because there is no data to support the kind of productivity increases that have been seen in sheep. Sheep were used rather than the IPCC default value for 'other animals' as the literature indicates that alpacas have a nitrogen intake close to that of sheep and no significant difference in the partitioning of nitrogen (Pinares-Patino et al, 2003). Therefore, using the much higher default value for 'other animals' would be overestimating the true N_{ex} value for alpacas.

Mules and asses*:* The IPCC default value for other livestock from the revised 1996 IPCC guidelines was used (25.0 kilograms N/head/year) for all years.

6.3.3 Uncertainties and time-series consistency

Methane emissions

The major sources of uncertainty in CH_4 emissions from manure management are the accuracy of emission factors for manure management system distribution and activity data that includes the livestock population (IPCC, 2000).

New Zealand does not currently have country-specific uncertainty values for CH_4 from manure management. Also, the IPCC good practice guidelines do not list default uncertainty values for CH_4 from manure management. Therefore, the IPCC 2006 guidelines default values have been used. The IPCC 2006 guidelines state that: "The uncertainty range for the default factors is estimated to be ± 30 per cent. Improvements achieved by tier 2 methodologies are estimated to reduce uncertainty ranges in the emission factors to ± 20 per cent".

Nitrous oxide emissions

The main factors causing uncertainty in N_2O emissions from manure management are the emission factors from manure and manure management systems, the livestock population, nitrogen excretion rates and the use of the various manure management systems (IPCC, 2000).

New Zealand uses the IPCC default values for EF_3 (direct emissions from waste) for all animal waste systems except for $EF_{3(PR\&P)}$ (manure deposited on pasture, range and paddock). The current New Zealand-specific emission factor for $EF_{3(PR\&P)}$ is 0.01 kilograms N_2O-N/kg. The IPCC default values have uncertainties of –50 per cent to +100 per cent (IPCC, 2000) and have been used.

6.3.4 Source-specific QA/QC and verification

Methane from manure management was identified as a key category (level assessment) in 2010. In the preparation for this inventory submission, the data for this category underwent Tier 1 and Tier 2 quality checks.

Table 6.3.4 shows a comparison of the New Zealand-specific 2009 implied emission factor for CH_4 from manure management with the revised IPCC 1996 Oceania default and the Australian and United Kingdom implied emission factor for dairy, beef cattle and sheep.

New Zealand has a lower implied emission factor for CH_4 from manure management than the 1996 IPCC Oceania default and the United Kingdom. This is due to the much higher proportion of animals in New Zealand that are grazed on pastures and not housed, resulting in less manure being stored in a management system. This is also reflected in the Australian implied emission factor (table 6.3.4) as Australia also has a significant number of pasture-grazed livestock.

Differences between the implied emission factors and the IPCC default factors are also due to the reasons outlined in the enteric fermentation section, that is, productivity of the animals and the use of different algorithms to determine energy intake as well as values used for nitrogen content of feed and digestibility.

Table 6.3.4 Comparison of IPCC default emission factors and country-specific implied emission factors for methane from manure management for dairy cattle, beef cattle and sheep

	Dairy cattle (kg CH_4/head/year)	Beef cattle (kg CH_4/head/year	Sheep (kg CH_4/head/year
IPCC (1996) developed temperate climate/Oceania default value	32	6	0.28
Australian-specific IEF 2010 value	8.84	0.04	0.00
United Kingdom-specific IEF 2010 value	33.80	2.70	0.12
New Zealand-specific 2010 value[36]	3.39	0.75	0.14

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 22 February 2013.

Note: IEF = implied emission factor.

6.3.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2012), Livestock Improvement Corporation statistics (2012)).

Changes to the livestock population, productivity and energy equations explained in 6.2.5 will flow through to the emissions from manure management and result in recalculations.

The 2011 review of the annual submission encouraged New Zealand to estimate emissions from emus and ostriches. There is no methodology in the IPCC 1996 guidelines or IPCC 2000 good practice guidance. The review report encouraged New Zealand to apply emissions factors for poultry (non-specific) to the numbers of emus and ostriches. Emus and ostriches first appeared in New Zealand in the mid-1990s and were most likely reported under other poultry prior to 2002 when Statistics New Zealand started surveying and reporting emus and ostriches. New Zealand has therefore included emus and ostriches with other poultry from 2002 and applied the default poultry (non-specific) emissions factors. This has increased emissions from 2002. For 2010 the inclusion of emus and ostriches increased CH_4 emissions from manure management by 0.006 Gg CO_2-e.

As noted in section 6.1.3, a small population of donkeys has been estimated for New Zealand and included under Mules and Asses, contributing to increasing manure management CH_4 emissions by 0.003 Gg CO_2-e in each year from 1990 to 2011.

The non-poultry specific emissions factor (EF_3) of 0.005 kg N_2O-N/kg was changed to a poultry specific emissions factor of 0.001 kg N_2O-N/kg for poultry excreta as recommended by Fick et al, (2011) This change was approved by the 2011 Agriculture Inventory Advisory Panel Meeting and was implemented after the 2012 submission.

6.3.6 Source-specific planned improvements

A long-term improvement to the disaggregation of dairy effluent into different manure management systems is being investigated by New Zealand scientists. Findings will be incorporated in future submissions.

[36] As reported in *New Zealand's Greenhouse Gas Inventory 1990–2010* (Ministry for the Environment, 2012).

While country-specific values have been determined for poultry broilers and layers, the current default values apply to all other poultry (turkeys, ducks and so on). Work is under way to obtain data to disaggregate poultry species further and to improve the representation of waste systems used in the poultry industry.

6.4 Rice cultivation (CRF 4C)

6.4.1 Description

Although it is possible to grow rice in New Zealand, it is uneconomical to do so. At present, no rice cultivation is being carried out in New Zealand. This has been confirmed with experts from Plant and Food Research, Lincoln, New Zealand. The 'NO' notation is reported in the common reporting format tables.

6.5 Agricultural soils (CRF 4D)

6.5.1 Description

In 2011, the agricultural soils category contributed 10,158.6 Gg CO_2-e (13.9 per cent) to New Zealand's total emissions and 95.0 per cent to total N_2O emissions. Emissions were 2,274.1 Gg CO_2-e (28.8 per cent) above the 1990 level of 7,884.5 Gg CO_2-e. The subcategories are:

- Direct N_2O emissions from animal production (pasture, range and paddock). In 2011, N_2O emissions from animal production contributed 5,705.4 Gg CO_2-e (56.2 per cent) to emissions from the agricultural soils category. This is an increase of 332.8 Gg CO_2-e (6.2 per cent) from the 1990 level of 5,372.5 Gg CO_2-e. Direct N_2O emissions from animal production were identified as a key category (trend and level assessment).
- Direct N_2O emissions from agricultural soils also result from adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation in crops, inputs from crop residues and cultivation of organic soils. Direct N_2O soil emissions contributed 1,874.8 Gg CO_2-e (18.5 per cent) to emissions from the agricultural soils category in 2011. This was an increase of 1,414.7 Gg CO_2-e (307.5 per cent) from the 1990 level of 460.1 Gg CO_2-e. Direct N_2O emissions from agricultural soils were identified as a key category (level and trend assessment).
- Indirect N_2O from nitrogen lost from the field as nitrate (NO_3), ammonia (NH_3) or nitrogen oxides (NO_x) through volatilisation and leaching. In 2011, indirect N_2O emissions from nitrogen used in agriculture contributed 2,578.4 Gg CO_2-e (25.4 per cent) to emissions from the agricultural soils category. This was an increase of 526.6 Gg CO_2-e (25.7 per cent) from the 1990 level of 2,051.8 Gg CO_2-e. Indirect N_2O emissions from agricultural soils were identified as a key category (level assessment).

Carbon dioxide emissions from limed soils are reported in the LULUCF sector (chapter 7).

6.5.2 Methodological issues

The two main inputs of nitrogen to the soil are excreta deposited during animal grazing and the application of nitrogen fertilisers. Emission factors and the fraction of nitrogen deposited on the soils are used to calculate N_2O emissions.

Six New Zealand-specific emission factors and parameters are used in the inventory: EF_1, $EF_{3(PR\&P\ DUNG)}$, $EF_{3(PR\&P)}$, $Frac_{LEACH}$, $Frac_{GASM}$ and $Frac_{GASF}$. The use of a country-specific emission factor for EF_1 (direct emissions from nitrogen input to soil) of 1 per cent is based on work by Kelliher and de Klein (2006). The country-specific $EF_{3(PR\&P)}$ emission factor of 1 per cent and $Frac_{LEACH}$ of 0.07 are based on extensively reviewed literature and field studies (Carran et al, 1995; de Klein et al, 2003; Muller et al, 1995; Thomas et al, 2005). Separate emission factors are allocated to dung and urine for cattle, sheep and deer; $EF_{3(PR\&P)}$ (0.01) for urine from cattle, sheep and deer and manure for all other species, and $EF_{3(PR\&P\ DUNG)}$ (0.0025) for dung from cattle, sheep and deer. Further details of this split can be found under the animal production section. A value of 0.1 has been adopted for the emission factor $Frac_{GASM}$ after an extensive review of scientific literature (Sherlock et al, 2009). The 1996 IPCC default value of 0.1 for $Frac_{GASF}$ has been verified as appropriate to New Zealand after an extensive review of the scientific literature (Sherlock et al, 2009) and has therefore been adopted as a country-specific emission factor.

The emission factors and other parameters used in this category are documented in annex 3.1. The calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment website (www.mfe.govt.nz/publications/climate).

Direct nitrous oxide emissions from agricultural soils

The N_2O emissions from the direct soils emissions subcategory arise from synthetic fertiliser use, spreading animal waste as fertiliser, nitrogen fixing in soils by crops and decomposition of crop residues left on fields. For all of these nitrogen inputs, a New Zealand-specific emission factor (EF_1) of 0.01 kilograms N_2O–N/kg N (Kelliher and de Klein, 2006) is applied to calculate total direct emissions from non-organic soils. Many of these subcategories have N_2O emissions from indirect pathways as well, but these calculations are described in detail in later sections.

Where N_{ex} values and allocation to animal waste management systems are used, these are the same as are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species in the Tier 2 model (section 6.1.1). This ensures the same base DMI values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz).

Synthetic nitrogen fertiliser

Anthropogenic N_2O emissions from nitrogen containing fertiliser are a relatively small proportion of total N_2O emissions, although still significant. The majority of synthetic nitrogen fertiliser used in New Zealand is urea applied to dairy pasture land to boost pasture growth during autumn and spring months.

Data on nitrogen fertiliser use is provided by the Fertiliser Association of New Zealand from sales records for 1990 to 2010. During this time there has been a six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser, from 59,265 tonnes in 1990 to 360,284 tonnes in 2011. This has resulted in an increase of direct N_2O emissions, from 259.8 Gg CO_2-e in 1990 (0.8 per cent of agricultural emissions) to 1,579.6 Gg CO_2-e (4.6 per cent of agricultural emissions) in 2011.

In accordance with IPCC good practice guidance (IPCC, 2000), the following equations are used to determine direct N_2O emissions from the application of nitrogen fertiliser.

$$F_{SN} = N_{fert} \times (1\text{-}Frac_{gasf})$$

$$N_2O_{direct\ from\ SN}\text{-}N = F_{SN} \times EF_1$$

Where:

F_{SN} = annual amount of synthetic fertiliser nitrogen applied to soils after adjusting for the amount that volatilises

N_{fert} = amount of nitrogen fertiliser applied to soils

$Frac_{gasf}$ = fraction of total synthetic fertiliser emitted as NO_x or NH_3

EF_1 = proportion of direct emissions from nitrogen input to the soil.

Animal waste

The majority of animal waste in New Zealand is excreted directly onto pasture, 95 per cent of dairy and 100 per cent of sheep, beef and deer. However, some manure is kept in waste systems and is then applied to soils at a later date as an organic fertiliser. Some manure is also collected but not stored, rather it is spread onto pasture daily (eg, swine). The calculation for animal waste includes all manure that is spread on agricultural soils, irrespective of the animal waste management system it was initially stored in. This includes all agricultural waste in New Zealand except for emissions from the pasture, range and paddock animal waste management system. Because the majority of animal manure is excreted directly onto pasture, the animal waste subcategory is relatively small. However, it has almost doubled since 1990 due to the increase in the dairy population numbers. In 1990, animal waste levels were 108.6 Gg CO_2-e (0.4 per cent of agricultural emissions) and, in 2011, this had increased to 197.2 Gg CO_2-e (0.6 per cent of agricultural emissions).

In accordance with IPCC good practice guidance (IPCC, 2000), the following equations are used to determine direct N_2O emissions from the application of animal waste to soil.

$$F_{AW} = N_{AW} \times (1\text{-}Frac_{GASM})$$

$$N_2O_{direct\ from\ AW}\text{-}N = F_{AW} \times EF_1$$

Where:

F_{AW} = the total amount of animal manure nitrogen applied to soils from waste management systems (other than pasture, range and paddock) after adjusting for the amount that volatilises during storage

N_{AW} = the amount of animal manure nitrogen in each waste management system, other than pasture, range and paddock, for all species

$= N_{ex} \times MS$

Where: N_{ex} = nitrogen excreted for each species

MS = fraction of nitrogen in each management system except pasture, range and paddock for each species

$Frac_{GASM}$ = fraction of total animal manure emitted as NO_x or NH_3

EF_1 = proportion of direct emissions from nitrogen input to soil.

Nitrogen-fixing crops

The tonnage of nitrogen-fixing crops grown in New Zealand is supplied by Statistics New Zealand from its Agricultural Production Survey. It is made up of peas grown for both processing and seed markets as well as lentil production and legume seeds grown for pasture production. Emissions from this subcategory make up a very small amount of New Zealand's agricultural emission. In 2011, N_2O emissions from this subcategory totalled 10.6 Gg CO_2-e (0.03 per cent of agricultural emissions), which is a decrease from the 1990 value of 17.3 Gg CO_2-e (0.06 per cent of agricultural emissions). This is mainly due to a decrease in pea and lentil production in New Zealand. A country-specific methodology is used to calculate emissions from this section as detailed below. This new approach uses harvest index values, root to shoot ratios and nitrogen contents of above- and below-ground residues compiled and used in the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003). The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. OVERSEER® is a source of scientific consensus where nutrient factors are estimated, reviewed and generally agreed among New Zealand experts.

$$TRG_N = AG_N + BG_N$$

$$AG_N = dmf \times (CropT/HI\text{-}CropT) \times (1 - Frac_{BURN} - Frac_R) \times N_{AG}$$

$$BG_N = dmf \times (CropT/HI) \times N_{BG} \times RatioBG$$

$$N_2O_{direct\ N\ fix}\text{-}N = TRG_N \times EF_1$$

Where:

TRG_N = Total Ground Nitrogen (above- and below-ground residue)

AG_N = amount of above-ground nitrogen returned to soils annually through incorporation of crop residues

BG_N = amount of below-ground nitrogen returned to soils annually through incorporation of crop residues

dmf = dry-matter factor

CropT = annual crop production of crops

HI = Harvest Index

$Frac_{BURN}$ = fraction of above-ground biomass that is burned

$Frac_R$ = fraction of above-ground biomass that is removed from the field as product

N_{AG} = above-ground nitrogen fraction

N_{BG} = below-ground nitrogen fraction

RatioBG = Root Shoot Ratio

EF_1 = proportion of direct emissions from nitrogen input to soil.

Crop-specific factors are provided in annex 3.1.

Nitrous oxide from crop residue returned to soil

Crop residues are made up from both nitrogen-fixing and non-nitrogen-fixing crops. The non-nitrogen-fixing crops in New Zealand include crops such as barley, wheat, maize, oats, onions, squash, potato and some seed crops. The tonnage of these crops is supplied by Statistics New Zealand from its Agricultural Production Survey. Additional information on seed crops is provided by AsureQuality, which certifies seeds in New Zealand. Although there has been a decline in oat crops in New Zealand since 1990, there has been an increase in maize and wheat, resulting in an overall slight increase in emissions from crop residue since 1990. However, the contribution of crop residues to the overall agricultural emissions is very small, with 43.2 Gg CO_2-e (0.1 per cent of agricultural emissions) in 1990 and, in 2011, 56.2 Gg CO_2-e (0.2 per cent of agricultural emissions).

For the 2012 submission, New Zealand has introduced emissions from additional cropping activity not previously estimated (such as onions, squash and sweet corn) and has implemented a country-specific approach to calculate N_2O emissions from crop residue. This methodology is the same as that detailed above under nitrogen-fixing crops. However, N_2O nitrogen from crop residue is determined rather than N_2O nitrogen from nitrogen-fixing crops.

$$N_2O_{direct\ crop\ residue}\text{-}N = TRG_N \times EF_1$$

Cultivation of histols

Direct N_2O emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor (EF_2). The area of ‘organic agricultural soils’ cultivated in New Zealand is 160,385 hectares (Dresser et al, 2011). This area includes the proportion of organic agricultural soil as reported within the LULUCF sector that has been cultivated (135,718 hectares) and the area of mineral agricultural soils with a peaty layer that is cultivated (24,667 hectares).

Mineral soils with a peaty layer are included in the definition of organic soils under the agriculture section as it was determined that these soils will have similar emissions behaviour to that of organic soils. Therefore, for the agriculture sector, mineral soils with a peaty layer should be included with organic soils when estimating N_2O emissions from cultivation of organic soils (Dresser et al, 2011).

The full definition used in the agriculture section for organic soils (plus mineral soils with a peaty layer) is:

- 17 per cent organic matter content (includes slightly peaty, peaty and peat soils of 17–30 per cent, 30–50 per cent and greater than 50 per cent organic matter content)
- 0.1 metres of this depth occurring within 0.3 metres of the surface.

Dresser et al (2011) determined that the current assumption that 5 per cent of organic soils (plus mineral soils with a peaty layer) under agricultural pasture is cultivated on an annual basis (Kelliher et al, 2002) should be retained until further information has been gathered. This results in 8,019 hectares of ‘organic agricultural soils’ being cultivated annually.

New Zealand uses the IPCC default emission factor (EF_2 equal to 8 kilograms N_2O-N/kg N) and Tier 1 methodology for all years of the time series. The contribution of organic soils (plus mineral soils with a peaty layer) to the overall agricultural emissions is relatively small, with 31.3 Gg CO_2-e (0.1 per cent of agricultural emissions) in 1990 and, in 2010, 31.3 Gg CO_2-e (0.1 per cent of agricultural emissions).

Animal production (nitrous oxide)

Direct soil emissions from animal production refers to the N_2O produced from the pasture, range and paddock animal waste management system. This system is the predominant regime for animal waste in New Zealand, as 95 per cent of dairy cattle excreta and 100 per cent of sheep, deer and non-dairy cattle excreta are allocated to it (table 6.3.1).

The emissions calculation is based on the livestock population multiplied by nitrogen excretion (N_{ex}) values and the percentage of the population on the pasture, range and paddock animal waste management system. The N_{ex} values and allocation to animal waste management systems are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species in the Tier 2 model. This ensures the same base values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the inventory methodology document (www.mpi.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx). In accordance with IPCC good practice guidance (IPCC, 2000), the following equation is used to determine direct N_2O emissions from animal production.

$$(N_2O\text{-}N) = N \times Nex \times MS \times EF_{3(PR\&P)}$$

Where: N = population

N_{ex} = nitrogen excreted by each species (these values are the same as used in section 6.3)

MS = proportion of manure excreted directly onto pasture (table 6.3.2)

$EF_{3(PR\&P)}$ = emission factor for direct emissions from waste in the pasture, range and paddock animal waste management system (i.e. manure deposited directly onto pasture during grazing).

New Zealand uses a country-specific emission factor for $EF_{3(PR\&P)}$ of 0.01 (Carran et al, 1995; Muller et al, 1995; de Klein et al, 2003; Kelliher et al, 2003) for the urine of cattle, sheep and deer and the manure from all other livestock classes. For the dung of cattle, sheep and deer, a new country-specific emission factor for $EF_{3(PR\&P\ DUNG)}$ of 0.0025 has been implemented.

Considerable research effort has gone into establishing a New Zealand-specific emission factor for $EF_{3(PR\&P)}$. Field studies have been performed as part of a collaborative research effort called NZOnet. The $EF_{3(PR\&P)}$ parameter has been measured by NzOnet researchers in the Waikato (Hamilton), Manawatu (Palmerston North), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al, 2003). This regional data is comparable because the same measurement methods were used at the four locations. The percentage of applied nitrogen emitted as N_2O, and relevant environmental variables, were measured in four separate trials in autumn 2000, summer 2002, spring 2002 and winter 2003. Measurements were carried out for up to 250 days at each trial site or until urine-treated pasture measurements dropped back to background emission levels.

Kelliher et al (2003, 2005), assessed all available $EF_{3(PR\&P)}$ data and its distribution to pastoral soil drainage class, to determine an appropriate national annual mean value. The complete $EF_{3(PR\&P)}$ data set of NzOnet was synthesised using the national assessment of three pastoral soil drainage classes. These studies recognise that:

- environmental (climate) data is not used to estimate N_2O emissions using the methodology in the revised 1996 IPCC guidelines (IPCC, 1996)
- the N_2O emission rate can be strongly governed by soil water content
- soil water content depends on drainage that can moderate the effects of rainfall and drought
- drainage classes of pastoral soils, as a surrogate for soil water content, can be assessed nationally using a geographic information system.

An earlier analysis in New Zealand showed that the distribution of drainage classes for pasture land is highly skewed, with 74 per cent well drained, 17 per cent imperfectly drained and 9 per cent poorly drained (Sherlock et al, 2001).

As with the $EF_{3(PR\&P)}$ parameter, considerable research effort has gone into establishing a New Zealand-specific value for dung. This included field studies ranging over eight years being performed in Waikato, Southern Hawke's Bay, Manawatu, Canterbury and Otago regions on free and poorly drained soils in the spring, summer, autumn and winter. These field studies used methodologies developed during the research into the original New Zealand-specific parameter for $EF_{3(PR\&P)}$.

Luo et al (2009) assessed all available $EF_{3(PR\&P\ DUNG)}$ data and its distribution to the pastoral soil drainage class, and carried out a further trial to confirm data during the spring, to determine an appropriate national annual mean value. This review found that:

- results confirm a disaggregation of $EF_{3(PR\&P)}$ between dung and urine is warranted
- EF_3 decreases as follows: cow urine > cow or cattle dung > sheep dung
- however, when seasonal data was pooled, there was no significant difference between cattle and sheep dung.

It was recommended that the N_2O emission factor for urine remain at the country-specific value of 1 per cent and the N_2O emission factor for cattle and sheep dung be reduced to one-quarter of a per cent.

Incorporation of the mitigation technology DCD into the agricultural inventory

A methodology to incorporate an N_2O mitigation technology, the nitrification inhibitor dicyandiamide (DCD),[37] into the agricultural sector of the inventory has been developed. A detailed description of the methodology can be found in Clough et al (2008). The N_2O emissions reported in the agricultural soils category take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al (2008). For the 2011 calendar year, DCD mitigated 23.6 Gg CO_2-e, a 0.07 per cent decrease in total agricultural emissions.

Dicyandiamide has been well researched, and research to date has shown DCD to be an environmentally safe nitrification inhibitor that reduces N_2O emissions and nitrate leaching in pastoral grassland systems grazed by ruminant animals. There have been 28 peer reviewed and published New Zealand studies on the use and effects of DCD.

The method to incorporate DCD mitigation of N_2O emissions into New Zealand's agricultural inventory is by an amendment to the existing IPCC methodology. Activity data on livestock numbers is drawn from Statistics New Zealand's Agricultural Production Survey. This survey has recently included questions on the area that DCD is applied to grazed pastures.

The DCD product is applied to pastures based on research that has identified good management practice to maximise N_2O emission reductions. This is at a rate of 10 kilograms per hectare of DCD, applied twice per year in autumn and early spring within seven days of the application of excreta. 'Good practice' application methods of DCD can be by slurry or granule.

[37] As at Thursday 24 January 2013 there has been a voluntary suspension to the sales of DCD.

Changes to the emission factors $EF_{3PR\&P}$ and parameter $Frac_{LEACH}$ were established for use with DCD application. These emission factors and parameters were modified based on comprehensive field-based research that showed significant reductions in direct and indirect N_2O emissions and nitrate leaching where DCD was applied.

The peer-reviewed literature on DCD use in grazed pasture systems was peer reviewed, and it was determined that, on a national basis, reductions in $EF_{3PR\&P}$ and $Frac_{LEACH}$ of 67 per cent, 67 per cent and 53 per cent could be made respectively (Clough et al, 2008). There has been some research into the effect of DCD on $EF_{3(PR\&P\ DUNG)}$, however, this data is limited and further work needs to be assessed before incorporating this research into the New Zealand inventory.

The reductions in the emission factors and parameters are used along with the fraction of dairy land treated with DCD to calculate DCD weighting factors.

$$DCD\ weighting\ \ factor = \ (1 - \frac{\%\ reduction\ in\ EF_x}{100} \times \frac{DCD\ treated\ area}{Effective\ dairy\ area})$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of N_2O from grazed pastures. The calculations use a modified $EF_{3(PR\&P)}$ of 0.0099 and $Frac_{LEACH}$ of 0.0696 for dairy grazing area in the months that DCD is applied (May to September). The modified emission factors (table 6.5.1) are based on information from the Agricultural Production Statistics Survey that 3.0 per cent of the effective dairying area in New Zealand received DCD in 2011.

Table 6.5.1 Emission factors and parameters for New Zealand's DCD calculations

	New Zealand emission factor or parameter value for untreated area (kg N_2O-N/kg N)	Reduction from DCD treatment (%)	Proportion land treated with DCD (%)	Final modified emission factor or parameter (kg N_2O-N/kg N)
$EF_{3PR\&P}$	0.01	67	3.0	0.0099
$Frac_{LEACH}$	0.07	53	3.0	0.0696

All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when DCD is used as an N_2O mitigation technology. DCD was found to have no effect on ammonia volatilisation during May to September when DCD is applied. This is supported by the results of field studies (Clough et al, 2008; Sherlock et al, 2009).

The derivations of the modified emission factors and the resulting calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

The method will be refined over time to reflect any updated information that may arise from ongoing research into this area.

Indirect nitrous oxide from nitrogen used in agriculture

Nitrous oxide is emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off. This nitrogen enters water systems and eventually reaches the sea, with N_2O being emitted along the way. The amount of nitrogen that leaches is a fraction ($Frac_{LEACH}$) of that deposited or spread on land.

Research studies and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the revised 1996 IPCC guidelines (IPCC, 1996). A New Zealand parameter for $Frac_{LEACH}$ of 0.15 was used in inventories submitted before 2003. However, using a $Frac_{LEACH}$ of 0.15, IPCC-based estimates for different farm systems were found, on average, to be 50 per cent higher than those estimated using the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003). The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. In pastoral systems, nitrogen leaching is determined by the amount of nitrogen applied in fertiliser, in dairy farm effluent and that excreted in urine and dung by grazing animals. The latter is calculated from the difference between nitrogen intake by grazing animals and nitrogen output in animal products, based on user inputs of stocking rate or production and an internal database with information on the nitrogen content of pasture and animal products and calibrated against field measurements.

The IPCC estimates were closer for farms using high rates of nitrogen fertiliser, indicating that the IPCC-based estimates for nitrogen leaching associated with animal excreta were too high for New Zealand. When the IPCC method was applied to field sites where nitrogen leaching was measured (four large-scale, multi-year animal grazing trials), it resulted in values that were double the measured values. This indicated that a value of 0.07 for $Frac_{LEACH}$ more closely followed actual field leaching in New Zealand (Thomas et al, 2005). The 0.07 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances. In 2011, N_2O emissions from leaching made up 4.8 per cent (1,639.4 Gg CO_2-e) of agricultural emissions, an increase of 25.5 per cent from the 1990 value of 1,305.8 Gg CO_2-e.

Some of the nitrogen contained in animal excreta and fertiliser deposited or spread on land is emitted into the atmosphere as NH_3 and NO_x through volatilisation. A fraction of this returns to the ground during rainfall and is then re-emitted as N_2O. This is calculated as an indirect emission of N_2O. The fraction of nitrogen that is deposited or spread on land that then indirectly becomes N_2O through this process is calculated using the fractions $Frac_{GASM}$ from animal excreta and $Frac_{GASF}$ from nitrogen fertiliser.

International and New Zealand-based scientific research and a literature review of this work have shown that the current 1996 IPCC default value for $Frac_{GASM}$ is too high for New Zealand conditions. In most European countries, ammonia emitted from pasture soils following grazing is just one of several sources contributing to their reported $Frac_{GASM}$ inventory values, whereas in New Zealand, 97 per cent of all livestock urine and dung is deposited directly on soils during grazing. Excluding studies on nitrification inhibitors, eight international papers covering 45 individual trials and nine New Zealand papers covering 19 individual trials were reported on. The authors recommended a value of 0.1 for $Frac_{GASM}$ was more appropriate for New Zealand conditions (Sherlock et al, 2009). The 0.1 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances.

Seventeen peer reviewed papers covering 79 individual trials have also been reviewed for $Frac_{GASF}$. Taking into account that approximately 80 per cent of nitrogen fertiliser used in New Zealand is urea with the remaining being diammonium phosphate (DAP), a value of 0.096 for $Frac_{GASF}$ was determined (Sherlock et al, 2009). As this is almost identical to the IPCC default value of 0.1 currently used, 0.1 has been adopted as a country-specific value for $Frac_{GASF}$.

New Zealand uses the IPCC default EF_4 emission factor for indirect emissions from volatilisation of nitrogen in the form of NH_3 and oxides of NO_x. In 2011, N_2O emissions from volatilisation made up 2.7 per cent (939.0 Gg CO_2-e) of agricultural emissions, an increase of 25.8 per cent from the 1990 value of 746.2 Gg CO_2-e.

6.5.3 Uncertainties and time-series consistency

Uncertainties in N_2O emissions from agricultural soils were assessed for the 1990 and 2002 inventory using a Monte Carlo simulation of 5,000 scenarios with the @RISK software (Kelliher et al, 2003) (table 6.5.2). The emissions' distributions are strongly skewed, reflecting pastoral soil drainage whereby 74 per cent of soils are classified as well drained and 9 per cent are classified as poorly drained. For the 2011 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value (ie, in 2002, the uncertainty in annual emissions was +74 per cent and –42 per cent).

Table 6.5.2 New Zealand's uncertainties in nitrous oxide emissions from agricultural soils for 1990, 2002 and 2010 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2011)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	25.4	14.8	44.3
2002	31.9	18.5	55.5
2011	32.8	19.0	57.0

The overall inventory uncertainty analysis shown in annex 7 demonstrates that the uncertainty in annual emissions from agricultural soils is a major contributor to uncertainty in the total estimate and to the uncertainty in the trend from 1990. The uncertainty between years was assumed to be correlated. Therefore, the uncertainty is mostly in the emission factors, and the uncertainty in the trend is much lower than the uncertainty for an annual estimate.

The Monte Carlo numerical assessment is also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N_2O emissions in 1990 and 2002. These parameters are shown in table 6.5.3, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2011 data. The Monte Carlo analysis confirmed that uncertainty in parameter $EF_{3(PR\&P)}$ has the most influence on total uncertainty, accounting for 91 per cent of the uncertainty in total N_2O emissions in 1990. This broad uncertainty reflects natural variance in EF_3, determined largely by the vagaries of the weather and soil type.

Table 6.5.3 Proportion contribution of the nine most influential parameters on the uncertainty of New Zealand's total nitrous oxide emissions for 1990 and 2002

Parameter	1990 Contribution to uncertainty (%)	2002 Contribution to uncertainty (%)
$EF_{3(PR\&P)}$	90.8	88.0
EF_4	2.9	3.3
Sheep N_{ex}	2.5	1.8
EF_5	2.2	2.8

Parameter	1990 Contribution to uncertainty (%)	2002 Contribution to uncertainty (%)
Dairy N_{ex}	0.5	0.7
$Frac_{GASM}$	0.5	0.5
EF_1	0.3	2.4
Beef N_{ex}	0.2	0.3
$Frac_{LEACH}$	0.1	0.2

6.5.4 Source-specific QA/QC and verification

In preparation for the 2012 inventory submission, the data for the direct soil, pasture, range and paddock manure, and indirect emissions categories underwent Tier 1 and Tier 2 quality checks.

In 2008 and 2011, the Ministry for Primary Industries commissioned a report investigating N_2O emission factors and activity data for crops (Thomas et al, 2008; Curtin et al, 2011). Statistics New Zealand's Agricultural Production Survey activity data for wheat and maize was verified with the Foundation for Arable Research production database between 1995 and 2007. Data for wheat and maize between the two data sources was very similar.

Fertiliser sales data (year-end May 2011) received from the Fertiliser Association of New Zealand was verified with data collected from the Agricultural Production Survey for year-end June 2011. The Agricultural Production Survey data for fertiliser use in New Zealand was 96,000 tonnes lower (approximately 27 per cent).

The New Zealand Fertiliser of Association data is used rather than the Agricultural Production Survey data as 95 per cent of New Zealand nitrogen fertiliser is provided by two large companies. Therefore, this information will be more accurate than the errors associated with a survey of some 35,000 farmers. There are a large number of differently named nitrogen fertilisers, and the Agricultural Production Survey respondents often have difficulty filling in the fertiliser question in the annual questionnaire.

Dicyandiamide data obtained from the Agricultural Production Survey was verified with data from the main supplier of DCD. This company has a 90 per cent share of the market. Values obtained from this company were approximately 87 per cent of the reported DCD usage data obtained from the Agricultural Production Survey, indicating the values were reasonably accurate.

Table 6.5.4 compares the New Zealand-specific values for EF_1, $EF_{3PR\&P}$ and $EF_{3(PR\&P\ DUNG)}$ with the 1996 IPCC default value and emission factors used by Australia and the United Kingdom, where available. For EF_1 and $EF_{3PR\&P}$ the New Zealand value is lower than the IPCC default value. This is due to the large proportion of well-drained soils within New Zealand as well as the types of soils as indicated in table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996). Although there is no IPCC default value or United Kingdom value for $EF_{3(PR\&P\ DUNG)}$, Australia applies a country-specific value. Although slightly higher than the New Zealand value, it is of similar magnitude. Table A-1 (IPCC, 1996) demonstrates that New Zealand silt loams have significantly less N_2O emissions from dung and urine deposits than other countries and soil types.

Table 6.5.4 Comparison of IPCC default emission factors and country-specific implied emission factors for EF_1 and $EF_{3PR\&P}$

	EF_1 (kg N_2O-N/kg N)	$EF_{3PR\&P}$ (kg N_2O-N/kg N excreted)	$EF_{3(PR\&P\ DUNG)}$ (kg N_2O-N/kg N excreted)
IPCC (2006) developed temperate climate/Oceania default value	0.0125	0.02	NA
Australian-specific IEF 2010 value	0.0125 (except animal manure and fertiliser = 0.006)	0.004	NA
United Kingdom-specific IEF 2010 value	0.0125	0.02	NA
New Zealand-specific 2010 value	0.01	0.01	0.0025

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 22 February 2013.

Note: IEF = implied emission factor.

Table 6.5.5 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the 1996 IPCC default and fractions used by Australia and the United Kingdom. Details on these three fractions can be found in further detail in section 6.5.2. Although New Zealand has taken a country-specific value for $Frac_{GASF}$ of 0.1, it is the same as the IPCC default and that of Australia and the United Kingdom. Research showed that the 0.1 value was appropriate to New Zealand conditions.

However, research showed that the default value of 0.2 for $Frac_{GASM}$ was too high and, therefore, New Zealand has adopted a lesser value of 0.1. The reduction is due to the proportion of the different sources that make up this value. In New Zealand, 97 per cent of animal excreta is deposited onto pasture and only 3 per cent is managed. Whereas the 1996 IPCC default value was calculated taking into account a much higher percentage of manure management and storage. Manure management and storage results in a much higher proportion of nitrogen being volatilised and, hence, the higher $Frac_{GASM}$ for the default value compared with the country-specific New Zealand value (Sherlock et al, 2009).

New Zealand also has a much lower $Frac_{LEACH}$. Research showed that New Zealand applies a much lower rate of nitrogen fertiliser than what was assumed when developing the 1996 IPCC default value. When the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003) took this lower rate into account, the rate of leaching was much lower than when compared with farms with a high nitrogen fertiliser rate, which can be typical in other developed countries.

Table 6.5.5 Comparison of IPCC default emission factors and country-specific implied emission factors for $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$

	$Frac_{GASF}$ (kg NH_3-N and NO_x-N/kg of N input)	$Frac_{GASM}$ (kg NH_3-N and NO_x-N/kg of N excreted)	$Frac_{LEACH}$ (kg N/kg fertiliser or manure N)
IPCC (1996) developed temperate climate/Oceania default value	0.1	0.2	0.3
Australian-specific IEF 2010 value	0.1	0.0	0.3
United Kingdom-specific IEF 2010 value	0.1	0.20	0.3
New Zealand-specific 2010 value	0.1	0.1	0.07

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 22 February 2013.

Note: IEF = implied emission factor.

6.5.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2012) and Livestock Improvement Corporation statistics (2012)).

Enhancements, described in 6.2.5, to New Zealand's Tier 2 inventory model have resulted in recalculations of nitrogen inputs from excreta by dairy cattle, non-dairy cattle, sheep and deer.

As noted in section 6.1.3, a small population of donkeys has been estimated for New Zealand and included under Mules and Asses increasing N_2O emissions from nitrogen excreta on pasture, range and paddock by 0.02 Gg CO_2-e in all years 1990 to 2011. For 2010 the inclusion of emus and ostriches increased N_2O emissions from agricultural soils by 0.008 Gg CO_2-e.

Improvements made to the methodology to estimate nitrogen inputs from crop residues, and nitrogen-fixing crops in 2012 were reviewed by Plant and Food Research as part of a periodic review (as explained in 6.1.5). Plant and Food Research recommended some corrections to formula and provided updated crop data where some data has been missing and interpolated. Plant and Food Research also recommended using the alternative harvest index 0.41 (instead of the spring-sown crop harvest index of 0.46) for wheat because this reflects the autumn sowing normally used for wheat in New Zealand. The recalculation increased emissions from nitrogen-fixing crops by 10.1 Gg CO_2-e in 1990 and by 5.8 Gg CO_2-e in 2010; for crop residues, the recalculation increased emissions by 1.2 Gg CO_2-e in 1990 and 1.0 Gg CO_2-e in 2010.

6.5.6 Source-specific planned improvements

New Zealand scientists are continuing to research N_2O emission factors for New Zealand's pastoral soils. New Zealand is also continuing research to refine the methodology used to estimate N_2O emission reductions using DCD nitrification inhibitors.

Enhancements to the New Zealand Tier 2 inventory model that will improve usability are currently in progress. These enhancements will also permit the use of regional DCD data as activity data allows, as well as the use of regional emission factors as they are developed. The use of regional activity data and emission factors will improve the accuracy of emissions estimations.

Assessment of the fertiliser question in the Agricultural Production Survey is being carried out with the view to try to improve data obtained from the questionnaire and therefore improve the verification of nitrogen fertiliser data from the Fertiliser Association of New Zealand.

Further Monte Carlo simulations on the uncertainties in N_2O emissions from agricultural soils are planned for future submissions.

The emission factor for indirect N_2O emissions from leaching and run-off (EF_5) default comprises three components for N_2O emissions from groundwater and surface drainage (EF_{5-g}), estuaries (EF_{5-e}) and rivers (EF_{5-r}). The revised 1996 IPCC guidelines default emission factors for groundwater and surface drainage, estuaries and rivers are: 0.015, 0.0025 and 0.0075 kilograms N_2O-N/kg $N_{LEACHED}$, respectively. Therefore the combined EF_5 in the revised 1996 IPCC guidelines is 0.025 kilograms N_2O-N/kg $N_{LEACHED}$.

Rivers in New Zealand are short and fast flowing, compared with rivers in other parts of the world on which the current international defaults were based. A study of N_2O emissions from New Zealand's longest river, the Waikato River, did not measure an EF_{5-r} higher than 0.005 kilograms N_2O-N/kg $N_{LEACHED}$. The river is situated in the Waikato region in New Zealand's North Island. The paper also cited two recent studies of N_2O of South Island rivers that confirmed emissions from New Zealand rivers were typically less than 0.005 kilograms N_2O-N/kg $N_{LEACHED}$. Further work is planned to review other studies and consider what value should be a country-specific emission factor for New Zealand (EF_{5-r} and EF_{5-g}).

Several research projects have confirmed that emissions of N_2O from excreta on sloping pastoral land are less than flat pastoral land. In New Zealand, sheep, beef and deer are grazed on hill country with sloping pastures. Dairy cattle are grazed on flat to low sloping pasture. A project is in progress to determine a sufficiently robust method to use spatial data to determine the distribution of sheep, beef and deer excreta by hill slope.

The assumptions for nitrogen retained in liveweight gain, milk protein and fibre affect the estimates of nitrogen in livestock excreta. A project has been started to assess whether there are any better estimates available and appropriate to New Zealand livestock and circumstances. The project will assess whether the nitrogen retention rates need to be differentiated by gender and age cohorts for each livestock group. The project will also determine whether there have been any changes since 1990 to nitrogen retention rates.

Field trials are being conducted on N_2O emissions from nitrogen fertiliser and effluent applied to soils including the impact of mitigation technologies such as DCD, Urease and combinations on these nitrogen treatments to derive acceptable emissions factors and methodologies specific for New Zealand conditions.

6.6 Prescribed burning of savanna (CRF 4E)

6.6.1 Description

In 2011, prescribed burning of savanna was not a key category in New Zealand. The inventory includes burning of tussock (*Chionochloa*) grassland in the South Island for pasture renewal and weed control. The amount of burning has been steadily decreasing over the past 50 years as a result of changes in lease tenure and a reduction in grazing pressure. In 2011, prescribed burning emissions accounted for 8.3 Gg CO_2-e, a 22.0 Gg CO_2-e (72.5 per cent) reduction in emissions from the 30.3 Gg CO_2-e reported in 1990.

The revised 1996 IPCC guidelines (IPCC, 1996) state that, in agricultural burning, the CO_2 released is not considered to be a net emission as the biomass burned is generally replaced by regrowth over the subsequent year. Therefore, the long-term net emissions of CO_2 are considered to be zero. However, the by-products of incomplete combustion (CH_4, carbon monoxide (CO), N_2O and NO_x) are net transfers from the biosphere to the atmosphere.

6.6.2 Methodological issues

New Zealand has adopted a modified version of the IPCC methodology (IPCC, 1996). The same equations are used to calculate emissions as detailed in the revised 1996 IPCC guidelines.

However, instead of using total grassland and a fraction burnt, New Zealand uses statistics of the total area of tussock grassland that has been burnt. Expert opinion concludes that, from 1990 to 2004, information on land that has been granted consent (a legal right) for burning, under New Zealand's Resource Management Act 1991, provides the best option for estimating tussock burning (Curtin et al, 2011). However, from 2003, this data has become less reliable as burning has become permitted in some regions. Since 2005, however, Statistics New Zealand has started to collect data on tussock grassland burning, and it is therefore recommended that this data be used from 2005 (Curtin et al, 2011).

Curtin et al (2011) reviewed the methodology and activity data to estimate emissions from tussock burning in New Zealand and recommended changes to the emission factors and activity data. Analysis of the data showed that the original assumption that only 20 per cent of consented area is burned is likely to be underestimating actual burning. The consents last for five years. Therefore, the burning may not actually occur in the year of the burn, and the consenting data does not include illegal burns and accidents. Comparing data from Statistics New Zealand on tussock burning with data on all land consented for burning indicates that the total area consented provides a more accurate estimate and improves the consistency of activity data over the time series.

Current practice in New Zealand is to burn in damp spring conditions, reducing the amount of biomass consumed in the fire. Most of the composition and burning ratios used in calculations are from New Zealand-specific research and have been updated (Payton and Pearce, 2009). Curtin et al (2011) also recommended small modifications to the methodology incorporating new variables from this updated research. The variables carbon content of live biomass and carbon content of dead biomass have been replaced by one variable – ratio of carbon loss to above-ground biomass loss. The fractions of live and dead material have been combined into one value and only one equation is now required to determine the carbon released from live and dead biomass. One value for the fraction of live and dead material oxidised is now only required.

The following equations are used to estimate the total amount of carbon released during the burning of tussock land in New Zealand. Table 6.6.1 details the emission factors used.

Biomass burned (Gg dam) = area of tussock burned annually × above-ground biomass density (t dm/ha) × fraction actually burned/1000

C released biomass (Gg C) = biomass burned (t dm) × Ratio of C loss to above-ground biomass × fraction that is live and dead biomass × fraction oxidised

Total carbon released is then used to estimate CH_4, CO, N_2O and NO_x emissions.

N_2O emissions (Gg N_2O) = C released biomass (Gg C) × Ratio of N:C loss × N_2O emissions factor × 44/28

NO_x emissions = total C released × C released biomass (Gg C) × Ratio of N:C loss × NO_x emission factor × 46/14

CH_4 emissions = total C released × CH_4 emission factor × 16/12

CO emissions = total C released × CO emission factor × 28/12

Table 6.6.1 Emission factors used to estimate emissions from tussock burning in New Zealand

Description	Factor	Source
Tussock above-ground biomass density	28	Payton and Pearce, 2001
Biomass fraction burned (fraction actually burned)	0.356	Payton and Pearce, 2009
Ratio of C loss to above-ground biomass	0.45	Payton and Pearce, 2009
Fraction that is live and dead biomass	1	Curtin et al, 2011
Fraction oxidised	1	Curtin et al, 2011
Ratio of N:C loss	0.45	Payton and Pearce, 2009
CH_4 emission factor	0.005	Revised IPCC 1996 guidelines
CO emission factor	0.06	Revised IPCC 1996 guidelines
N_2O emission factor	0.07	Revised IPCC 1996 guidelines
NO_x emission factor	0.121	Revised IPCC 1996 guidelines

Source: Payton and Pearce, 2009; Payton and Pearce, 2001; and IPCC, 1996 – all cited in Curtin et al, 2011.

6.6.3 Uncertainties and time-series consistency

The same emission factors were used for the whole time series. However, the source of the area of tussock land burned changes in 2005. Analysis between the two sources does, however, indicate that they are comparable around the time of the change over. The major sources of uncertainty are the extrapolation of biomass data from two study sites for all areas of tussock and the change in activity data sources. Uncertainty in the New Zealand biomass data has been quantified at ±6 per cent (Payton and Pearce, 2001). However, many IPCC parameters vary by ±50 per cent and some parameters do not have uncertainty estimates.

6.6.4 Source-specific QA/QC and verification

Data on consented area of tussock burning has been compared against data from Statistics New Zealand for tussock burning area in the years where both data sources are available. Plant and Food Research was hired to review the implementation of the methodology to estimate emissions of N_2O from Crop residues, Nitrogen-fixing crops, Prescribed burning of savanna and Field burning of agricultural residues.

6.6.5 Source-specific recalculations

No improvements are currently planned for this emissions source category.

6.6.6 Source-specific planned improvements

No improvements are currently planned for this emissions source category.

6.7 Field burning of agricultural residues (CRF 4F)

6.7.1 Description

Burning of agricultural residues produced 19.8 Gg CO_2-e in 2011. This was a decrease of 4.2 Gg CO_2-e (17.4 per cent) above the level of 24.0 Gg CO_2-e in 1990. Burning of agricultural residues was not identified as a key category in 2011.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize and other crop residues are not burnt in New Zealand.

Burning of crop residues is not considered to be a net source of CO_2, as the CO_2 released into the atmosphere is reabsorbed during the next growing season. However, the burning is a source of emissions of CH_4, CO, N_2O and NO_x (IPCC, 1996). The area of burning of residues varies between years due to climatic conditions and the value of the burnt straw.

6.7.2 Methodological issues

The emissions from burning agricultural residues are estimated using country-specific methodology and emission factors (Curtin et al, 2011). The methodology is aligned with the 1996 IPCC methodology but utilises country-specific parameters. This calculation uses crop production and burning statistics, along with country-specific parameters for the proportion of residue actually burnt, harvests indices, dry-matter fractions, fraction oxidised and the carbon and nitrogen fractions of the residue. The country-specific values for these parameters are those from the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003) and are the same as those used for estimates of emissions from crop residues. This provides consistency between the two emissions estimates for crop residue and crop burning. See section 6.5.2 for further details on these values.

These parameters were multiplied to calculate the carbon and nitrogen released based on estimates of carbon and nitrogen fractions in different crop biomass. The emissions of CH_4, CO, N_2O and NO_x were calculated using the carbon and nitrogen released and an emissions ratio.

IPCC good practice guidance suggests that an estimate of 10 per cent of residue burned may be appropriate for developed countries but also notes that the IPCC default values: "are very speculative and should be used with caution. The actual percentage burned varies substantially by country and crop type. This is an area where locally developed, country-specific data are highly desirable" (IPCC, 2000).

For the years 1990 to 2004, the following equations are used for each individual crop implementing annual crop production values for wheat, barley and oats from Statistics New Zealand. The methodology, parameters and data sources for 2005 onwards are discussed later in this section. Neither legume nor maize crops are burnt in New Zealand but, rather, crop residue is incorporated back into the soil or harvested for supplementary feed for livestock.

Annual dry matter production (t dm) = Total crop production (t) × dry matter fraction

Above-ground dry-matter residue (t dm) = (Annual dry-matter production (t dm) / crop-specific Harvest Index) – dry-matter production (t dm)

Biomass burned (Gg) = Above-ground dry-matter residue (t dm) × Area burned as a proportion of total production area × Proportion of residue remaining after any removal × Proportion of remaining residue actually burned/1000

Total biomass burned is then used to estimate N_2O, NO_x, CH_4, and CO.

N_2O = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × N_2O emission factor × 44/28

NO_x = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × NO_x emission factor × 44/28

CH_4 = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CH_4 emission factor × 16/12

CO = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CO emission factor × 16/12

Statistics New Zealand did not collect statistics on crop residue burning prior to 2005. Therefore, there was no annual data series for crop residue previously and other methods for obtaining these data were determined.

The recommended proportion of crop area burned for 1990 to 2004 was determined by a farmer survey and is 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops (Curtin et al, 2011). These values are in alignment with Statistics New Zealand data for 2005–2007 (2005 being the first year Statistics New Zealand gathered these data) and, therefore, are applied to the years 1990–2004. Values for 2005 onwards are discussed later in this section.

Expert opinion suggests that if crop residue is to be burned, there is generally no prior removal for feed and bedding. Therefore, 100 per cent of residue is left for burning after the harvested proportion has been removed (Curtin et al, 2011).

The proportion of residue actually burned has been estimated as 70 per cent for the years 1990–2004 as this takes into account required fire break areas and differences in the methods used. It is also assumed that farmers will generally be aiming to have as close to complete combustion as possible.

Table 6.7.1 Values used to calculate New Zealand emissions from burning of agricultural residues

	Barley	Wheat	Oats
Fraction of residue actually burnt	0.7	0.7	0.7
Fraction oxidised	0.9	0.9	0.9
Fraction of nitrogen in biomass	0.005	0.005	0.005
Fraction of carbon in biomass	0.4567	0.4853	0.4567
Dry-matter fraction	0.86	0.86	0.86
Harvest index	0.46	0.41	0.30
Wheat residue remaining in field	1	1	1

Source: Curtin et al, 2011.

Table 6.7.2 Emission ratios for agricultural residue burning

Compound	Emission ratio (Revised IPCC 1996 guidelines)
CH_4	0.005
CO	0.06
N_2O	0.007
NO_x	0.121

A slightly different methodology is used for estimating emissions from agricultural residue burning from 2005 to account for, and take advantage of, extra data available from this year onwards.

From 2005, data on the total area of crop residues burned in New Zealand are collected. Estimates of the proportion of this total area of wheat, barley and oats is then made using the same proportion for wheat as used for the 1990–2004 calculations (70 per cent). The remaining residue burning area is then allocated to barley and oats using the same proportion as the area of each of these crops grown in relation to the total area of barley and oats grown.

The following are the equations used for estimating emissions from agricultural residue burning from 2005 onwards.

Production dry-matter area burned (t dm) = Estimated area burned (ha) × Average crop yield (t/ha) × dry-matter fraction

Above ground dry-matter residue (t dm) = (Production dry- matter area burned (t dm)/ crop-specific Harvest Index) – Area of crop burned (t dm)

Biomass burned (Gg) = Above-ground dry-matter residue (t dm) × Proportion of residue remaining after any removal × Proportion of remaining residue actually burned/1000

Total biomass burned is then used to estimate N_2O, NO_x, CH_4 and CO using the same equations as for 1990–2004.

All parameters used in the calculation of emissions from agricultural residue burning for all years are detailed in table 6.7.1 and emission ratios in table 6.7.2.

6.7.3 Uncertainties and time-series consistency

The fraction of agricultural residue burned in the field was considered to make the largest contribution to uncertainty in the estimated emissions. Expert opinion for the fraction of crops burnt in fields between 1990 and 2004 is 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops. These values are taken from farmer surveys in the Canterbury area, where 80 per cent of cereal production occurs, and, between 2005 and 2009, an average of 86 per cent of residue burning occurred. Estimates of crop burning for 2010 are 49 per cent and have ranged from a high in 2006 of 61 per cent to a low in 2009 of 40 per cent reflecting variations in annual weather patterns.

6.7.4 Source-specific QA/QC and verification

Table 6.7.3 compares the New Zealand-specific values $Frac_{BURN}$ with the revised 1996 IPCC guidelines default value and fractions used by Australia and the United Kingdom.

New Zealand's value is higher than that of the revised 1996 IPCC guidelines default value, Australian and the United Kingdom values. This is because the IPCC default value was based on the assumption that little field residue burning was carried out in developed countries. This appears to be the case for both Australia and the United Kingdom. However, in some regions of New Zealand, burning of barley and wheat is still carried out, although this has been declining since 1990.

Plant and Food Research was hired to review the implementation of the methodology to estimate emissions of N_2O from Crop residues, Nitrogen-fixing crops, Prescribed burning of savanna and Field burning of agricultural residues.

Table 6.7.3 Comparison of IPCC default emission factors and country-specific implied emission factors for $Frac_{BURN}$

	$Frac_{BURN}$ (kg N/kg crop-N)
IPCC-developed temperate climate/Oceania default value	0.1
Australian-specific IEF 2010 value	NA[38]
United Kingdom-specific IEF 2010 value	0
New Zealand-specific 2010 value	0.49

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 22 February 2013.

Note: IEF = implied emission factor.

6.7.5 Source-specific recalculations

There were recalculations for 1990 to 2010 for this submission due to recalculations in the crop model, as elaborated in 6.5.5. The recalculations to the crop biomass for wheat, barley and oats flow onto recalculations for field burning of agriculture residues. The recalculation decreased emissions by 0.4 Gg CO_2-e in 1990 and increased emissions by 1.8 Gg CO_2-e in 2010.

6.7.6 Source-specific planned improvements

No improvements are currently planned.

[38] Australia reports that there is no field residue burning and therefore it does not use $Frac_{BURN}$.

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Chapter 7: Land use, land-use change and forestry (LULUCF)

7.1 Sector overview

In 2011, net emissions by the land use, land-use change and forestry (LULUCF) sector were –13,540.2 Gg carbon dioxide equivalents (CO_2-e). This comprises net removals of 13,606.0 Gg carbon dioxide, emissions of 51.5 Gg CO_2-e of methane (CH_4) and 14.3 Gg CO_2-e of nitrous oxide (N_2O). The greatest contribution to removals was from the land converted to forest land subcategory. The largest source of emissions was from the forest remaining forest subcategory.

Net emissions in 2011 have increased by 14,572.5 Gg CO_2-e (51.8 per cent) from the 1990 level of –28,112.7 Gg CO_2-e (table 7.1.1 and figure 7.1.1). This is largely the result of increased harvesting of plantation forests as a larger proportion of the estate reaches harvest age. The increase in emissions in the grassland land-use category is primarily due to the shift in land-use changes occurring among the grassland subcategories since 1990 and the conversion of plantation forests to grassland that has occurred since 2003. The biomass emissions from land-use change are reported in the 'land converted to' category in the year of the event; changes in the mineral soil carbon stock transition between land-use subcategories over 20 years.

Table 7.1.1 New Zealand's greenhouse gas emissions for the LULUCF sector by land-use category in 1990 and 2011 as well as their share and trend

Land-use category	1990 Emissions (Gg CO_2-e)	2011 Emissions (Gg CO_2-e)	Difference 1990–2011	% Change 1990–2011	1990 Share (%)	2011 Share (%)
Forest land	–27,717.3	–17,741.2	9,976.1	36.0	98.6	131.0
Cropland	568.3	390.8	–177.5	–31.2	–2.0	–2.9
Grassland	–1,233.1	3,753.3	4,986.5	404.4	4.4	–27.7
Wetlands	167.3	20.9	–146.4	–87.5	–0.6	–0.2
Settlements	97.6	34.7	–62.9	–64.4	–0.3	–0.3
Other land	4.5	1.3	–3.2	–70.9	–0.02	–0.01
Total LULUCF	**–28,112.7**	**–13,540.2**	**14,572.5**	**51.8**	**100.0**	**100.0**

Note: Net removals are expressed as a negative value in the table to help the reader in clarifying that the value is a removal and not an emission. Columns may not add due to rounding.

Emissions in the LULUCF sector are primarily caused by harvesting production forests, deforestation and the decomposition of organic material, whereas removals are primarily because of the uptake of carbon dioxide from plant growth. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and de-nitrification, and the burning of organic matter. Other gases released during biomass burning include CH_4, carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs).

Between 2010 and 2011, net emissions from the LULUCF sector increased by 4,274.2 Gg CO_2-e (24 per cent). The main contributor to the change occurred within the forest land category as a greater proportion of forest land was harvested in 2011 compared with 2010 due to its age-class profile. Emissions have also increased in the grassland category due to larger areas of forest land being converted to grassland in 2011 than in 2010.

New Zealand has adopted the six broad categories of land use as described in *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), hereafter referred to as GPG-LULUCF.

The land-use categories forest land remaining forest land, conversion to forest land, conversion to cropland, grassland remaining grassland, conversion to grassland and conversion to wetlands are key categories for New Zealand in 2011.

Figure 7.1.1 New Zealand's annual emissions from the LULUCF sector from 1990 to 2011

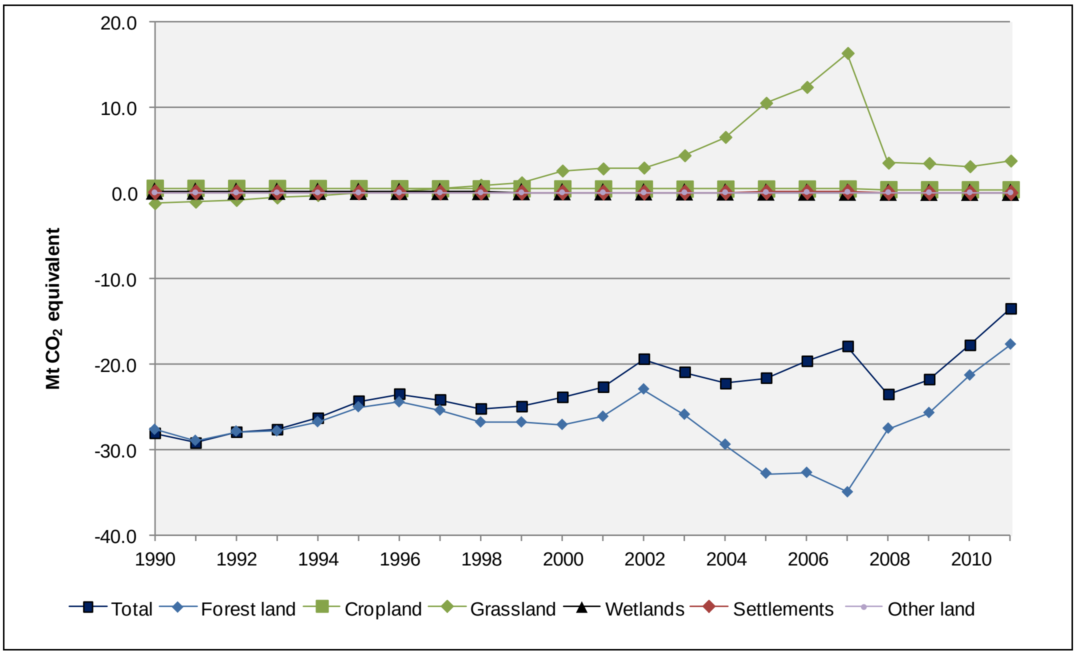
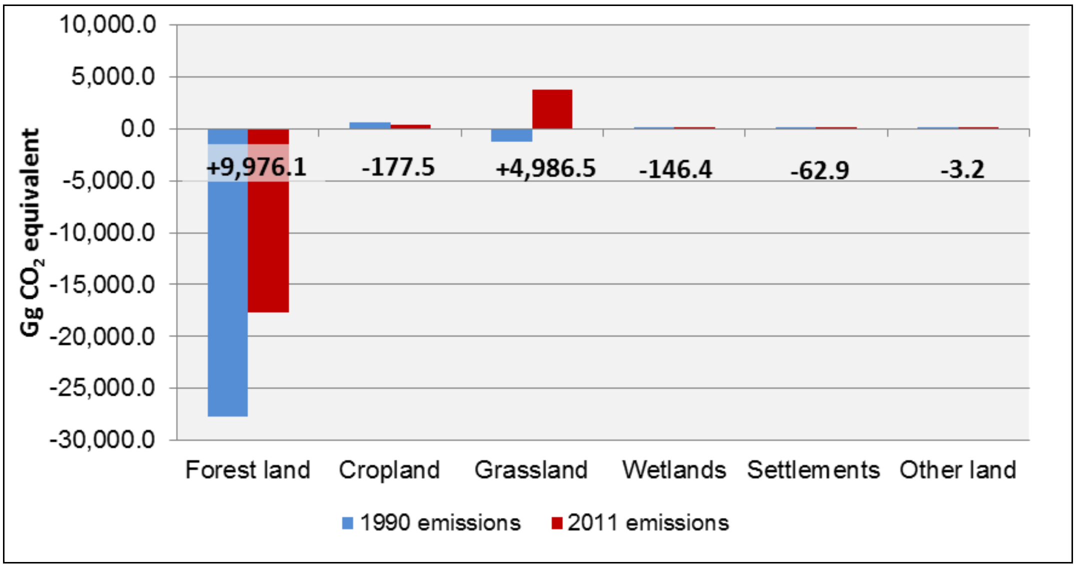


Figure 7.1.2 Change in New Zealand's emissions from the LULUCF sector from 1990 to 2011



7.1.1 Land use, land-use change and forestry in New Zealand

New Zealand has a land area of approximately 270,000 km^2 with extensive coastlines (11,500 kilometres). New Zealand has a temperate climate, which is highly influenced by the surrounding ocean. Sixty per cent of the land is hilly or mountainous, with many lakes and fast-flowing rivers and streams.

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 75 per cent of total land area. Today, natural forest covers around 30 per cent of the total land area of New Zealand (see table 7.1.2). Nearly all lowland areas have been cleared of natural forest for agriculture, horticulture, plantation forestry and urban development. Much of the remaining natural vegetation, however, is now legally protected, with 31 per cent of the total country (8.4 million hectares) within the conservation estate.

Forestry and agriculture are core to the New Zealand economy and the main determinants of its LULUCF emissions profile. Intensive forest management combined with a temperate climate, fertile soils and high rainfall mean New Zealand has amongst the highest rates of exotic forest growth among Annex 1 countries.

New Zealand's exotic forest plantation estate is intensively managed for production forestry, with rapid growing genotypes selected and enhanced for optimum growth. In 2011, plantation forests covered approximately 2 million hectares – around 7.7 per cent of New Zealand's total land area. This includes areas not managed for timber supply: for instance, areas planted for erosion control.

Table 7.1.2 Land use in New Zealand in 2011

Land-use category	Subcategory	Hectares	Proportion of total area (%)
Forest land	Natural forest	8,060.392	29.9
	Pre-1990 planted forest	1,492.817	5.5
	Post-1989 forest	599.269	2.2
	Subtotal	*10,152.478*	*37.7*
Cropland	Annual	334.852	1.2
	Perennial	104.077	0.4
	Subtotal	*438.929*	*1.6*
Grassland	High producing	5,792.117	21.5
	Low producing	7,661.334	28.5
	With woody biomass	1,118.082	4.2
	Subtotal	*14,571.532*	*54.1*
Wetlands		662.930	2.5
Settlements		207.292	0.8
Other land		892.228	3.3
Total		**26,925.391**	**100.0**

Note: Areas as at 31 December 2011. Totals may not add due to rounding.

Since 1990, New Zealand has undergone land-use change on approximately 3.1 per cent of the total land area.

7.1.2 Methodological issues for the LULUCF sector

New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating and reporting emissions for the LULUCF sector (tables 7.1.3 and 7.1.4). A Tier 1 approach, based on a land-use change matrix, has been used to estimate carbon change in the four biomass pools for all land-use categories except for forest land, perennial cropland and grassland with woody biomass, which use a Tier 2 approach.

For all land-use categories, Tier 1 modelling approaches have been used to estimate carbon stocks in organic soils and soil organic carbon (SOC) stocks in mineral soils.

Emission factors

The emission factors required to estimate carbon stock changes using the Tier 1 and Tier 2 equations are provided in tables 7.1.3 and 7.1.4. Table 7.1.3 contains biomass carbon stocks in each land prior to conversion and table 7.1.4 contains the annual growth in carbon stocks after land-use change.

Table 7.1.3 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2013 submission emission factors (t C ha^{-1})	Carbon pools	Reference
Forest land	Natural forest national average	173.0$^{(1)}$	All biomass pools	Beets et al, 2009
	Natural forest: shrub	57.1$^{(2)}$	All biomass pools	Beets et al, 2009
	Natural forest: tall forest	217.9$^{(2)}$	All biomass pools	Beets et al, 2009
	Pre-1990 planted forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
	Post-1989 forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
Cropland	Annual	5	Above- and below-ground biomass	Table 3.3.8 (IPCC, 2003)
	Perennial	18.76	Above-ground biomass	Davis and Wakelin, 2010
Grassland	High producing	6.75	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	Low producing	3.05	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	With woody biomass	29	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	Section 3.5.2.2 and annex 3A (IPCC, 2003)
Settlements		NE	NA	Section 3.6.2 (IPCC, 2003)
Other land		NE	NA	Section 3.7.2.1 (IPCC, 2003)

Note: NA = not applicable; NE = not estimated. (1) The indicated amount is emitted instantaneously for conversions from natural forest prior to 2008. (2) For conversions from natural forest since 1 January 2008, the indicated stock is emitted instantaneously depending on the vegetation type present (tall forest or shrub) immediately before conversion. Biomass pools include above- and below-ground biomass, litter and dead organic matter. See below in section 7.1.3 and under Methodological issues in each category-specific section for further details.

Table 7.1.4 New Zealand's emission factors for annual growth in biomass for land converted to another use

Land-use category	Land-use subcategory	2013 submission emission factor (t C ha^{-1})	Years to reach steady state	Carbon pools	Reference
Forest land	Natural forest	NO(1)	NA	NA	NA
	Pre-1990 planted forest	Based on age-based carbon yield table	28	All biomass pools	LUCAS plot-based estimate
	Post-1989 forest	Based on age-based carbon yield table	28	All biomass pools	LUCAS plot-based estimate
Cropland	Annual	5	1	Above- and below-ground biomass	Table 3.3.8 (IPCC, 2003)
	Perennial	0.67	28	Above-ground biomass	Davis and Wakelin, 2010
Grassland	High producing	6.75	1	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	Low producing	3.05	1	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	With woody biomass	1.04	28	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	NA	Assume steady state (IPCC, 2003)
Settlements		NE	NA	NA	Assume steady state (IPCC, 2003)
Other land		NE	NA	NA	Assume steady state (IPCC, 2003)

Note: NA = not applicable; NE = not estimated; NO = not occurring. (1) No conversions to natural forest have occurred since 1962. See section 7.3 for further details.

To meet reporting requirements under the Kyoto Protocol, New Zealand is estimating carbon stock change for each of the five Kyoto Protocol carbon pools and aggregating the results to the three Climate Change Convention reporting pools. Table 7.1.5 summarises the methods being used to estimate carbon by pool for each land use.

Table 7.1.5 Relationships between carbon pool, land-use category, LULUCF activity and model calculations used by New Zealand

Climate Change Convention reporting pool		Living biomass		Dead organic matter		Soils	
						Soil organic matter	
Kyoto Protocol reporting pool		Above-ground biomass	Below-ground biomass	Dead wood	Litter	Mineral soils	Organic soils
Land-use category	Natural forest	Allometric equations	Per cent of above-ground biomass	Allometric equations	Lab analysis	IPCC Tier 1 default parameters	Not applicable
	Natural forest [D]	Emission factor based on natural forest national average for deforestation occurring before 1 January 2008 or the vegetation type present (tall forest or shrub) immediately before deforestation occurring since 1 January 2008					
	Pre-1990 planted forest	Age-based carbon yield table by pool derived from the Land Use and Carbon Analysis System (LUCAS) plot network and the Forest Carbon Predictor model				IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Pre-1990 planted forest [D]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model					
	Post-1989 forest [AR]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model				IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Post-1989 forest [D]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model					
	Cropland – annual	IPCC Tier 1 default parameters	Not estimated	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Cropland – perennial	Country-specific emission factor	Not estimated	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Grassland (high and low producing)	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Grassland with woody biomass	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Wetlands	IPCC Tier 1 default parameters (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated
	Settlements	IPCC Tier 1 default parameter (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated
	Other land	IPCC Tier 1 default parameter (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated

Note: AR = afforestation/reforestation; D = deforestation; NE = not estimated and NEFD = the National Exotic Forest Description (Ministry of Agriculture and Forestry, 2012). See the methodology sections for an explanation of soil carbon calculations (section 7.1.3) and forest models, C_Change and Forest Carbon Predictor (section 7.3.2).

Calculation of national emission estimates

To calculate emissions for the New Zealand LULUCF sector, the following data are used:

- land use and land-use change areas from 1962 to 1989, which provides land in a transition state as at 1990 for each land-use subcategory
- annual land use and land-use change area data from 1990 to 2011 (see section 7.2)
- biomass carbon stocks per hectare prior to land-use conversion, and annual growth in biomass carbon stocks per hectare following conversion (tables 7.1.3 and 7.1.4)
- age-based biomass carbon yield tables for pre-1990 planted forests and post-1989 forests (see section 7.3.2)
- emission factors and country-level activity data on biomass burning and liming (section 7.9)
- Intergovernmental Panel on Climate Change (IPCC) default conversion factors.

The formula used to calculate emissions from biomass changes is:

$$\left(\text{Loss of biomass present in previous crop} \times \text{Activity data (Area)}\right) + \left(\text{Annual growth in biomass carbon stocks in new land use} \times \text{Activity data (Area)}\right)$$

The formula used to calculate emissions from soil changes is:

$$\frac{\text{Soil carbon at steady state in the new land use} - \text{Soil carbon at steady state in the previous land use}}{\text{20 years (transition period)}} \times \left(\text{Activity data (Area)}\right)$$

For example, the annual change in carbon stock in the first year of conversion of 100 hectares of low-producing grassland to perennial cropland would be calculated as follows:

Biomass change = (–3.05 x 100) + (0.67 x 100) = –238 t C
Soil change = (((97.76 – 105.55) / 20) x 100) = –39 t C
Total carbon stock change = –277 t C

Total emissions = (carbon stock change / 1000 x –1) x (44/12)
Total emissions = 1.015 Gg CO_2-e

These calculations are performed to produce estimates of annual carbon stock and carbon stock changes since 1990 to inform the Climate Change Convention and Kyoto Protocol Article 3.3 reporting.

New Zealand land use and carbon analysis system

New Zealand's LULUCF estimates are calculated using a programme of data collection and modelling called the Land Use and Carbon Analysis System (LUCAS). The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The Data Management system comprises: the Geospatial System, a data warehousing 'Gateway' and the Calculation and Reporting Application. These systems are used for managing the land-use spatial databases and the plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting. Details on these databases and applications are provided in annex 3.2.

7.1.3 Soils

In this submission, New Zealand uses Tier 1 methods to estimate soil carbon changes in mineral and organic soils.

Mineral soils

New Zealand uses a Tier 1 method to estimate soil carbon stock and stock change for mineral soils. The method estimates a steady state carbon stock for each land use in New Zealand and calculates changes in soil carbon stocks associated with land-use change.

Data

New Zealand-specific climate and soil data were analysed in a GIS system to estimate the areas of each soil type found in each climate zone (table 7.1.6). Soil-type data are based on the Fundamental Soils Layer (FSL) associated with the New Zealand Land Resources Inventory (NZLRI) (Newsome et al, 2000) and converted to the IPCC classification (Daly and Wilde, 1997). Climate data are based on two underlying data layers of the Land Environments of New Zealand (LENZ) classification (Leathwick et al, 2002). These layers provide data about the temperature and moisture conditions necessary to characterise the GPG-LULUCF climate zones (IPCC, 2003).

Some areas around the margins of mainland New Zealand and offshore islands do not have underlying soil or climate data. Values have been assigned to areas around the margins of New Zealand using the attributes of neighbouring polygons. The soil and climate types of islands not touching mainland New Zealand remain unknown, meaning they are not included in New Zealand's estimation of emissions from mineral soils. Areas with no data represent around 109,000 hectares (0.0004 per cent of New Zealand's land area). About 300 hectares of this land underwent land-use change. The omission of these areas has a negligible impact on the reported emissions from mineral soil.

Table 7.1.6 Distribution of mineral soil across soil type and climatic zone (hectares)

Climatic zone	HAC soil	LAC soil	Sandy soil	Spodic soil	Volcanic soil	Aquic soil	Estuarine soil	Total
Boreal	696		4,620					5,316
Cold dry	84,609		97			4,330		89,036
Cold wet	8,533,706		497,171	2,400,409	652,178	120,596	833	12,204,893
Warm dry	19,652		1,402			621		21,675
Warm wet	8,261,744	128,553	372,214	940,441	2,927,123	628,378	9,364	13,267,817
Total	**16,900,407**	**128,553**	**875,504**	**3,340,850**	**3,579,301**	**753,925**	**10,197**	**25,588,737**

Note: The total area of table 7.1.6 does not equal the total area of New Zealand due to missing soil type data (eg, the FSL contains no soil information for areas denoted as ice field, riverbed, lakebed or settlement). Organic soils are reported separately.

Calculations

The general approach of the Tier 1 method follows the equations (IPCC, 2003):

$$\Delta C = [(SOC_0 - SOC_{(0\text{-}T)}) * A]/T$$
$$SOC = SOC_{REF} * F_{LU} * F_{MG} * F_I$$

Where:

ΔC = annual change in carbon stocks, tonnes C yr^{-1}

SOC_0 = organic carbon stock in the inventory year, tonnes C yr^{-1}

$SOC_{(0\text{-}T)}$ = organic carbon stock T years prior to the inventory year, tonnes C yr^{-1}

A = land area of parcels with these SOC terms, ha

T = inventory time period, yr (New Zealand uses the 20-year default)

SOC_{REF} = the reference carbon stock, tonnes C ha^{-1}

F_{LU} = stock change factor for land use or land-use change type, dimensionless

F_{MG} = stock change factor for management regime, dimensionless

F_I = stock change factor for input of organic matter, dimensionless.

New Zealand has estimated a national value of SOC_{REF} based on the areas of each soil type found in each climatic zone (table 7.1.6) and the default reference SOC stock under native vegetation for each climate–soil combination (IPCC, 2003). SOC_{REF} has been calculated as 92.59 tonnes C ha^{-1}.

GPG-LULUCF stock change factors have been assigned to each of the LULUCF land-use classes and then applied to the national SOC_{REF} to determine a steady state organic carbon stock for each land use (table 7.1.7, annex A3.2.2). These are then used to calculate annual changes in carbon stocks (using the equation above).

Table 7.1.7 Stock change factors and steady state soil organic carbon stocks for land-use classes

Land-use class	Land-use factor (FLU)	Management regime factor (FMG)	Input factor (FI)	SOC at 0–30 cm (t C ha^{-1})
Natural forest	1.0	1.0	1.0	92.59
Planted forest	1.0	1.0	1.0	92.59
Annual cropland	0.71	1.0	0.91	59.82
Perennial cropland	0.82	1.16	1.11	97.76
High-producing grassland	1.0	1.14	1.11	117.16
Low-producing grassland	1.0	1.14	1.0	105.55
Grassland with woody biomass	1.0	1.0	1.0	92.59
Open water	0	0	0	0
Vegetated wetlands	1.0	1.0	1.0	92.59
Settlements*	1.0	0.70	1.0	64.81
Other land	1.0	1.0	1.0	92.59

Note: * The stock change factors for unimproved grassland with severe degradation were used in the absence of IPCC default stock change factors for settlements for this land use.

Organic soils

Organic soils occupy a relatively small proportion of New Zealand's total land area (0.9 per cent), and the area of organic soils subject to land-use change is approximately 0.01 per cent of New Zealand's total land area. New Zealand uses a Tier 1 method to estimate soil carbon stock change in organic soils.

The definition of organic soils is derived from the New Zealand Soil Classification (Hewitt, 1998), which defines organic soils as those soils with at least 18 per cent organic carbon in horizons at least 30 centimetre thick and within 60 centimetres of the soil surface. New Zealand-specific climate and soil data are used to estimate the areas of organic soil found in each climate zone. Climate data is based on the temperature data layer of the LENZ classification (Leathwick et al, 2002). Soil-type data is based on the FSL associated with the NZLRI (Newsome et al, 2000) and converted to the IPCC classification (Daly and Wilde, 1997). These data layers have been analysed in a GIS system to determine the areas of organic soils in warm and cold climate zones. These areas are compared with the land-use mapping layer to determine area data for organic soils by IPCC land use.

The LUCAS organic soils definition has been aligned with that used for the agriculture sector (Dresser et al, 2011).

New Zealand has used IPCC default emission factors for organic soils under forest, grassland and cropland (IPCC, 2003) to estimate organic soil emissions (table 7.1.8). IPCC guidance for organic soils under forest is limited to estimates associated with the drainage of organic soils in managed forests. In New Zealand, natural forests are not drained and therefore the default emission factor is not applicable. It is assumed that all planted forests on organic soils are drained prior to forest establishment. The warm temperate and cold temperate defaults for grassland and cropland are applied in proportion to the area of land in New Zealand where the mean annual temperature is above or below 10°C respectively. There are no default emission factors for organic soils under settlements, wetlands or other land; therefore, emissions from organic soils under these land uses are not estimated.

Table 7.1.8 New Zealand emission factors for organic soils

Land use	Climatic temperature regime	IPCC Tier 1 default emission factor applied & ranges (t C ha^{-1} yr^{-1})	Reference
Natural forest	Temperate	NA	IPCC guidance applies only to drained forest organic soils, which do not occur in natural forests in New Zealand. IPCC (2003), section 3.2.1.3
Planted forest	Temperate	0.68 (range 0.41–1.91)	IPCC (2003), section 3.2.1.3, table 3.2.3
Cropland	Cold temperate Warm temperate	1.0 ± 90 % 10.0 ± 90 %	IPCC (2003), section 3.3.1.2, table 3.3.5
Grassland	Cold temperate Warm temperate	0.25 ± 90 % 2.5 ± 90 %	IPCC (2003), section 3.4.1.2, table 3.4.6
Wetlands	NA	NE	IPCC guidance applies only to peat extraction, which is not a significant activity in New Zealand. IPCC (2003), section 3.5.2.1
Settlements	NA	NE	No IPCC guidance is available. IPCC (2003), chapter 3.6
Other land	NA	NE	No IPCC guidance is available. IPCC (2003), chapter 3.7

Note: NA = not applicable; NE = not estimated.

Uncertainties and time-series consistency

- Mean annual temperature: standard errors of temperature estimates are mostly less than 0.35°C, though this generally increases (up to 0.5°C) with increasing elevation, reflecting the paucity of records from montane environments (Leathwick et al, 2002).
- Water balance ratio: no estimates of error have been made because of conceptual difficulties in combining the errors of the contributing surfaces (Leathwick et al, 2002).
- Uncertainties associated with the default SOC contents in each soil climate zone are given in table 3.3.3 of GPG-LULUCF (IPCC, 2003).
- Uncertainties associated with the default stock change factors (95–107 per cent) are given in tables 3.3.4 and 3.4.5 of GPG-LULUCF (IPCC, 2003).

Source-specific quality assurance/quality control (QA/QC) and verification

Quality-control and quality-assurance procedures have been adopted for all data analyses, to be consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan. The data layers used in the analyses have also undergone independent quality assurance prior to publication.

Source-specific planned improvements

New Zealand continues to pursue returning to using a Tier 2 methodology for reporting SOC stocks. Improvement activities include data collection for under-represented land-use categories, further recalibration of the Soil CMS model and investigation of other modelling options.

7.1.4 Uncertainties in LULUCF

Table 7.1.9 shows the six land-use subcategories within the LULUCF sector with the greatest contribution to uncertainty in the net carbon emissions for the LULUCF sector. These are given in descending order.

Table 7.1.9 Land-use subcategories with the greatest contribution to uncertainty in the LULUCF sector

Land-use subcategory	Net emissions by subcategory	Uncertainty introduced into net emissions for LULUCF (%)
Pre-1990 planted forest remaining pre-1990 planted forest	–2,740,314.8	76.2
Low producing grassland to post-1989 forest	3,155,542.5	12.7
High producing grassland remaining high producing grassland	–306,582.1	7.1
Grassland with woody biomass to pre-1990 planted forest	1,314,187.9	5.5
Low producing grassland to pre-1990 planted forest	1,080,685.4	4.6
High producing grassland to post-1989 forest	781,563.8	4.4

The land-use subcategory that introduces the greatest uncertainty (when expressed as a proportion of net emissions) is pre-1990 planted forest remaining pre-1990 planted forest. The biomass uncertainties are low for pre-1990 planted forest (14.1 per cent). However, the uncertainty for the subcategory is calculated on the net change. The age structure of the estate results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. The net change is within the error bounds of the emissions and removals estimates and, therefore. its uncertainty is high. Land in transition to pre-1990 planted forest and post-1989 forest also features in the top six uncertainties due to high removals from forest growth, despite the low biomass uncertainties (14.1 per cent and 10.2 percent respectively). Emissions from organic soils in high producing grassland remaining high producing grassland introduce the third greatest uncertainty into the LULUCF sector due to high uncertainty in the IPCC default emission factor used.

The uncertainties were recalculated and independently reviewed for the 2011 submission.

Further details on the emission factor and activity data uncertainties for specific land uses and non-carbon emissions are given within the relevant sections of this chapter.

7.1.5 Recalculations in LULUCF

For the 2013 submission, New Zealand has recalculated its emission estimates for the LULUCF sector from 1990 to 2010 to incorporate new activity data, New Zealand-specific emission factors and improved methodology.

The recalculations have resulted in improvements to the accuracy and completeness of the LULUCF estimates. The overall effect of the recalculations has been to decrease emissions in 1990 by 2.6 per cent and to increase emissions in 2010 by 10.8 per cent (table 7.1.10).

Table 7.1.10 Recalculations to New Zealand's total net LULUCF emissions

	Reported net emissions		Change in estimate	
	2012 submission (Gg CO_2-e)	2013 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	–27,388.3	–28,112.7	–724.4	–2.6
2010	–19,980.5	–17,814.4	2,166.1	10.8

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2012 submission are the result of (in decreasing order of magnitude):

- the activity data used to estimate harvesting emissions in pre-1990 planted forests, which is scaled by 17 per cent throughout the time series to account for differences in forest definitions used in the inventory and the source of the activity data (Wakelin and Paul, 2012)
- the correction of an error detected in the calculation process when upgrading to the Forest Carbon Predictor, version 3, for last year's submission, which affected the implementation of the new post-1989 planted forest yield table
- continued improvements to the 1990 and 2008 land-use maps. Mapping data provided from the New Zealand Emissions Trading Scheme (NZ ETS) was integrated into the 1990 and 2008 maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest

- emissions being reported for controlled burning in forest land remaining forest land for the first time in the 2011 inventory. Estimates are provided for the burning of post-harvest slash prior to restocking.

The impact of these recalculations on net CO_2-e emissions in each land-use category is provided in table 7.1.11. The differences shown are a result of recalculations for all carbon pools used for Climate Change Convention and Kyoto Protocol reporting for the whole time series for the LULUCF sector. This table includes only recalculations from 1990 to 2010, to enable a comparison of the two approaches.

Table 7.1.11 Recalculations to New Zealand's net LULUCF emissions for 1990 and 2010

Land-use category	Net emissions (Gg CO_2-e) 2012 submission: 1990 estimate	2013 submission: 1990 estimate	2012 submission: 2010 estimate	2013 submission: 2010 estimate	Change in 1990 estimate (%)	Change in 2010 estimate (%)
Forest land	–27,149.9	–27,717.3	–23,539.1	–21,363.2	2.1	–9.2
Cropland	567.1	568.3	392.1	391.8	0.2	–0.1
Grassland	–1,075.4	–1,233.1	3,120.8	3,091.2	14.7	–0.9
Wetlands	165.7	167.3	0.0	20.9	1.0	∞
Settlements	97.7	97.6	34.9	34.7	–0.1	–0.4
Other land	6.5	4.5	10.8	10.2	–30.0	–5.5
Total	**–27,388.3**	**–28,112.7**	**–19,980.5**	**–17,814.4**	**2.6**	**–10.8**

Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Columns may not total due to rounding.

Detailed information on the recalculations is provided below in the relevant source-specific recalculations sections and in chapter 10.

7.1.6 LULUCF planned improvements

Category-specific planned improvements are reported separately under each of the relevant sections of this chapter. The major themes are:

- completion of ground- and aerial-based forest carbon stock inventories
- improvements to carbon stock and change assessments for natural and planted forests and associated emissions relating to forest management practices
- complete land-use mapping at 2012 along with improvements to the 2008 and 1990 land-use mapping
- improvements to soil carbon assessment.

7.2 Representation of land areas

7.2.1 Land-use category definitions

The New Zealand land-use categories and subcategories are shown in table 7.2.1. The land-use subcategories are consistent with those used for the 2012 submission.

Table 7.2.1 New Zealand's land-use categories and subcategories

IPCC land-use category	New Zealand land-use subcategory
Forest land	Natural forest Pre-1990 planted forest Post-1989 forest
Cropland	Cropland – annual Cropland – perennial
Grassland	Grassland – high producing Grassland – low producing Grassland – with woody biomass
Wetlands	Wetlands[(1)]
Settlements	Settlements
Other land	Other land

Note: (1) Mapped as 'wetlands – open water' and 'wetlands – vegetated non-forest'.

The land-use subcategories were chosen for their conformation with the dominant land-use types in New Zealand, while still enabling reporting under the land-use categories specified in the IPCC good practice guidance (2003).

The national thresholds used by New Zealand to define forest land for both Climate Change Convention and Kyoto Protocol reporting are:

- a minimum area of 1 hectare
- a crown cover of at least 30 per cent
- a minimum height of 5 metres at maturity *in situ* (Ministry for the Environment, 2006).

Wetlands have been mapped separately as 'open water' and 'vegetated non-forest'. These subcategories are then aggregated for reporting in the common reporting format (CRF) tables. See section 7.6 for details.

The definitions of New Zealand's land-use subcategories, as they have been mapped, are provided in table 7.2.2, and further details are included in Ministry for the Environment, 2012.

Table 7.2.2 New Zealand's mapping definitions for land-use subcategories

Land-use subcategory	Definition
Natural forest	Areas that, on 1 January 1990, were and presently include: • tall indigenous forest • self-sown exotic trees, such as wilding pines and grey willows, established before 1 January 1990 • broadleaved hardwood shrubland, manuka–kanuka shrubland and other woody shrubland (≥ 30 per cent cover, with potential to reach ≥ 5 metres at maturity *in situ* under current land management within 30–40 years) • areas of bare ground of any size that were previously forested but, due to natural disturbances (eg, erosion, storms, fire), have temporarily lost vegetation cover • areas that were planted forest at 1990 but are subsequently managed to regenerate with natural species that will meet the forest definition • roads and tracks less than 30 metres in width and other temporarily unstocked areas associated with a forest land use

Land-use subcategory	Definition
Pre-1990 planted forest	• radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species (with potential to reach ≥ 5 metre height at maturity *in situ)* established before 1 January 1990 or replanted on land that was forest land as at 31 December 1989 • exotic forest species that were planted after 31 December 1989 into land that was natural forest • riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 • harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected) • roads, tracks, skid sites and other temporarily unstocked areas associated with a forest land use • areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover
Post-1989 forest	• exotic forest (with the potential to reach ≥ 5 metre height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (eg, radiata pine, Douglas fir, eucalypts or other planted species) • harvested areas within post-1989 forest land (assumes these will be replanted, unless deforestation is later detected) • forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 • self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989 • riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • roads, tracks, skid sites and other temporarily unstocked areas associated with a forest land use • areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover
Cropland – annual	• all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland
Cropland – perennial	• all orchards and vineyards • linear shelterbelts associated with perennial cropland
Grassland – high producing	• grassland with high-quality pasture species • linear shelterbelts that are < 1 hectare in area or 30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • areas of bare ground of any size that were previously grassland but, due to natural disturbances (eg, erosion), have lost vegetation cover
Grassland – low producing	• low fertility grassland and tussock grasslands (eg, *Chionochloa* and *Festuca* spp.) • mostly hill country • montane herbfields at either an altitude higher than above-timberline vegetation or where the herbfields are not mixed up with woody vegetation • linear shelterbelts that are < 1 hectare in area or < 30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • other areas of limited vegetation cover and significant bare soil, including erosion and coastal herbaceous sand-dune vegetation
Grassland – with woody biomass	• grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (eg, mahoe – *Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), manuka–kanuka (*Leptospermum scoparium–Kunzea ericoides*) shrubland, coastal and other woody shrubland (< 5 metres tall and any per cent cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30–40 year time period • above-timberline shrubland vegetation intermixed with montane herbfields (does not have the potential to reach > 5 metres in height *in situ*) • grassland with tall tree species (< 30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database (LCDB) has classified these as settlements)

Land-use subcategory	Definition
	• grassland with riparian or erosion control plantings (< 30 per cent cover) • linear shelterbelts that are > 1 hectare in area and < 30 metres in mean width • areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (eg, erosion, fire), have lost vegetation cover
Wetlands	• classified and mapped separately as 'wetlands – open water' and 'wetlands – vegetated non-forest' • open water comprises lakes, rivers, dams and reservoirs • vegetated non-forest wetlands comprise herbaceous and/or non-forest woody vegetation that may be periodically flooded. Includes scattered patches of tall tree-like vegetation in the wetland environment where cover reaches < 30 per cent • estuarine–tidal areas including mangroves
Settlements	• built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas, urban parklands and open spaces that do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction
Other land	• montane rock and/or scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries • permanent ice and/or snow and glaciers • any other remaining land that does not fall into any of the other land-use categories

Further refinements are planned to improve New Zealand's estimates of land-use change, as stated at the end of this section under planned improvements. Land areas reported as 'converted' and 'remaining' within each land-use category are the best current estimates and will be improved should additional activity data become available.

7.2.2 Land-use mapping

Land-use area

In this submission, the total land area of New Zealand used for all estimates of activity data is 26,925.4 kilohectares. This area includes all significant New Zealand land masses, the two main islands, the North Island and South Island, as well as Stewart Island, Great Barrier Island, Little Barrier Island, the Chatham Islands, the sub-Antarctic islands and other, small outlying islands.

New Zealand has used Method 1 and a mix of Approaches 2 and 3 to map land-use changes between 1 January 1990 and 31 December 2007 (IPCC, 2003, chapter 2.3.2.3). The areas of forest as at 1 January 1990 and 1 January 2008 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990 and 2008. The area includes improvements made up to August 2012 using additional satellite imagery, aerial photography and data from the NZ ETS. Land-use changes during 2008, 2009, 2010 and 2011 are then interpolated from other sources. This is described in further detail in section 7.2.3.

Land-use mapping – 1 January 1990

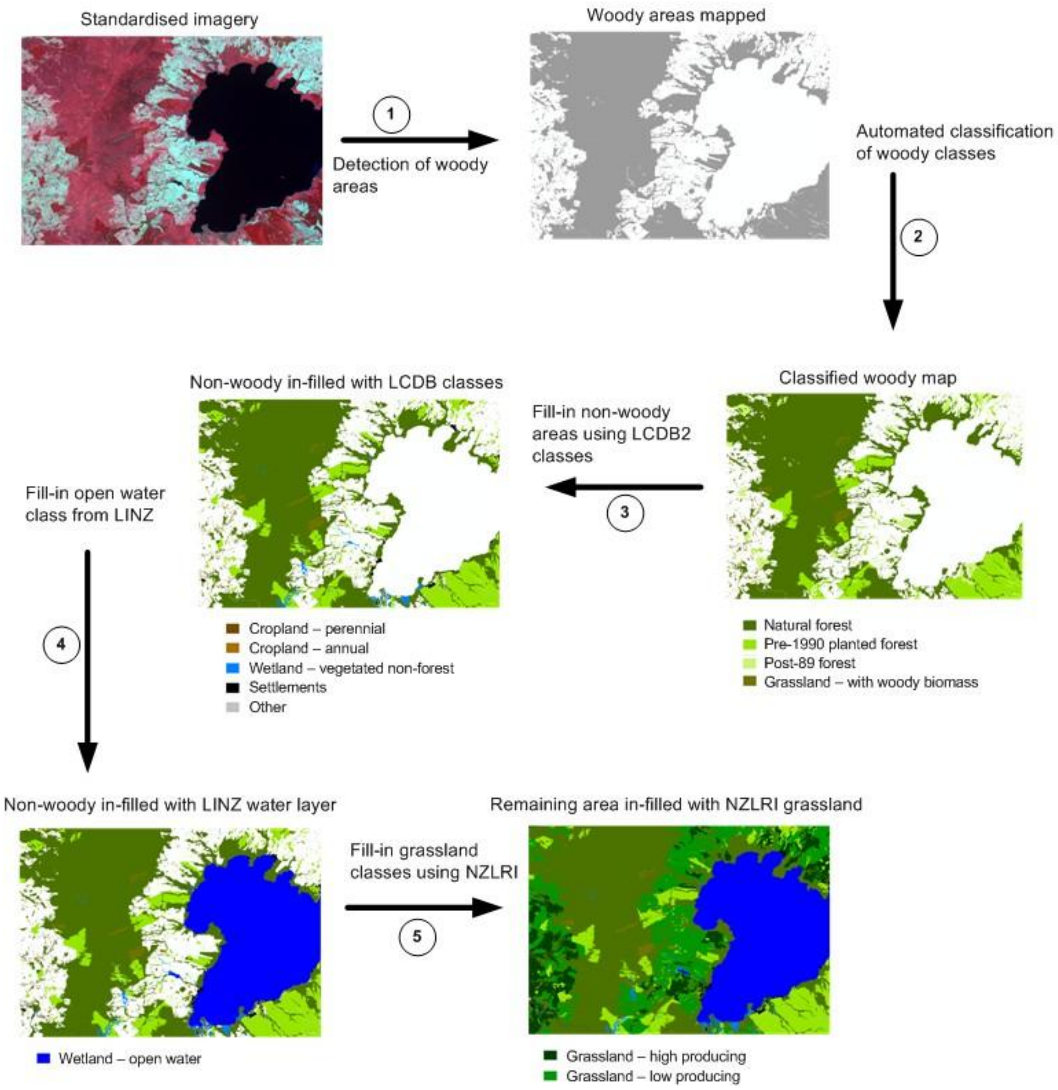
The 1990 land-use map is derived from 30-metre spatial resolution Landsat 4 and Landsat 5 TM satellite imagery taken in, or close to, 1990. The first of the images used were taken in November 1988 and the last in February 1993. In addition to orthorectification and atmospheric correction, the satellite images were standardised for spectral reflectance using the Ecosat algorithms documented in Dymond et al (2001), Shepherd and Dymond, (2003), as well as Dymond and Shepherd (2004). These standardised images were used for the automated mapping of woody biomass and then to map woody biomass classes into the land-use subcategories being used for reporting. These land-use subcategories at 1990 included natural forest, pre-1990 planted forest and grassland with woody biomass.

This classification process was validated and improved using 15-metre resolution Landsat 7 ETM+ imagery acquired in 2000–2001 and SPOT 2 and 3 data acquired in 1996–1997. The use of this higher-resolution imagery (coupled with the use of concurrent aerial photography) enabled more certain land-use mapping decisions to be made.

To determine the spatial location of the other land-use categories and subcategories as at 1990 and 2008, information from two Land Cover Databases, LCDB1 (1996) and LCDB2 (2001) (Thompson et al, 2004), the NZLRI (Eyles, 1977) and hydrological data from Land Information New Zealand (a government agency) have been used (Shepherd and Newsome, 2009).

The NZLRI database was used to better define the area of high- and low-producing grassland. Areas tagged as 'improved pasture' in the NZLRI vegetation records were classified as grassland – high producing in the land-use maps. All other areas were classified as grassland – low producing. Figure 7.2.1 illustrates this mapping process.

Figure 7.2.1 New Zealand's land-use mapping process

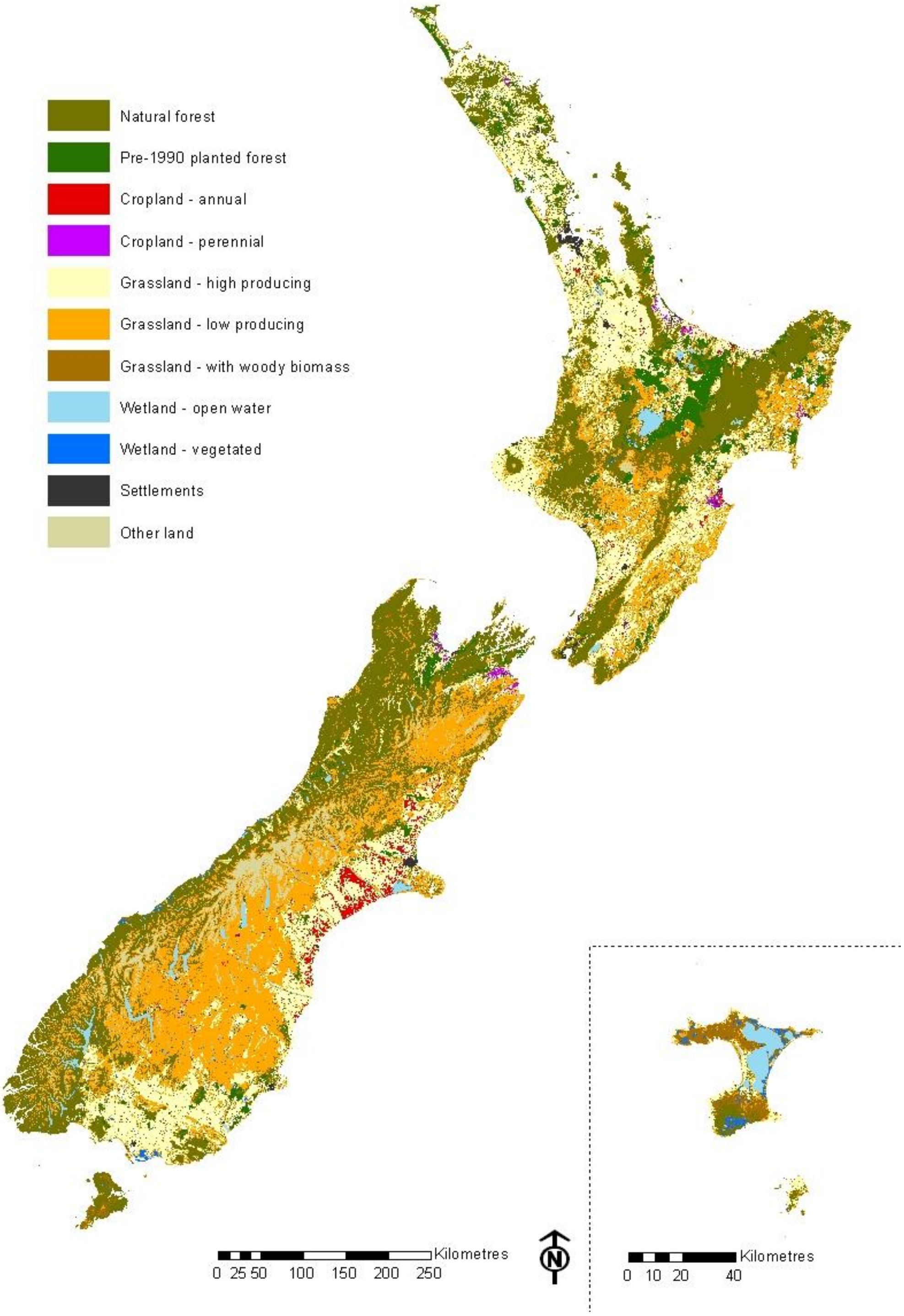


Note: LINZ = Land Information New Zealand.

An interpretation guide for automated and visual interpretation was prepared and used to ensure a consistent basis for all mapping processes (Ministry for the Environment, 2012). Independent quality control was performed for all mapping. This involved an independent agency looking at randomly selected points across New Zealand and using the same data as the original operator to decide within what land-use category the point fell. The two operators were in agreement at least 95 per cent of the time. This is described in more detail in GNS Science (2009).

Figure 7.2.2 shows the land-use map of New Zealand as at 1 January 1990.

Figure 7.2.2 Land-use map of New Zealand as at 1 January 1990

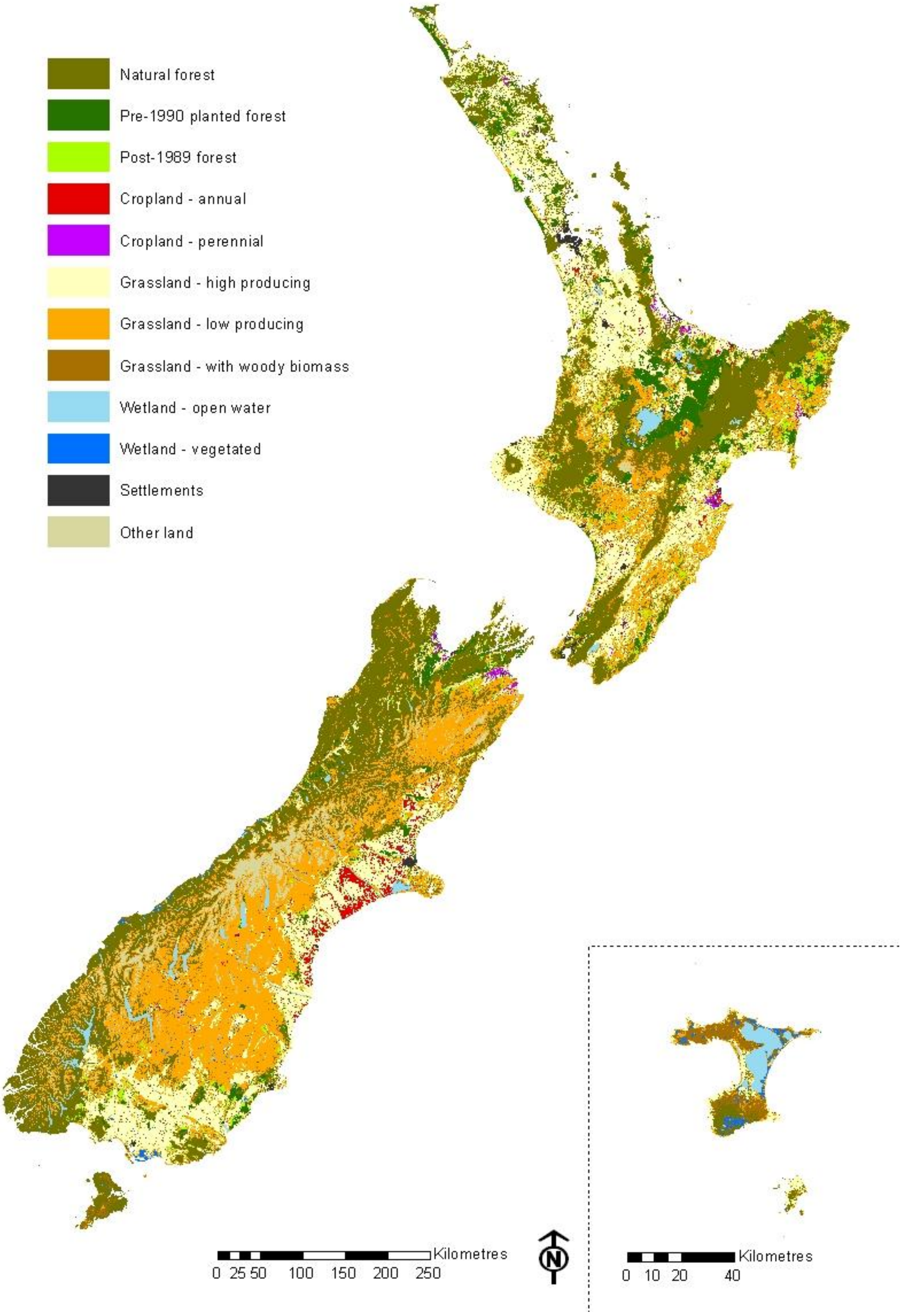


Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the Wairarapa coast or 800 kilometres due east of Banks Peninsula.

Land-use mapping – 1 January 2008

The 2008 land-use map (land use as at 1 January 2008) is derived from 10-metre spatial resolution SPOT 5 satellite imagery and was processed into standardised reflectance images, using the same approach as for the 1990 imagery. The SPOT 5 imagery was taken over the summers of 2006–2007 and 2007–2008 (November to April), to establish a national set of cloud-free imagery. Where the SPOT 5 imagery pre-dates 1 January 2008, a combination of aerial photography, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery and field verification has been used to identify where deforestation has occurred, to ensure that the 2008 land-use map is as accurate as possible. Figure 7.2.3 shows the land-use map of New Zealand as at 1 January 2008.

Figure 7.2.3 Land-use map of New Zealand as at 1 January 2008



Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the Wairarapa coast or 800 kilometres due east of Banks Peninsula.

Decision process for mapping post-1989 forests

The use of remote sensing has some limitations, in particular, the ability to map young planted forest of less than three years of age. Where trees are planted within three years of the image acquisition date they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature in satellite imagery. This occurs particularly with coarse resolution (30 metres) 1990 Landsat imagery. This situation is compounded by the lack of ancillary data at 1990 to support land-use classification decisions; however, in the past two years the NZ ETS has provided valuable spatial information that has been used to confirm 1990 forest land-use classifications.

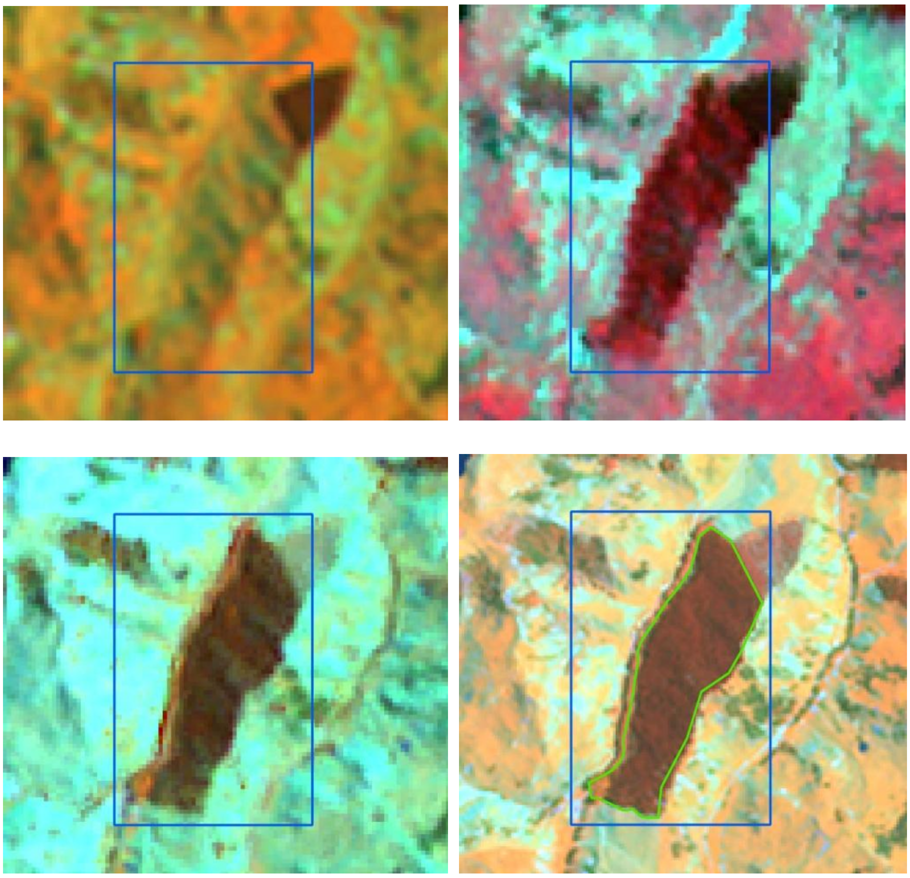
Owners of post-1989 forest are able to lodge their forests with the NZ ETS to obtain credit for increases in carbon stock since 1 January 2008. Mapping received by the Ministry for Primary Industries for these applications is used to improve LUCAS land-use maps.

Mapping from the NZ ETS has also provided a significant source of planting date information to help with the determination of the correct classification of planted forest. The Forestry Allocation Plan, which forms part of the NZ ETS, partially compensates private owners of pre-1990 planted forest for the loss in land value arising from the introduction of penalties for deforesting pre-1990 forest land. Forest owners must apply for this compensation, providing detailed mapping and evidence of their forest planting date. This mapping data is used regularly to improve the classification accuracy of the LUCAS land-use maps.

To aid the decision-making process, the LUCAS mapping also uses nationwide and cloud-free 1996 SPOT and 2001 Landsat 7 satellite image mosaics to determine the age of forest that might have been planted between 1990 and 1993. Figure 7.2.4 illustrates how mapping operators determined the status of an area of planted forest established between 1990 and 1993. The 1996 and 2000 images show strong forestry spectral signatures consistent with a planting date near to 1990. In the 1990 image, which was acquired on 2 December 1990, there is little evidence of an outline matching the forest boundary in the later imagery; however, information from the NZ ETS confirms a 1990 planting date, therefore, this area is classified as post-1989 forest.

Where possible, information obtained directly from forest owners and the national planted forest plot network is also used to improve the accuracy of the pre-1990–post-1989 forest classification.

Figure 7.2.4 Identification of post-1989 forest in New Zealand



Images:	1990 Landsat 4 (top left) 1996 SPOT 2 (top right) 2000 Landsat 7 ETM+ (bottom left) 2008 SPOT 5 (bottom right)
Location:	2,017,800, 5,730,677 (NZTM)
1990 land use:	Grassland – low producing
2008 land use:	Post-1989 forest
Explanation:	In the Landsat 1990 imagery acquired on 2 December 1990, there is little evidence of the forest within the blue box that is clearly apparent in later imagery. The strength of the spectral response in the SPOT 1996 imagery suggests that the forest must have been planted near to 1990. Final confirmation of the planting date is provided via the NZ ETS application (delineated in green in the 2008 imagery), which states that the forest was planted in 1990 and, therefore, is classed as a post-1989 forest.

7.2.3 Land-use change

Land-use change prior to 1990

The estimation of land-use change prior to 1990 was introduced in the 2011 submission and further details on the methodology used are available in that report. In the 2010 submission, New Zealand assumed that all land was in a steady state at 1990. A consequence of this was land-use change that occurred prior to 1990 was ignored and the associated carbon changes were not accurately reflected. As this assumption was not consistent with international IPCC good practice guidance, which requires identification of land in a conversion state as at 1990 (IPCC, 2003, volume 4, chapter 3, page 9), New Zealand developed and applied a procedure for estimating land use and land-use change back to 1962 (28 years prior to 1990, equivalent to the average plantation rotation length in New Zealand (Ministry of Agriculture and Forestry, 2012)).

A variety of data sources were used to determine land areas prior to 1990. Data sources suitable for determining land use at a national level typically comprise either maps or scaled images depicting land use or proxies for land use (eg, a 'map of forest areas'), or tabulated land-use area data collected for an administrative area (eg, county, district or region) or production sector (eg, the area of orchard crops).

The same land-use data and methodology used to determine land use prior to 1990 in the 2011 submission have been used for the 2012 submission. This methodology was peer reviewed by Landcare Research Ltd (Hunter and McNeill, 2010), which provided independent subject-matter expertise. The land-use change matrix from 1962 to 1989 is presented in table 7.2.3.

Land-use change from 1990 to 2011

Land-use change from 1 January 1990 to 1 January 2008 is based on:

- mapped land-use change from 1 January 1990 to 1 January 2008
- deforestation trends between 1990 and 1 January 2008 for pre-1990 planted forest from the 2008 Deforestation Survey (Manley, 2009) and unpublished work by Scion (the New Zealand Forest Research Institute). The work by Scion is referred to in Wakelin (2008). The mapped deforestation between 1990 and 2008 is attributed by year using this data
- deforestation estimates between 1990 and 2008 for post-1989 forest from the 2008 Deforestation Survey (Manley, 2009) and Wakelin (2008)
- afforestation trends based on estimates from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2011a). The mapped afforestation between 1990 and 2008 is attributed to year using this data.

Land-use change from 1 January 2008 to 31 December 2011 is based on:

- mapped deforestation occurring in 2008 and 2009 as described below
- partially mapped and partially estimated deforestation occurring in 2010 as described below
- estimated deforestation for 2011 based on the 2011 Deforestation Survey (Manley, 2012)
- afforestation in 2008, 2009, 2010 and 2011, estimated from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2012)
- all other 2008 to 2010 land-use change, which is extrapolated from pre-2008 trends.

Table 7.2.4 shows a land-use change matrix for the years 1990 to 2011 based on these inputs.

Prominent land-use changes between 1990 and 2011 include:

- forest establishment of 618,053 hectares (classified as post-1989 forest) that has occurred mostly on land that was previously grassland, primarily low-producing grassland. Approximately 18,784 hectares of this post-1989 forest has subsequently been deforested

- deforestation of 105,512 hectares. This includes the 18,784 hectares of post-1989 forest mentioned above. This deforestation has occurred mainly in planted forests since 2004. Between 1990 and 2004, there was little deforestation of planted forests in New Zealand due to market conditions.

Table 7.2.5 shows a land-use change matrix for the period 31 December 2010 to 31 December 2011.

Mapping of deforestation 2008–2009

New Zealand has used a combination of data sources to identify the location and timing of deforestation after 1 January 2008. Land-use data generated from classification of SPOT 5 satellite imagery acquired between November 2006 and April 2008 was compared with Disaster Monitoring Constellation (DMC) satellite imagery acquired over the summer of 2009–2010 in conjunction with some field verification. From this, temporarily destocked land and land converted from a forest land use to a non-forest land use was identified. Evidential information to confirm land-use change was collected using higher-resolution aerial photography and field visits. This is illustrated in figure 7.2.5.

Areas of possible deforestation were confirmed using oblique aerial photography. Supporting information from regional councils, Ministry for Primary Industries district offices and forestry consultants was also consulted to see if deforestation or restocking could be confirmed.

Areas of forest destocking that were unable to be confirmed as either harvesting or deforestation were flagged for tracking. Those areas that are not replanted within four years will be deemed to be deforested at the clearing date.

Mapping of deforestation 2010

Deforestation mapping for 2010 was carried out over four priority areas where the largest extent of deforestation was anticipated based on the 2008 and 2009 deforestation mapping. Figure 7.2.6 shows the four priority areas. High resolution (10 metre) SPOT satellite imagery was acquired over these priority areas in Northland, Waikato, Marlborough and Southland. The area mapped represents approximately one-quarter of the total land area of New Zealand. For areas not mapped in 2010, the deforestation area has been estimated. These areas will be mapped and, in the course of the next two years, 2010 deforestation events identified.

Estimation of deforestation 2011

Deforestation occurring in 2011 has been estimated from:

- the 2011 Deforestation Survey (Manley, 2012)
- deforestation information received by the NZ ETS
- trends in deforestation from earlier years
- estimates of the impact of a falling price of carbon on deforestation decisions owing to reductions in pre-1990 planted forest deforestation liabilities incurred under the NZ ETS.

When the 2012 deforestation mapping is completed, which will map all deforestation occurring between 2008 and 2012 across New Zealand, the 2011 estimates will be updated.

Figure 7.2.5 New Zealand's identification of deforestation

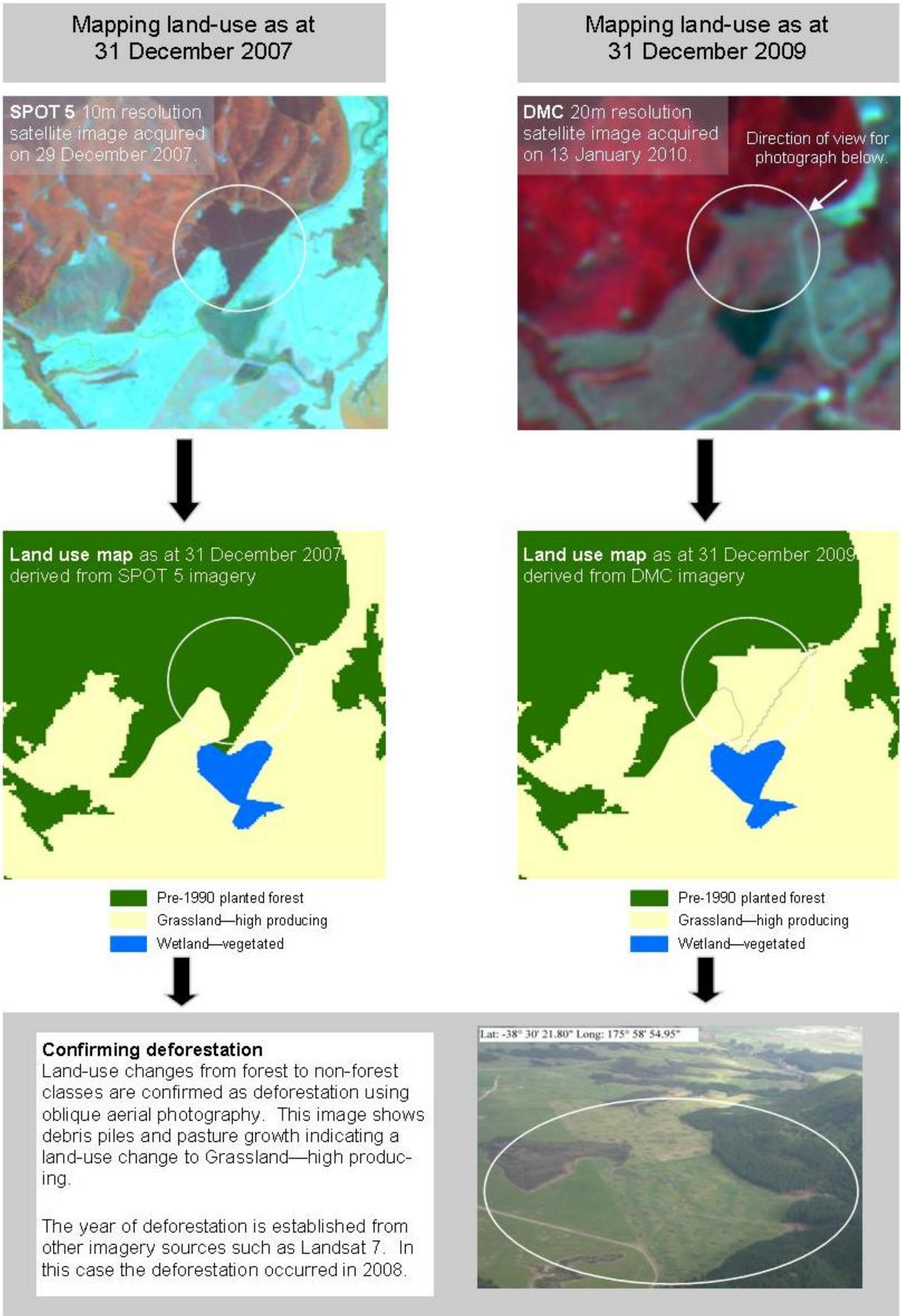


Figure 7.2.6 Four priority areas where deforestation mapping was carried out in 2010

Table 7.2.3 New Zealand's land-use change matrix from 1962 to 1989

1989 \ 1962		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 1 Jan 1989 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,056.4							50.4				8,106.8
	Pre-1990 planted	245.1	446.2					355.8	485.9				1,533.1
	Post-1989			NA									–
Cropland	Annual				305.6	1.7	21.0	7.4					335.8
	Perennial				1.3	67.7	5.0	3.7					77.7
Grassland	High producing	54.4			82.3	21.3	4,822.1	420.4	409.6	47.0			5,857.1
	Low producing	304.9						7,641.2	44.2				7,990.3
	With woody biomass	26.7						302.5	932.1				1,261.3
Wetlands	Wetlands	14.4								647.6			662.0
Settlements	Settlements	5.3			3.6		6.6	3.9	3.8		180.0		203.3
Other land	Other land											897.9	897.9
Net area as at 31 Dec 1962 (kha)		8,707.2	446.2	NA	392.8	90.7	4,854.8	8,735.0	1,926.1	694.6	180.0	897.9	26,925.4
Net change 1962–1989		–600.4	1,086.9	NA	–57.0	–13.0	1,002.3	–744.7	–664.8	–32.6	23.3	0.0	NA
Net change 1962–1989 (%)		–6.90	243.61	NA	–14.50	–14.32	20.64	–8.53	–34.52	–4.70	12.93	0.00	NA

Note: Units in 000's hectares; NA = not applicable.

Table 7.2.4 New Zealand's land-use change matrix from 1990 to 2011

2011 \ 1990		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2011 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,060.4											8,060.4
	Pre-1990 planted	13.6	1,479.2										1,492.8
	Post-1989			NA			100.2	360.8	133.7			4.5	599.3
Cropland	Annual				331.1		2.7	1.1					334.9
	Perennial		0.3		4.8	76.8	19.8	2.3	0.1				104.1
Grassland	High producing	9.0	42.2			0.3	5,722.3		18.1	0.2			5,792.1
	Low producing	20.6	10.6					7,595.3	34.3			0.4	7,661.3
	With woody biomass	2.9	0.2			0.4	9.5	28.9	1,074.7			1.5	1,118.1
Wetlands	Wetlands							1.2		661.8			662.9
Settlements	Settlements	0.1	0.4			0.2	2.4	0.8	0.2		203.3		207.3
Other land	Other land	0.2	0.3				0.2					891.5	892.2
Area as at 1 Jan 1990 (kha)		8,106.8	1,533.1	NA	335.8	77.7	5,857.1	7,990.3	1,261.3	662.0	203.3	897.9	26,925.4
Net change 1 Jan 1990–31 Dec 2011		–46.4	–40.3	599.3	–1.0	26.4	–64.9	–329.0	–143.2	1.0	4.0	–5.7	NA
Net change 1990–2011 (%)		–0.57	–2.63	NA	–0.30	33.91	–1.11	–4.12	–11.35	0.14	1.97	–0.64	NA

Note: Units in 000's hectares; NA = not applicable. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares; however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change during the period greater than 100 hectares. Land-use change areas do not include deforestation of post-1989 forest since 1990 (18,784 hectares), as this land became forest after 1990. Land-use change values refer to change over the course of the period. Land-use area values are as at the point in time indicated (31 December for 2011 and 1 January for 1990.) Columns and rows may not total due to rounding.

Table 7.2.5 New Zealand's land-use change matrix from 2010 to 2011

2011 \ 2010		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2011 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,060.4											8,060.4
	Pre-1990 planted		1,492.8										1,492.8
	Post-1989			587.3			2.1	6.9	2.9			0.1	599.3
Cropland	Annual				334.7		0.1	0.1					334.9
	Perennial				0.2	102.9	0.9	0.1	0.01				104.1
Grassland	High producing					0.01	5,791.3		0.8	0.01			5,792.1
	Low producing	0.7	1.5	1.5				7,656.1	1.6			0.02	7,661.3
	With woody biomass					0.02	0.4	1.3	1,116.3			0.1	1,118.1
Wetlands	Wetlands							0.1		662.9			662.9
Settlements	Settlements					0.01	0.1	0.03	0.01		207.1		207.3
Other land	Other land						0.01					892.2	892.2
Net area as at 31 Dec 2010 (kha)		8,061.1	1,494.3	588.8	334.9	102.9	5,795.0	7,664.5	1,121.6	662.9	207.1	892.4	26,925.4
Net change 31 Dec 2010–31 Dec 2011		–0.7	–1.5	10.5	0.1	1.2	–2.8	–3.1	–3.5	0.0	0.2	–0.2	NA
Net change 2010–2011 (%)		–0.01	–0.10	1.78	–0.01	1.15	–0.05	–0.04	–0.31	0.01	0.08	–0.02	NA

Note: Units in 000's hectares; NA = not applicable. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares, however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change during the period greater than 100 hectares. Land-use change areas do not include deforestation of post-1989 forest since 1990 (18,784ha), as this land became forest after 1990. Land-use change values refer to change over the course of the period. Land-use area values are as at the point in time indicated (31 December for 2009 and 2010, 1 January for 1990.) Columns and rows may not total due to rounding.

7.2.4 Methodological change

For 2008 and 2009 deforestation reporting, wall-to-wall mapping was completed using DMC 22-metre resolution satellite imagery. For 2010, only a partial mapping of deforestation across New Zealand was completed using 10-metre resolution SPOT satellite imagery with the remaining area of unmapped deforestation estimated based on trends from earlier years.

No deforestation mapping was undertaken for 2011, given that the two-year national image acquisition programme for the 2012 land-use map commenced in October 2011. Deforestation mapping for 2011 will be derived from this imagery, be confirmed by oblique aerial observations (figure 7.2.5) and provided as part of next year's submission. In the interim, estimates have been provided based on a range of data as noted in section 7.2.3 above.

7.2.5 Uncertainties and time-series consistency

Due to constraints in time and resources, New Zealand has not completed a full accuracy assessment to determine uncertainty in the mapping data. However, the approach to mapping land-use change between 1990 and 2011 is based on a peer-reviewed and published work by Dymond et al (2008). With this approach, it was estimated that an accuracy of within ±7.0 per cent of actual afforestation can be achieved in mapping change in planted forests in New Zealand. Preliminary accuracy assessment has shown some uncertainty between the grassland – woody biomass and natural forest classes; a reference layer has been developed to indicate where woody biomass is unlikely to grow to forest stature based on environment conditions. This mapping will be used to improve the accuracy of areas mapped as grassland – woody biomass and natural forest. The levels of uncertainty for non-woody classes (±6.0 per cent) and natural forest (±4.0 per cent) are similar to what was reported in previous submissions because the same data sources have been used.

7.2.6 Source-specific QA/QC and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans are established for each type of data used to determine carbon stock and stock changes, as well as for the mapping of the areal extent and spatial location of land-use changes.

The 1990 and 2008 land-use mapping data has been checked to determine the level of consistency in satellite image classification to the requirements set out in the *Land-Use and Carbon Analysis System: Satellite imagery interpretation guide for land-use classes* (Ministry for the Environment, 2012). Through this process, approximately 28,000 randomly selected points in the 1990 and 2008 woody classes were evaluated by independent assessors. From this exercise, 91 per cent of the time, independent assessors agreed with the original classification. Where there was disagreement, the points were recorded in a register and this has been used as the basis for preparing the improvement plan described in this report. The process does not determine errors of omission and/or commission that would provide an accuracy assessment and definitive level of uncertainty. (An error of commission is where a particular class has been mapped incorrectly, for example, as a result of similarities in spectral signatures; an error of omission is where mapping has failed to detect a particular land use, for example, a planted forest block visible in imagery.)

Each mapping improvement activity carried out on the 1990 and 2008 maps has been subjected to quality-assurance checks to ensure accuracy and consistency. Quality-assurance strategies have been tailored to each improvement activity, usually including a combination of random sampling of updated areas and analysis of the changes in land-use areas.

During 2011, data from the NZ ETS was reconciled with the 1 January 2008 land-use map. The NZ ETS data contains pre-1990 and post-1989 forest boundaries as submitted by forest owners and verified by the Ministry for Primary Industries. The NZ ETS forest areas were checked against the 2008 land-use map. Where mapping differences were identified, these areas were assessed against satellite imagery and the LUCAS forest land-use definitions to determine whether the 2008 and/or 1990 land-use map should be changed. After integration, quality-assurance checks were performed to ensure that updates to the 1990 and 2008 land-use maps were accurate and completed.

Quality assurance of the 2008–2009 and 2010 deforestation mapping activities was a multi-stage process. The contractor undertook initial quality assurance by cross-checking operator interpretation of harvesting and/or deforestation events in satellite imagery. For the 2008–2009 deforestation mapping, key areas of deforestation identified in satellite imagery were then field checked using oblique aerial photography acquired from light aircraft (figure 7.2.5). For the 2010 deforestation mapping activity, all areas of deforestation and a stratified sample of areas mapped as either harvested or 'awaiting'[39] were field checked using oblique aerial photography. This allowed an uncertainty analysis to be completed on the 2010 deforestation mapping.

Finally, all areas of mapped deforestation were visually checked by LUCAS analysts to verify both the deforestation decision and the original mapped land use.

The approach used to implement quality-assurance processes is documented in the LUCAS Data Quality Framework (PricewaterhouseCoopers, 2008).

7.2.7 Source-specific planned improvements

The quality-control and quality-assurance process followed during mapping exposed a number of limitations in the mapping method. Future improvements to both the 1990 and 2008 maps will focus on these areas:

- the mapping of 1990 land use presented challenges, particularly in identifying newly established exotic forests using Landsat satellite imagery. Where trees are planted within three years of the image acquisition date, they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature on 30-metre resolution imagery. For LUCAS mapping, this situation is compounded by the lack of ancillary data to support land-use classification decisions at 1990. Land-use mapping will continually be updated and improved with information from the NZ ETS. The Ministry for Primary Industries is administering the forestry component of the NZ ETS, and applicants to the scheme are providing new land-management and land-use information as at 1990

[39] For further information on the 'awaiting' category, introduced for 2010 deforestation mapping, see section 11.4.3.

- the Ministry for Primary Industries administers a number of other funds to encourage forest planting and preservation. Spatial data from the Afforestation Grants Scheme, the Permanent Forest Sink Initiative and the East Coast Forestry Project will also be used to improve the accuracy of forest mapping in the 1990 and 2008 land-use maps.

At the end of the first commitment period, New Zealand will create a 2012 land-use map using high-resolution satellite imagery data as the key source of information. This mapping will be used to make comparisons with the 2008 land-use map (prepared using similar high-resolution imagery) to improve the spatial determination of harvesting, deforestation and land-use changes between 1 January 2008 and 31 December 2012.

7.3 Forest land (CRF 5A)

7.3.1 Description

In New Zealand's *Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), national forest definition parameters were specified as required by UNFCCC Decision 16/CMP.1. The New Zealand parameters are a minimum area of 1 hectare, a height of 5 metres and a minimum crown cover of 30 per cent. Where the height and canopy cover parameters are not met at the time of mapping, the land has been classified as forest land if the land-management practice(s) and local site conditions (including climate) are such that the forest parameters will be met over a 30 to 40 year timeframe.

New Zealand also uses a minimum forest width of 30 metres from canopy edge to canopy edge. This removes linear shelterbelts from the forest land category. The width and height of linear shelterbelts can vary, because they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely cropland and grassland (as shelter to crops and/or animals).

New Zealand has adopted the definition of managed forest land as provided in GPG-LULUCF: "Forest management is the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest". Accordingly, all of New Zealand's forests, both those planted for timber production and natural forests managed for conservation values, are considered managed forests.

Forest land is the most significant contributor to carbon stock changes in the LULUCF sector. Forests cover 37.7 per cent (just over 10 million hectares) of New Zealand. In 2011, forest land contributed –17,741.2 Gg CO_2-e of net emissions. This value includes removals from the growth of pre-1990 planted forests and post-1989 forests, and emissions from the conversion of land to planted forest, harvesting and fire. Natural forests are assumed to be in steady state. Net emissions from forest land have increased by 9,976.1 Gg CO_2-e (36.0 per cent) on the 1990 level of –27,717.3 Gg CO_2-e (table 7.3.1).

In 2011, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

Table 7.3.1 New Zealand's land-use change within the forest land category in 1990 and 2011, and associated CO_2-e emissions

Forest land land-use category	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$-e)		Change from 1990 (%)
				1990	2011	
Forest land remaining forest land	8,749,413	9,282,070	6.1	–4,522.9	9,480.1	309.6
Land converted to forest land	902,643	870,408	–3.6	–23,194.4	–27,221.3	–17.4
Total	**9,652,056**	**10,152,478**	**5.2**	**–27,717.3**	**–17,741.2**	**36.0**

Note: 1990 and 2011 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding.

For Climate Change Convention and Kyoto Protocol reporting, New Zealand has subdivided its forest land into three forest land subcategories: natural forest (predominantly native forest pre-dating 1990), pre-1990 planted forest and post-1989 forest (all forest established after 31 December 1989). The definitions used for mapping these land-use subcategories are given in table 7.2.2.

Table 7.3.2 shows land-use change by forest subcategory since 1990 and the associated CO_2 emissions from carbon stock change alone.

Table 7.3.2 New Zealand's land-use change within forest land subcategories in 1990 to 2011, and associated CO_2 emissions from carbon stock change

Forest land land-use category	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$ only)		Change from 1990 (%)
				1990	2011	
Natural forest[1]	8,104,387	8,060,392	–0.5	NA	NA	NA
Pre-1990 planted forest	1,533,857	1,492,817	–2.7	–27,956.0	687.5	–102.5
Post-1989 forest	13,812	599,269	4,238.8	217.5	–18,445.8	–8,580.8
Total	**9,652,056**	**10,152,478**	**5.2**	**–27,738.5**	**–17,758.3**	**–36.0**

Note: NA = not applicable. 1990 and 2011 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding. (1) At the national scale, natural forest carbon stocks are assumed to be at steady state. Emissions associated with the conversion of natural forest are reported in the land-use category the land is converted to.

Table 7.3.3 shows New Zealand's carbon stock change by carbon pool within the forest land category from 1990 to 2011. From 1990 to 2011, the total carbon stock stored in forest land had increased by 161,861.6 Gg C, equivalent to emissions of –593,492.4 Gg CO_2 since 1990.

Table 7.3.3 New Zealand's net carbon stock change by carbon pool within the forest land category from 1990 to 2011

Forest land subcategory	Net carbon stock change 1990–2011 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2011 (Gg CO_2)
Natural forest[1]	NA	NA	NA	NA	NA
Pre-1990 planted forest	87,525.3	16,523.7	–2,597.8	101,451.2	–371,987.8
Post-1989 forest	52,494.8	13,551.6	–5,636.1	60,410.3	–221,504.6
Total	**140,020.1**	**30,075.3**	**–8,233.8**	**161,861.6**	**–593,492.4**

Note: NA = not applicable. (1) At the national scale, natural forest is assumed to be at steady state. Emissions associated with the conversion of natural forest are reported in the land-use category the land is converted to. Columns may not total due to rounding.

Natural forest

Natural forest is the term used to distinguish New Zealand's native and unplanted (self-sown or naturally regenerated) forests that existed prior to 1990 from pre-1990 planted and post-1989 forests. The category includes both mature forest and areas of regenerating vegetation that have the potential to return to forest under the management regime that existed in 1990. Natural forest ecosystems comprise a range of indigenous and some naturalised exotic species. In New Zealand, two principal types of natural forest exist: beech forests (mainly *Nothofagus* species) and podocarp–broadleaf forests. In addition, a wide range of seral plant communities fit into the natural forest category where they have the potential to succeed to forest *in situ*. At present, New Zealand has just under an estimated 8.1 million hectares of natural forest (including these successional communities).

In 2011, it was estimated that 0.05 per cent of New Zealand's total forest timber production was from harvesting of natural forests, as New Zealand's wood needs are now almost exclusively met from planted production forests (Ministry of Agriculture and Forestry, 2012). No timber is legally harvested from New Zealand's publicly owned natural forests (an area approximately 5.5 million hectares in size). Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis. The only natural forest harvesting that is not required by law to be on a sustainable basis is the harvesting of forests on land returned to Māori under the South Island Landless Natives Act 1906. These forests are currently exempt from provisions that apply to all other privately owned natural forests that require a sustainable forest management plan or permit before any harvesting. Approximately 57,500 hectares are covered by the Act. A survey of this land was completed in 1999; this indicated that 17,300 hectares of this land was natural forest available for harvest (Ministry of Agriculture and Forestry, 2011b).The New Zealand Government provides assistance to the South Island Landless Natives Act 1906 forest owners who wish to develop sustainable forestry practices, and, because timber that is harvested without a sustainable forest management plan or permit cannot be exported, the unsustainable harvesting of natural forest has virtually ceased.

Harvesting under the sustainable forest plans and permits is restricted to the removal of growth and sometimes takes place on a selective logging basis. This means the area from where trees are extracted still meets the forest definition chosen by New Zealand. Therefore, over the long term, the carbon stored in these forests is in steady state.

Carbon stock change in natural forest remaining natural forest is not estimated, because, while we now have evidence that natural forests are not in steady state (preliminary analysis suggests they are a slight carbon sink (Beets et al, 2009), we require the full set of plot re-measurement data to quantify carbon stock changes. The emissions associated with the conversion of natural forest to other land uses are reported in the land-use category the land was converted to.

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber-supply purposes. In 2011, pre-1990 planted forests covered an estimated 1.49 million hectares of New Zealand (5.5 per cent of the total land area). New Zealand's planted forests are intensively managed and there is well-established data on the estate's extent and characteristics. Having a renewable timber resource has allowed New Zealand to protect and sustainably manage its natural forests. *Pinus radiata* is the dominant species, making up about 90 per cent of the planted forest area. These forests are usually composed of stands of trees of a single age class and all forests are subject to relatively standard silvicultural management regimes.

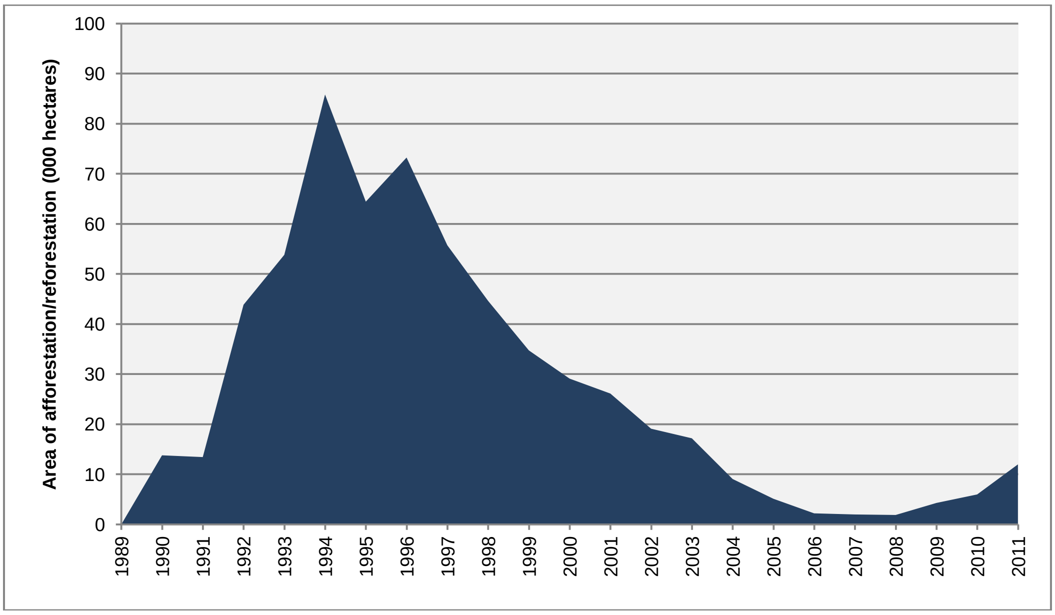
Post-1989 forest

Between 1 January 1990 and 31 December 2011, the net area of forest established as a result of reforestation activities was 599,269 hectares (taking into account deforestation of post-1989 forests). Based on the plots measured, 95 per cent of this forest subcategory comprises planted tree species (Paul et al, 2009), with the remaining area comprising regenerating native tree species. *Pinus radiata* comprises 89 per cent of the planted tree species in this forest subcategory, with Douglas fir (*Pseudotsuga menziesii*) and *Eucalyptus* being the two species making up most of the remainder (Ministry of Agriculture and Forestry, 2010).

The new forest planting rate (land reforested) between 1990 and 2011 was, on average, 28,000 hectares per year (figure 7.3.1). New planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year). This followed a change in the taxation regime, an unprecedented price spike for forest products with subsequent favourable publicity, a government focus on forestry as an instrument for regional development and the conclusion of the state forest assets sale (Rhodes and Novis, 2002). The removal of agricultural subsidies and the generally poor performance of the New Zealand and international share markets also encouraged investors to seek alternatives (Rhodes and Novis, 2002).

Since 1998, the rate of new planting declined, reaching a low of 1,900 hectares in 2008. In 2011, it was estimated that 12,000 hectares of new plantation forest were established (Ministry of Agriculture and Forestry, 2011a). This compares with 6,000 hectares of new planting in 2010 (Ministry of Agriculture and Forestry, 2012). The increase in planting between 2008 and 2011 is largely attributable to the NZ ETS, Afforestation Grants Scheme and Permanent Forest Sink Initiative, which have been introduced by the New Zealand Government to encourage new planting and regeneration of natural species (Ministry of Agriculture and Forestry, 2009).

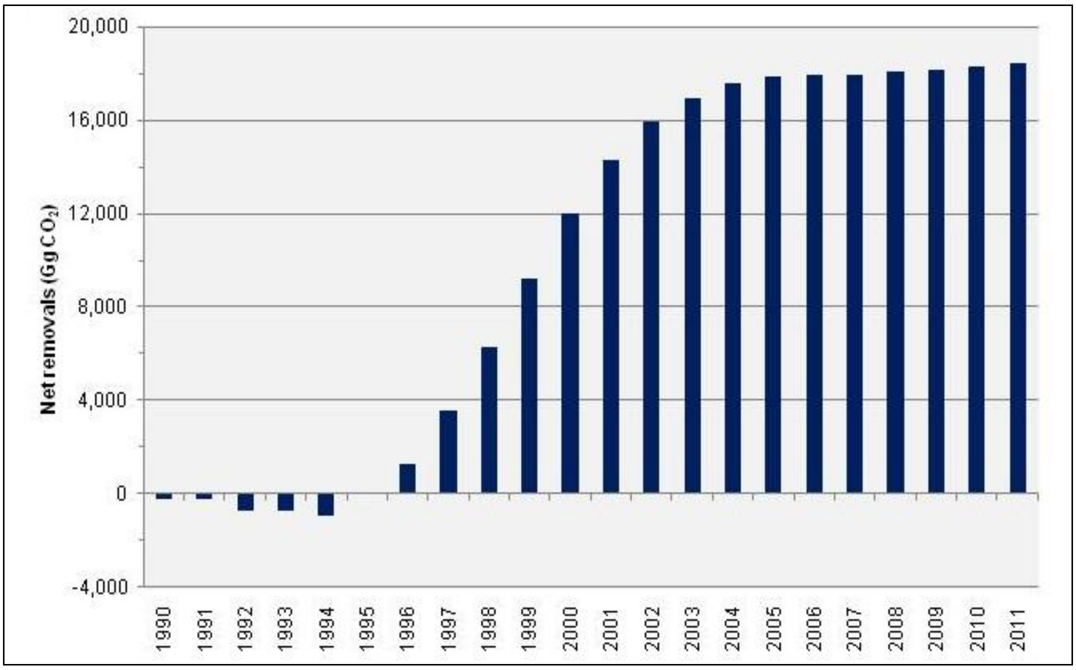
Figure 7.3.1 Annual areas of afforestation/reforestation in New Zealand from 1990 to 2011



Note: Annual planting estimates are derived from annual surveys of forest nurseries, as published in the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2011a) and have been scaled downwards using a ratio derived from the LUCAS mapping of post-1989 forest area.

Post-1989 forests did not become a net sink until 1995 (figure 7.3.2). This is due to the emissions from loss of biomass carbon stocks associated with the previous land use and the change (loss) of soil carbon with a land-use change to forestry, outweighing removals by forest growth.

Figure 7.3.2 New Zealand's net carbon dioxide removals by post-1989 forests from 1990 to 2011



Deforestation

In 2011, an estimated 3,700 hectares of forest land were converted to other land uses, primarily grassland. Table 7.3.4 shows the areas of forest land subject to deforestation in 2011 and since 1990. The land uses that forest land has been converted to following deforestation are shown in tables 7.2.4 and 7.2.5.

Table 7.3.4 New Zealand's forest land subject to deforestation

Forest land subcategory	Area of forest in 1990 (hectares)	Deforestation since 1990		Deforestation in 2011	
		Area (hectares)	Proportion of 1990 area (%)	Area (hectares)	Proportion of 1990 area (%)
Natural forest	8,106,837	32,826	0.45	700	0.001
Pre-1990 planted forest	1,533,100	53,902	3.52	1,500	0.10
Post-1989 forest	0	18,784	NA	1,500	NA
Total	**9,639,937**	**105,512**	**1.09**	**3,700**	**0.04**

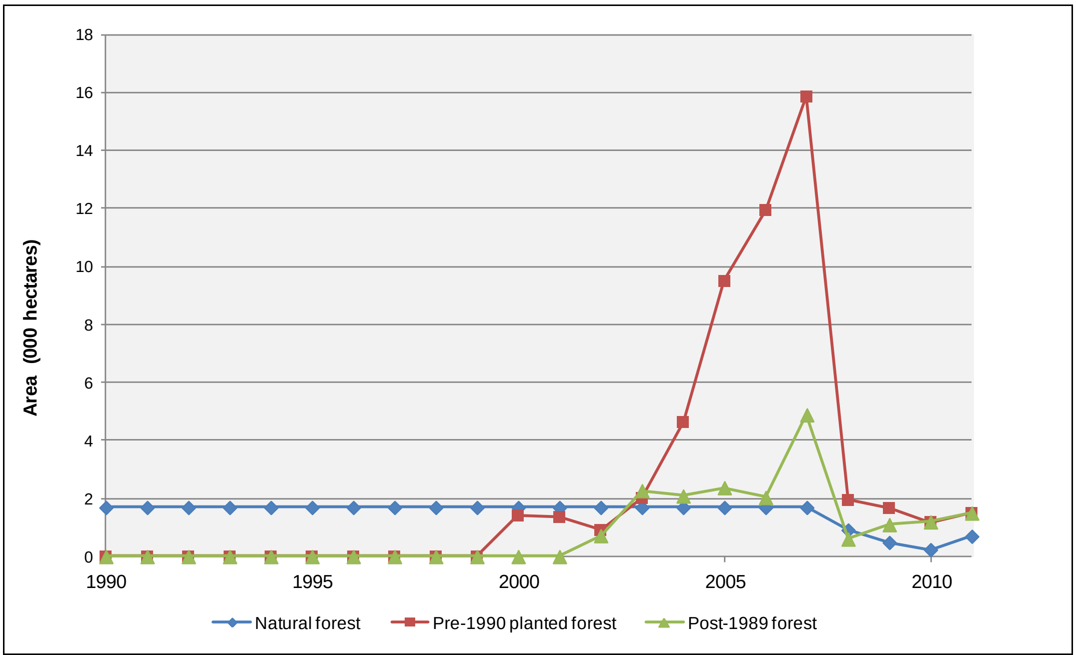
Note: NA = not applicable. 2011 areas are as at 31 December 2011, 1990 areas are as at 1 January 1990 and, therefore, differ from 1990 area values in the common reporting format tables, which are as at 31 December 1990. Columns may not total due to rounding.

The conversion of forest land to grassland is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry.

Figure 7.3.3 illustrates the increase in the planted forest deforestation that occurred leading up to 2008 and the decrease after the introduction of the NZ ETS in 2008.

During the remainder of the first Kyoto Protocol commitment period (2008–2012), it was expected that the level of planted forest deforestation would continue to be less than that seen prior to the introduction of the NZ ETS in 2008 (Manley, 2009). However, since the introduction of the NZ ETS, the carbon price has been in steady decline. It is possible that the low carbon price will have an impact on levels of deforestation activity by reducing the liability on forest owners.

Figure 7.3.3 New Zealand's area of deforestation since 1990, by forest subcategory



The rate of natural forest deforestation has decreased since 2007. A number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007 but, instead, occurred mostly prior to 2002. The area available for harvesting (and potentially deforestation) was higher before 1993 when the Forests Act 1949 was amended to bring an end to unsustainable harvesting and deforestation of natural forest. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. Both of these developments are likely to have reduced natural forest deforestation since 2002.

As there is no data on the deforestation profile for natural forests between 1990 and 2007, the total area of deforestation detected over this period is allocated evenly across the years. The reduced rate of natural forest deforestation has been confirmed from 2008 to 2010 through satellite image mapping of deforestation (see figure 7.2.5 in section 7.2).

New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, based on the following:

- the majority of deforestation since 2000 has resulted from land converted to high-producing grassland, resulting in the rapid removal of all biomass as the land is prepared for intensive dairy farming (see figure 7.2.4)
- it is not practical to estimate the volume of residues left on site after the deforestation activity, given the rapid conversion from one land use to another. Further estimating any residue biomass carbon pools and decay rates is difficult and costly
- there is insufficient data prior to 2008 to estimate deforestation biomass residue coming into the first commitment period. If a different approach was adopted for deforestation before and after 2008, this would raise issues around consistency and would not meet GPG-LULUCF.

Soil carbon changes associated with deforestation are modelled over a 20-year period (section 7.1.3).

These deforestation emissions are reported in the relevant 'land converted to' category, as are all emissions from land-use change. See section 11.1 of chapter 11 for further information on deforestation.

Harvesting

The estimated area of pre-1990 planted forest harvested each year between 1990 and 2009 is based on the harvested area reported in the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2011a). Roundwood statistics (Ministry for Primary Industries, 2012) are used where an increase in reported harvest volume is not consistent with harvest area reported in the *National Exotic Forest Description* (as in 2010) and where published area data are not yet available (as in 2011). In these situations, a combination of roundwood statistics, and the ratio of roundwood volume-to-area harvested over the five-year period 2004–2009, is used to estimate the area harvested in 2010 and 2011 from the volume of roundwood reported.

There are differences in the area defined and reported as pre-1990 planted forest for the Convention on Climate Change reporting and the area captured by the *National Exotic Forest Description* from which the harvesting statistics are sourced. Convention on Climate Change reporting uses a gross stocked area standard, which includes forest tracks, skid sites and unstocked areas. The *National Exotic Forest Description* generally uses a net stocked area standard. The activity data used to estimate harvesting emissions in pre-1990 planted forests is therefore scaled by 17 per cent throughout the time series to account for the different forest definitions. The scaling factor is made up of a 10 per cent estimate of unstocked area as measured within the pre-1990 planted forest plot network and a 7 per cent estimate to account for cutover area within the estate (Wakelin and Paul, 2012).

The total area harvested is then split by forest type.

- *Pre-1990 planted forest harvesting:* This was estimated as the difference between total harvesting (based on statistics from the Ministry for Primary Industries, as outlined above) and the amount of post-1989 forest harvesting estimated.
- *Post-1989 forest:* There is no published information available for the area of post-1989 forest harvesting in New Zealand but, because of the young age of this resource, most post-1989 forest harvesting is likely to be short rotation eucalypt species for the supply of pulp for export or to local pulp and paper mills. Experts in the various regions where eucalypts are commercially grown were contacted and asked about the level of harvesting they knew was occurring. Where possible, these expert opinions were corroborated with publically available information from companies' websites and other various reports.

In 2011, it is estimated that 0.05 per cent of New Zealand's total forest timber production was from the harvesting of natural forests (Ministry of Agriculture and Forestry, 2012). The harvesting that occurs in natural forests is carried out under sustainable practices and the activity is captured within the natural forest carbon stock estimates.

7.3.2 Methodological issues

Forest land remaining forest land

Only natural forest and pre-1990 planted forest are described in this section because land in the post-1989 forest subcategory is included in the 'land converted to forest land' category. Land areas converted to post-1989 forest had been in that land use for a maximum of 21 years in 2011 so are still within the land converted to forest land subcategory, given New Zealand has chosen 28 years as the time it takes for land to reach a state of equilibrium. Where there has been land-use change between natural forest and pre-1990 forest, the associated carbon changes are reported under forest land remaining forest land.

Land is transferred to the 'land remaining' category after a conversion period of 28 years. New Zealand has chosen 28 years as the time taken for land to reach a state of equilibrium (or maturity) under its new land use, as this is the average age at which the majority of planted forests are harvested (Ministry of Agriculture and Forestry, 2008).

New Zealand has established a sampling framework for forest inventory purposes based on an 8-kilometre national grid system. The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or Light Detection and Ranging (LiDAR) measurements. The network is subdivided into a 4-kilometre grid for measurement of post-1989 forests.

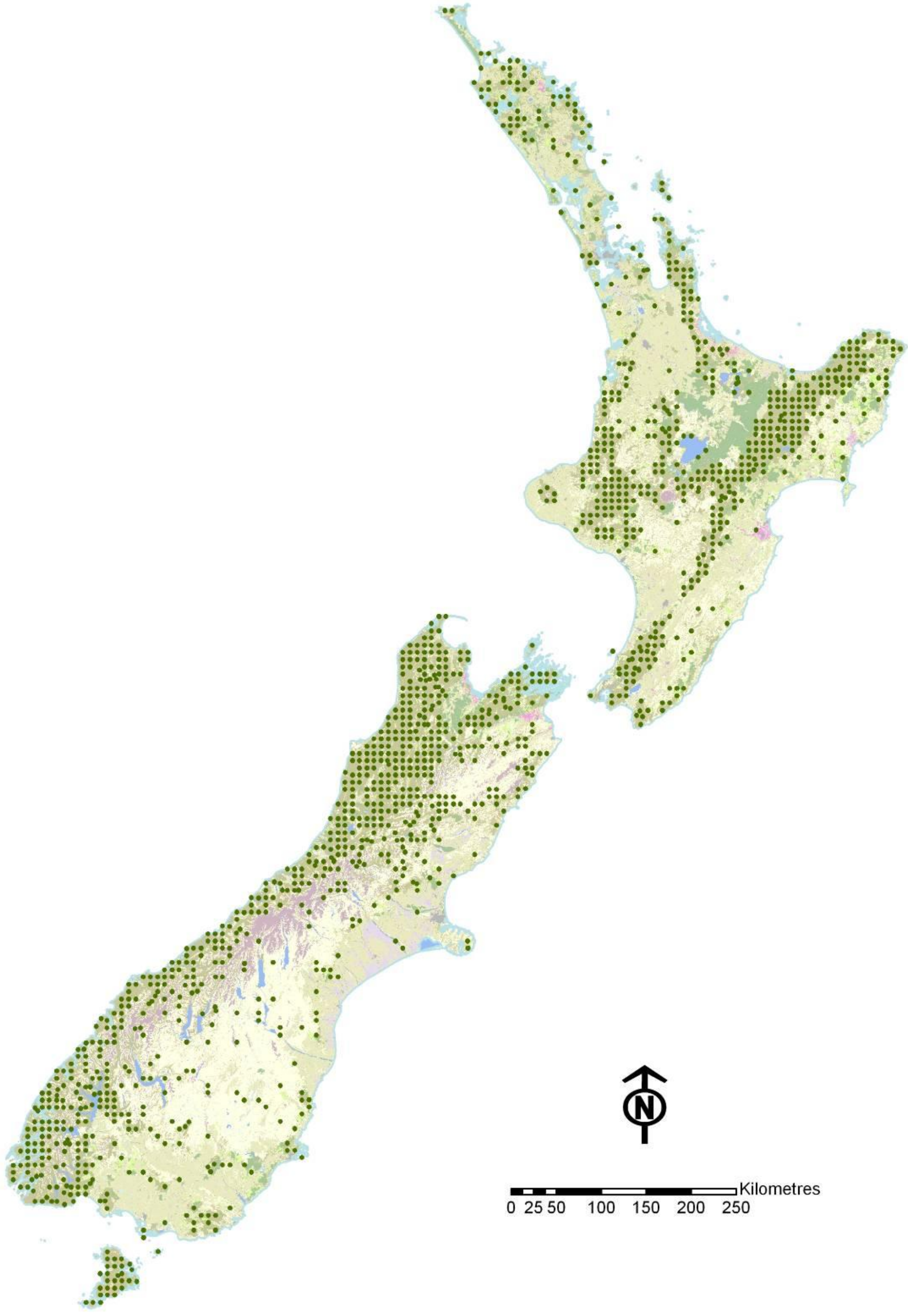
Natural forest

A national monitoring programme to enable unbiased estimates of carbon stock and change for New Zealand's natural forests was developed between 1998 and 2001

(Goulding et al, 2001). There were 1,255 permanent sample plots installed systematically on the 8-kilometre grid across New Zealand’s natural forests and these were first measured between 2002 and 2007.

The plots were sampled using a method designed specifically for the purpose of calculating carbon stocks (Payton and Moss, 2001; Payton et al, 2004b). As the plot network is re-measured, the data collected will be suitable for determining if New Zealand’s natural forests are carbon neutral (as assumed in this submission) or whether they are a net source of emissions or a sink for carbon. Where possible, the network incorporated plots that had been previously established and re-measured them during the establishment phase of the national network to enable an initial assessment of forest changes over time. Figure 7.3.4 shows the distribution of the carbon monitoring plots throughout New Zealand.

Figure 7.3.4 Location of New Zealand's natural forest carbon monitoring plots



Re-measurement of the national plot network is under way. The re-measurement programme will run until 2014 following methodology revised for this purpose (Payton and Brandon, 2010). Once field work has been completed and the data has been quality assured and analysed, national carbon estimates will be updated for the 2012 inventory (to be submitted in 2014).

At each plot, data is collected to calculate the volumes of trees, shrubs and dead organic matter present. These measurements are then used to estimate the carbon stocks for the following biomass pools:

- living biomass (comprising above-ground biomass and below-ground biomass)
- dead organic matter (comprising dead wood and litter).

Table 7.3.5 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Table 7.3.5 Summary of methods used to calculate New Zealand's natural forest biomass carbon stock from plot data

Pool		Method	Source
Living biomass	Above-ground biomass	Plot measurements; Allometric equations	Beets et al, 2009;
	Below-ground biomass	Estimated at 20 per cent of total biomass	Coomes et al, 2002
Dead organic matter	Dead wood	Plot measurements; Allometric equations	Beets et al, 2009;
	Litter	Plot samples; Laboratory analysis of samples collected at plots	Beets et al, 2009 Garrett et al, 2009

Living biomass

Living biomass is separated into two carbon pools.

- Above-ground biomass: the carbon content of individual trees and shrubs is calculated using species-specific allometric relationships between diameter, height and wood density (for trees), a non-specific conversion factor with diameter and height (for tree ferns) or volume and biomass (for shrubs) (Beets et al, 2012b). Shrub volumes are converted to carbon stocks using species and/or site-specific conversion factors, determined from the destructive harvesting of reference samples.
- Below-ground biomass is derived from above-ground biomass and is assumed to be 25 per cent of above-ground biomass (or 20 per cent of total biomass). This value is based on a review of studies that report root to total biomass ratios of 9 to 33 per cent (Coomes et al, 2002). This paper acknowledges more work is needed but uses the average of the cited studies to justify allocating 20 per cent of total biomass to below-ground biomass.

Dead organic matter

Dead organic matter is separated into two carbon pools.

- Dead wood: the carbon content of dead standing trees is determined in the same way as live trees but excludes branch and foliage biomass calculations. The carbon content of the fallen wood and stumps is derived from the volume of the piece of wood, its species (if able to be identified) and what stage of decay it is at. Dead wood comprises woody debris with a diameter greater than 10 centimetres.
- Litter: the carbon content of the fine debris is calculated by laboratory analysis of sampled material. Litter comprises fine woody debris (dead wood from 2.5 to 10 centimetres in diameter), the litter (all material less than 2.5 centimetres in diameter) and the fermented humic horizons. Samples were taken at approximately one-third of the natural forest plots.

Biomass carbon stocks in New Zealand's natural forests (excluding the soils pool) of 173 (±6) tonnes C ha^{-1} were estimated from the first full round of measurements (Beets et al, 2009) and this data is used for this report. The subset of plots for historic data that exist were separately analysed to estimate the change. Thirteen per cent of the natural forest LUCAS plots were used in the analysis, which found that natural forests in New Zealand were a net carbon sink between 1990 and 2004 (Beets et al, 2009). Until the entire plot network has been re-measured, New Zealand will continue to report natural forests remaining natural forests as carbon neutral and, therefore, no removals or emissions are estimated in this submission.

Soil organic carbon

Mineral soil organic carbon stocks in natural forest land remaining natural forest land are estimated using a Tier 1 method derived from IPCC default values. The steady state mineral soil carbon stock in natural forest is estimated to be 92.59 tonnes C ha^{-1} (table 7.1.7).

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with the drainage of organic soils in managed forests (IPCC, 2003, section 3.2.1.3). In New Zealand, natural forests are not drained and, therefore, oxidation processes associated with drainage are not occurring. It is therefore assumed that there are no carbon emissions from organic soils in natural forest remaining natural forest.

Natural forest carbon

Total carbon stocks in natural forest are determined by multiplying the area of natural forest land remaining natural forest land by the emission factors for each pool to give a national total.

Non-CO_2 emissions for natural forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the subcategory 'Direct soils emissions'.

Pre-1990 planted forest

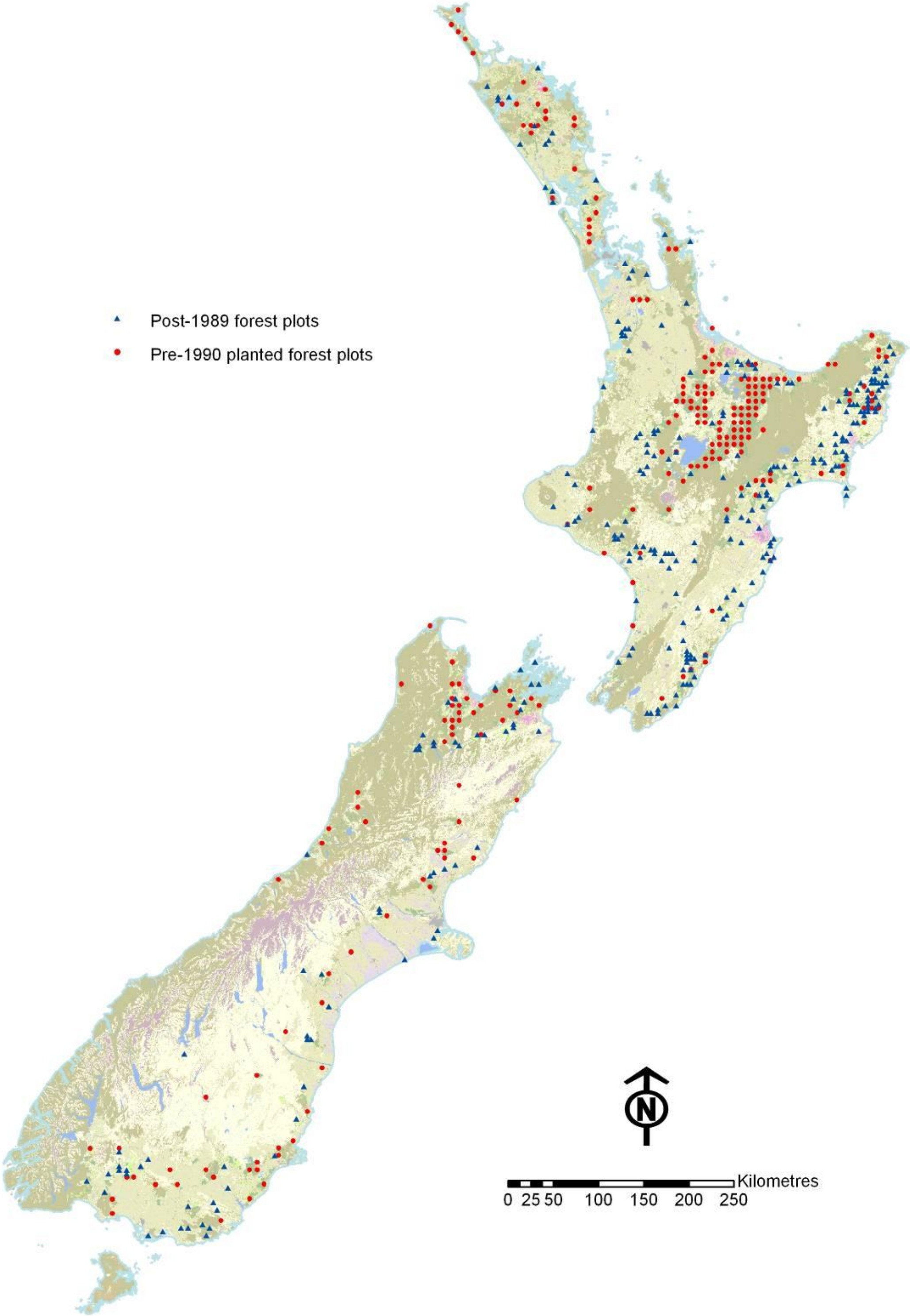
All planted forest land established prior to 1990, whether established for wood production or soil control purposes, is included in the pre-1990 planted forests subcategory. This subcategory also includes areas that were natural forest in 1990 but have since been planted with exotic planted forest. The emissions associated with this area are calculated as the removal of biomass associated with natural forest and the subsequent growth of pre-1990 planted forest. The pre-1990 planted forest yield table is thought to best represent the forest growth on ex-natural forest land because it remains in the forest land category, as opposed to the post-1989 forest yield table, which represents new forest growth mostly on land that originates from the grassland category (see table 7.2.4).

Pre-1990 planted forest inventory

New Zealand's pre-1990 planted forests were sampled in 2010, and the analysis of the data collected has provided a plot-based estimate of carbon stock and mean carbon density within this forest subcategory. The pre-1990 inventory is closely linked, in terms of design and methodology, with the post-1989 forest inventory described later. A double sampling or two-phase sampling approach (described later, see LiDAR double sampling) is employed in the pre-1990 planted forest inventory to improve the precision of the carbon stock and carbon density estimates and reduce the overall cost of the inventory (Beets et al, 2012a).

For the pre-1990 planted forest inventory, 192 circular 0.06 hectare plots (see figure 7.3.5) were established on a systematic 8-kilometre grid consistent with that used for all forest subcategories. These plots were ground measured using procedures as described in Payton et al (2008). Stand records and ground measurements were recorded between June and September 2010 at each plot. Measurements included: tree age; stocking (stems per hectare); stem diameters of live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights; and the timing of pruning and thinning activities. Ground plot centres were located using a 12-channel differential GPS for accurate LiDAR co-location and relocation for future measurements (Beets et al, 2012a).

Figure 7.3.5 Location of New Zealand's pre-1990 planted forest and post-1989 forest plots



Airborne scanning LiDAR data was collected from 893 plots, including those that were ground measured. The LiDAR only plots are located on a 1 kilometre (north–south) by 8 kilometre (east–west) grid within the mapped area of pre-1990 planted forest (Beets et al, 2012a).

Living biomass and dead organic matter

The crop tree plot data collected from the planted forest inventories was modelled using a forest carbon modelling system called the 'Forest Carbon Predictor', version 3 (FCPv3) (Beets and Kimberley, 2011) developed for *Pinus radiata*, the most common plantation tree species in New Zealand. This integrates the 300 Index Growth Model (Kimberley et al, 2005), a wood density model (Beets et al, 2007a), a stand tending model (Beets and Kimberley, 2011) and the C_Change carbon allocation model (Beets et al, 1999), to enable predictions of carbon stocks and changes in New Zealand's planted forests.

The individual components of the Forest Carbon Predictor are explained below.

The 300 Index Growth Model produces a productivity index for forest plots derived from stand parameters. Stand parameters gathered from the national planted forest plot network are entered into the 300 Index Growth Model. These inputs include: stand age, mean top height, basal area, stocking and stand silvicultural history. Plot latitude and altitude are also required to run the model. The 300 Index Growth Model uses these parameters to predict stem volume under bark over a full rotation (planting to harvest). A specific productivity index (or 300 Index) is produced for each plot, which is used to estimate the total live and dead stem volume by annual increment. The 300 Index Growth Model accounts for past and future silviculture treatments using plot data, information on past silvicultural treatments and assumptions of future management events based on plot observations and standard regimes. As Douglas fir is the second most common plantation species in New Zealand, a specific Douglas fir module has been incorporated into the 300 Index Growth Model for the 2012 submission. This includes a specific growth trajectory for plots containing that species (Beets and Kimberley, 2011).

The wood density model within the Forest Carbon Predictor uses site mean annual temperature, soil nitrogen fertility, ring age and stocking to determine the mean density of stem wood growth sheaths produced annually in *Pinus radiata*. Wood density is an important variable in the estimation of carbon. Of the parameters entered into the wood density model, temperature and stand age have the greatest influence on wood density, followed by site fertility and stocking. The influence of the individual effects on wood density is provided in table 7.3.6. The combined result of these individual effects can be large. For example, the 15-year growth sheath of a stand of standard genetics *Pinus radiata* at a low stocking (200 stems ha^{-1}) on a fertile (C/N=12), cool (8°C) site has a predicted wood density of 339 kg m^{-3}, while a stand of the same age and genetics at a high stocking (500 stems ha^{-1}) on a moderately fertile (C/N=25), warm (16°C) site has a predicted wood density of 467 m^{-3} (Beets et al, 2007a).

Table 7.3.6 Influence of individual site and management factors on predicted wood density for New Zealand planted forest

Factor affecting wood density	Range in predicted density (kg m^{-3})	Range in predicted density (% difference)
Temperature: 8°C versus 16°C	359–439	22
Age: 10-year old versus 30-year old	380–446	17
C/N ratio: 12 versus 25	384–418	9
Stocking: 200 versus 500 stems ha^{-1}	395–411	4

New Zealand's plantation forests are intensively managed and therefore pruning and thinning provides the majority of the inputs to the deadwood and litter pools. The Forest Carbon Predictor requires silvicultural history inputs to predict changes between biomass pools over time. The information required includes initial stocking, the timing of management events, stocking following each thinning operation and the pruned height and number of stems pruned for each pruning lift. Information on silvicultural events prior to the plot measurement date is normally gathered from forest owners but sometimes this data is incomplete. A history module has been incorporated into the FCPv3 that makes use of existing data to identify potential gaps in the stand history. Within the history module, assumptions are made to complete the stand history based on field observations, standard management regimes and known silviculture to date (Beets and Kimberley, 2011). The history module enables reasonable estimates of stand history and, therefore, biomass transfers between pools resulting from past silvicultural events.

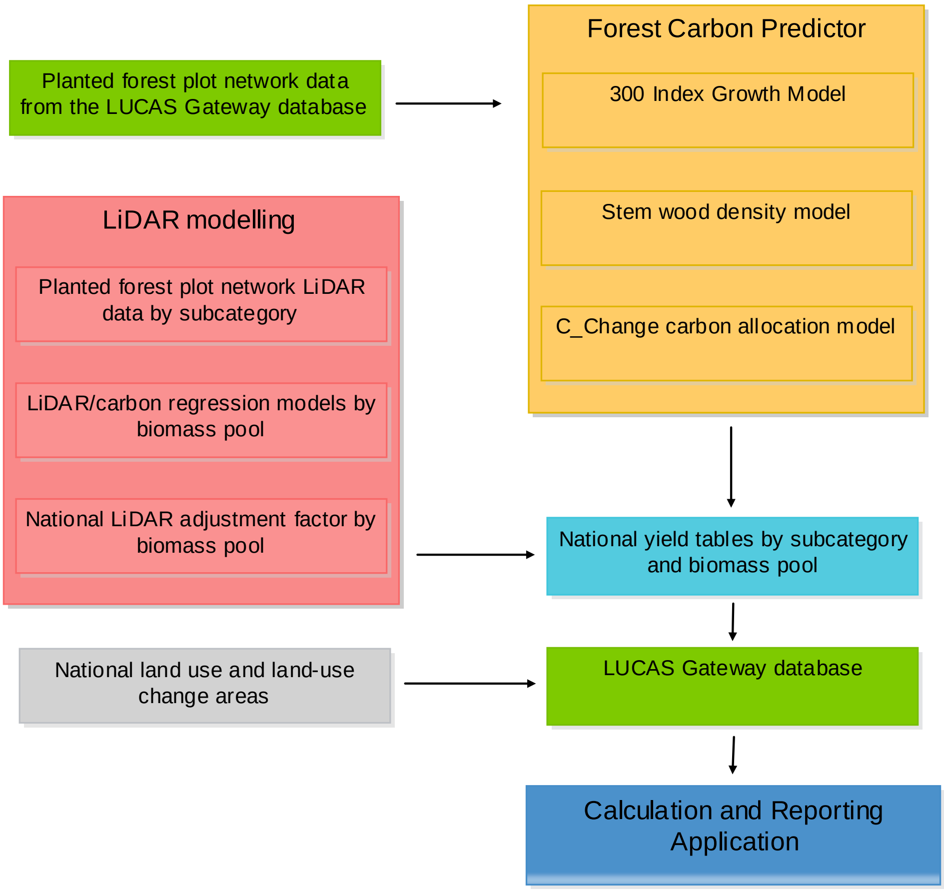
The C_Change carbon allocation model is integrated into the Forest Carbon Predictor and is designed to apportion carbon to needles, branches, stems, roots and reproductive parts via growth partitioning functions. Dead wood and litter pools are estimated by accounting for losses to the live pools from natural mortality, disease effects on needle retention, branch and crown mortality and silvicultural management activities, for example, pruning and thinning. Component-specific and temperature-dependent decay functions are used to estimate losses of carbon to the atmosphere (Beets et al, 1999). The Forest Carbon Predictor also takes into account biomass removals during production thinning. For the 2012 submission, Douglas fir adjustment factors have been added to C_Change to more accurately estimate live and dead biomass in plots that contain this species. These include adjustment factors for stem wood plus bark, crown needles, live and dead branches and root:shoot ratio (Beets and Kimberley, 2011).

The individual plot yield curves generated by the Forest Carbon Predictor are combined into estimates of above-ground live biomass, below-ground live biomass, deadwood and litter in an area-weighted and age-based carbon yield table for each planted forest subcategory. Estimates from plots in unstocked areas within the mapped forest boundary are included in the summarised yield table (T Paul, New Zealand Forest Research Institute, pers. comm., 12 January 2012).

Below-ground biomass is derived from the above-ground biomass estimates. For plantation crop trees, the above- to below-ground biomass ratio is 5:1 (Beets et al, 2007b). The ratio for non-crop trees and shrubs is 4:1 (Coomes et al, 2002).

The carbon content of the dead wood pool within rotation is estimated using the FCPv3 model as described above. Immediately following harvesting, 30 per cent of the above-ground biomass pool is transferred to the dead wood pool; with the other 70 per cent being instantaneously emitted (Wakelin and Garrett, 2010). All material in the deadwood and litter pools is decayed using an empirically derived, temperature-dependent decay profile as described in Garrett et al (2010).

Figure 7.3.6 New Zealand's planted forest inventory modelling process



Analysis by Paul and Kimberley (2009) has demonstrated that using the Forest Carbon Predictor for all planted forest tree species produces an average tonne C ha^{-1} value similar to the values produced using more specific carbon models and/or allometric equations for non-radiata species (mainly Douglas fir (*Pseudotsuga menziesii*) and eucalypts (*Eucalyptus* spp.)). The authors established there was a marginal decrease (0.77 tonnes C ha^{-1}) in the average amount of carbon removals per plot using the one model for all planted forest species. Since this analysis, a correction factor for the growth trajectory and biomass of Douglas fir in the 300 Index has been implemented. New Zealand is currently investigating the reporting of the post-1989 forest and pre-1990 planted forest subcategories by species.

For shrubs and non-crop tree species measured within the planted forest plot network, the carbon content is estimated using species-specific allometric equations. These equations estimate carbon content from diameter and height measurements, and wood density by species (Beets et al, 2012b).

When non-forest land is converted to forest land, all living biomass that was present at the time of forest establishment is assumed to be instantly emitted as a result of forest land preparation. Between 1990 and 2010, approximately 30 per cent of the non-forest land converted to post-1989 forest has been from grassland with woody biomass, and this land-use subcategory provides the largest source of emissions associated with land-use change to forestry.

LiDAR double sampling

The outputs of the FCPv3 and LiDAR metrics are used to develop subcategory-specific regression models that are used in a double-sampling framework to improve the precision of carbon stock and stock change estimates in pre-1990 planted forests.

The analysis of the pre-1990 planted forest ground and LiDAR data closely followed that of the post-1989 analysis, where regression models were developed for total carbon and each of the four biomass pools. Good relationships were found between carbon stocks estimated using ground-based measurements and LiDAR metrics in pre-1990 planted forests. The LiDAR metric found to most accurately predict total carbon was a height metric. Additional variation was also explained by a canopy cover metric. With these metrics combined a regression model was developed to explain 81 per cent of the variation in total carbon.

Regression models applied to the above- and below-ground biomass pools provided good correlations, with R^2 values around 80 per cent. The model was less successful predicting deadwood and litter, with R^2 values of 18 and 48 per cent respectively. This was also the case in the post-1989 inventory. The regression models employed in this analysis used the same model form for both forest types with carbon in the four biomass pools summed to total carbon. In the pre-1990 planted forest inventory, the LiDAR metric, 95th height percentile, had a very high correlation with ground measured mean top height with an R^2 of 96 per cent (Kimberley, 2011).

The double-sampling approach used to sample pre-1990 forests utilised nearly four times as many LiDAR plots as ground plots and, therefore, produced carbon estimates with improved precision when compared with an analysis based on the ground plots alone. The confidence interval for the estimate reduced from 14.1 per cent to 11.1 per cent with the addition of LiDAR (Kimberley, 2011).

The double-sampling approach improves the precision of the national plot-based yield table by applying an adjustment factor derived from the LiDAR regression models. The yield table was adjusted to include the additional information obtained from the LiDAR-only plots by using a multiplier based on the ratio of the LiDAR regression estimate to the ground-based estimate (0.9984). The end result is a LiDAR-adjusted national yield table for pre-1990 planted forest (Kimberley, 2011).

The carbon stock in pre-1990 planted forest as at 1 January 2008, estimated from the national plot network, is 123.97 ± 9.93 t C ha^{-1} (at the 95 per cent confidence interval). The average age of pre-1990 planted forest is 15.2 years as at 1 January 2008 (Paul et al, 2011).

Soil organic carbon

Soil carbon stocks in pre-1990 planted forest land remaining pre-1990 planted forest land are estimated using a Tier 1 method for both mineral and organic soils (section 7.1.3). The steady state mineral soil carbon stock in pre-1990 planted forest is estimated to be 92.59 t C ha^{-1} (table 7.1.7).

The IPCC default emission factor for organic soils under planted forest is 0.68 t C ha^{-1} per annum. Soil carbon change with harvesting is not explicitly estimated, as the long-term soil carbon stock for this land use includes any emissions associated with harvesting.

Non-CO_2 emissions for pre-1990 planted forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the subcategory 'direct soils emissions'.

Land converted to forest land

Post-1989 forests

All land converted to forest land since 1 January 1990, either by planting or as a result of human-induced changes in land-management practice (eg, removing grazing stock and actively facilitating the regeneration of tree species), is included in the post-1989 forest subcategory.

Living biomass and dead organic matter

The majority of post-1989 forests in New Zealand are privately owned and ground access cannot be guaranteed. A double-sampling approach involving LiDAR and ground-based measurements has been employed to reduce the possibility of sampling bias arising from unmeasured plots. This approach enables data to be gathered from sample points when ground access is restricted while simultaneously improving the precision of the carbon stock estimates (Stephens et al, 2012).

The double-sampling approach used in the post-1989 forest inventory is described in detail in Stephens et al, 2012. The approach follows that described in Parker and Evans, (2004) and Corona and Fattorini (2008). Double sampling combines ground-based plot measurements with auxiliary data (LiDAR) obtained from a larger sample of the population. The auxiliary data is used to improve the precision of the forest carbon estimates when compared with those based on ground measurements alone. Regression or ratio estimators, based on ground-measured variables and LiDAR parameters, are utilised to improve the precision of the carbon stock estimates. The approach relies on good relationships between LiDAR parameters and ground-measured variables (Stephens et al, 2012). These relationships were verified during pilot studies carried out in two geographically separate study areas independent of the post-1989 and pre-1990 planted forest plot networks during 2006 and 2007 (Stephens et al, 2007). The pilot studies were also used to develop the plot design and the measurement methodology used in both the post-1989 and pre-1990 planted forest inventories.

A plot-based forest inventory system has been developed for carbon estimation in New Zealand's post-1989 forest and is described in detail in Beets et al (2011a). In the inventory, circular 0.06 hectares of permanent sample plots have been established within post-1989 forests on a systematic 4-kilometre square grid coincident with that used for the natural forest and pre-1990 planted forest inventories (Moore and Goulding, 2005). Permanent sample plots were selected over temporary sample plots because historical trend data is more easily analysed for change in plots with multiple measurements (Beets et al, 2011a).

The initial post-1989 forest inventory was carried out during the winters of 2007 and 2008. There were 246 plots of ground sampled using methodology as described in Payton et al, 2008. The ground measurements included: stem diameters of live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights, measurement of deadwood and soil fertility samples for predicting wood density (Beets et al, 2007a). Silvicultural information, including tree age, stocking (stems per hectare) and timing of pruning and thinning activities, was gathered from the individual forest owners. Ground plot centres were located using a 12-channel differential GPS for sub-meter LiDAR co-location and for relocation in future inventories.

LiDAR data was captured from 292 plots (see figure 7.3.5), including those that were ground sampled (Beets et al, 2011a). LiDAR data was acquired at a minimum of three points (or returns) per square metre. Aerial photography, at 200 millimetre resolution, was captured at the same time to aid in data analysis and for plot centre location during ground sampling.

At the time of the initial post-1989 forest inventory, the mapped area of the post-1989 forest had not been defined. Subsequent remapping of post-1989 forest has resulted in 100 additional plots that have been established during the post-1989 forest plot re-measurement that took place during the winters of 2011 and 2012. Re-measurement will provide a plot-based estimate of carbon stock change for the 2014 submission. Stock change in post-1989 forests is currently estimated using a subcategory-specific national yield table approach similar to that described in *Living biomass and dead organic matter* in the pre-1990 planted forest section 7.3.2 above.

New Zealand plantation forests are actively managed, with thinning and pruning activities undertaken early in the rotation. The majority of these activities are completed before trees reach the age of 13. Thus, there is a gradual increase in the dead wood and litter pools from these management practices leading up to this age. This is followed by a decline in these pools after age 13 where pruning and thinning ceases and decay exceeds inputs. Due to the age-class structure of post-1989 forest in New Zealand, this can be seen as a rapid increase in the dead wood and litter pools over consecutive years.

LiDAR double sampling

The outputs of the FCPv3 and LiDAR metrics are used to develop subcategory-specific regression models to improve the precision of carbon stock and stock change estimates in post-1989 planted forests.

Good relationships were found between carbon stocks from ground-based tree measurements and LiDAR metrics for post-1989 forests. The best fitting LiDAR metric for predicting total carbon was a height metric (the 30th height percentile), but significant variation was also explained by a canopy cover metric (percentage cover). A regression model explaining 74 per cent of the variation in total carbon was developed using these two LiDAR metrics (Stephens et al, 2012).

Regression models using the same model form were fitted for each of the four biomass pools, providing good predictions for above-ground biomass carbon (R^2=81 per cent and below-ground biomass carbon (R^2=80 per cent), but less successful predictions for litter carbon (R^2=38 per cent) and dead wood carbon (R^2=21 per cent). The R^2 for the regression between the LiDAR metric, 95th height percentile and mean top height calculated from ground measurements was 96 per cent, with a root mean square error of 1.09 metres (Stephens et al, 2012).

These regression models were used to obtain estimates, as at 1 January 2008, of the national level of carbon stock in the post-1989 forests using double-sampling procedures, and to develop a national age-based and area-weighted carbon yield table for the subcategory. Carbon estimates from 246 ground plots were supplemented with LiDAR data from 46 additional plots. The regression estimators (using the LiDAR data) improved precision by 6 per cent compared with the ground-based estimates alone. The updated carbon stock estimate derived from LiDAR double sampling is 84.43 ± 2.60 tonnes C ha^{-1} (at the 95 per cent confidence interval) and the comparable value from just the ground-measured plot data is 84.62 ± 2.76 tonnes C ha^{-1} (Paul et al, 2011). This carbon stock estimate, while high, is consistent with the international comparisons provided in table 3A.1.4 (IPCC, 2003) and reflects the composition of the forest subcategory made up of 95 per cent actively managed production forestry. The average age of post-1989 forest trees as at 1 January 2008 is 12 years (Paul et al, 2009).

Quality assurance and quality control

Quality-assurance and quality-control activities were conducted throughout the post-1989 forest data capture and processing steps. These activities were associated with the following: inventory design (Moore and Goulding, 2005; Brack, 2009); acquisition of raw LiDAR data and LiDAR processing; checking eligibility of plots; independent audits of field plot measurements; data processing and modelling; regression analysis and double-sampling procedures (Woollens, 2009); and investigating LiDAR and ground plot co-location (Brack and Broadley, 2010). These activities are described more fully in section 7.3.4.

Soil organic carbon

Soil carbon stocks in land converted to post-1989 forest are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3. The steady state mineral soil carbon stock in post-1989 forest is estimated to be 92.59 tonnes C ha^{-1} (table 7.1.7).

In the absence of country- and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in SOC stocks between the original land use and planted forest land for any given period. For example, the soil carbon change associated with a land-use change from low-producing grassland (soil carbon stock 105.55 tonnes C ha^{-1}) to planted forest (soil carbon stock 92.59 tonnes C ha^{-1}) would be a loss of 12.96 tonnes C ha^{-1} over the 20-year period.

The IPCC default emission factor for organic soils under planted forest is 0.68 tonnes C ha^{-1} per annum. This is also applied to organic soils on land converted to post-1989 forest.

Non-CO_2 emissions for post-1989 forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the subcategory ‘direct soils emissions’.

7.3.3 Uncertainties and time-series consistency

Emissions from forest land are 12.1 per cent of New Zealand’s net emissions uncertainty in 2011 (annex 7). Forest land introduces 8.4 per cent uncertainty into the trend in the national total from 1990 to 2011. This is the largest impact on the trend and second-largest impact on the 2011 net emissions following agricultural soils.

Natural forest

The uncertainty in mapping natural forest is ± 4 per cent. Further details on this are given in section 7.2.5.

The natural forest plot network provides biomass carbon stock estimates that are within 95 per cent confidence intervals of 3.63 per cent of the mean (173 ± 6.27 t C ha^{-1}) in natural forests (Beets et al, 2009). Natural forests are assumed to be in steady state, therefore, no emissions are reported from this forest type and no uncertainty is introduced into net emissions from this land-use subcategory. The IPCC default uncertainty of soil carbon stocks for natural forests is ± 95.0 per cent.

Table 7.3.7 Uncertainty in New Zealand's 2011 estimates from natural forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	4.0
Emission factors	
Uncertainty in biomass carbon stocks	3.6
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**0**

Note: NO = not occurring.

Pre-1990 planted forest

A national plot-based inventory system in conjunction with a suite of models is being used to estimate carbon stock and change within New Zealand's planted forest. These models are collectively called the Forest Carbon Predictor version 3 (Beets and Kimberley, 2011) and are described in further detail in *Living biomass and dead organic matter* in the pre-1990 planted forest section above. Extensive work has been carried out to reduce the uncertainty in the estimates including the use of a specifically designed plot network and research-based improvements to the models.

New Zealand's pre-1990 planted forests were sampled in 2010 and the analysis of the data collected has provided a plot-based estimate of carbon stock within this forest subcategory. This has reduced the uncertainty of the biomass estimates and growth from the previous estimate based on the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010). Double sampling using airborne scanning LiDAR is employed in the pre-1990 planted forest inventory to further improve the precision of the carbon stock estimates over that obtained using ground measurements alone. The confidence interval for the estimate reduced from 14.1 per cent to 11.1 per cent with the addition of LiDAR (Kimberley, 2011).

Recently, a Forest Carbon Predictor validation paper was published (Beets et al, 2011b) describing the recent improvements to the models and the associated improvement in precision. This study found that estimates of total carbon stock per plot were predicted with an accuracy of approximately 5 per cent using the Forest Carbon Predictor. The Forest Carbon Predictor provides estimates of above-ground biomass per plot with an accuracy of approximately 1 per cent. Carbon stock change was estimated within 5 per cent accuracy when linked with plot data at the start and end of each five-year period, linking closely with the scheduled duration between the national plot-based inventories (Moore and Goulding, 2005).

The accuracy associated with the Forest Carbon Predictor and the pre-1990 planted forest inventory data for the 2012 submission are provided in table 7.3.8.

Table 7.3.8 Uncertainty in New Zealand's 2011 estimates from pre-1990 planted forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	7.0
Emission factors	
Uncertainty in biomass carbon stocks	14.1
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**76.5**

Note: The biomass uncertainties are low for pre-1990 planted forest (14.1 per cent). However, the total uncertainty for the subcategory is calculated on the net change. The age structure of the estate results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. The net change is within the error bounds of the emissions and removals estimates, and therefore its uncertainty is high. Land area includes land in transition in 2011. Lime application to pre-1990 planted forest does not occur (NO) in New Zealand. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equations 5.2.1 and 5.2.2 from GPG-LULUCF (IPCC, 2003).

Post-1989 forest

Biomass

A national plot-based inventory system, in conjunction with a suite of models, is being used to estimate carbon stock and change within New Zealand's planted forest. The modelling process for post-1989 forest is identical to pre-1990 planted forest, and the uncertainty in the modelling process is outlined above. Additionally, the Forest Carbon Predictor validation is described in Beets et al (2011b) and New Zealand's inventory approach is described in Beets et al (2011a).

New Zealand's post-1989 forests were first sampled during the winters of 2007 and 2008. The inventory provides a plot-based estimate of carbon stock within this forest subcategory. A double-sampling approach involving LiDAR and ground-based measurements has been employed to reduce the possibility of sampling bias arising from unmeasured plots due to access restrictions. Double sampling also increases the precision of the carbon stock estimates over that obtained using ground measurements alone. Double sampling in the post-1989 forest inventory resulted in a 6 per cent improvement in precision. The confidence interval for the estimate reduced from 5.7 per cent to 5.4 per cent with the addition of LiDAR (Beets et al, 2011a).

Re-measurement of the post-1989 forest plot network is currently under way and will be completed by October 2012. Re-measurement of the plot network will provide a plot-based estimate of carbon stock change, reduce assumptions on future silviculture events and further validate the Forest Carbon Predictor model.

When post-1989 forests were initially inventoried in 2007 and 2008, the mapping of the forest extent had yet to be completed. Consequently, the initial post-1989 forest sample was incomplete. The national forest map has now been completed, and 140 additional plots have been identified. The inclusion of these plots in the re-measurement will provide an unbiased and representative sample of post-1989 forests. The re-measurement data, including the additional plots, will be introduced from the 2014 submission.

Table 7.3.9 Uncertainty in New Zealand's 2011 estimates from post-1989 forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	7.0
Emission factors	
Uncertainty in biomass carbon stocks	10.2
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**20.7**

Note: Land area includes land in transition in 2011. Lime application to post-1989 forest does not occur (NO) in New Zealand. Nitrous oxide emissions are calculated as a proportion of carbon stock change, with the same uncertainty as for CO_2 and, therefore, do not add to the combined uncertainty value. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF (IPCC, 2003). National statistics are a new source of uncertainty that previously were not included in the calculation of total uncertainty.

7.3.4 Category-specific QA/QC and verification

Carbon dioxide emissions from both 'forest land remaining forest land' and 'land converted to forest land' are key categories (for both level and trend assessments). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality-assurance and quality-control checks as well as Tier 2, category-specific quality-assurance and quality-control checks. Details of these checks are provided below.

Natural forest

During the initial measurement of the natural forest plot network, 5 per cent of plots measured in the first field season were subject to audit (Beets and Payton, 2003). In all field seasons, data collection followed quality-assurance and quality-control processes as described in Payton et al (2004a) and Payton et al (2004b). This included on-site quality-control checks of field data and review by senior ecologists. Data was collected in the field and recorded by hand on paper field sheets. The electronic data entry of all data has been subject to ongoing quality assurance and quality control, including line-by-line checking of the transcription of all data used in carbon calculations.

As the natural forest plot network is re-measured, 10 per cent of plots measured are subject to independent audit. This involves a partial re-measure of the plot and the assessment of measurements against data quality standards as described in Payton and Brandon (2010). Data entry of all data is subject to quality assurance by the Ministry for the Environment for 10 per cent of plots.

Pre-1990 planted forest and post-1989 forest

During the ground-measurement season, 10 per cent of plots were randomly audited without the prior knowledge of the inventory teams. Plots were fully re-measured with feedback supplied no later than one month after measurement to ensure prompt identification of data collection errors and procedural issues. Differences between the inventory and audit measurements were objectively and quantitatively scored. Measurements that exceeded predefined tolerances incurred incremental demerit points. Demerit severity depended on the size of error and the type of measurement. Special attention was given to the most influential measurements, for example, tree diameter, tree height and the number of trees in a plot. Plots that failed the quality control had to be re-measured (Beets et al, 2011a). Following each inventory season, the data collection manual (Herries et al, 2011) is revised to clarify procedures and highlight potential sources of error.

The inventory data was pre-processed using the New Zealand Forest Research Institute's Permanent Sample Plot (PSP) system. The PSP system has been programmed to check for erroneous values over a wide range of attributes. The system automatically identifies fields that do meet predetermined validation rules so these can be repaired manually before plot data are modelled by the Forest Carbon Predictor. The PSP data validation system and the Forest Carbon Predictor model were independently reviewed by Woollens (2009). The Forest Carbon Predictor has been recently validated in Beets et al (2011b).

Quality-assurance and quality-control procedures for LiDAR collected during the planted forest inventories involved the checking of data as it was acquired following the methodology outlined in Stephens et al (2008). To ensure that the data was supplied within the predetermined specifications, the following activities were carried out: LiDAR sensor calibration and bore-sight alignment, checking of LiDAR point positional accuracy and point densities, correct point cloud classification and accuracy of digital terrain mapping. For example, the post-1989 forest inventory LiDAR acquisition included four individual sensor calibrations; six LiDAR point positional accuracy tests and a summary of returns describing LiDAR specifications were provided for all data deliveries. Sites that failed to meet the required specifications were re-flown. These analyses were carried out using the LiDAR analysis software FUSION (McGaughey et al, 2004; McGaughey, 2010) and the Esri Arc Map GIS application. LiDAR metrics or parameters describing the forest from the canopy to the ground were extracted using FUSION. The process of extracting LiDAR metrics and the extracted metrics were audited by an organisation independent of the data capture and analysis (Stephens et al, 2008).

7.3.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emissions estimates for the whole LULUCF sector from 1990, including the forest land category. These recalculations have involved improved country-specific methods, activity data and emission factors. The impact of the recalculations on net CO_2-e emissions estimates for the forest land category is provided in table 7.3.10. The differences shown are a result of recalculations for all carbon pools used in Climate Change Convention and Kyoto Protocol reporting for the whole time series for the LULUCF sector.

Table 7.3.10 Recalculations of New Zealand's estimates for the forest land category in 1990 and 2010

Forest land recalculations		Net emissions and areas		Change from the 2012 submission	
		2012 submission	2013 submission		(%)
Net emissions	1990	–27,149.9 Gg CO_2-e	–27,717.3 Gg CO_2-e	–567.4 Gg CO_2-e	2.1
	2010	–23,539.1 Gg CO_2-e	–21,363.2 Gg CO_2-e	2,175.9 Gg CO_2-e	–9.2
Land areas	1990	9,627,992 ha	9,652,056 ha	24,064 ha	0.2
	2010	10,120,118 ha	10,144,178 ha	24,060 ha	0.2

Note: Areas are as at the end of the year indicated.

For forest land, the reasons for the recalculation differences are explained below.

Methods

Forest land remaining forest land

New methods have been developed to enable the reporting of estimates for biomass burning associated with the clearance of natural forest prior to the establishment of exotic planted forest and the burning of post-harvest residues prior to restocking. These are provided for the first time in 2011.

Activity data

Deforestation

The area estimates of deforestation within forest land subcategories have been updated from the previous submission. These areas and the associated emissions are reported in the 'land converted to' category.

Forest land remaining forest land

The activity data used to estimate harvesting emissions in pre-1990 planted forests is obtained from a national survey of forest owners. The survey respondents report harvested areas as net stocked area rather than gross stocked area, the use of the raw data will, therefore, underestimate harvesting emissions. To enable these data to be used for inventory emissions calculations, a range of options was considered to align the data. The preferred approach was to scale up harvest areas reported by 17 per cent throughout the time series to account for the differences in forest definitions used in the inventory and the source of activity data (Wakelin and Paul, 2012),

Emission factors

Planted forest carbon stock change

In the 2012 submission, New Zealand applied an updated version of the Forest Carbon Predictor (FCPv3) to improve the post-1989 planted forest yield table. However, an error occurred in the calculation process that affected the results derived from the updated yield table. Last year's estimates of carbon stock and change in post-1989 forests were over estimated due to this error. The error has been corrected in the calculation process for this year's estimates.

7.3.6 Category-specific planned improvements

Re-measurement of the natural forest permanent sample plot network is under way. After this re-measurement is completed, New Zealand will be better able to illustrate whether its natural forests are a net source or sink of carbon or whether they are carbon neutral.

Re-measurement of the post-1989 forest plot network has recently been completed. Re-measurement of the plot network will provide a plot-based estimate of carbon stock change, reduce assumptions on future silviculture events and further validate the Forest Carbon Predictor model. Since the initial post-1989 forest inventory, 100 additional plots have been identified from updated forest mapping. The inclusion of these plots in the inventory will provide an unbiased and representative sample of post-1989 forests. The re-measurement data, including data from the additional plots, will be introduced from the 2014 submission.

Mapping of forest areas will be iteratively improved by comparison with other spatial forest data sets administered by the Ministry for Primary Industries. These include post-1989 forest areas lodged with the NZ ETS, pre-1990 planted forest areas lodged with the Forestry Allocation Scheme and new post-1989 forests planted through the Afforestation Grants Scheme and the Permanent Forest Sink Initiative.

New Zealand has a long-term research programme that underpins forest carbon inventory and modelling. The specific improvements expected from this research effort include work to increase the accuracy in the estimates of carbon stock and change that is occurring due to land-use change within the first commitment period.

Work to implement a recommendation from the review of New Zealand's 2010 submission to enable reporting by forest type within post-1989 forest is under way. This includes the following:

- the development of the methodology for reporting by forest type within the pre-1990 planted forests and post-1989 forests
- the expansion of the post-1989 forest inventory plot network to include the regenerating shrubland component of post-1989 forest to estimate carbon stock in this forest type.

7.4 Cropland (CRF 5B)

7.4.1 Description

Cropland in New Zealand is separated into two subcategories: annual and perennial. In 2011, there were 334,852 hectares of annual cropland in New Zealand (1.2 per cent of total land area) and 104,077 hectares of perennial cropland (0.4 per cent of total land area).

Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and their associated shelterbelts except where these shelterbelts meet the criteria for forest land.

The amount of carbon stored in, emitted by or removed from permanent cropland depends on crop type, management practices and soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, the amount of carbon stored in woody vegetation in orchards can be significant, with the amount depending on the species, density, growth rates and harvesting and pruning practices.

In 2011, the net emissions from cropland were 390.8 Gg CO_2-e, comprising 342.5 Gg CO_2 from carbon stock change, 0.03 Gg N_2O (8.9 Gg CO_2-e) from the cultivation of land converted to cropland and 39.4 Gg CO_2 from liming.

Net emissions from cropland have decreased by 177.5 Gg CO_2-e (31.2 per cent) from the 1990 level when net emissions were 568.3 Gg CO_2-e (table 7.4.1). This decrease is largely due to the gradual reduction in the area of land in a state of conversion to cropland since 1990 as it transfers to the land remaining category.

Conversion to cropland category was identified as a key category for 2011 in CO_2 (trend assessment).

Table 7.4.1 New Zealand's land-use change within the cropland category from 1990 to 2011 and associated emissions

Cropland land-use category	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$-e) 1990	2011	Change from 1990 (%)
Cropland remaining cropland	377,631	404,715	7.2	334.7	311.4	–6.9
Land in conversion to cropland	37,079	34,214	–7.7	233.7	79.4	–66.0
Total	**414,710**	**438,929**	**5.8**	**568.4**	**390.8**	**–31.2**

Note: 1990 and 2011 areas are as at 31 December. Land in conversion to cropland includes land that was converted prior to 1990. Net emission values are for the whole year indicated.

The cropland remaining cropland category is responsible for the majority of cropland emissions. This category comprised 92.9 per cent of all cropland area in 2011. The emissions for this land use are the result of annual cropland being converted to perennial cropland. Table 7.4.2 shows land-use change by cropland subcategory since 1990, and the associated CO_2 emissions from carbon stock change.

Table 7.4.2 New Zealand's land-use change within cropland subcategories from 1990 to 2011, and associated CO_2 emissions from carbon stock change

Cropland land-use subcategory	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$ only) 1990	2011	Change from 1990 (%)
Annual cropland	335,804	334,852	–0.3	420.9	252.7	–40.0
Perennial cropland	78,907	104,077	31.9	105.5	89.8	–14.9
Total	**414,710**	**438,929**	**5.8**	**526.4**	**342.4**	**–34.9**

Note: 1990 and 2011 areas are as at 31 December. Columns may not total due to rounding.

A summary of land-use change within the cropland category, by subcategory and land conversion status, is provided in table 7.4.3. This shows that land-use change within the cropland category has been dominated by conversions to perennial cropland, both from within the cropland category as well as from other land-use categories. This conversion has predominantly been for the establishment of vineyards (Davis and Wakelin, 2010).

Table 7.4.3 New Zealand's land-use change within the cropland category from 1990 to 2011

Cropland category	Subcategory	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	306,507	324,594	5.9
	Perennial remaining perennial	68,031	74,699	9.8
	Annual to perennial	1,445	5,055	249.8
	Perennial to annual	1,648	366	–77.8
	Subtotal	*377,631*	*404,715*	*7.2*
Land in conversion to cropland	Annual cropland	27,649	9,891	–64.2
	Perennial cropland	9,431	24,323	157.9
	Subtotal	*37,079*	*34,214*	*–7.7*
Total		**414,710**	**438,929**	**5.8**

Note: Columns may not total due to rounding.

From 1990 to 2011, the total carbon stock stored in cropland decreased by 2,629.0 Gg C, equivalent to emissions of 9,639.7 Gg CO_2 from cropland since 1990 (table 7.4.4). The majority of these emissions are from losses in the soil organic carbon pool.

Table 7.4.4 New Zealand's carbon stock change by carbon pool within the cropland category from 1990 to 2011

Crop land subcategory	Net carbon stock change 1990–2011 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2011 (Gg CO_2)
Annual cropland	–2.5	NE	–1,972.4	–1,974.9	7,241.4
Perennial cropland	71.6	–4.4	–721.2	–654.1	2,398.3
Total	**69.1**	**–4.4**	**–2,693.6**	**–2,629.0**	**9,639.7**

Note: Dead organic matter (DOM) is not estimated (NE) for cropland as there is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in this pool (IPCC, 2003). The reported DOM losses result from the loss of DOM of woody land-use classes on conversion to cropland.

7.4.2 Methodological issues

Emissions and removals for living biomass and dead organic matter have been calculated using: IPCC Tier 1 emission factors for annual cropland, Tier 2 emission factors for perennial cropland (Davis and Wakelin, 2010) and activity data as described in section 7.2. Emissions and removals by the soil organic carbon pool are estimated using IPCC Tier 1 defaults for both mineral and organic soils (section 7.1.3).

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for cropland is provided in table 7.4.5.

Table 7.4.5 Summary of New Zealand's carbon stock change emission factors for cropland

Cropland land-use subcategory	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon stock change (t C ha^{-1})	Years to reach steady state	Source
Annual	**Biomass**				
	Living biomass	5.0	NA	1	IPCC default EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral		[1]	20	IPCC Tier 1 default parameters
	Organic	NE	–1.0 / –10.0		IPCC Tier 1 default parameters
Perennial	**Biomass**				
	Living biomass	18.76	0.67	28	NZ-specific EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	97.76	[1]	20	IPCC Tier 1 default parameters
	Organic	NE	–1.0 / 10.0		IPCC Tier 1 default parameters

Note: EF = emission factor; NA = not applicable; NE = not estimated. [1] Annual carbon stock change in mineral soils on land undergoing land-use change will depend on the land-use category the land has been converted to or from.

Cropland remaining cropland

For cropland remaining cropland, the Tier 1 assumption is that for annual cropland there is no change in carbon stocks after the first year (GPG-LULUCF, section 3.3.1.1.1.1, IPCC, 2003). The rationale is that the increase in biomass stocks in a single year is equal to the biomass losses from harvest and mortality in that same year. For perennial cropland, there is a change in carbon stocks associated with a land-use change. New Zealand has reported NA (not applicable) in the common reporting format tables where there is no land-use change at the subcategory level because no emissions or removals are assumed to have occurred. However, where there has been land-use change between the cropland subcategories, carbon stock changes are reported under cropland remaining cropland. Between 1990 and 2011, there were 4,783 hectares converted from one cropland subcategory to another.

Living biomass

To estimate carbon change in living biomass for annual cropland converted to perennial cropland, New Zealand is using Tier 1 defaults for biomass carbon stocks at harvest. The value being used for annual cropland is 5 tonnes C ha^{-1} (see table 7.4.5). This is the carbon stock in living biomass after one year as given in GPG-LULUCF, table 3.3.8 (IPCC, 2003). The Tier 1 method for estimating carbon change assumes carbon stocks in biomass immediately after conversion are zero, that is, the land is cleared of all vegetation before planting crops (5 tonnes C ha^{-1} is removed).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 tonnes C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

The activity data available do not provide information on areas of perennial cropland temporarily destocked; therefore, no losses in carbon stock due to temporary destocking can be calculated.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation NE (not estimated) is used in the common reporting format tables. There is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in cropland remaining cropland (IPCC, 2003).

Soil organic carbon

Soil carbon stocks in cropland remaining cropland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3. The steady state mineral soil carbon stock for annual cropland is estimated to be 59.82 tonnes C ha^{-1} with an uncertainty of 96 per cent; for perennial cropland it is estimated to be 97.76 tonnes C ha^{-1} with an uncertainty of 97 per cent.

Mineral soil carbon change for annual cropland converted to perennial cropland is estimated using a Tier 1 method with the change in soil carbon reflecting a linear rate of change over 20 years (the IPCC default method).

The IPCC default emission factors for organic soils under cropland are 1.0 and 10.0 tonnes C ha^{-1} per annum for cold temperate and warm temperate regimes respectively (table 7.1.8).

Liming

The calculation of carbon dioxide emissions from the liming of cropland soil is based on equation 3.4.11 in GPG-LULUCF (IPCC, 2003) as outlined in section 7.9.4. The total amount of agricultural lime (limestone) applied is provided by Statistics New Zealand (New Zealand's official statistics agency). This is split into lime and dolomite applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2008 Agricultural Census. This analysis indicates that, each year, around 6 per cent of agricultural lime used in New Zealand is applied to cropland. The amount of lime applied to cropland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Land converted to cropland

Living biomass

New Zealand uses a Tier 1 method, and a combination of IPCC default and New Zealand-specific emission factors to calculate emissions for land converted to cropland. The Tier 1 method multiplies the area of land converted to cropland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass and dead organic matter immediately after conversion is zero, that is, the land is cleared of all vegetation before planting crops. The amount of biomass cleared when land at steady state is converted is shown in tables 7.1.3 and 7.1.4.

The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5 tonnes C ha^{-1} for the first year following conversion (GPG-LULUCF, table 3.3.8, IPCC, 2003). After the first year, any increase in biomass stocks in annual cropland is assumed equal to biomass losses from harvest and mortality in that same year and, therefore, after the first year there is no net accumulation of biomass carbon stocks in annual cropland remaining annual cropland (IPCC, 2003, section 3.3.1.1.1).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 tonnes C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

Dead organic matter

New Zealand reports only losses in dead organic matter associated with the previous land use for this category. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to cropland. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate gain in carbon stock in dead organic matter pools after land is converted to cropland (IPCC, 2003).

Consequently, where there is no dead organic matter losses associated with the previous land use, the notation key NE (not estimated) is used in the common reporting format tables.

Soil organic carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original and new land use.

The IPCC default emission factors for organic soils under cropland are also applied to land converted to cropland.

Non-CO_2 emissions

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland are described in section 7.9.3.

7.4.3 Uncertainties and time-series consistency

The uncertainty in mapping cropland is ± 6 per cent. Further details on this are given in section 7.2.5 and Dymond et al (2008).

New Zealand uses IPCC default values for biomass accumulation in annual cropland. For perennial cropland, we use a New Zealand-specific emissions factor (Davis and Wakelin, 2010). As the perennial and annual cropland emission factors are based on a limited number only of biomass studies, the uncertainty in these figures is estimated as ± 75 per cent.

For soils, New Zealand uses IPCC default values for annual and perennial cropland. The uncertainty associated with the IPCC default values is 95 per cent (based on GPG-LULUCF, table 3.2.4, IPCC, 2003).

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand. This is estimated as ± 6 per cent for limestone and ± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

As shown in table 7.4.6, while uncertainty in activity data is low, the uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand.

Table 7.4.6 Uncertainty in New Zealand's 2011 cropland estimates (including land in transition)

Variable	**Uncertainty at a 95% confidence interval**	
Land-use subcategory	Annual cropland (%)	Perennial cropland (%)
Activity data		
Uncertainty in land area	6.0	6.0
Emission factors		
Uncertainty in biomass carbon stocks	75.0	75.0
Uncertainty in soil carbon stocks	95.0	95.0
Uncertainty in liming emissions	95.2	95.2
Uncertainty introduced into net emissions for LULUCF	**1.4**	**0.8**

7.4.4 Category-specific QA/QC and verification

Carbon dioxide emissions from 'conversion to cropland' were identified as a key category in the trend analysis for this submission. In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.4.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the cropland category is shown in table 7.4.7. Recalculations of the entire time series were carried out for this category as a result of:

- updated liming activity data following the release of the final results from the 2012 Agricultural Production Survey.

Table 7.4.7 Recalculations of New Zealand's net emissions from the cropland category in 1990 and 2010

	Net emissions (Gg CO_2-e)		**Change from the 2012 submission**	
Year	**2012 submission**	**2013 submission**	**(Gg CO_2-e)**	**(%)**
1990	567.1	568.3	1.2	0.2
2010	392.1	391.8	–0.3	–0.1

7.4.6 Category-specific planned improvements

The main improvement planned for this category is associated with a return to Tier 2 modelling for mineral soils. New Zealand has obtained additional data for perennial cropland soils. The Tier 2 approach using the soil CMS model is undergoing continued improvement.

Activity data on the land area of croplands will be updated as part of the 2012 land-use mapping process. New data from the Land Cover Database 3 (LCDB3) will be incorporated in the 1990, 2008 and 2012 land-use maps to more accurately reflect changes in the extent of croplands over this period. This improvement will be included in the 2014 submission.

7.5 Grassland (CRF 5C)

7.5.1 Description

In New Zealand, grassland covers a range of land-cover types. In this submission, three subcategories of grassland are used: high producing, low producing and with woody biomass.

High-producing grassland consists of intensively managed pasture land. Low-producing grassland consists of low-fertility grasses on hill country, areas of native tussock or areas composed of low, shrubby vegetation, both above and below the timberline. Grassland with woody biomass consists of grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor have the potential to meet, the New Zealand forest definition due to either the current management regime (eg, periodically cleared for grazing) or the characteristics of the vegetation (eg, shrubland). A summary of land-use change within the grassland category is provided in table 7.5.1.

Land-use research indicates that, under business-as-usual grassland farming operations, areas of woody shrublands within farmland do not become forest over a 30- to 40-year timeframe (Trotter and MacKay, 2005). This is the case as long as the farmer's intention is to manage the land as grassland for grazing animals. When it becomes evident that the farmer has modified land management in a way that encourages sustained growth of woody vegetation, such as by removing stock, then these areas will be mapped as forest. A description of the land-management approaches that result in the sustained growth of woody vegetation is contained in the mapping interpretation guide (Ministry for the Environment, 2012).

In 2011, there were 5,792,117 hectares of high-producing grassland (21.5 per cent of total land area), 7,661,334 hectares of low-producing grassland (28.5 per cent of total land area) and 1,118,082 hectares of grassland with woody biomass (4.2 per cent of total land area).

The net emissions from grassland were 3,753.3 Gg CO_2-e in 2011 (table 7.5.1). These emissions comprise 3,713.5 Gg CO_2 emissions from carbon stock change and agricultural lime application, and 1.7 Gg CH_4 emissions and 0.01 Gg N_2O emissions from biomass burning.

The grassland remaining grassland and conversion to grassland categories were identified as key categories for the level and trend assessment in 2011.

Net emissions from grassland have increased by 4,986.5 Gg CO_2-e (404.4 per cent) from the 1990 level of –1,233.1 Gg CO_2-e. This increase has occurred primarily on grassland remaining grassland and is due to the influence of land-use changes between grassland subcategories on mineral soil carbon.

Table 7.5.1 New Zealand's land-use change within the grassland category from 1990 to 2011

Grassland land-use category	Area in 1990 (ha)	Area in 2011 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e) 1990	Net emissions (Gg CO_2-e) 2011	Change from 1990 (%)
Grassland remaining grassland	14,578,823	14,414,075	–1.1	–1,031.6	2,103.3	303.9
Land in conversion to grassland	516,554	157,457	–69.5	–201.5	1,650.0	918.7
Total	**15,095,378**	**14,571,532**	**–3.5**	**–1,233.1**	**3,753.3**	**404.4**

Note: 1990 and 2011 areas are as at 31 December. Net emission estimates are for the whole year indicated. Land in conversion to grassland includes land converted up to 28 years prior to 1990. Columns may not total due to rounding.

The largest change is due to changes between grassland with woody biomass and high-producing grassland. The mineral soil carbon net stock change associated with this particular land-use change is 24.6 t C ha^{-1}.

Since 1990, the proportion of grassland within each subcategory has changed, as have the associated CO_2 emissions and removals from carbon stock change (table 7.5.2).

Table 7.5.2 New Zealand's land-use change within grassland subcategories from 1990 to 2011, and associated CO_2 emissions from carbon stock change

Grassland land-use subcategory	Area in 1990 (ha)	Area in 2011 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2 only) 1990	Net emissions (Gg CO_2 only) 2011	Change from 1990 (%)
Grassland – high producing	5,854,276	5,792,117	–1.1	–1,502.0	855.2	156.9
Grassland – low producing	7,983,182	7,661,334	–4.0	649.9	2,270.7	249.4
Grassland – with woody biomass	1,257,920	1,118,082	–11.1	–774.4	–13.3	98.3
Total	**15,095,378**	**14,571,532**	**–3.5**	**–1,626.4**	**3,112.6**	**291.4**

Note: 1990 and 2011 areas are as at 31 December. Net emission estimates are for the whole year indicated. Non-CO_2 emissions included in table 7.5.1 are not included here. Columns may not total due to rounding.

From 1990 to 2011, the net carbon stock change attributed to grassland was a decrease of 15,811.7Gg C, equivalent to emissions of 57,976.4 Gg CO_2 from grassland since 1990 (table 7.5.3). The majority of these emissions are due to the loss of living biomass carbon stock associated with forest land conversion to grassland.

Table 7.5.3 New Zealand's carbon stock change by carbon pool within the grassland category from 1990 to 2011

Grassland subcategory	Net carbon stock change 1990–2011 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2011 ($Gg\ CO_2$)
Grassland – high producing	–10,758.4	–1,348.5	2,293.7	–9,813.2	35,981.8
Grassland – low producing	–5,723.6	–1,243.0	–295.0	–7,261.6	26,625.9
Grassland – with woody biomass	1,345.5	774.4	–856.8	1,263.1	–4,631.3
Total	**–15,136.5**	**–1,817.2**	**1,142.0**	**–15,811.7**	**57,976.4**

Note: Columns may not total due to rounding.

Non-CO_2 emissions from grassland in 2011 comprised 1.7 Gg CH_4 (35.9 Gg CO_2-e) and 0.01 Gg N_2O (3.9 Gg CO_2-e) from biomass burning, while emissions from liming of grassland accounted for 600.9 Gg CO_2-e of net grassland emissions in 2011 (17 per cent). Net liming emissions from grassland have increased by 250.1 Gg CO_2-e (71 per cent) compared with the 1990 level of 350.8 Gg CO_2-e.

Grassland remaining grassland

There were 14,414,075 hectares of grassland remaining grassland in 2011, equivalent to 53.5 per cent of New Zealand's total land area. Estimates of land-use change in this category have been split into three subcategories of grassland and the changes between them, as shown in table 7.5.4.

Table 7.5.4 New Zealand's land-use change between grassland subcategories from 1990 to 2011

Land-use changes within grassland remaining grassland	Net area in 1990 (ha)	Net area in 2011 (ha)	Change from 1990 (ha)	(%)
High producing remaining high producing	4,854,939	5,487,053	632,114	13.0
Low producing remaining low producing	7,646,264	7,559,099	–87,165	–1.1
With woody biomass remaining with woody biomass	943,829	1,069,670	125,842	13.3
Subtotal	*13,445,032*	*14,115,822*	*670,790*	*5.0*
High producing to low producing	0	0	0	NA
High producing to with woody biomass	432	9,504	9,072	2,100.0
Low producing to high producing	395,585	66,244	–329,341	–83.3
Low producing to with woody biomass	287,788	33,717	–254,070	–88.3
With woody biomass to high producing	406,316	142,537	–263,778	–64.9
With woody biomass to low producing	43,671	46,250	2,579	5.9
Subtotal	*1,133,792*	*298,253*	*–835,539*	*–73.7*
Total	**14,578,823**	**14,414,075**	**–164,748**	**–69**

Note: The areas of land converted to another land use are cumulative net values for land-use change since 1 January 1990, as at 31 December 2011. Columns may not total due to rounding.

Land undergoing land-use change from one land-use subcategory to another remains in a state of conversion for 28 years (the New Zealand maturity period), until it reaches steady state and transfers to the land remaining land category (or subcategory remaining subcategory). The most significant trend observable within the grassland remaining grassland category is the overall movement of land from a state of conversion between grassland subcategories – in particular, away from low-producing grassland – to a steady state as mature, high-producing grassland.

Land converted to grassland

Between 1990 and 2011, 88,319 hectares of land were converted to grassland, while 625,463 hectares of grassland were converted to other land-use categories, resulting in a net reduction in the total grassland area of 537,144 hectares. As at the end of 2011, however, there was a total of 157,457 hectares of land in a state of conversion to grassland, as areas of land converted prior to 1990 remain in a state of conversion for 28 years (New Zealand's land-use maturity period).

Much of New Zealand's grassland is grazed, with agriculture being the main land use. The majority of New Zealand's agriculture is based on extensive pasture systems, with animals grazed outdoors year-round. Increased profitability of dairy farming relative to other land uses has seen a recent trend for conversion of planted forest to pasture (deforestation).

The majority (99.2 per cent) of land converted to grassland since 1990 is land that was previously forest land. The 85,509 hectares of forest land converted to grassland since 1990 comprises an estimated 32,496 hectares of natural forest deforestation and 53,013 hectares of pre-1990 planted forest deforestation. A further 18,784 hectares of post-1989 forest (land that was not forest land at the start of 1990) has also been deforested and converted to grassland. (For more information on deforestation, see sections 7.2 and 7.3 and chapter 11.). Land-use change of forest land to grassland between 1990 and 2011 resulted in a net carbon stock loss of 451.49 Gg C, equivalent to net emissions of 1,655.48 Gg CO_2.

7.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using a combination of IPCC Tier 1 emission factors and country-specific factors (table 7.5.5). Emissions and removals from soils are estimated using a Tier 1 method (section 7.1.3).

Table 7.5.5 Summary of New Zealand's biomass emission factors for grassland

Grassland subcategory	Carbon pool	Steady state carbon stock (t c ha^{-1})	Annual carbon accumulation (t c ha^{-1})	Years to reach steady state	Source
High producing	*Biomass*	6.75	6.75	1	IPCC default EF
	AGB	1.35	1.35	1	
	BGB	5.4	5.4	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
Low producing	*Biomass*	3.05	3.05	1	IPCC default EF
	AGB	0.8	0.8	1	
	BGB	2.25	2.25	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines

Grassland subcategory	Carbon pool	Steady state carbon stock (t c ha^{-1})	Annual carbon accumulation (t c ha^{-1})	Years to reach steady state	Source
With woody biomass	*Biomass*	29	1.04	28	NZ-specific EF
	AGB	16.0	0.57	28	
	BGB	4.0	0.14	28	
	Dead organic matter	9.0	0.32	28	NZ-specific EF
	Deadwood	3.0	0.11	28	
	Litter	6.0	0.21	28	

Note: AGB = above-ground biomass; BGB = below-ground biomass; EF = emissions factor; NA = not applicable; NE = not estimated. Columns may not total due to rounding.

Grassland remaining grassland

For grassland remaining grassland, the Tier 1 assumption is there is no change in carbon stocks (GPG-LULUCF, section 3.4.1.1.1.1, IPCC, 2003). The rationale is that, where management practices are static, carbon stocks will be in an approximate steady state, that is, carbon accumulation through plant growth is roughly balanced by losses. New Zealand has reported NA (not applicable) in the common reporting format tables where there is no land-use change at the subcategory level because no emissions or removals are assumed to have occurred. However, there is a significant area (298,253 hectares) in a state of conversion from one grassland subcategory to another. The carbon stock changes for these land-use changes are reported under grassland remaining grassland.

Living biomass

To calculate carbon change in living biomass on land converted from one subcategory to another (eg, high-producing grassland converted to low-producing grassland), it is assumed the carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation. In the same year, carbon stocks in living biomass increase by the amount given in table 7.1.4 representing the annual growth in biomass for land converted to another land use. The values given in table 7.1.4 for high-producing and low-producing grassland are Tier 1 defaults. The value given for grassland with woody biomass is a country-specific factor based on Wakelin (2004).

Dead organic matter

New Zealand does not report estimates of dead organic matter for high-producing grassland or low-producing grassland because GPG-LULUCF states there is insufficient information to develop default coefficients for estimating the dead organic matter pool (IPCC, 2003). The notation key NE (not estimated) is used in the common reporting format tables.

For grassland with woody biomass, an estimate of dead organic matter is available from Wakelin (2004), and estimates of changes in dead organic matter stocks with conversion to and from this land use are given in the common reporting format tables.

Soil carbon

Soil carbon stocks in grassland remaining grassland are estimated using a Tier 1 method for both mineral and organic soils (section 7.1.3). The mineral soil carbon values for the three grassland subcategories at equilibrium state are given in table 7.5.6. The IPCC default emission factors for organic soils under grassland are 0.25 and 2.5 t C ha^{-1} per annum for cold temperate and warm temperate regimes, respectively (IPCC 2003).

Table 7.5.6 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock density (t C ha^{-1})
High-producing grassland	117.16
Low-producing grassland	105.55
Grassland with woody biomass	92.59

Liming

The calculation of carbon dioxide emissions from the liming of grassland soil is based on equation 3.4.11 in GPG LULUCF (IPCC, 2003) as outlined in section 7.9.4. The total amount of carbonate applied in the form of agricultural lime (eg, calcic limestone ($CaCO_3$)) and dolomite ($CaMg(CO_3)_2$) is provided by Statistics New Zealand. This is split into lime and dolomite applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2007 Agricultural Census. This analysis indicates that, each year, around 94 per cent of agricultural lime used in New Zealand is applied to grassland. The amount of lime applied to grassland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Land converted to grassland

Living biomass

New Zealand uses a Tier 1 method to calculate emissions for land converted to grassland. The Tier 1 method multiplies the area of land converted to grassland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation at conversion. The amount of biomass cleared when land at steady state is converted is shown in table 7.1.3. The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

Dead organic matter

For land conversion to high- and low-producing grassland, New Zealand reports only losses in dead organic matter. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to grassland. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate changes in carbon stock in dead organic matter pools after land is converted to high- or low-producing grassland (IPCC, 2003). Therefore, where there are no dead organic matter losses associated with the previous land use the notation key NE (not estimated) is used in the common reporting format tables.

For land converted to grassland with woody biomass, there is a country-specific value for carbon in dead organic matter. Where land is converted to grassland with woody biomass, dead organic matter accumulates to 9 t C ha^{-1} over 28 years (the maturity period New Zealand has chosen for land to reach steady state) (Wakelin, 2004).

Soil organic carbon

Soil carbon stocks in land converted to grassland are estimated using a Tier 1 method for both mineral and organic soils (section 7.1.3). In the absence of country- and land-use-specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and the new land use.

The IPCC default emission factors for organic soils under grassland are also applied to land converted to grassland (IPCC 2003).

Liming

The activity data on lime and dolomite consumption do not distinguish between grassland remaining grassland and land converted to grassland. The activity data are provided for cropland and grassland by Statistics New Zealand. Lime and dolomite are attributed to land converted to grassland by the proportion that this subcategory makes up of the total grassland area. Calculations and methodology are described further in section 7.9.4 ‘Liming’ and in ‘Liming’ above in ‘Grassland remaining grassland’.

7.5.3 Uncertainties and time-series consistency

While the uncertainty introduced into the LULUCF net emissions by activity data is low, uncertainty in the IPCC default variables (table 3.4.2, IPCC, 2003) dominate the overall uncertainty in the estimate for grassland provided by New Zealand (table 7.5.7).

The uncertainty in mapping grassland is ± 6 per cent. Further details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in high-producing and low-producing grassland. The uncertainty in these figures is given as ± 75 per cent. New Zealand uses a New Zealand-specific value for biomass accumulation in grassland with woody biomass. No uncertainty is available for this so the uncertainty value used is the same as for the IPCC default.

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand. This is estimated as ± 6 per cent for limestone and ± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

Of the grassland subcategories, the largest per cent uncertainty is introduced into the net emissions by high-producing grassland.

Table 7.5.7 Uncertainty in New Zealand's 2011 estimates for the grassland category (including land in transition)

Variable	Uncertainty at a 95% confidence interval		
Land-use subcategory	High producing (%)	Low producing (%)	With woody biomass (%)
Activity data			
Uncertainty in land area	6.0	6.0	6.0
Emission factors			
Uncertainty in biomass carbon stocks	75.0	75.0	75.0
Uncertainty in soil carbon stocks	95.0	95.0	95.0
Uncertainty in liming emissions	95.2	95.2	95.2
Uncertainty introduced into net emissions for LULUCF	**7.3**	**2.4**	**0.0**

7.5.4 Category-specific QA/QC and verification

Carbon dioxide emissions from the 'grassland remaining grassland' and 'land converted to grassland' categories are key categories (level and trend). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the grassland category is shown in table 7.5.8 below.

Table 7.5.8 Recalculations of New Zealand's net emissions from the grassland category in 1990 and 2010

	Net emissions		Change from the 2012 submission	
Grassland recalculations	**2012 submission (Gg CO_2-e)**	**2013 submission (Gg CO_2-e)**	**(Gg CO_2-e)**	**(%)**
1990 estimate	–1,075.4	–1,233.1	–157.8	14.7
2010 estimate	3,120.8	3,091.2	–29.6	–0.9

Further explanation of these recalculations is provided below.

7.5.6 Category-specific planned improvements

Additional work to improve the mapping of the grassland with woody biomass land-use category will be carried out during the next year.

7.6 Wetlands (CRF 5D)

7.6.1 Description

New Zealand has 425,000 kilometres of rivers and streams, and almost 4,000 lakes that are larger than 1 hectare. Damming, diverting and extracting water for power generation, irrigation and human consumption has modified the nature of these waterways and can deplete flows and reduce groundwater levels. Demand for accessible land has also led to the modification of a large proportion of New Zealand's vegetated wetland areas in order to provide pastoral land cover. Just over 10 per cent of wetlands present prior to European settlement remain across New Zealand (McGlone, 2009).

Section 3.5 of GPG-LULUCF defines wetlands as "land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories". This category can be further subdivided into managed and unmanaged wetlands according to national definitions. The definition includes reservoirs and flooded land as managed subdivisions, and natural rivers and lakes as unmanaged subdivisions. Flooded lands are defined in GPG-LULUCF as "water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc, and where substantial changes in water area due to water regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands". As the majority of New Zealand's hydro-electric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river, they are not defined as flooded lands.[40] As no other areas of New Zealand's wetlands qualify as 'managed' under the GPG-LULUCF wetlands definition, all of New Zealand's wetlands have been categorised as 'unmanaged', even though, more broadly, it can be said that all land in New Zealand is under some form of management and management plan (see section 11.4.1).

New Zealand's wetlands are mapped into two subcategories: 'wetlands – open water', which includes lakes and rivers, and 'wetlands – vegetated non-forest', which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing land cover database (LCDB) data (see section 7.2, for more information). Areas of open water have been mapped using hydrological boundaries defined by Land Information New Zealand (LINZ).

There were 530,305 hectares of wetlands – open water in 2011 and 132,625 hectares of wetlands – vegetated non-forest. These two subcategories combined make up 2.5 per cent of the total New Zealand land area.

In 2011, there were 20.9 Gg CO_2-e emissions from wetlands, compared with emissions of 167.3 Gg CO_2-e from wetlands in 1990. This declining trend is due to the emissions from mineral soils decreasing as the area of land converted to wetlands transitions to wetlands remaining wetlands.

Conversion to wetlands was a key category in 2011 in the trend assessment. Conversion to wetlands shows up as a key category because the trend analysis compares 1990 emissions of 167.3 with the 2011 emissions of 20.9 and a small absolute change is significant in relative terms.

As at 2011, there were 4,235 hectares in a state of conversion to wetlands (table 7.6.1). These lands have been converted to wetlands during the previous 28 years but have not yet reached steady state and entered the wetlands remaining wetlands category.

[40] An exception to this occurred in the creation of the Clyde Dam. The Clutha River in the South Island, was dammed creating Lake Dunstan. The area flooded was mostly low-producing grassland.

Table 7.6.1 New Zealand's land-use change for the wetlands category in 1990 and 2011, and associated CO_2-equivalent emissions

Wetlands land-use category	Net area (ha) 1990	Net area (ha) 2011	Change from 1990 (%)	Net emissions (Gg CO_2-e) 1990	Net emissions (Gg CO_2-e) 2011	Change from 1990 (%)
Wetlands remaining wetlands	648,096	658,695	1.6	NE	NE	NA
Land in conversion to wetlands	13,925	4,235	–69.6	167.3	20.9	–87.5
Total	**662,020**	**662,930**	**0.14**	**167.3**	**20.9**	**–87.5**

Note: NA = not applicable. 1990 and 2011 area values are as at 31 December. Net emission values are for the whole year indicated. Net emissions from the wetlands remaining wetlands land-use category are not estimated (NE); see section 7.6.2 for details. Land in conversion to wetlands consists of land converted to hydro lakes prior to 1990. Columns may not total due to rounding.

From 1990 to 2011, the net carbon stock change for wetlands decreased by 524.5 Gg C, equivalent to emissions of 1,923.3 Gg CO_2 in total since 1990 (table 7.6.2). These carbon stock losses are from the loss of living biomass carbon stock, associated with grassland conversion to wetlands, in addition to historical (pre-1990) conversion of forest land to hydro-electric dams, the lagged effect of which continues to affect soil organic carbon in the inventory period.

Table 7.6.2 New Zealand's carbon stock change by carbon pool within the wetlands category from 1990 to 2011

Wetlands subcategory	Net carbon stock change 1990–2011 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2011 (Gg CO_2)
Wetlands – vegetated non-forest	0.0	0.0	0.0	0.0	0.0
Wetlands – open water	–3.5	0.0	–521.0	–524.5	1,923.3
Total	**–3.5**	**0.0**	**–521.0**	**–524.5**	**1,923.3**

7.6.2 Methodological issues

Wetlands remaining wetlands

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in wetlands remaining wetlands is provided in appendix 3A.3 of GPG-LULUCF. The appendix covers emissions from flooded land and extraction from peat land. Recultivation of peat land is included under the agriculture sector.

Due to the current lack of data on biomass carbon stock changes in wetlands remaining wetlands, New Zealand has not prepared estimates for change in living biomass or dead organic matter for this category, as allowed for in the IPCC GPG-LULUCF, chapter 1.7. New Zealand reports the notation key NE (not estimated) in the common reporting format table for this category.

Soil carbon

Soil carbon stocks in wetlands remaining wetlands are estimated using a Tier 1 method for mineral soils (section 7.1.3). The mineral soil steady state carbon stock for wetlands – vegetated non-forest is estimated to be 92.59 t C ha^{-1}, with an uncertainty of 95.0 per cent. For wetlands – open water, the soil carbon stock at equilibrium is estimated to be zero.

For mineral soils, as with living biomass and dead organic matter, there are no emissions for wetlands in steady state so the notation key NE (not estimated) is used.

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with peat extraction, which is not a significant activity in New Zealand. It is therefore assumed that there are no carbon emissions from organic soils in wetlands remaining wetlands.

Land converted to wetlands

Between 1990 and 2011, 1,152 hectares of land were converted to wetlands, while 199 hectares of wetlands were converted to grassland, resulting in a net increase in total wetland area of 953 hectares.

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions from land converted to wetlands (GPG-LULUCF, equation 3.5.6, IPCC, 2003). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place. For wetlands – open water, the carbon stock in living biomass and dead organic matter following conversions are equal to zero. For wetlands – vegetated non-forest, the carbon stock in living biomass and dead organic matter are not estimated as there is no guidance in GPG-LULUCF for estimating carbon stock following land-use change to wetlands, and all emissions from land-use change to wetlands from removal of the previous vegetation are instantly emitted. The notation keys NO (not occurring) and NE (not estimated) are reported in the CRF tables.

Soil carbon

Soil carbon stocks in land converted to wetlands are estimated using a Tier 1 method, as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and wetlands for any given period.

Non-CO_2 emissions

Non-CO_2 emissions from drainage of soils and wetlands

New Zealand has not prepared estimates for this category as allowed for in IPCC GPG-LULUCF, chapter 1.7. The drainage of soils and wetlands is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE (not estimated) is used in the common reporting format tables.

7.6.3 Uncertainties and time-series consistency

The uncertainty in mapping wetlands is ± 6.0 per cent. Further details are given in section 7.2.5.

New Zealand uses the IPCC default value for biomass accumulation in wetlands, which is ± 75 per cent.

The uncertainties in soil carbon stocks for wetlands – open water is 0.0 per cent (as there is no soil carbon stock change for this land use) and 95.0 per cent for wetlands – vegetated non-forest (IPCC 2003).

Table 7.6.3 Uncertainty in New Zealand's 2011 estimates for the wetlands category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	7.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**0**

Note: NO = not occurring. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF (IPCC, 2003).

7.6.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data and emissions factor for carbon change underwent Tier 1 quality checks.

7.6.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the wetlands land-use category is shown in table 7.6.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process, as described in section 7.2.

The carbon stock in soils at equilibrium state has also been recalculated since the last submission. Details of this process are described in section 7.1.3.

Table 7.6.4 Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2010

Wetlands recalculations	Net emissions		Change from the 2012 submission	
	2012 submission (Gg CO_2-e)	2013 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	165.7	167.3	1.6	1.0
2010	0.0	20.9	20.9	∞

7.6.6 Category-specific planned improvements

For the 2013 submission, New Zealand has improved mapping of wetlands by updating both the 1990 and 2008 land-use maps to show land-use changes associated with a major hydro power scheme development in the South Island. This accounted for 943 hectares of new land-use change from grassland to wetlands between 1990 and 2008.

Additional improvements to the estimates for the wetlands category will be realised after the 2012 land-use mapping is completed. This will be reported in the 2014 submission.

7.7 Settlements (CRF 5E)

7.7.1 Description

The settlements land-use category, as described in GPG-LULUCF chapter 3.6, includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories". Settlements include trees grown along streets, in public and private gardens, and in parks associated with urban areas.

There were 207,292 hectares of settlements in 2011 in New Zealand, an increase of 4,002 hectares since 1990. This category comprised 0.8 per cent of New Zealand's total land area in 2011. The largest area of change to settlements between 1990 and 2011 was from high-producing grassland, with 2,373 hectares of high-producing grassland converted to settlements between 1990 and 2011.

In 2011, the net emissions from settlements were 34.7 Gg CO_2-e. These emissions are entirely from the subcategory of land converted to settlements.

Settlements were not a key category in 2011.

Table 7.7.1 New Zealand's land-use change within the settlements category from 1990 to 2011, and associated CO_2-equivalent emissions

Settlements land-use category	Net area (ha)		Change from	Net emissions (Gg CO_2-e)		Change from
	1990	2011	1990 (%)	1990	2011	1990 (%)
Settlements remaining settlements	180,850	198,752	9.9	NE	NE	NA
Land converted to settlements	22,606	8,541	–62.2	97.6	34.7	–64.4
Total	**203,456**	**207,292**	**1.9**	**97.6**	**34.7**	**–64.4**

Note: NA = not applicable. 1990 and 2011 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for the settlements remaining settlements land-use category are not estimated (NE) as New Zealand has insufficient activity data for this subcategory; see section 7.7.2 for details. Columns may not total due to rounding.

In 2011, there were 198,752 hectares of settlements remaining settlements (table 7.7.1). Carbon in living biomass and dead organic matter is not estimated for this land-use category. The carbon stock in soil for this land use is assumed to be in steady state. There were 8,541 hectares of land converted to settlements between 1990 and 2011.

From 1990 to 2011, the net carbon stock change for settlements decreased by 456.1 Gg C, equivalent to emissions of 1,672.4 Gg CO_2 in total since 1990 (table 7.7.2). These carbon stock losses are predominantly due to the loss of soil carbon on land conversion to settlements.

Table 7.7.2 New Zealand's carbon stock change by carbon pool within the settlements category from 1990 to 2011

Land-use category	Net carbon stock change 1990–2011 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2011 (Gg CO_2)
Settlements	–118.1	–10.2	–327.8	–456.1	1,672.4

7.7.2 Methodological issues

Greenhouse gas emissions within the settlements land-use category derive principally from carbon stock changes within the living biomass pool. The IPCC notes that "while dead organic matter and soil carbon pools may also be sources or sinks of CO_2 in settlements, and CH_4 and N_2O emissions may result from urban land management practices, little is known about the role and magnitude of these pools in overall greenhouse gas fluxes" (GPG-LULUCF, section 3.6, IPCC, 2003). Therefore, the focus of New Zealand's methodological approach to estimating greenhouse gas emissions for the settlements land-use category is on changes in carbon stock change in living biomass (table 7.7.3).

Table 7.7.3 Summary of New Zealand emission factors for the settlements land-use category

Settlements greenhouse gas source category	Steady state carbon stock (t C ha^{-1})	Years to reach steady state	Carbon stock change on conversion to settlements (t C ha^{-1})	Reference
Biomass – all pools	NE	28	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default (section 3.6.2, IPCC, 2003)
Soils – mineral	64.81	20	Linear change over the conversion period between new and previous stock values	IPCC Tier 1 default (table 7.1.7)
Biomass burning	NE	NA	NE	

Note: NA = not applicable; NE = not estimated.

Settlements remaining settlements

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in settlements remaining settlements is provided in appendix 3A.4 of GPG-LULUCF (IPCC, 2003). The methods and available default data for this land use are preliminary and based on an estimation of changes in carbon stocks per tree crown cover area or carbon stocks per number of trees as a removal factor (IPCC, 2003). New Zealand does not have this level of activity data and is therefore unable to estimate emissions for this subcategory. The reporting of settlements remaining settlements is optional (GPG-LULUCF, chapter 1.7, IPCC, 2003).

Soil carbon

Soil carbon stocks in settlements remaining settlements are estimated using a Tier 1 method (section 7.1.3). The steady state mineral soil carbon stock in settlements is estimated to be 64.81 t C ha^{-1} (table 7.1.7). In the absence of default stock change factors for this land use, the stock change factors for severely depleted unimproved grassland is used, which implies major long-term loss of productivity and vegetation cover.

Land converted to settlements

Living biomass and dead organic matter

New Zealand has applied a Tier 1 method for estimating carbon stock change with land conversion to settlements (GPG-LULUCF, equation 3.6.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The default assumptions for a Tier 1 estimate are that all living biomass and dead organic matter present before conversion are lost in the same year as the conversion takes place and that carbon stocks in living biomass and dead organic matter following conversion are equal to zero (GPG-LULUCF, section 3.6.2, IPCC, 2003).

Soil carbon

Soil carbon stocks in land converted to settlements are estimated using a Tier 1 method (section 7.1.3). In the absence of either country- or land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and settlements for any given period.

7.7.3 Uncertainties and time-series consistency

The uncertainty in mapping settlements is ± 6 per cent. Further details on this are given in section 7.2.5.

New Zealand uses the IPCC default values for biomass accumulation. The uncertainty in these figures is ± 75 per cent.

For soils, New Zealand applies the default values and default uncertainty of 95 per cent (based on GPG-LULUCF, table 3.2.4, IPCC, 2003).

Table 7.7.4 Uncertainty in New Zealand's 2011 estimates for the settlements category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	7.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**0.1**

Note: NO = not occurring. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF (IPCC, 2003).

7.7.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data for these emissions underwent Tier 1 quality checks.

7.7.5 Category-specific recalculations

Recalculations were carried out for this category as a result of changes in activity data from the improved mapping process as described in section 7.2

Table 7.7.5 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2010

Settlements recalculations	Net emissions (Gg CO_2-e) 2012 submission	2013 submission	Change from the 2012 submission (Gg CO_2-e)	(%)
1990 estimates	97.7	97.6	–0.1	–0.1
2010 estimates	34.9	34.8	–0.2	–0.5

7.7.6 Category-specific planned improvements

Activity data on the land area of settlements will be updated as part of the 2012 land-use mapping process. New data from the Land Cover Database 3 (LCDB3) will be incorporated in the 1990, 2008 and 2012 land-use maps to reflect more accurately changes in the extent of settlements over these periods. This improvement will be included in the 2014 submission.

No other changes to the settlements emission factors or methodology are planned.

7.8 Other land (CRF 5F)

7.8.1 Description

Other land is defined in GPG-LULUCF section 3.7 as including bare soil, rock, ice and all unmanaged land areas that do not fall into any of the other five land-use categories (IPCC, 2003). It consists mostly of steep, rocky terrain at high elevation, often covered in snow or ice. This category is 3.3 per cent of New Zealand's total land area.

In 2011, the net emissions from other land were 1.3 Gg CO_2-e. These emissions occur in the land converted to other land category and are 3.2 Gg CO_2-e (70.9 per cent) lower than the 1990 level of 4.5 Gg CO_2-e. This is primarily due to the area of land estimated as having been converted to other land steadily declining since 1990.

An analysis of change in area shows that most of the land converted to other land between 1990 and 2011 (679 hectares) was from the forest land category (table 7.2.4). Between 1990 and 2011, 182 hectares of natural forest and 259 hectares of pre-1990 planted forest were converted to other land. This is likely to be mainly due to conversion of forest land to roads, mines and quarries.

Other land was not a key category in 2011.

Table 7.8.1 New Zealand's land-use change within the other land land-use category from 1990 to 2011

Other land land-use category	Net area as at 1990 (ha)	Net area as at 2011 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$-e) 1990	Net emissions ($Gg\ CO_2$-e) 2011	Change from 1990 (%)
Other land remaining other land	897,753	891,515	–0.7	NE	NE	NA
Land in conversion to other land	17	714	3,978.6	4.5	1.3	–70.9
Total	**897,771**	**892,228**	**–0.6**	**4.5**	**1.3**	**–70.9**

Note: NA = not applicable; NE = not estimated. 1990 and 2011 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for other land remaining other land are not applicable (NA) as change in carbon stocks and non-CO_2 emissions are not assessed for this category; see section 7.8.2 for details. Columns may not total due to rounding.

7.8.2 Methodological issues

Other land remaining other land

The area of other land has been estimated based on LCDB2. The method used is described more fully in section 7.2.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for other land is provided in table 7.8.2.

Table 7.8.2 Summary of New Zealand emission factors for the other land land-use category

Other land greenhouse gas source category	Steady state carbon stock ($t\ C\ ha^{-1}$)	Years to reach steady state	Carbon stock change on conversion to other land ($t\ C\ ha^{-1}$)	Reference
Biomass	NE	NA	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default assumption (equation 3.7.1, GPG-LULUCF, IPCC, 2003)
Soils (mineral)	92.59	20	Linear change over the conversion period between new and previous stock values	Section 7.1.3
Biomass burning	NE	NA	NE	

Note: NA = not applicable; NE = not estimated.

Living biomass and dead organic matter

All of New Zealand's land area in the other land category is classified as 'managed'. New Zealand considers all land to be managed, as all land is under some form of management plan, regardless of the intensity and/or type of land-management practices. No guidance is provided in GPG-LULUCF for estimating carbon stocks in living biomass or dead organic matter for other land that is managed, and, as a result, the change in carbon stocks and non-CO_2 emissions is not assessed for this category.

Soil carbon

Soil carbon stocks in other land remaining other land are estimated using a Tier 1 method for mineral soils (section 7.1). The steady state mineral soil carbon stock in other land is estimated to be 92.59 t C ha^{-1}, with an associated uncertainty of 95 per cent. In the absence of default stock change factors for this land use, it is assumed that other land represents native conditions, and the reference soil organic stock value is used.

Land converted to other land

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions for land converted to other land (GPG-LULUCF, equation 3.7.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place and that carbon stock in living biomass and dead organic matter following conversion is equal to zero. There is no Tier 1 method for calculating carbon accumulation in living biomass or dead organic matter for land converted to other land.

Soil carbon

Soil carbon stocks in land converted to other land prior to conversion are estimated using a Tier 1 method (section 7.1.3). The IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and other land for any given period.

7.8.3 Uncertainties and time-series consistency

Uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. Uncertainty in other land introduces 0.0004 per cent uncertainty into the LULUCF net carbon emissions. This is low because the area in other land and the emissions from other land are low.

Table 7.8.3 Uncertainty in New Zealand's 2011 estimates for the other land land-use category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	7.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	95.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**0.0**

Note: NO = not occurring. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF (IPCC, 2003).

7.8.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.8.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the other land category is shown in table 7.8.4. Recalculations were carried out for this category as a result of new activity data and error corrections to the mapping data, as explained in section 7.1.5.

Table 7.8.4 Recalculations for New Zealand's net emissions from the other land land-use category in 1990 and 2010

	Net emissions		Change from the 2012 submission	
	2012 submission (Gg CO_2-e)	2013 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	6.5	4.5	–1.9	–30.0
2010	17.7	18.2	0.5	3.0

Activity data

New Zealand has reviewed its mapping of forest land converted to other land that is due to erosion. Land within the forest land category that was eroded was removed from the other land category because erosion results in a change in land cover (but is not a land-use change), and the emissions from the change in land cover are estimated on harvest or when the land undergoes land-use change.

7.8.6 Category-specific planned improvements

There are no category-specific planned improvements for other land.

7.9 Non-CO_2 emissions (CRF 5(I–V))

7.9.1 Direct N_2O emissions from nitrogen fertilisation of forest land and other (CRF 5.I)

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the subcategory 'direct soils emissions' (CRF 4D). The notation key IE (included elsewhere) is reported in the CRF tables for the LULUCF sector.

7.9.2 Non-CO_2 emissions from drainage of soils and wetlands (CRF 5.II)

New Zealand has not prepared estimates for this voluntary reporting category as allowed for in the IPCC good practice guidance for LULUCF (chapter 1.7, IPCC, 2003). The notation key NE (not estimated) is reported in the CRF tables for the LULUCF sector.

7.9.3 N_2O emissions from disturbance associated with land-use conversion to cropland (CRF 5.III)

Description

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion to cropland. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (GPG-LULUCF, section 3.3.2.3, IPCC, 2003).

Nitrous oxide emissions from disturbance associated with land-use conversion to croplands are minor in New Zealand, estimated at 0.03 Gg N_2O in 2011, and 0.95 Gg N_2O (295.6 Gg CO_2-e) in total since 1990 (table 7.9.1). This reflects the relatively small area of land converted to croplands since 1990 and the moderately high carbon stocks of New Zealand's cropland soils (section 7.1.3).

Table 7.9.1 N_2O emissions from disturbance associated with land-use conversion to cropland

Area and associated emissions	1990	2011	Change since 1990 (%)
Area of land in conversion to cropland (ha)	37,079	34,214	–7.7
Emissions from disturbance (Gg N_2O)	0.06	0.03	52.9

Methodological issues

To estimate N_2O emissions from disturbance associated with land-use conversion to cropland, New Zealand uses the method outlined in GPG-LULUCF, equations 3.3.14 and 3.3.15 (IPCC, 2003). The inputs to these equations are:

- change in carbon stocks in mineral soils, and estimated carbon losses from organic soils, on land converted to cropland: these values are calculated from the land converted to cropland soil carbon calculations
- EF1: the emission factor for calculating emissions of N_2O from nitrogen in the soil. New Zealand uses a country-specific value of 0.01 kg N_2O – N/kg N (Kelliher and de Klein, 2006)
- C:N ratio: the IPCC default ratio of carbon to nitrogen in soil organic matter (1:15) is used (IPCC, 2003)
- where an area of land converted to cropland has a lower original mineral soil organic carbon stock than the subcategory of cropland it has been converted to, no N_2O emissions have been estimated as occurring because there is no associated loss of soil organic carbon. For instance, forest land converted to cropland is accordingly estimated not to result in net N_2O emissions because this land-use conversion is associated with a net gain in soil organic carbon in New Zealand (refer to table 7.1.7). In these situations, the notation key NO (not occurring) is reported in the CRF tables.

Uncertainties and time-series consistency

New Zealand uses a country-specific value for calculating N_2O emissions from nitrogen in soil. This value has a high level of uncertainty, which is estimated at 40.0 per cent.

New Zealand uses the IPCC default values for carbon accumulation in soils. The uncertainty in this figure is given as 97 per cent.

Table 7.9.2 Uncertainty in New Zealand's 2011 estimates for N_2O emissions from disturbance associated with land-use conversion to cropland

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	6.0
Emission factors	
Uncertainty in N_2O calculation	40.0
Uncertainty in carbon calculation	97.0
Uncertainty introduced into net emissions for LULUCF	**0.0**

Source-specific planned improvements

No additional improvements are currently planned to New Zealand's estimation of emissions from disturbance associated with land-use conversion to cropland.

7.9.4 Liming (CRF 5(IV))

Description

In New Zealand, agricultural lime is mainly applied to acidic grassland and cropland soils to maintain or increase the productive capability of soils and pastures.

Emissions from the application of lime in 2011 were 640.33 Gg CO_2, up 2.2 per cent from emissions of 626.31 Gg CO_2 in 2010 and up 71.3 per cent from 373.8 Gg CO_2 in 1990.

Methodological issues

Information on agricultural lime (limestone and dolomite) application is collected by the national statistics agency, Statistics New Zealand, as part of its annual Agricultural Production Survey. The Agricultural Production Survey has gaps in its time series. No survey was carried out in 1991, or between 1997 and 2001. Linear interpolation has been used to represent the data for these years. Lime quantities applied vary from year to year depending on a number of factors, including farming profitability.

Analysis of the results of the Agricultural Production Survey indicates that, each year, around 94 per cent of agricultural lime used in New Zealand is applied to grassland, with the remaining 6 per cent applied to cropland. The activity data on lime consumption does not distinguish between grassland remaining grassland and land converted to grassland. Lime and dolomite are attributed to land converted to grassland by the proportion that this subcategory makes up of the total grassland area.

Emissions associated with liming are estimated using a Tier 1 method (GPG-LULUCF equation 3.4.11, IPCC, 2003), and the IPCC default emission factor for carbon conversion of 0.12.

Uncertainties and time-series consistency

The uncertainty in LULUCF net emissions introduced by liming has been reported under the relevant land use, namely cropland and grassland.

Source-specific QA/QC and verification

In the preparation of this inventory, the data for liming underwent Tier 1 quality checks. Statistics New Zealand, which collects the activity data for liming, also carries out a series of quality-assurance and quality-control procedures as part of the Agricultural Production Survey carried out each year.

Source-specific recalculations

Emissions from liming in 2010 have been updated as a result of the activity data from the Agricultural Production Survey being finalised. Provisional data is provided for the latest reporting year.

Source-specific planned improvements

New Zealand will continue to update activity data on liming as it becomes available from Statistics New Zealand. No other future improvements are currently planned.

7.9.5 Biomass burning (CRF 5.V)

Description

Biomass burning may occur as a result of wildfires or controlled burning, and results in emissions of CO_2, CH_4, N_2O, CO and NO_x. The general approach for estimating greenhouse gas emissions from biomass burning is the same regardless of the specific land-use type.

Biomass burning is not a significant source of emissions for New Zealand, as the practice of controlled burning is limited and wildfires are not common due to New Zealand's temperate climate and vegetation.

Emissions of CO_2 are reported as either IE (included elsewhere) (when associated with a land-use change or where subsequent regrowth is not captured in the inventory) or NE (not estimated) (where no data exists) in the CRF tables. The reason for this is explained below under methodological issues. Non-CO_2 emissions from biomass burning in 2011 were 2.45 Gg CH_4 (51.5 Gg CO_2-e) and 0.02 Gg N_2O (5.5 Gg CO_2-e).

Table 7.9.3 Non-CO_2 emissions from biomass burning

Emissions	1990	2011	Change since 1990 (%)
CH_4 emissions (Gg CH_4)	2.74	2.45	10.5
N_2O emissions (Gg N_2O)	0.02	0.02	11.4

Methodological issues

New Zealand reports on emissions from wildfire in forest land and grassland in the inventory. Controlled burning associated with the conversion of grassland to forest land is also included. For the first time in 2011, estimates are provided for burning associated with the clearing of vegetation (natural forest) prior to the establishment of exotic planted forest and the burning of post-harvest slash prior to restocking. Emissions from the burning of crop stubble and controlled burning of savanna are reported in the agriculture sector (chapter 6).

Tier 2 methodologies are employed to estimate emissions from biomass burning in New Zealand. Country-specific emission factors are employed along with IPCC equations to derive emissions (sections 3.4.2.1.1.2 and 3A.1.12, IPCC 2003). Activity data (area of land-use change) for the grassland with woody biomass converted to forest category is based on annual land-use changes as estimated in section 7.2 and an estimate of area burnt from a survey of forest owners. Wildfire activity data is sourced from the National Rural Fire Authority (NRFA) database, which has data from 1992 onwards. The average area burnt between 1991/92 and 2010/11 from this database is used as the estimate of area burnt where data is unavailable. The April year data is then converted to calendar years for use in the inventory (Wakelin, 2012a).

There has not been a significant change in wildfire activity since 1990. Natural disturbance (lightning) induced wildfires are estimated to account for only 0.1 per cent of burning in grassland and forest land in New Zealand (Wakelin, 2006; Doherty et al, 2008). Non-CO_2 emissions from these events are reported in the inventory because the National Rural Fire Authority does not distinguish between anthropogenic and natural wildfire events in the data. Given the small incidence of natural disturbance induced wildfires in New Zealand, this is not regarded as a significant source of error.

The emission of CO_2 from the combustion of biomass due to wildfires in forest land is not estimated at the time of burning. In planted forest, burnt stands are either harvested or left to grow on at reduced stocking. Carbon dioxide emissions are reported when the stand is harvested or deforested (with no reduction in stock when compared with an un-burnt stand). Given the few incidences of wildfire in New Zealand's planted forest lands, this is not regarded as a significant source of error. Carbon dioxide lost in natural forest wildfires can be ignored since these fires do not result in land-use change and regrowth is not reported in the inventory (IPCC, 2003).

A single weighted biomass density is used to estimate non-CO_2 emissions from wildfire in the forest land remaining forest land subcategory. Wildfire activity data is attributed to each subcategory by proportion of forest type estimated to be burned over the time series. This is split by 87.5 per cent to planted forest with the remaining to natural forest (Wakelin et al, 2009). The planted forest activity data is further split into pre-1990 and post-1989 forest by the proportion of area each subcategory makes up of the total planted forest area. In planted forest, it is assumed that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age in each subcategory (Wakelin, 2011). The individual forest subcategory estimates that make up the single weighted figure are derived from the national plot network described in section 7.3.

A survey of planted forest based controlled burning activities was carried out in 2011 to estimate controlled burning activity on forest land in New Zealand. Estimates were provided for burning associated with the clearing of vegetation (ie, natural forest and grassland with woody biomass) prior to the establishment of exotic planted forest. The survey indicated that 5 per cent of conversions to planted forest involved burning to clear vegetation. This was allocated to pre-1990 planted forest (conversions from natural forest) and post-1989 forest (conversions from grassland with woody biomass) on a pro rata basis (Wakelin, 2012b).

Activity data is combined with an emission factor derived from the natural forest national plot network (see table 7.1.3) to estimate non-CO2 emissions from burning associated with the clearing of vegetation prior to the establishment of exotic planted forest. Below-ground biomass is assumed not to burn. The IPCC default combustion proportion for the burning of non-eucalypt temperate forest in land clearing fires (0.51) is then applied to estimate emissions from this activity (Wakelin, 2012b).

The survey also provided data on the burning of post-harvest slash prior to restocking. This activity was found to occur mainly as a training exercise for wildfire control or for the clearing of slash heaps on skid sites. The data indicated that 0.8 per cent of restocked area was burnt each year in recent years. This estimate was combined with two earlier estimates of controlled burning in planted forest (Robertson, 1998 and Forest Industry Training, 2000) to provide activity data throughout the time series. It is assumed that 1.6 per cent of restocked area is burnt from 1990 to 1997. From 1997, the area burnt declines linearly to 0.8 per cent, which is used from 2005 onwards (Wakelin, 2012b).

Activity data is combined with an emission factor derived from the pre-1990 planted forest carbon-yield table to estimate emissions from the burning of post-harvest slash (harvest residue) on forest land. The harvest residue is calculated by subtracting the amount of above-ground biomass that is taken off site as logs (70 per cent) from the total above-ground biomass predicted at age 28 (the average harvest age in New Zealand). Below-ground biomass is assumed not to burn. The IPCC default combustion proportion for the burning of harvest residue in non-eucalypt temperate forest (0.62) is applied to estimate emissions from this activity (Wakelin, 2012b).

Carbon dioxide emissions from controlled burning in pre-1990 planted forest in the inventory are captured at the time of conversion or harvest.

In New Zealand, it is assumed that 20 per cent of grassland with woody biomass converted to forest land is cleared using controlled burning. This burning proportion was recently updated by a survey of forest owners and managers carried out to estimate controlled burning activity on forest land in New Zealand (Wakelin, 2012b).

Different biomass-density values for wildfire and controlled burning on grassland with woody biomass are used in the inventory. The differences are due to the vegetation that is typically converted to forest, which is generally of a lesser stature when compared with other shrubland (Wakelin, 2008). Controlled burning of grassland with woody biomass for the establishment or re-establishment of pasture has not been included in the inventory. Conversions of planted forest land to grassland (pasture) were at high levels between 2004 and 2008. A survey of planted forest-based controlled burning activities was carried out in 2011 but failed to provide data on burning associated with this activity (Wakelin, 2012b).

Uncertainties and time-series consistency

Uncertainties arise from relatively coarse activity data for wildfires and controlled burning activities in New Zealand. The biomass burning statistics have gaps in the time series where data collection did not occur or survey methodologies changed. Assumptions are made for some emission factors and burning fractions where insufficient data exists.

Table 7.9.4 Uncertainty in New Zealand's 2011 estimates for CH_4 and N_2O emissions from biomass burning

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in activity data	30.0
Emission factors	
Uncertainty in emission factors	42.4
Uncertainty introduced into net emissions for LULUCF	**0.0**

Source-specific QA/QC and verification

Quality-control and quality-assurance measures are applied to the biomass burning activity data and emission factors. The biomass burning dataset is verified whenever new data is supplied. In 2006 and 2009, the biomass burning parameters (emission factors, burning and emissions factors), assumptions and dataset were reviewed and updated (Wakelin et al, 2009).

Source-specific recalculations

Estimates are provided for burning associated with the clearing of natural forest prior to the establishment of exotic planted forest and the burning of post-harvest residue prior to restocking, for the first time in 2011. The effect of the changes to the inventory is small due to the relatively minor incidence of controlled burning occurring in New Zealand.

Source-specific planned improvements

The LUCAS plot network is currently being analysed to develop a more appropriate emission factor for the grassland with woody biomass category.

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Chapter 8: Waste

8.1 Sector overview

In 2011, the waste sector contributed 1,985.4 Gg carbon dioxide equivalent (CO_2-e) (2.7 per cent) of New Zealand's total greenhouse gas emissions. The largest source of waste sector emissions in 2011 was the solid waste disposal on land category, which contributed 1,331.1 Gg CO_2-e (or 67.0 per cent of waste sector emissions). The wastewater handling category contributed 652.1 Gg CO_2-e (32.8 per cent) of waste sector emissions and the waste incineration category contributed the remaining 2.2 Gg CO_2-e (0.1 per cent).

Emissions from the waste sector are predominantly methane emissions (90.8 per cent), followed by nitrous oxide emissions (9.2 per cent) and then carbon dioxide emissions (0.05 per cent).

Changes to emissions between 1990 and 2011

Emissions from the waste sector were 73.7 Gg CO_2-e (3.6 per cent) below the 1990 baseline value of 2,059.1 Gg CO_2-e (figure 8.1.1). This reduction, despite an increase in New Zealand's population and economic activity, occurred largely in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices. Emissions from municipal solid waste disposal on land decreased by 183.3 Gg CO_2-e (12.1 per cent) between 1990 (1,514.4 Gg CO_2-e) and 2011 (1,331.1 Gg CO_2-e) (figure 8.1.2) and by 34.9 Gg CO_2-e (2.6 per cent) since 2010.

Figure 8.1.1 New Zealand's waste sector emissions from 1990 to 2011

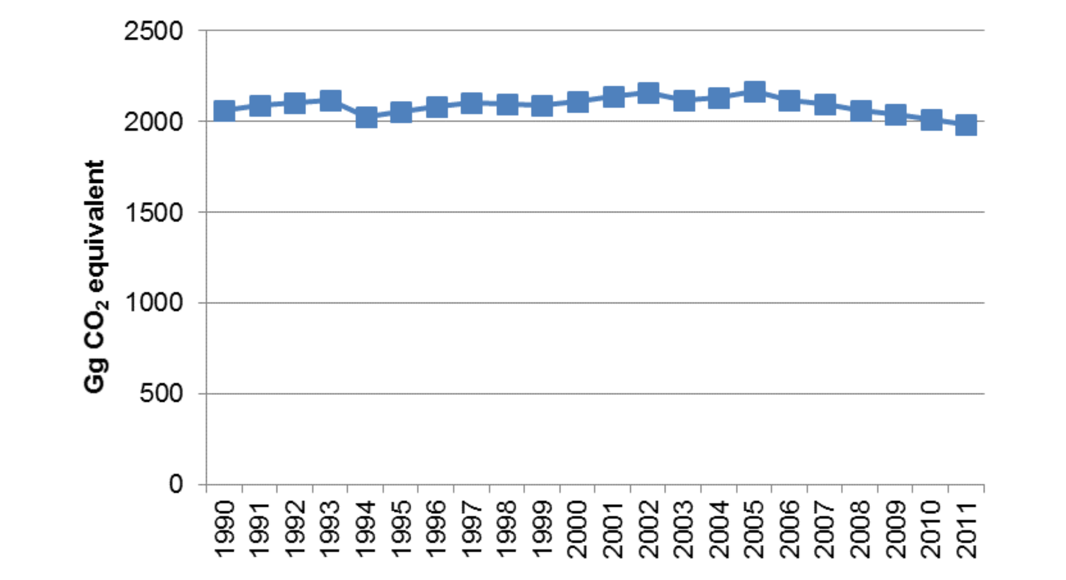
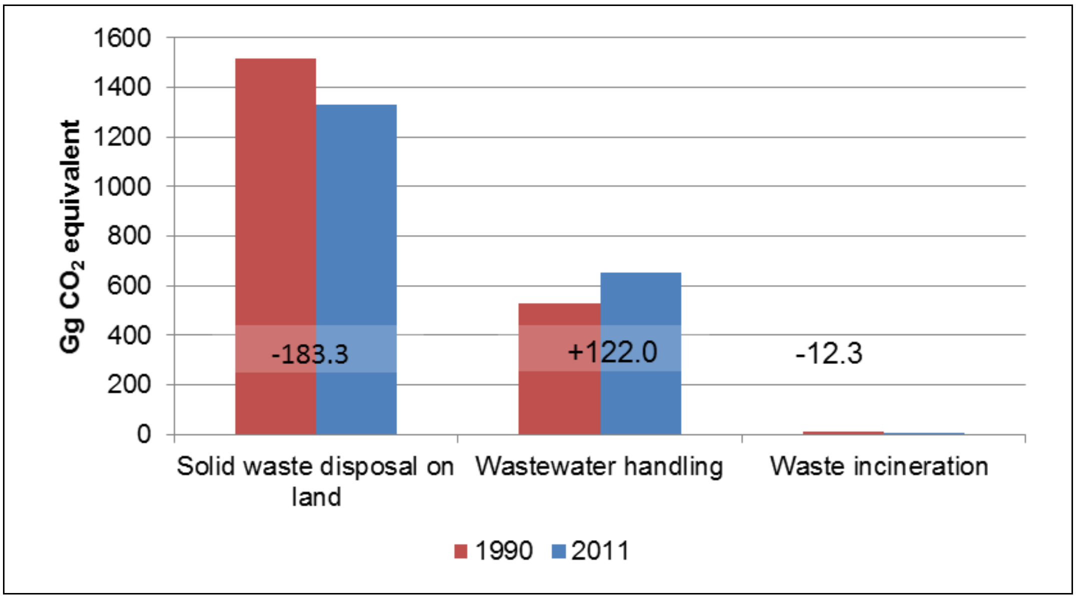


Figure 8.1.2 Change in New Zealand's emissions from the waste sector from 1990 to 2011



Changes to emissions between 2010 and 2011

Total waste emissions in 2011 were 27.4 Gg CO_2-e (1.4 per cent) lower than the 2010 level. This was largely due to the increase in the recovery of emissions from solid waste disposal sites.

8.1.1 Summary of improvements

The estimates for the waste sector have been recalculated. This is largely due to the availability of a new national waste composition estimate for 2008 and updated activity data for the wastewater sector.

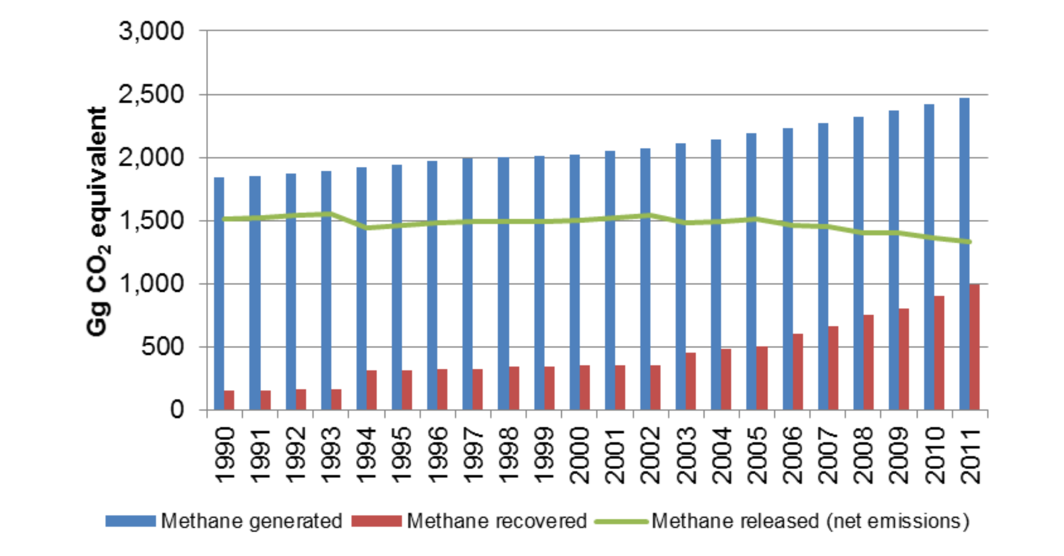
8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

In 2011, solid waste disposal on land contributed 1,331.1 Gg CO_2-e (67.0 per cent) of total emissions from the waste sector. Solid waste disposal emissions in 2011 were 183.3 Gg CO_2-e (12.1 per cent) below the 1990 level of 1,514.4 Gg CO_2-e.

In 2011, the amount of methane recovered from solid waste disposal on land was 995.5 Gg CO_2-e. Methane recovered in 2011 was 840.4 Gg CO_2-e above the 1990 level of 155.1 Gg CO_2-e and 89.3 Gg CO_2-e (9.9 per cent) above the 2010 level (see figure 8.1.3).

Figure 8.1.3 New Zealand's solid waste disposal to land emissions from 1990 to 2011



Methane emissions from solid waste disposal were identified as a key category in the 2011 level assessment and in the 1990–2011 trend assessment.

Organic waste in solid waste disposal sites is broken down by bacterial action in a series of stages that result in the formation of carbon dioxide and methane. The carbon dioxide from aerobic decomposition is not required to be reported in the waste sector of the inventory because of its biogenic origin. The amount of methane generated depends on a number of factors including waste disposal practices (eg, managed versus unmanaged landfills), the composition of the waste and physical factors, such as the moisture content and temperature of landfills. The methane produced can go directly into the atmosphere via venting or leakage, or it can be flared off and converted to carbon dioxide.

Solid waste management in New Zealand

In New Zealand, managing solid wastes has traditionally meant disposing of solid waste in landfills. In 1995, a national landfill census showed there were 327 legally operating landfills or solid waste disposal sites in New Zealand that accepted approximately 3.18 million tonnes of solid waste (Ministry for the Environment, 1997).

Since 1995, there have been a number of initiatives to improve solid waste management practices in New Zealand. These include the release of guidelines for:

- the development and operation of landfills
- the management of closing and closed landfills
- landfill resource consent conditions under New Zealand's Resource Management Act 1991.

As a result of these initiatives, a number of poorly located and substandard landfills have been closed, and communities are relying increasingly on modern regional disposal facilities for disposal of their solid waste. The *National 2006/07 Landfill Census* reported that there were 60 legally operating municipal landfills in New Zealand, a reduction of 82 per cent from 1995 (Ministry for the Environment, 2007). The same census reported that 3.156 million tonnes of solid waste were disposed of to landfills in 2006.

In March 2002, the Government released the *New Zealand Waste Strategy* (Ministry for the Environment, 2002a). The strategy, which was revised in 2010, sets out the Government's long-term priorities for waste management and minimisation (Ministry for the Environment, 2010). The strategy's two goals provide direction to local government, businesses (including the waste industry) and communities on where to focus their efforts to deliver environmental, social and economic benefits to all New Zealanders. The goals are:

- reducing the harmful effects of waste
- improving the efficiency of resource use.

As part of the implementation and monitoring of the waste strategy, the Government developed the *Solid Waste Analysis Protocol*, which provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams (Ministry for the Environment, 2002b).

In 2008, the Government passed the Waste Minimisation Act, which imposes a levy of NZ$10 per tonne of municipal solid waste from 1 July 2009, extends product stewardship regimes and enables regulations to require landfill operators and others to report on various waste targets and measures. Reporting required under this Act significantly improves New Zealand's knowledge of solid waste volumes. Work will be undertaken to attempt to determine if this information can be incorporated into future inventory submissions (see section 8.2.6).

8.2.2 Methodological issues

New Zealand has applied a Tier 2 approach by using the Intergovernmental Panel on Climate Change (IPCC) first order decay model to report emissions from solid waste disposal in the inventory (IPCC, 2006a). The 2006 IPCC guidelines (IPCC, 2006a) are used because New Zealand considers them to contain the most appropriate and current methodologies, particularly regarding default methane generation rates, for estimating emissions from solid waste disposal.

The following discusses the parameters for each type of landfill (ie, landfills with methane recovery systems and those without methane recovery systems) where they differ and then discusses the common parameters used for both types of landfills.

Landfills with methane recovery systems

In 2011, 22 landfills had operational methane recovery systems, with a known further two landfills expecting to have methane recovery systems operating by 2012. For each of these 24 landfills, a landfill-specific first order decay model, based on the model contained within the IPCC 2006 guidelines, was used to develop estimates of net methane emissions from waste disposal. In 2011, these 24 landfills accepted approximately 63 per cent of waste disposed to municipal landfills in New Zealand.

Waste placement

Landfill-specific information on annual solid waste placement was determined for the 24 landfills with methane recovery systems (or with plans to install methane recovery systems by 2012) through direct contact with landfill operators (SKM, Unpublished(a)).

Methane correction factor

The methane correction factor accounts for the different amounts of methane produced by the different levels of management of landfills. A methane correction factor of 1.0 is applied for all years to all landfills with methane recovery systems, as all these landfills are considered to be managed solid waste disposal sites.

Methane generation rate/half-life

The methane generation rate/half-life is the time taken for the degradable organic carbon in waste to decay to half of its initial mass. Methane generation rates/half-life values for waste disposed of to the 24 landfills with methane recovery systems (or with plans to install methane recovery systems by 2012) were determined based on local rainfall information and the values used in the Inventory of US Greenhouse Gas Emissions and Sinks 1990–2007 (SKM, Unpublished(a)). These values were then adjusted to reflect the management practices at each landfill. The practices considered were leachate collection, leachate recirculation, leachate treatment and quality of capping (SKM, Unpublished(a)).

Recovery

In the 22 landfills identified as having methane recovery systems in 2011, estimates of methane recovery efficiency were developed either through the use of metered system data (for four landfills) or through consideration of landfill capping quality, landfill lining, well placement, active or passive gas control and retrofitted or original wells (SKM, Unpublished(a)). To check that the modelling approach was accurate, modelled results were determined for the four landfills with metered data and the two sets of results were compared. The modelled results and the metered data were, on average, very similar, although the modelled results had a slight tendency to underestimate recovery efficiency (by approximately 3 per cent).

Efficiencies ranged from 42 per cent to 90 per cent, with an average efficiency of 62.4 per cent.

All landfills that recover methane for energy generation, and therefore the emissions associated with the electricity generation in the methane recovery process are included in the Energy sector’s estimates. There are some variances between the Waste sectors and Energy sectors estimates of the amount of methane recovered at some individual landfills. However, the total methane recovered for energy generation is very similar between the two sectors. These estimates will be validated in future inventory submissions using information that will become available through the New Zealand Emissions Trading Scheme (NZ ETS) (see section 8.2.6).

Landfills without methane recovery systems

In 2011, landfills without methane recovery systems accepted approximately 37 per cent of waste disposed to municipal landfills in New Zealand. A first order decay model was used to estimate net methane emissions from this waste.

Waste placement

Annual total waste placement to all landfills has been estimated based on national surveys for the years 1995, 1998, 2002 and 2006. For the years between surveys, when data is not available, solid waste-placement per person is estimated by interpolation. For the years before the earliest survey and after the latest survey, the closest survey-based waste-placement per person value (1995 and 2006 respectively) is used (table 8.2.1). The solid waste-placement per person estimate is then multiplied by population estimates to determine the total waste placement to all landfills. The reduction in solid waste per person per year since 1995 is assumed to be due to waste minimisation initiatives from central and local government and increased recycling.

The annual solid waste placement for landfills without methane recovery systems is the difference between the sum of the estimated annual solid waste placement for the 24 landfills with methane recovery systems (or with plans to install methane recovery systems) (SKM, Unpublished(a)) and the total annual solid waste placement discussed above.

Table 8.2.1 New Zealand's generation rate of solid waste to landfill

Year	Generation rate (kilograms per person per year)	Source
1950–1994	857.9	1995 figure applied retrospectively
1995	857.9	Ministry for the Environment (1997)
1996	812.6	Interpolation
1997	767.4	Interpolation
1998	722.1	Ministry for the Environment (2000)
1999	730.9	Interpolation
2000	739.8	Interpolation
2001	748.6	Interpolation
2002	757.5	Ministry for the Environment (2003)
2003	757.1	Estimated using population growth and limited placement data
2004	774.4	Estimated using population growth and limited placement data
2005	761.9	Interpolation
2006	749.4	Ministry for the Environment (2007) and Waste Not Consulting (Unpublished)
2007–2011	749.4	2006 figure applied

Methane correction factor

In 1997, it was estimated that 90 per cent of New Zealand's waste in 1995 was disposed to managed solid waste disposal sites and 10 per cent disposed to uncategorised sites (Ministry for the Environment, 1997). However, it was estimated and subsequently confirmed that 100 per cent of solid waste would be disposed to managed sites by 2010, due to the closure of unmanaged landfills. Consequently, the methane correction factor for landfills without methane recovery systems has increased from 0.90 in 1995 to a value of 1.00 from 2010.

Methane generation rate/half-life

New Zealand applies the IPCC default methane generation rate (referred to as the half-life value (k)) for a wet temperate climate (IPCC, 2006a). Default half-life values are applied to these landfills as there is no New Zealand-specific data on the half-life values of the solid waste within these landfills. This climate type is considered the best fit for New Zealand's complex climate system and geography.[41]

[41] Mean average temperatures vary from 10 degrees Celsius in the south to 16 degrees Celsius in the north. Mean annual precipitation ranges from 600 to 1,600 millimetres (National Institute of Water and Atmospheric Research, 2010). Mean annual potential evapo-transpiration ranges from 200 millimetres to 1,100 millimetres.

The New Zealand waste composition categories do not match the definition categories required for the IPCC methane generation and degradable organic carbon calculations (IPCC, 2006a). The difference is that New Zealand's putrescibles category combines the food waste stream and the garden waste stream for the methane generation rate and degradable organic carbon calculation. A separation of the combined waste stream into the two IPCC categories was not possible, given the available data. New Zealand applies a conservative approach to estimating the combined food and garden stream by applying the half-life for food waste to the combined food and garden waste category. For consistency, the degradable organic carbon content for food waste has also been applied to the combined category. This approach results in the garden waste component of the category biodegrading sooner and, therefore, producing emissions sooner than if it was in its own category. It also results in a lower degradable organic carbon for the garden waste component than if it was in its own category.

Landfills with and without methane recovery systems

The following parameters are applied to both landfills with and without methane recovery systems.

Waste class

New Zealand has insufficient data to categorise solid waste as either municipal solid waste or industrial solid waste, because many municipal landfills accept industrial waste. All national data is therefore reported in the municipal solid waste class and industrial waste is included in the composition estimates for this class.

Waste composition

Solid waste composition was estimated in the national surveys for 1995 and 2004, and an estimate for 2008 has been made using a reduced national survey and other solid waste composition studies (Ministry for the Environment, 1997; Waste Not Consulting, Unpublished; Ministry for the Environment, Unpublished). Linear interpolations were used to provide estimates for the years between the three estimates. The 1995 estimate is used for preceding years, and the 2008 estimate is used for subsequent years, including 2011. Table 8.2.2 shows the measured and calculated proportions each waste category has contributed to the total waste stream from 1950 to 2011.

As discussed above, New Zealand uses a putrescibles category that combines the IPCC food waste category and garden waste category.

Table 8.2.2 Composition of New Zealand's waste

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Inert (%)	Source
1950–1994	0	28	16	7	1	3	45	1995 values applied
1995	0	28	16	7	1	3	45	Ministry for the Environment (1997)
1996	0	28	16	8	1	3	45	Interpolation
1997	0	27	16	9	1	3	44	Interpolation
1998	0	27	16	9	2	3	44	Interpolation
1999	0	26	16	10	2	3	43	Interpolation
2000	0	25	16	11	2	3	43	Interpolation
2001	0	25	15	12	3	3	43	Interpolation

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Inert (%)	Source
2002	0	24	15	12	3	3	42	Interpolation
2003	0	24	15	13	4	3	42	Interpolation
2004	0	23	15	14	4	3	41	Waste Not Consulting (Unpublished)
2005	0	25	15	13	4	3	40	Interpolation
2006	0	26	15	13	4	3	40	Interpolation
2007	0	27	14	12	4	3	39	Interpolation
2008	0	29	14	11	5	3	38	Ministry for the Environment (Unpublished)
2009–2012	0	29	14	11	5	3	38	2008 values applied

Degradable organic carbon

The combined degradable organic carbon (DOC) value varies across the time series according to the New Zealand-specific composition data, discussed above. The default IPCC values of the degradable organic carbon in the different waste composition categories are used – the exception being the combined food and garden category, which uses the food category DOC value.

A new DOC value has been determined for 2008. This value remains constant from 2008, as there is no new data available for solid waste composition. The estimate of degradable organic carbon content in 1995 was 0.146 Gg C/Gg waste. This estimate has been applied to preceding years. The estimate increased over time to 0.170 Gg C/Gg waste in 2004 and decreased to 0.166 Gg C/Gg waste in 2008. The 2008 value has been applied to subsequent years, including 2011. This decrease was mainly due to a decrease in the proportion of wood, and to a lesser extent paper, in each tonne of waste going to landfills.

Default parameters applied

New Zealand uses the IPCC default values for the starting year, the delay time, the fraction of degradable organic carbon that actually decomposes and the fraction of methane in landfill gas (table 8.2.2) (IPCC, 2006a).

An oxidation factor of 0.1 is applied to all landfills because landfills in New Zealand are capped at the end of operational life and have daily cover applied, and are categorised as well managed (IPCC, 2006a). However, prior to 2010, there were a small proportion of landfills that were considered not well managed and therefore applying an oxidation factor was not appropriate. This small proportion of landfills was accommodated through the adjusted methane correction factor, discussed above.

Summary of parameters used

Table 8.2.3 provides a summary of the parameter values applied for estimating methane emissions from solid waste disposal to land.

Table 8.2.3 Parameter values applied by New Zealand for estimating solid waste disposal to land

Parameter	Value	Source	Reference
Landfills with methane recovery systems			
Methane generation rate/half-life ($year^{-1}$)	Range of 0.038–0.090	New Zealand specific	SKM (Unpublished(a))
Methane correction factor	1.0	IPCC default	IPCC (2006a)
Methane recovery efficiencies (%)	Range of 42–90	New Zealand specific	SKM (Unpublished(a))
Landfills without methane recovery systems			
Methane generation rate/half-life ($year^{-1}$):			
Food and garden	0.185	IPCC default for food	IPCC (2006a)
Paper	0.060	IPCC default	IPCC (2006a)
Wood and straw	0.030	IPCC default	IPCC (2006a)
Textiles	0.060	IPCC default	IPCC (2006a)
Disposable nappies	0.100	IPCC default	IPCC (2006a)
Sewage sludge	0.185	IPCC default	IPCC (2006a)
Methane correction factor	Range of 0.90–1.0	New Zealand specific	Ministry for the Environment (1997)
All landfills			
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)
Fraction of degradable organic carbon (DOC) that decomposes	0.50	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas	0.50	IPCC default	IPCC (2006a)
Oxidation correction factor	0.10	IPCC default	IPCC (2006a)
Degradable organic carbon (Gg C/Gg waste)	Range of 0.146–0.170	New Zealand specific	Ministry for the Environment (1997); Waste Not Consulting (Unpublished)

8.2.3 Uncertainties and time-series consistency

The overall level of uncertainty is estimated at ±40 per cent. The uncertainty is based on the uncertainty provided for the recovery modelling (SKM, Unpublished(a)) and sits within the IPCC default uncertainty range for methane recovery, as some metered data is used.

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or parameters have occurred, the entire time series was recalculated (see section 8.2.5).

8.2.4 Source-specific quality assurance/quality control (QA/QC) and verification

In the preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

8.2.5 Source-specific recalculations

Emission estimates between 2006 and 2010 have been recalculated to reflect a change in waste composition. A 2008 waste composition estimate has been made using a limited national survey and other commissioned solid waste composition studies. This resulted in amendments to composition estimates between 2004 (the previous composition estimate) and 2008 due to interpolation and from 2008, as the 2008 values replace the previous estimates for subsequent years.

8.2.6 Source-specific planned improvements

Waste-placement information is collected under the Waste Minimisation Act 2008. The Act provides a robust framework for collecting data on waste disposal to municipal landfills. This information has been collected from July 2009. Data collected prior to this date was collected using a variety of methods and has high uncertainties.

The waste-placement data collected under the Act for 2011 is approximately 25 per cent less than the waste-placement data used in this submission, resulting in a potential overestimate of emissions from solid waste disposal on land. The differences between the two datasets are being investigated. If an inconsistent time series approach was used, a sudden decrease in the waste placement and emissions from solid waste disposal would be reported.

As the time period of waste-placement information collected under the Act increases, work will be undertaken to attempt to determine if this information can be incorporated into future inventory submissions.

From 1 January 2013, the waste sector (landfills) has surrender obligations under the NZ ETS. Reporting from solid waste disposal sites for the 2013 year is required by March 2014. The information reported under the NZ ETS (see section 1.10) will be used to validate current estimates in the first year and will be considered to be incorporated into future inventory submissions. The waste sector (landfills) does have reporting obligations under the NZ ETS for the 2012 year. However, these reporting obligations are unlikely to provide information useful to validate current estimates.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2011, wastewater handling produced 652.1 Gg CO_2-e (32.8 per cent) of emissions from the waste sector. This was an increase of 122.0 Gg CO_2-e (23.0 per cent) from the 1990 level of 530.1 Gg CO_2-e and is due to increases in emissions from both the industrial and domestic sectors.

Methane emissions from wastewater handling were identified as a key category in the 2010 level assessment, but only in the analysis of total emissions.

Domestic and commercial wastewater

Domestic and commercial wastewater contributed 275.5 Gg CO_2-e (42.2 per cent) of the 2011 emissions from the wastewater handling category.

Wastewater from almost every town in New Zealand with a population over 1,000 is collected and treated in community wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and nearly a further 50 government or privately owned treatment plants serving populations of more than 100 people (SCS Wetherill Environmental, 2002).

Although most of the wastewater treatment processes are aerobic, there are a significant number of wastewater treatment plants that use partially anaerobic processes such as oxidation ponds or septic tanks. Small communities and individual rural dwellings are served mainly by simple septic tanks, followed by ground soakage trenches.

Industrial wastewater

Industrial wastewater contributed 376.7 Gg CO_2-e (57.8 per cent) of the 2011 emissions from the wastewater handling category. The major sources of industrial wastewater in New Zealand are the meat and pulp and paper industries. Most of the industrial wastewater treatment is aerobic and most methane from anaerobic treatment is flared. However, there are a number of anaerobic ponds that do not have methane collection, particularly serving the meat industry. This is discussed further below in methodological issues.

8.3.2 Methodological issues

Methane emissions from domestic wastewater treatment

Method

Methane emissions from domestic wastewater handling have been calculated using the default IPCC method (IPCC, 1996).

Activity data

Estimates are derived from applying information on the number of treatment plants in New Zealand, the population connected to each treatment plant and the treatment methods of each plant (Beca, Unpublished).

Population served by municipal wastewater treatment plants

The population using each municipal treatment plant and an estimation of the population using septic tanks has been determined (SCS Wetherill Environmental, 2002; Beca, Unpublished). In 2011, the total connected population was estimated to be 4.1 million. This is a minor difference between the estimated official 2011 population of 4.4 million. The relative difference is similar to other years and is considered unlikely to be significant within the accuracy of the calculations (Tonkin and Taylor, Unpublished). The connected population includes an estimated 432,000 people connected to rural septic tanks.

The population treated by each plant is updated each year based on the population growth rate of the district in which the plant is located. This information is obtained from Statistics New Zealand (Statistics New Zealand, 2012).

Methane conversion factors for handling systems

Methane conversion factors for the different handling systems in New Zealand have been determined by SCS Wetherill Environmental (2002). These factors range from zero, for the different types of aerobic treatment, and up to 0.65 for the different types of anaerobic treatment.

Biochemical oxygen demand

New Zealand uses a value of 26 kilograms biochemical oxygen demand per person per year. This is equivalent to the IPCC high-range default value for the Oceania region of 70 grams per person per day (IPCC, 1996). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca, Unpublished). This value has been increased by 25 per cent for most treatment plants to allow for commercial and industrial activity within a municipal area. Ten treatment plants have been identified to accept much larger amounts of industrial and/or commercial activity, and the increases in the biochemical oxygen demand value for these plants range from 77 per cent to 1,490 per cent (Beca, Unpublished).

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

Methane removal via flaring or for energy production is known to occur at eight plants in New Zealand. All methane generated at these plants is flared or used for energy production and, consequently, the net result is zero methane emissions (Beca, Unpublished). Plants using methane for energy generation are included in the Energy sector estimates.

Summary of parameters used

Table 8.3.1 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater treatment.

Table 8.3.1 Parameter values applied by New Zealand for estimating methane emissions for domestic wastewater treatment

Parameter	Value	Source	Reference
Methane conversion factors (MCF)			
Handling systems MCF	Range of 0–0.65	New Zealand specific	SCS Wetherill Environmental (2002)
Aggregated MCF	Range of 0.35–0.37	New Zealand specific	Derived from SCS Wetherill Environmental (2002)
Biochemical oxygen demand (BOD) (kg DC/person/year)	26	New Zealand specific	Beca (Unpublished)
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished)
Maximum methane producing capacity (kg CH_4/kg DC)	0.625	IPCC default	IPCC (1996)

Note: DC = degradable organic compound.

Methane emissions from industrial wastewater treatment

The IPCC default method is used to calculate methane emissions from industrial wastewater treatment (IPCC, 1996).

The following industries were identified as having organic-rich wastewaters that are treated anaerobically (in order of significance): meat processing, pulp and paper, and dairy processing. Emissions from wine production and wool scouring wastewater have also been included to ensure all industries known to have wastewater treatment facilities are accounted for.

Meat processing industry

Activity data

An estimate of the wastewater output from meat processing is based on the total production (kills) from the different producers of the meat industry – beef, sheep/lambs, goats, pigs (obtained from Statistics New Zealand, 2012), venison (obtained from Deer Industry New Zealand, pers. comm., 2012) and poultry (obtained from Poultry Industry Association of New Zealand, pers. comm., 2012).

The total organic wastewater from meat rendering was determined in 2006 (Beca, Unpublished). Using the 2006 figure, a ratio of wastewater from rendering to kills has been determined and has been applied to all years.

Degradable organic component

SCS Wetherill Environmental (2002) determined there was a range of 50 to 123 kilograms of chemical oxygen demand per tonne of product for the different producers within the meat industry.

Methane conversion factor

The meat processing methane conversion factor for all of the different producers is 0.55, as reported by SCS Wetherill Environmental (2002).

Default parameters applied

New Zealand uses the 1996 default IPCC value for both the maximum methane producing capacity and the methane conversion factor for the rendering calculations.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.2 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the meat industry.

Table 8.3.2 Parameter values applied by New Zealand for estimating methane emissions from wastewater treatment by the meat industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	Range of 0.05–0.12	New Zealand specific	SCS Wetherill Environmental (2002)
Methane conversion factors			
Processing	0.55	New Zealand specific	SCS Wetherill Environmental (2002)
Rendering	1.0	IPCC default	IPCC (1996)
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand; DC = degradable organic compound.

Pulp and paper industry

Activity data

An estimate of the pulp and paper wastewater output is based on the paper, paperboard and pulp production from the industry. This information is obtained from the Ministry for Primary Industries (Ministry for Primary Industries, 2012).

Degradable organic component

The degradable organic component was derived from the chemical oxygen demand per tonne of product, which is determined from industry data for biochemical oxygen demand (Beca, Unpublished).

Methane conversion factor

The methane conversion factor of 0.02 was determined by SCS Wetherill Environmental (2002). This same conversion factor was also determined by Beca (Unpublished) in 2006.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.3 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the pulp and paper industry.

Table 8.3.3 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the pulp and paper industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	0.03	New Zealand specific	Beca (Unpublished)
Methane conversion factor	0.02	New Zealand specific	SCS Wetherill Environmental (2002); Beca (Unpublished)
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand; DC = degradable organic compound.

Dairy industry

The dairy industry predominantly uses aerobic treatment. There is only one factory that uses anaerobic treatment. The emissions from the wastewater treatment process are recovered and the majority of the captured biogas (consisting of 55 per cent methane) is used to operate the boilers. The emissions generated from the operation of the boilers are accounted for in the Energy sector. The remainder is flared. Consequently, there are no emissions from this industry (Beca, Unpublished).

Wine industry

Emissions from the wine industry have been estimated using expert judgement and are based on total industry output values and values of methane production in septic tanks (Savage, Unpublished). These estimates are then extrapolated for the time series. Work is under way to improve the reporting of wastewater emissions from the wine industry (see section 8.3.5).

Wool scouring industry

Activity data

Emissions from wastewater for the wool scouring industry are based on the outputs obtained and projected by SCS Wetherill Environmental (2002).

Methane conversion factor

The methane conversion factor of the wool scouring industry is 0.29, as determined by SCS Wetherill Environmental (2002).

Degradable organic component

SCS Wetherill Environmental (2002) determined there were 22 kilograms of chemical oxygen demand per tonne of product for the wool scouring industry.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.4 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the wool scouring industry.

Table 8.3.4 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wool scouring industry

Parameter	Value	Source	Reference
Methane conversion factor	0.29	New Zealand specific	SCS Wetherill Environmental (2002)
Degradable organic component (kg COD/tonne of product)	0.02	New Zealand specific	SCS Wetherill Environmental (2002)
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand; DC = degradable organic compound.

Methane emissions from domestic sludge treatment

In large domestic wastewater treatment plants in New Zealand, sludge is handled anaerobically and the methane is almost always flared or used (Tonkin and Taylor, Unpublished). Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds (SCS Wetherill Environmental, 2002).

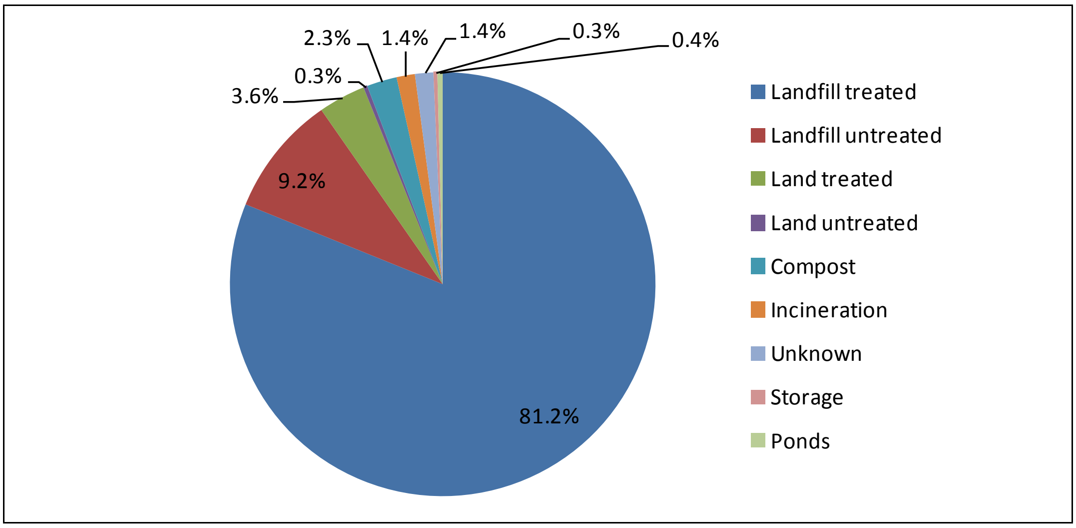
Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only de-sludged every 20 years. The sludge produced is well stabilised with an average age of approximately 10 years. It has a low, biodegradable organic content and is considered unlikely to be a significant source of methane (SCS Wetherill Environmental, 2002).

Sludge from septic tank clean-out, known as 'septage', is often removed to the nearest municipal treatment plant. In those instances, it is included in the methane emissions from domestic wastewater treatment. There are a small number of treatment lagoons specifically treating septage. These lagoons are likely to produce a small amount of methane and their effect is included in the calculations (SCS Wetherill Environmental, 2002).

Disposal

In New Zealand, the majority of sludge from domestic wastewater treatment plants is sent to landfills. In 2006, 90.4 per cent of sludge disposed of was sent to landfills – 81.2 per cent of this sludge was treated and 9.2 per cent was untreated (figure 8.3.1) (Tonkin & Taylor, Unpublished). The treated sludge sent to landfill is considered inert (as emissions from this sludge are included in the wastewater handling estimates), and therefore no emissions are produced. Untreated sludge emissions are included in the estimates for solid waste disposal to land (section 8.2).

Figure 8.3.1 Domestic sludge disposal in New Zealand, 2006



Method

The IPCC (1996) Tier 1 method is used to calculate emissions from domestic sludge treatment.

Activity data

Estimates are derived from applying information on the number of treatment plants in New Zealand, the population connected to each treatment plant and the treatment methods of each plant (Beca, Unpublished; Tonkin and Taylor, Unpublished).

Population served by municipal wastewater treatment plants, biochemical oxygen demand and biochemical oxygen demand correction factors

These values have been determined (and adjusted in the case of population) as discussed above in the methane emissions from domestic wastewater treatment section.

Fraction of degradable organic component removed as sludge

The fraction of degradable organic component removed as sludge for the different types of wastewater treatment plants has been based on the average ranges reported in Metcalf and Eddy (1992), as recommended by Tonkin & Taylor (Unpublished). These fractions range from 0 to 0.88.

Methane conversion factors

A methane conversion factor of 1 has been used for anaerobic treatment systems, and a methane conversion factor of 0 used for aerobic treatment/handling systems.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

In 2011, anaerobic digestion treated approximately 59 per cent of total domestic sludge in New Zealand. Of the sludge treated by anaerobic digestion, 96 per cent is treated by plants that utilise or flare methane.

A methane recovery value of 90 per cent is used for anaerobic digesters with known utilisation or flaring. This is a conservative method as much higher destruction efficiency is expected. In accordance with the IPCC method, where the fate of the gas from an anaerobic digester is unknown, no methane recovery is assumed.

Summary of parameters used

Table 8.3.5 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater sludge treatment.

Table 8.3.5 Parameter values applied by New Zealand for estimating methane emissions from domestic wastewater sludge treatment

Parameter	Value	Source	Reference
Fraction of degradable organic component removed as sludge	Range of 0–0.88	New Zealand specific	Tonkin & Taylor (Unpublished)
Methane conversion factors			
Anaerobic treatment systems	1	IPCC default	IPCC (1996)
Aerobic treatment systems	0	IPCC default	IPCC (1996)
Biochemical oxygen demand (BOD) (kg BOD/person/year)	26	New Zealand specific	Beca (Unpublished)

Parameter	Value	Source	Reference
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished)
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)
Methane recovery factor for anaerobic digestion treatment with utilisation or flaring	0.9	New Zealand specific	Tonkin & Taylor (Unpublished)

Note: DC = degradable organic compound

Methane emissions from industrial sludge treatment

Method

The IPCC (1996) Tier 1 method is used to calculate emissions from industrial sludge treatment.

Activity data

In New Zealand, the pulp and paper industry has been determined as the only industry to produce a source of methane from sludge treatment (Tonkin and Taylor, Unpublished).

An estimate of the pulp and paper wastewater output is based on the paper, paperboard and pulp production (tonnes) from the industry. This information is updated quarterly by the Ministry for Primary Industries (Ministry for Primary Industries, 2012).

The meat industry typically uses anaerobic treatment processes – mostly anaerobic lagoons with no sludge discharges. Emissions from these processes have been accounted for under the wastewater category. The dairy industry uses a variety of typically aerobic processes for treatment. Any sludge removed from these treatment processes is generally treated aerobically and discharged to land.

Fraction of degradable organic component removed as sludge

An 80 per cent chemical oxygen demand removal as sludge has been assumed (Tonkin and Taylor, Unpublished).

Methane conversion factor

A methane conversion factor of 0.6 has been used for the pulp and paper industry, as not all pulp and paper plants in New Zealand treat their sludge anaerobically. This figure is likely to be conservative as conversion factors are expected to be lower (Tonkin and Taylor, Unpublished).

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.6 provides a summary of the parameter values applied for estimating methane emissions from wastewater sludge treatment by industry.

Table 8.3.6 Parameter values applied by New Zealand for estimating methane emissions from industry wastewater sludge treatment

Parameter	Value	Source	Reference
Fraction of degradable organic component removed as sludge	0.8	New Zealand specific	Tonkin & Taylor (Unpublished)
Methane conversion factor	0.6	New Zealand specific	Tonkin & Taylor (Unpublished)
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)

Note: DC = degradable organic compound

Nitrous oxide emissions from domestic wastewater

There are no methodologies to estimate nitrous oxide emissions from domestic wastewater within New Zealand.

Nitrous oxide emissions from industrial wastewater treatment

Compared with domestic wastewater, the nitrous oxide emissions from industrial wastewater are insignificant and can therefore be ignored (IPCC, 2006a). However, this guidance does not take into account the significance of the meat industry in New Zealand in relation to nitrogenous-rich wastewaters. Due to the prevalence of anaerobic treatment plants within the meat industry, New Zealand has chosen to report nitrous oxide emissions from this source for completeness.

Method

The IPCC does not have a method for calculating nitrous oxide emissions from industrial wastewater; consequently, a New Zealand-derived method has been applied. The total nitrogen is calculated by adopting the chemical oxygen demand load from the methane emission calculations, and using a ratio of chemical oxygen demand to nitrogen in the wastewater for each of the different producers in the meat industry.

Activity data

The meat industry activity is consistent with the activity data used for calculating methane emissions from the meat industry under the industrial wastewater treatment section.

Ratio of nitrogen to total organic wastewater

New Zealand uses a ratio of 0.08 to determine the amount of nitrogen in the total organic wastewater from the meat industry.

Emission factor

An emission factor of 0.02 is used to calculate the emissions from the total nitrogen in wastewater (SCS Wetherill, 2002).

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.7 provides a summary of the parameter values applied for estimating nitrous oxide emissions from wastewater sludge treatment by the meat industry.

Table 8.3.7 Parameter values applied by New Zealand for estimating nitrous oxide emissions from wastewater treatment for the meat industry

Parameter	Value	Source	Reference
Ratio of nitrogen to total organic wastewater	0.08	New Zealand specific	SCS Wetherill Environmental (2002)
Emission factor	0.02	New Zealand specific	SCS Wetherill Environmental (2002)

Nitrous oxide emissions from domestic wastewater sludge treatment/human sewage treatment

Method

To estimate nitrous oxide emissions from domestic wastewater sludge/human sewage treatment, New Zealand uses the IPCC Tier 1 method, which calculates nitrogen production based on average per capita protein intake (IPCC, 2006a).

Activity data

Nitrous oxide emissions from domestic wastewater sludge/human sewage treatment are updated based on population data from Statistics New Zealand (Statistics New Zealand, 2012).

Per capita protein consumption

A value of 36.135 kilograms of protein per person per year is used. This figure was reported by New Zealand to the Food and Agriculture Organization, United Nations. It is the maximum value reported by New Zealand between 1990 and 2011.

Default parameters applied

New Zealand uses the default IPCC values for the fraction of nitrogen in protein, fraction of non-consumption protein, the fraction of industrial and commercial co-discharged protein, nitrogen removed with sludge, emission factor and the emissions from wastewater treatment plants.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.8 provides a summary of the parameter values applied for estimating nitrous oxide emissions from domestic and commercial wastewater sludge treatment.

Table 8.3.8 Parameter values applied by New Zealand for estimating nitrous oxide emissions from domestic and commercial wastewater sludge treatment

Parameter	Value	Source	Reference
Per capita protein consumption (kg/person/year)	36.135	New Zealand specific	Beca (Unpublished)
Fraction of nitrogen in protein	0.16	IPCC default	IPCC (2006a)
Fraction of non consumption protein	1.4	IPCC default	IPCC (2006a)
Fraction of industrial and commercial co-discharged protein	1.25	IPCC default	IPCC (2006a)
Nitrogen removed with sludge (kg)	0	IPCC default	IPCC (2006a)
Emission factor	0.005	IPCC default	IPCC (2006a)
Emissions from wastewater treatment plants	0	IPCC default	IPCC (2006a)

Nitrous oxide emissions from industrial sludge treatment

There are no methodologies to estimate these emissions within New Zealand.

8.3.3 Uncertainties and time-series consistency

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, the entire time series has been recalculated.

Methane emissions from domestic wastewater treatment

The domestic wastewater methane emissions have an accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished). It is not possible to perform rigorous statistical analyses to determine uncertainty levels for domestic wastewater because of biases in the data collection methods (SCS Wetherill Environmental, 2002). This uncertainty stems from:

- uncertainties in the factors used to calculate emissions from the different wastewater treatment processes
- uncertainties in the quantities of wastewater handled by the different wastewater treatment plants
- uncertainties in the accuracy and completeness of the data relating to each plant.

Methane emissions from industrial wastewater treatment

Total methane production from industrial wastewater has an estimated accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished). This uncertainty stems from:

- uncertainties in the factors used to calculate the degradable organic content in the wastewater
- uncertainties in the wastewater treatment methods.

Methane emissions from domestic sludge treatment

The uncertainty of methane emissions from domestic sludge is assessed as being ±50 per cent. This uncertainty stems from:

- uncertainties in the factors used to calculate emissions from the sludge
- uncertainties in the quantities of sludge produced from different wastewater treatment processes
- using average removal efficiencies
- uncertainties in the accuracy and completeness of the data relating to each plant.

Methane emissions from industrial sludge treatment

The uncertainty is assessed as being +100 per cent to –50 per cent. This uncertainty stems from:

- uncertainties in the method and factors used to calculate emissions from the sludge
- uncertainties in the quantities of sludge produced
- the use of average removal efficiencies.

Nitrous oxide emissions from domestic sludge and industrial wastewater treatment

There are very large uncertainties associated with nitrous oxide emissions from wastewater treatment, and no attempt has been made to quantify this uncertainty. The IPCC default emissions factor, EF_6, has an uncertainty of –80 per cent to +1,200 per cent (IPCC, 1996), which means the estimates have only order of magnitude accuracy.

8.3.4 Source-specific QA/QC and verification

In the preparation for this inventory submission, the data for the domestic and industrial sludge component of this category underwent Tier 1 quality checks. The largest improvement recommended by the Tier 1 quality checks was in the transparency of the compilation. This will be addressed in future submissions.

8.3.5 Source-specific recalculations

Methane emissions from domestic and commercial wastewater and sludge treatment

The time series for methane emissions from domestic wastewater treatment and from domestic sludge were recalculated to reflect corrections made to the activity data. These changes were to the population served by some of the wastewater treatment plants.

Methane and nitrous oxide emissions from industrial wastewater treatment

The time series for methane and nitrous oxide emissions from industrial wastewater were recalculated to incorporate activity data for calendar years for some of the industry sectors. Previous estimates were based on financial years.

8.3.7 Source-specific planned improvements

Further work is under way to refine the methane emissions from industrial sludge. This work intends to refine production rates and reassess disposal methods for the pulp and paper, wine, and wool scouring industries.

The potential development of New Zealand-specific parameters for the pulp and paper industry is also under way. Parameters include the methane producing capacity and the industrial degradable organic component removed as sludge.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2011, waste incineration accounted for 2.2 Gg CO_2-e (0.1 per cent) of waste emissions. This was a decrease of 12.3 Gg CO_2-e (84.9 per cent) from the 1990 level of 14.6 Gg CO_2-e. Emissions have remained fairly constant since 2007 and have not changed from 2009.

Waste incineration management in New Zealand

There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams, including medical, quarantine and hazardous wastes. The practice of incinerating these waste streams has declined since the early 1990s due to environmental regulations and alternative technologies, primarily improving sterilisation techniques. Resource consents under New Zealand’s Resource Management Act 1991 control non-greenhouse gas emissions from these incinerators.

Further, in 2004, New Zealand introduced a national environmental standard for air quality. The standard effectively required all existing, low temperature waste incinerators in schools and hospitals to obtain resource consent by 2006, irrespective of existing planning rules. Incinerators without consents are prohibited.

8.4.2 Methodological issues

Method

Estimates of direct emissions from the incineration of waste are made using the default Tier 1 methodology (IPCC, 2006a). The 2006 IPCC guidelines (IPCC, 2006a) are used because New Zealand considers the guidelines to contain the most appropriate and current methodologies for estimating emissions from waste incineration.

Activity data

Information on the annual amount of waste burnt per facility, per year is used to estimate waste incineration emissions. Limited information was provided by some individual sites, and some activity data had to be interpolated or extrapolated from the available data. There is generally no detailed information about the actual composition of the waste incinerated, only the consented types of waste allowed (SKM, Unpublished(b)).

Incineration devices that do not control combustion to maintain adequate temperature and that do not provide sufficient residence time for complete combustion are considered as open burning systems (IPCC, 2006a). Applying this definition excluded potential emissions from many small facilities that may have burned plastics and other mixed waste, such as at schools.

Only carbon dioxide emissions resulting from the burning of carbon in waste that is fossil in origin is included by the IPCC, such as in plastics, synthetic textiles, rubber, liquid, solvents and waste oil (IPCC, 2006a). Biogenic carbon dioxide, such as that from paper, cardboard and food, is excluded in accordance with the IPCC guidelines (2006a). Also excluded are emissions from waste to energy incineration facilities, as they are reported within the energy sector of the inventory.

Quarantine waste

Many incinerators in New Zealand are quarantine waste incinerators. The IPCC does not have a default category for quarantine incinerators. However, for the purposes of the calculations, the composition of quarantine was assumed to be more closely aligned with clinical waste than with the other categories (SKM, Unpublished(b)).

Hazardous waste

All parameters applied are default parameters.

Default IPCC hazardous waste compositional values are used to estimate the dry-matter content and the fossil carbon fraction in the total carbon in the waste incinerated. The default IPCC 2006 incineration oxidation value is used. New Zealand uses the mid-point where these values are presented as ranges.

The default IPCC 2006 emission factor for industrial waste is used for calculating methane emissions from incinerating hazardous waste. As the methane factors are presented as kg/TJ, the calorific value for the relevant waste is needed to convert the figures to Gg/year. The calorific value was sourced from the *New Zealand Energy Information Handbook* (Baines, 1993). Only the gross calorific value was available from this handbook, so that value is used, although it is noted this is inconsistent with the IPCC approach, which uses net values (IPCC, 2006a; 2006b).

The default IPCC 2006 emission factor for industrial waste incineration is used for calculating nitrous oxide emissions from incinerating hazardous waste (SKM, Unpublished(b)).

Clinical waste

All parameters applied are default parameters.

The default IPCC 2006 clinical waste compositional value is used to estimate the dry-matter content in the waste incinerated. The default IPCC 2006 clinical waste incineration values for the fraction of carbon in the dry matter, fossil carbon fraction in the total carbon and oxidation factor are used.

The default IPCC 2006 emission factor for municipal/industrial waste is used for calculating methane emissions from incinerating clinical waste. As for hazardous waste, calorific values from the *New Zealand Energy Information Handbook* (Baines, 1993) are used.

The default IPCC 2006 emission factor for municipal solid waste – batch type incinerators is used for calculating nitrous oxide emissions from incinerating clinical waste (SKM, Unpublished(b)).

Sewage sludge

All parameters applied are default parameters.

The default IPCC 2006 domestic sludge compositional value is used to estimate the dry-matter content. The default IPCC 2006 sewage sludge incineration values for the fraction of carbon in the dry matter, fossil carbon fraction in the total carbon and oxidation factor are used. New Zealand uses the mid-point where these values are presented as ranges.

The Japanese emission factor for sludge, provided in the IPCC 2006 guidelines, is used to calculate methane emissions from incinerating sewage sludge. The IPCC 2006 guidelines note that the most detailed observations of methane emissions from waste incineration have been made in Japan (IPCC, 2006a).

The default IPCC 2006 emission factor for sewage sludge incineration is used for calculating nitrous oxide emissions from incinerating sewage sludge (SKM, Unpublished(b)).

Summary of parameters

Table 8.4.1 provides a summary of the parameter values applied for estimating emissions from incineration.

Table 8.4.1 Parameter values applied by New Zealand for estimating emissions from incineration

Parameter	Hazardous waste	Clinical waste	Sewage sludge
Dry matter content in the waste incinerated (%)	0.5	0.65	0.1
Fraction of carbon in the dry matter	NA	0.6	0.45
Fraction of fossil carbon in the total carbon	0.275	0.4	1.0
Oxidation factor	1.0	1.0	1.0
Methane emission factor	2.34	1.79	9.7
Nitrous oxide emission factor	100	60	900
Source			All IPCC defaults
Reference			All IPCC (2006a; 2006b)

Note: NA = not applicable.

8.4.3 Uncertainties and time-series consistency

As per the IPCC recommendation for uncertainties relating to activity data (IPCC, 2006a), estimated uncertainty for the amount of wet waste incinerated ranges from ±10 per cent to ±50 per cent, and uncertainty of ±50 per cent is applied.

The data collected for the composition of waste is not detailed. Therefore, as per the recommendation for uncertainties relating to emission factors (IPCC, 2006a), the estimated uncertainty for default CO_2 factors is ±40 per cent. Default factors used in the calculation of methane and nitrous oxide emissions have a much higher uncertainty (IPCC, 2006a); hence, the estimated uncertainty for default methane and nitrous oxide factors is ±100 per cent (SKM, Unpublished(b)).

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, a full time-series recalculation is conducted.

8.4.4 Source-specific QA/QC and verification

As there were minimal recalculated values in this sector, quality-assurance and quality-control efforts were focused on the solid waste disposal on land and wastewater handling categories.

8.4.5 Source-specific recalculations

There have been no recalculations for this category.

8.4.6 Source-specific planned improvements

No improvements are planned for this category.

Chapter 8: References

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Chapter 9: Other

New Zealand does not report any emissions under the United Nations Framework Convention on Climate Change category 7, 'Other'.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to New Zealand's greenhouse gas inventory following the 2012 submission. Further details on the recalculations for each sector are provided in chapters 3 to 8 and chapter 11.

Recalculations of estimates reported in the previous inventory can be due to improvements in:

- activity data
- emission factors and/or other parameters
- methodology
- additional sources identified within the context of the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003)
- activity data and emission factors that become available for sources that were previously reported as NE (not estimated) because of insufficient data.

It is good practice to recalculate the whole time series from 1990 to the current inventory year to ensure a consistent time series. This means estimates of emissions and/or removals in a given year may differ from emissions and/or removals reported in the previous inventory submission for the same year. There may be exceptions to recalculating the entire time series and, where this has occurred, explanations are provided for the inconsistency.

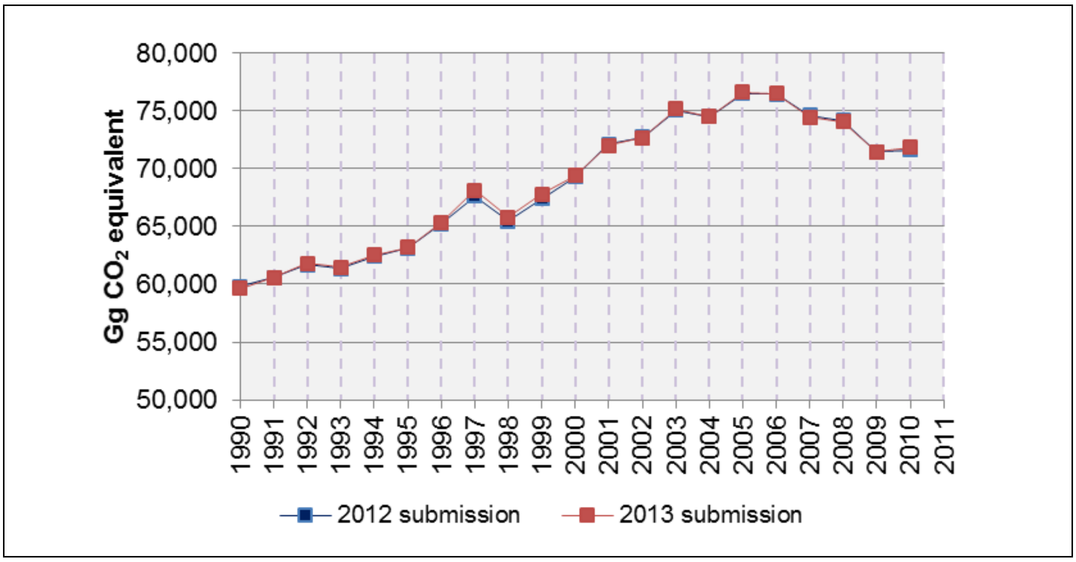
10.1 Implications and justifications

The effect of recalculations on New Zealand's total (gross) emissions in the 2013 inventory submission is shown in figure 10.1.1. There was a 0.3 per cent (153.5 Gg carbon dioxide equivalent (CO_2-e)) decrease in total (gross) emissions for the base year, 1990, and a 0.33 per cent (190.6 Gg CO_2-e) increase in total emissions for the 2010 year. The effect of recalculations when including the LULUCF sector was a decrease of 2.7 per cent (877.8 Gg CO_2-e) in net emissions for the base year, 1990, and a 4.6 per cent (2,356.7 Gg CO_2-e) increase in net emissions in 2010.

In New Zealand's 2012 inventory submission (1990–2010), total emissions were 19.8 per cent above 1990 levels. As a result of the recalculations in the 2013 inventory submission, total emissions for 2010 were 20.5 per cent above 1990. The greatest influence on recalculations of net emissions was the improvements made in the land use, land-use change and forestry (LULUCF) sector. The significant improvements in the LULUCF sector include the revised pre-1990 harvesting estimates, the correction of an error in the calculation of post-1989 forest carbon stocks and new activity data and estimates for biomass burning. The next largest sectoral improvements were in the waste sector, due to updated waste composition data being available for emission estimates between 2006 and 2010, and the energy sector where the most significant recalculation was a review of carbon dioxide emission factors for solid fuels across the time series from 1990–2011.

The following section details the effect of recalculations for each sector and summarises the improvements that resulted in the recalculations.

Figure 10.1.1 Effect of recalculations on New Zealand's total (gross) greenhouse gas emissions from 1990 to 2010



10.1.1 Energy

The improvements made in the energy sector have resulted in a 0.1 per cent (29.9 Gg CO_2-e) increase in energy emissions in 1990 and a 0.7 per cent (209.6 Gg CO_2-e) increase in energy emissions in 2010 (figure 10.1.2). The most significant contribution to this recalculation was a review of carbon dioxide emission factors for solid fuels across the time series from 1990–2011. Emission factors for solid fuels have been updated for this submission across the time series from 1990 to 2011. A comprehensive list of carbon content by coal mining is not currently available. However, a review of New Zealand's coal emission factors in preparation for the New Zealand Emissions Trading Scheme (CRL Energy Ltd, 2009) recommended re-weighting the current default emission factors to 2007 production rather than continue with those in the *New Zealand Energy Information Handbook* (Baines, 1993). A comparison of the original and updated emission factors can be found in table 3.3.1 of this submission. This has resulted in changes in emissions from solid fuel combustion across all sectors, including public electricity and heat production. For more information on this improvement, see section 3.3.1.

Explanations and justifications for recalculations of New Zealand's energy emission estimates in the 2013 submission are summarised in table 10.1.1.

Figure 10.1.2 Effect of recalculations on New Zealand's energy sector from 1990 to 2010

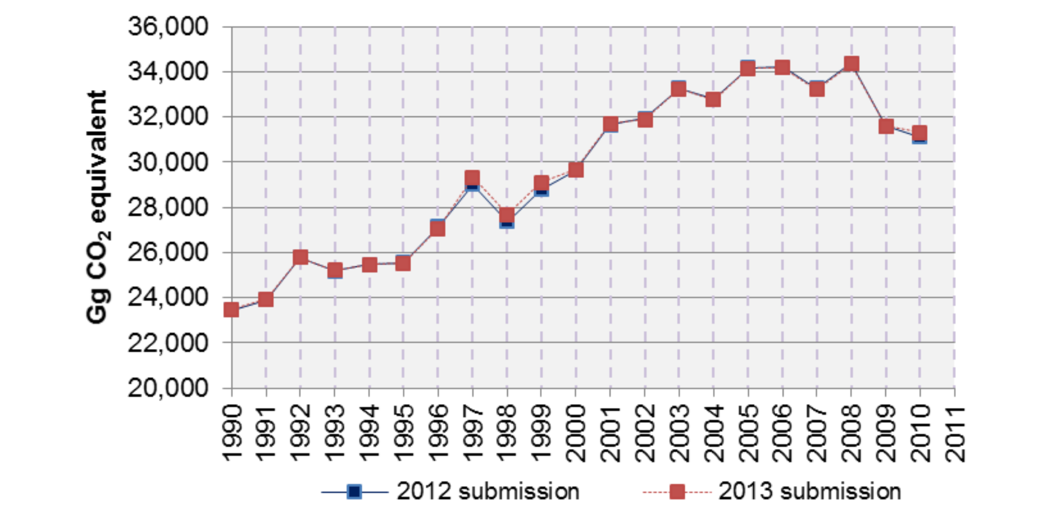


Table 10.1.1 Explanations and justification for recalculations in the energy sector

Explanation of recalculation	Good practice principle that was improved	Additional information
Emission factors for solid fuels have been updated for this submission. This has resulted in changes in emissions from solid fuel combustion across all sectors, including public electricity and heat production. In addition, this submission uses emission factors for solid fuel combustion for electricity generation that include the effect of imported coal use reported by the operator of the country's only primary producer of electricity. The net effect is an increase in carbon dioxide emissions in the public electricity and heat production sector across the time series. A full time series of the emission factor for sub-bituminous coal used for electricity generation can be found in annex 2 (table A2.2).	Accuracy	In response to Expert Review Team (ERT) recommendation.
Following ERT recommendations (2007 in-country review), New Zealand has continued to disaggregate liquid fuel consumption in the manufacturing industries and construction sector. For this submission, the method previously used to split diesel and gasoline combustion has been extended to fuel oil following new data becoming available from Statistics New Zealand. The result has been a significant reduction in fuel combustion allocated to sub-sector 1.AA.2.F manufacturing industries and construction – other non-specified, and increases in several other sub-sectors of the same category, in particular 1.AA.2.E – Food processing, beverages and tobacco. For details on the share of unallocated industrial fuels given to each sub-sector, see figures 3.3.10, 3.3.11 and 3.3.12.	Transparency	In response to ERT recommendation.
Fuel used in the auto-production of electricity has been allocated to the appropriate sub-sector. Previously, these emissions were reported under sub-sector 1.AA.2.F Manufacturing industries and construction – other non-specified. Reallocation occurred at the plant level using fuel consumption and electricity generation data supplied by operators for the purposes of national electricity statistics.	Transparency	In response to ERT recommendation.

Explanation of recalculation	Good practice principle that was improved	Additional information
These recalculations have led to further reductions in emissions allocated to this sub-sector and increases in sub-sectors 1.AA.2.D – Pulp, paper and print, 1.AA.2.E – Food processing, beverages and tobacco and 1.AA.4.A Other sectors – Commercial/ Institutional.		
Investigation found that some of the liquefied petroleum gas (LPG) previously assumed to be used in 1.AA.3.B road transport was sold to 1.AA.4.A O ther sectors residential.	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes.
The small amount of solid fuel use reported as sales to the transport sector was moved from rail transport to navigation, following the discovery that the fuel is used entirely by a single steamer operating in the South Island.	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes.
Historical coal production data has been revised due to revisions in data provided by companies. This has resulted in minor revisions in activity data and corresponding emissions for some years.	Accuracy	Corrections made by industry.
An error in the calculation of gas consumed at industrial plant and power stations was corrected in table 1.B.2.B.5.1.	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes.

10.1.2 Industrial processes

The improvements made in the industrial processes sector have resulted in a 0.1 per cent (4.1 Gg CO_2-e) increase in industrial processes emissions in 1990 and a 0.3 per cent (13.9 Gg CO_2-e) decrease in industrial processes emissions in 2010. These were minor recalculations for the sector. The overall effect of recalculations on New Zealand's industrial processes sector from 1990 to 2010 is presented in figure 10.1.3.

The improvement that had the largest impact on emissions in the 2010 year was the improvement made to the assumptions used for calculating emissions from the iron and steel category (see section 4.4.5 for further information). Other improvements are summarised in table 10.1.2 below.

Figure 10.1.3 Effect of recalculations on New Zealand's industrial processes sector from 1990 to 2010

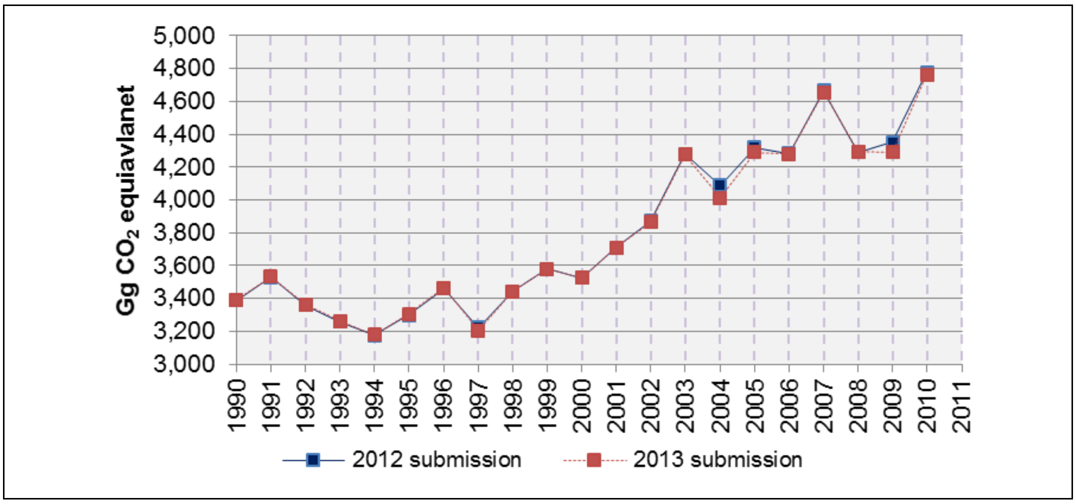


Table 10.1.2 Explanations and justifications for recalculations of New Zealand's previous industrial processes estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Improved assumptions in the application of a cement-kiln dust correction factor in the calculation of emissions from one cement producer. See section 4.2.5 for further detail.	Accuracy	Allows comparability with the methodology used in the calculation of emissions in the New Zealand Emissions Trading Scheme (NZ ETS).
Improved assumptions in the application of a purity correction factor in the calculation of emissions from one lime producer. See section 4.2.5 for further detail.	Accuracy	Allows comparability with the methodology used in the calculation of emissions in the NZ ETS.
New detailed data provided by one glass producer for the whole time series. This affects both the limestone use and soda ash use categories. See section 4.2.5 for further detail.	Accuracy	New data provided by industry.
Emissions figures from the NZ ETS (for 2010 and 2011) for one of the glass producers have been used for this submission. This affects both the limestone use and soda ash use categories. See section 4.2.5 for further detail.	Accuracy	Data for 2010 in the limestone use category was held constant from 2009 in previous submissions.
Small revision in the emission factor for distributed gas in ammonia production. See section 4.3.5 for further detail.	Accuracy	Improvement provided by Ministry of Business, Innovation and Employment.
Revised production data from one steel producer. See section 4.4.5 for further detail.	Accuracy	Correction provided by industry.
Incorporating the results of a review of HFC refrigerant charges in imported refrigeration and air conditioning goods. See section 4.7.5 for further detail.	Accuracy, transparency and consistency	Consistent with new national regulations to come into force in 2013.
Improved assumptions for the refrigeration and air conditioning estimates. See section 4.7.5 for further detail.	Accuracy	To account for new information provided by industry and government agencies.
Small errors corrected in the stationary and air conditioning equipment emissions calculations. See section 4.7.5 for further detail.	Accuracy	Corrections provided by contractor.
Error corrected in the calculation of emissions from mobile air conditioning. See section 4.7.5 for further detail.	Accuracy	Correction provided by contractor.
Improved assumptions on new and retired equipment for several line companies. See section 4.7.5 for further detail.	Accuracy	Improved information from industry.
Small mistake corrected in the emissions calculation from electrical equipment. See section 4.7.5 for further detail.	Accuracy	Correction provided by contractor.

10.1.3 Solvent and other product use

There have been no recalculations made to this sector.

10.1.4 Agriculture

The improvements made in the agriculture sector have resulted in a 0.6 per cent (193.3 Gg CO_2-e) decrease in agricultural emissions in 1990 and a 0.1 per cent (26.1 Gg CO_2-e) decrease in agricultural emissions in 2010 (figure 10.1.4). The improvements that made the largest change in emissions in the agriculture sector are the changes to the Tier 2 model used to estimate emissions from dairy, beef, sheep and deer.

All other recalculations, including the Tier 2 model changes, made within the agriculture sector are summarised in table 10.1.3 below.

Figure 10.1.4 Effect of recalculations on New Zealand's agriculture sector from 1990 to 2010

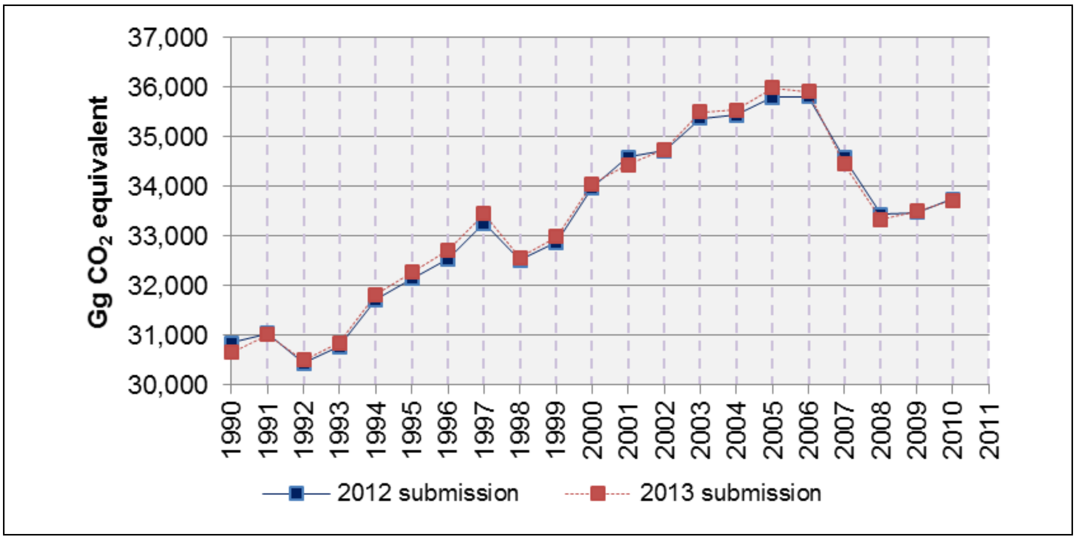


Table 10.1.3 Explanations and justifications for recalculations of New Zealand's previous agriculture estimates

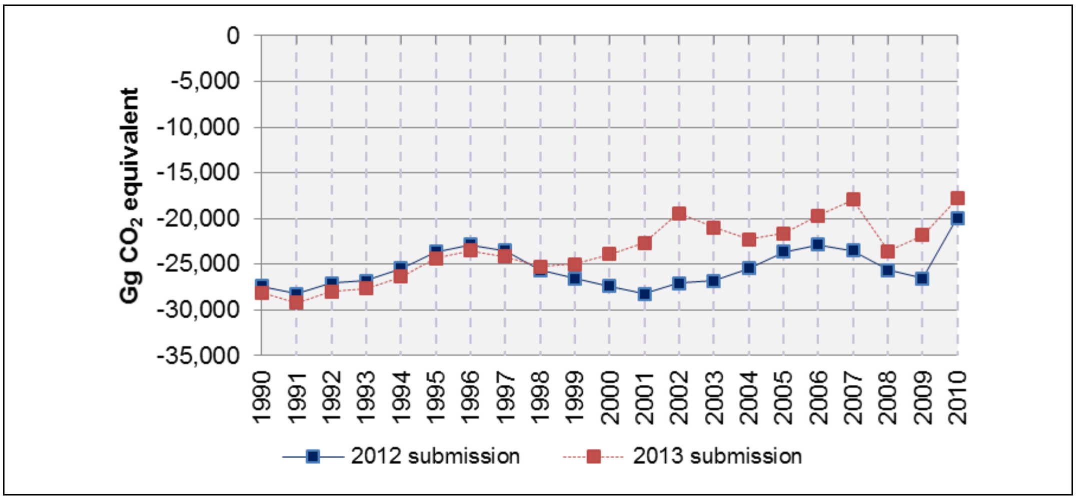
Explanation of recalculation	Good practice principle that was improved	Additional justification
Enhancements to New Zealand's Tier 2 inventory model to account for livestock population dynamics and productivity have resulted in recalculations of dairy, sheep, non-dairy and deer emissions from enteric fermentation, manure management and agricultural soils. See sections 6.2.5, 6.3.5 for further detail.	Transparency, consistency and accuracy	Planned improvement for key categories.
Corrections identified in the Tier 2 model through recoding the inventory programme and population models into Visual Basic. The recoding has made the model more transparent and accessible for quality assurance and quality control. See sections 6.2.5, 6.3.5 for further detail.	Transparency, consistency and accuracy	Correction identified and resolved through quality-assurance and quality-control processes.
Country-specific emission factors have been implemented for EF_3 other waste management – poultry. See section 6.3.5 for further detail.	Transparency, accuracy, completeness and consistency	Planned improvement for non-key categories.
Corrections to the Tier 2 model for crops. Recalculations to agricultural soils from crop residue and N-fixing crops, and to field burning of agricultural residues.	Transparency, accuracy, and consistency	Correction identified and resolved through quality-assurance and quality-control processes.
Additional activity data included for mules and asses for the first time to reflect the donkey population.	Transparency, accuracy, and completeness	Activity identified for the first time.
Additional activity data for emus and ostriches included in poultry from 2002.	Transparency, consistency, and completeness	Encouragement by expert review team from review of 2011 submission.
Enhancements to New Zealand's Tier 2 inventory model to account for livestock population dynamics and productivity have resulted in recalculations of dairy, sheep, non-dairy and deer emissions from enteric fermentation, manure management and agricultural soils. See sections 6.2.5, 6.3.5 for further detail.	Transparency, consistency and accuracy	Planned improvement for key categories.

10.1.5 Land use, land-use change and forestry

Improvements made to the LULUCF sector have resulted in a 2.6 per cent (724.4 Gg CO_2-e) increase in net LULUCF removals in 1990, and a 10.8 per cent (2,166.1 Gg CO_2-e) decrease in net LULUCF removals in 2010 (figure 10.1.5). These recalculations are the result of a fourth year of significant enhancements to the LULUCF inventory following the introduction in the 2010 submission of a new data collection and modelling programme for the New Zealand LULUCF sector – the Land Use and Carbon Analysis System (LUCAS). Further improvements and recalculations are expected to be introduced into the reporting in the LULUCF sector for the remainder of the first commitment period (see chapter 7 for details).

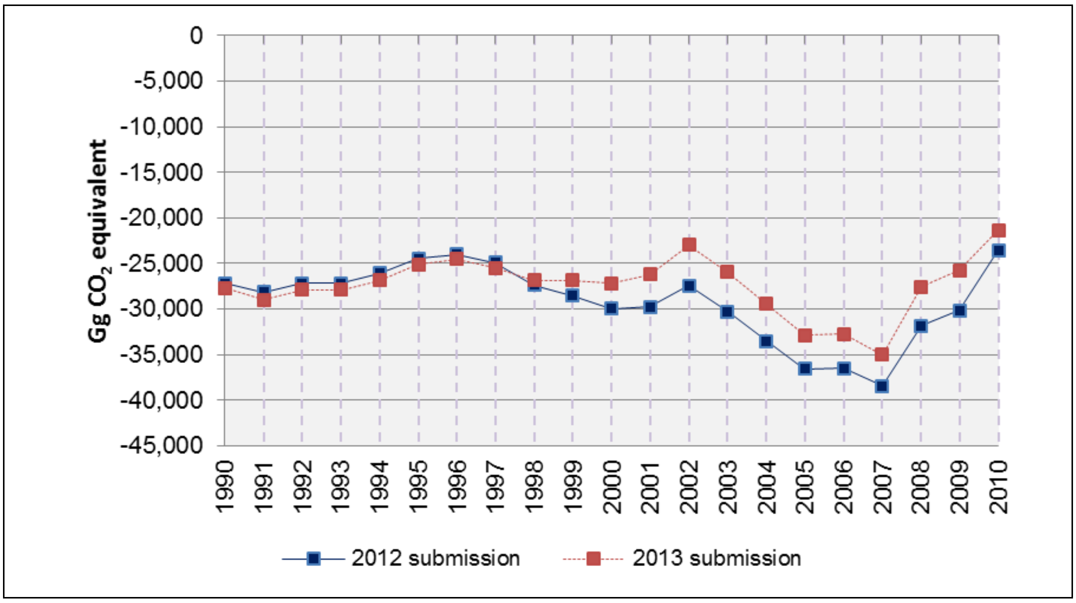
In the 2013 submission, significant improvements include the revised pre-1990 harvesting estimates, the correction of an error in the calculation of post-1989 forest carbon stocks and new activity data and estimates for biomass burning. Improved forest classification of pre-2011 deforestation areas had a small impact on the recalculations for 2011. Further detail on these changes is provided in section 7.1.5. The effect of recalculations on emissions and removals in the forest land and grassland categories are shown in figures 10.1.6 and 10.1.7. The explanations and justifications for all recalculations to New Zealand's LULUCF estimates in the 2013 submission are summarised in table 10.1.4.

Figure 10.1.5 Effect of recalculations on net removals from New Zealand's LULUCF sector from 1990 to 2010



Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Figure 10.1.6 Effect of recalculations on net removals from New Zealand's forest land category from 1990 to 2010



Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Figure 10.1.7 Effect of recalculations on net emissions from New Zealand's grassland category from 1990 to 2010

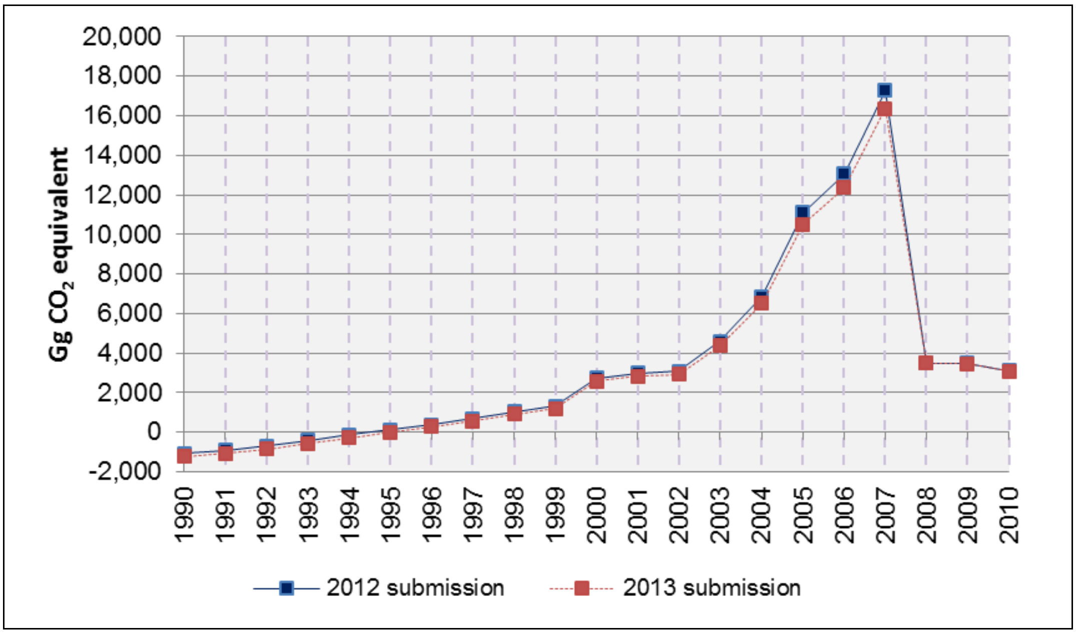


Table 10.1.4 Explanations and justifications for recalculations of New Zealand's previous LULUCF estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Improvements to the accuracy of the 1990 and 2008 land-use maps based on field visits and notified errors. These corrections included adding land-use change from grassland to wetlands to correctly represent a valley that was flooded as part of the Clyde dam development in 1993. Another minor correction involved filling two small gaps in the mapping in the Waikato region with a total area of 24 hectares. This correction has increased the overall area of New Zealand by 24 hectares.	Accuracy	
Mapping improvements to better distinguish pre-1990 planted forest from post-1989 forest, and to identify young newly planted post-1989 forest. See section 7.2.6 for further detail.	Accuracy	Key category improvement (*Land converted to forest land and Forest land remaining forest land*).
The correction of an error detected in the calculation process occurred when applying an updated yield table to estimate the post-1989 forest carbon stocks in the 2010 inventory. See sections 7.1.5 and 7.3.5 for further detail.	Accuracy	Error identified through quality-assurance and quality-control processes.
The activity data used to estimate harvesting emissions in pre-1990 planted forests is scaled throughout the time series to account for the different forest definitions used in the inventory and in the harvest activity data. See section 7.3.1 for further details.	Consistency	Key category improvement (*Forest land remaining forest land*).
Estimates are provided for the first time in 2011 for controlled burning associated with the clearing of natural forest prior to the establishment of exotic planted forest and the burning of post-harvest slash prior to restocking.	Accuracy, consistency, completeness	Key category improvement (*Forest land remaining forest land*). Expert review team feedback from in-country review 2010.

10.1.6 Waste

The methodological improvements made in the waste sector have resulted in a 0.3 per cent (5.9 Gg CO_2-e) increase in calculated waste emissions in 1990, and a 1.1 per cent (21.0 Gg CO_2-e) increase in waste emissions in 2010 (figure 10.1.8). The later changes are largely due to an estimate for New Zealand's waste composition in 2008 being incorporated. Other recalculations are provided in table 10.1.5.

Figure 10.1.8 Effect of recalculations on New Zealand's waste sector from 1990 to 2010

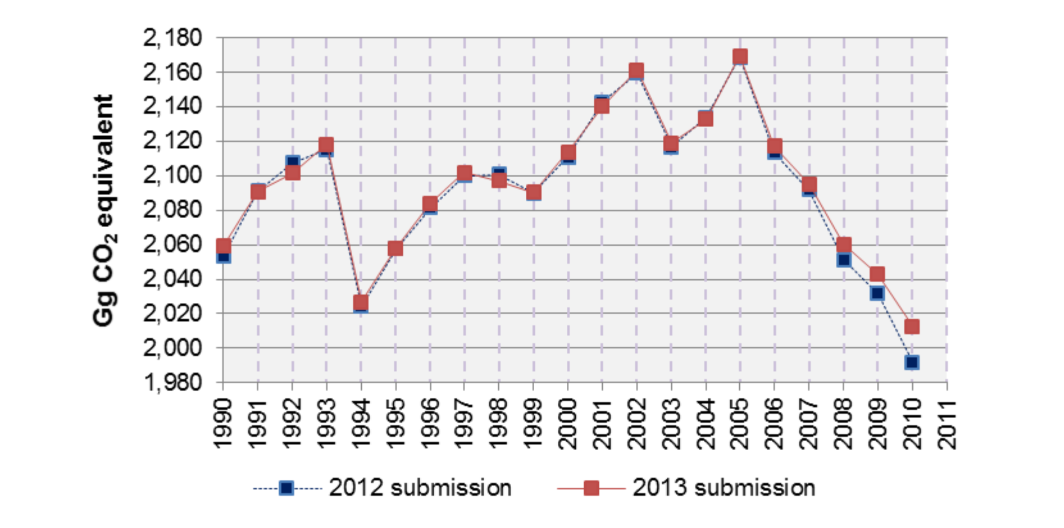


Table 10.1.5 Explanations and justifications for recalculations of New Zealand's previous waste estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
National waste composition values for 2008 have been calculated and incorporated into the Solid waste disposal on land emission (see section 8.2.5).	Accuracy	Key category improvement (*Solid waste disposal on land*).
The population served by some of the waste water treatment plants has been corrected (see section 8.3.5).	Accuracy	Corrections identified through quality-assurance and quality-control processes.
Calendar year activity data has been incorporated for some of the industry sectors. Previous estimates were based on financial years (see section 8.3.5).	Accuracy	Use of calendar year data.

10.1.7 Article 3.3 activities under the Kyoto Protocol

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission (table 10.1.6, table 10.1.7 and table 10.1.8). The recalculations incorporate improved New Zealand-specific methods, activity data and emission factors (see sections 7.1 and 7.2, and table 10.1.7).

The largest improvement made to the estimates for Article 3.3 activities under the Kyoto Protocol has been the correction of an error that occurred when the post-1989 forest yield table was updated for the last submission. This has now been corrected.

Table 10.1.6 Explanations and justifications for recalculations of New Zealand's previous Kyoto Protocol estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Mapping improvements to better distinguish pre-1990 planted forest from post-1989 forest and to identify young newly planted post-1989 forest. See section 7.2.6 for further detail.	Accuracy	Key category improvement (*Land converted to forest land* and *Forest land remaining forest land*)
The correction of an error detected in the calculation process occurred when applying an updated yield table to estimate the post-1989 forest carbon stocks in the 2010 inventory. See sections 7.1.5 and 7.3.5 for further detail.	Accuracy	Error identified through quality assurance and quality control processes.

Table 10.1.7 Impact of the recalculations of New Zealand's net removals under Article 3.3 of the Kyoto Protocol in 2010

Activity under Article 3.3 of the Kyoto Protocol	2010 net emissions and removals ($Gg\ CO_2$-e)		Change from 2012 submission (%)
	2012 submission	2013 submission	
Afforestation/reforestation	–19,357.0	–18,349.8	–5.2
Forest land not harvested since the beginning of the commitment period	–19,512.4	–18,455.9	–5.4
Forest land harvested since the beginning of the commitment period	155.4	106.1	–31.7
Deforestation since the beginning of the commitment period	1,049.9	1,029.4	–2.0
Total	**–18,307.1**	**–17,320.4**	**–5.4**

Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Table 10.1.8 Recalculations to New Zealand's 2010 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2010 areas (ha)		Change from 2012 submission (%)
	2012 submission	2013 submission	
Afforestation/reforestation	593,821	588,769	–0.9
Forest land not harvested since the beginning of the commitment period	592,021	586,969	–0. 9
New planting	6,000	6,000	0.0
Forest land harvested since the beginning of the commitment period	1,800	1,800	0.0
Deforestation	2,616	2,616	0.0
Natural forest	240	240	0.0
Pre-1990 planted forest	1,157	1,180	2.0
Post-1989 forest	1,220	1,196	–1.9

10.2 Recalculations in response to the review process and planned improvements

10.2.1 Response to the review process

The recommendations from the review of the 2011 submission (UNFCCC, 2012) and New Zealand's responses are included below in table 10.2.1. There were no recommendations made for solvent and other product use sectors. The expert review team report for the 2012 submission was not published in time to be taken into account for this submission.

Table 10.2.1 New Zealand's response to expert review team recommendations from the individual review of the greenhouse gas inventory submitted by New Zealand in 2011

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Energy	Para 32: Improve the energy sector's quality-assurance and quality-control (QA/QC) procedures in the national inventory report (NIR).	**Work in progress.** Quality control procedures for the Energy sector have been reviewed and relevant process maps have been created in consultation with each sector lead. The maps were used for refining sectoral QC processes and procedures. Regular meetings to discuss progress with QA/QC processes and relevant issues with the sector lead have been put in place (refer to chapter 13).
Fugitive emissions	Para 34: Disaggregating emissions from flaring and venting, which are currently reported together in the common reporting format (CRF) table 1.B.2 under flaring (combined).	**Work in progress.** New Zealand is currently working to improve the data on the split between natural gas flaring and venting. Current gas surveys request that gas field operators report venting and flaring separately, but data has been of poor quality and sporadic. Disaggregation will continue to be addressed in later inventories (refer to section 3.4.2, Activity data: Venting and flaring from oil and gas production).
Manufacturing industries and construction sector	Para 34: Disaggregating emissions for biomass fuels in manufacturing industries and construction for all subcategories.	**Work in progress.** This inventory submission further disaggregates emissions previously reported in subcategory 1.AA.F – manufacturing industries and construction – other non-specified into specific subcategories. This has resulted in the 'other' subcategory becoming much smaller. Currently, biomass fuels are disaggregated into solid and gaseous biomass. Also finer splits for the manufacturing industries and construction category is provided (for details, refer to section 3.3.2 and table 3.3.3 of this submission).
Manufacturing industries and construction sector	Para 34: Disaggregating emissions for solid and liquid fuels in iron and steel subcategory.	All solid fuel used in iron and steel manufacture is reported in the industrial processes sector to avoid double counting.
Stationary combustion: gaseous fuels – carbon dioxide (CO_2)	Para 40: Include detailed information on emission factors (EFs) and carbon content per gas field to improve the transparency of reporting.	**Work in progress.** Emission factors for solid fuels have been updated for this submission across the time series from 1990 to 2011. A comprehensive list of carbon content by coal mining is not currently available. However, a review of New Zealand's coal emission factors in preparation for the New Zealand Emissions Trading Scheme (NZ ETS) (CRL

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
		Energy Ltd, 2009) recommended re-weighting the current default emission factors to 2007 production rather than continue with those in the *New Zealand Energy Information Handbook* (Baines, 1993). A comparison of the original and updated emission factors can be found in table 3.3.1 of this submission.
Stationary combustion: solid fuels – CO_2, methane (CH_4) and nitrous oxide (N_2O)	Para 41: To improve the notation keys in the reporting of activity data and emissions.	**Implemented** (in CRF tables).
Civil aviation	Para 47: To adopt an appropriate CH_4 emission factor for civil aviation and recalculate CH_4 emissions from civil aviation in the next annual submission.	**Not implemented.** This is not the first priority due to resources needing to be applied to the key categories according to New Zealand's national circumstances.
Road transport	Para 48: To adopt a Tier 2 approach for non-CO_2 emissions from road transportation in the next inventory submission.	**Implemented** (included in 2012 submission).
Industrial processes and solvent and other product use	Para 51: To continue to increase transparency for all categories by adding information on the methodology, data sources and emission factors used.	**Implemented.** Added information has been provided for the Mineral Products (section 4.2), Metal Production (section 4.4) and Consumption of Halocarbons and SF_6 (section 4.7) categories.
Iron and Steel	Para 52: To improve transparency of the method and data used by iron and steel companies while maintaining confidentiality if needed.	**Implemented.** Further detail has been provided for this inventory submission in section 4.4.2 with regard to the methodology and data used by Pacific Steel.
Aluminium	Para 54: To correctly explain the equivalence of methodologies used to calculate process CO_2 emissions.	**Implemented.** The International Aluminium Institute (2006) Tier 3 method is described as equivalent to the IPCC (2006) Tier 3 method in this submission (see section 4.4.2).
Consumption of soda ash	Para 55: To improve the transparency of CO_2 emissions from soda ash use in both aluminium and glass production.	**Implemented.** Soda ash use emissions from both aluminium and glass production are reported in the 'soda ash production and use' category, in section 4.2.2.
Aluminium production – PFCs	Para 58: To document what Tier 2 quality checks have been conducted for this category.	**Work in progress.** New Zealand now uses the information provided by the New Zealand Aluminium Smelter in its NZ ETS as source data for the national inventory. For this reason, NZ ETS can no longer be used as a Tier 2 quality check. New Zealand is working with the company to develop an appropriate Tier 2 quality check system.
Consumption of halocarbons and SF_6	Para 60: Provide a transparent explanation of the improved models and parameters used for emissions estimations.	**Implemented.** Improvements in the models and parameters used to estimate emissions from this category have been provided in section 4.7.5.
Agriculture	Para 63: To improve transparency by explaining country-specific EFs and parameters adopted.	**Implemented.** Research supporting country-specific emissions has been referenced. A new section, 6.1.4, has been added to the NIR to explain the process of adopting changes and country-specific emissions factors. Research papers presented to the Agriculture Inventory Advisory Panel are put on the Ministry for Primary Industries website and this website is referenced in the NIR.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Enteric fermentation – CH_4	Para 68: To include more explanation for digestibility of this category.	**Implemented.** Sections 6.1 and 6.2.4 provide explanation specifically around the nitrogen fixation by legumes. The IPCC default is for Australia. A new research project has started to look at the quality of New Zealand data on pasture quality (specifically nitrogen and energy content) and is to report back on whether the data is robust enough to support inventory improvements (including the possibility of greater spatial disaggregation) or whether further research is required (and where). The values reported in CRF additional information tables are the annual averages of the monthly digestibility values.
Agricultural soils	Para 75: To ensure correct values of activity data for nitrogen leaching and run-off in the CRF tables are adopted.	**Implemented.** Corrected for the 2012 and 2013 submission. Previously, total nitrogen was reported as activity data, now total nitrogen leached is reported as activity data.
Agricultural soils	Para 76: To provide updated results for several other nitrogen inputs to the soil in future annual inventory submission.	**Work in progress.** New Zealand is continuing to work on this area with researchers and industry specialists to meet the requirement to report these emissions from 2015 under the revised reporting decision 15/CP17.
Land use, land-use change and forestry (LULUCF)	Para 85: New Zealand reports in the NIR, chapter 7, four key categories in the LULUCF sector for 2009; for cropland it reported that “cropland categories were not identified as key categories for 2009” (2011, NIR, p 206). However, in CRF table 7, cropland is indicated under key categories including LULUCF. The Expert Review Team (ERT) recommends that New Zealand check this information and ensure consistency in the next annual submission.	**Implemented.** In this submission, key category consistency has been checked between the text of the inventory and the CRF tables.
LULUCF	Para 87: As a result of the implementation of the back-casting method, New Zealand included in CRF table 5.A a new subcategory, natural forest (conversion) to pre-1990 planted forest. This category covers natural forest that has been cleared since 1990 and replanted with exotic planted forest. The area and the carbon stocks and changes for each of these subcategories (as used in the previous submission) have been adjusted to reflect this change. However, this new subcategory is not further elaborated in the NIR; for example, in sections 7.2.1 and 7.3.1 where New Zealand explains the land-use category definitions or section 7.3.2 dealing with methodological issues. The ERT recommends that New Zealand improve the transparency and present in its next annual submission more information on the subcategory natural forest (conversion) to pre-1990 planted forest and on the methods applied to estimate carbon stock changes.	**Implemented:** New Zealand has included an explanation of how this activity is modelled in section 7.3.2 under the heading *Pre-1990 planted forest*.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
LULUCF	Para 90: Almost all land converted to forest land is grassland (about 5 per cent is a change from other land). In this category, New Zealand reports the land conversion of the past 28 years; in 2009, this amounts to 983.41 kha and removals of 31,594.35 Gg CO_2. In this estimation, the carbon stock changes for soil are based on a period of 20 years, which is the IPCC default value. It is reported in the NIR that it is estimated that 25 per cent of the grassland converted to forest land is cleared using controlled burning. In such a case, 30 per cent of above-ground biomass and all biomass on un-burned sites are assumed to decay over 20 years. During the review, New Zealand informed the ERT that the carbon pools in living biomass following conversion should be calculated over 28 years. The ERT recommends that New Zealand ensure the period of 28 years is used in the calculations in the next annual submission.	**Implemented:** New Zealand has chosen 28 years as its land in transition period. This is a country-specific value based on the average plantation forest rotation length in New Zealand. New Zealand has ensured that, for the 2013 submission, the correct period of 28 years has been used for the calculation of carbon stock change following land-use change (with the exception of annual cropland, low producing grassland and high producing grassland, which all reach maximum biomass within a year – the IPCC default for these land-use types).
LULUCF	Para 91: Grassland remaining grassland is about 53.6 per cent of New Zealand's total land area and this area decreased between 1990 and 2009 by 186 kha (–1.3 per cent) while the emissions increased in the same period by 1,350.2 Gg CO_2-e (+159.9 per cent). In the NIR, New Zealand explained that this increase is due to multiple factors, including increased agricultural liming and the influence of land-use changes between grassland subcategories on soil and biomass carbon accumulation over time. The ERT welcomes these explanations and recommends that New Zealand provides this in its NIR in the next annual submission.	**Implemented:** New Zealand is now reporting the reasons for the increase in emissions in this category despite the decrease in grassland area. See section 7.5.1.
Kyoto Protocol land use, land-use change and forestry sector (KP-LULUCF)	Para 10: Under Article 3, paragraph 3, of the Kyoto Protocol, New Zealand reports for the first time CO_2 emissions from organic soils associated with reforestation and deforestation separately from CO_2 emissions from mineral soils. The ERT commends New Zealand for this improvement. In addition, CH_4 and N_2O emissions from biomass burning due to wildfires on reforested and deforested land and controlled burning on deforested land were not estimated. The ERT reiterates the recommendation from the previous review report that New Zealand provides estimates of these emissions in its next annual submission (see para 109 below).	**Partially implemented:** New Zealand is now estimating CH_4 and N_2O from wildfire on reforested land (see section 11.3.1). A survey of planted forest based controlled burning activities was carried out in 2011 but it failed to provide activity data on burning associated with deforestation. New Zealand is investigating sources of information on wildfire occurring on deforested land.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
KP-LULUCF	Para 108: Paragraph 8(a) of the annex to decision 15/CMP.1 requests complementary information on the size and geographical location of forest areas that have lost forest cover but that are not yet classified as deforested. On this issue, the Party has procedures in place (as described in the NIR) to distinguish deforestation from harvesting during and at the end of the commitment period. This is planned to be done using several available data sources as well as information on forest in the NZ ETS. However, New Zealand also reports that, following mapping at the end of 2012, the area of deforestation will be confirmed but that it may take up to four years. This approach is likely to cause some uncertainty for distinguishing deforestation from harvesting in the last reporting years of the commitment period. The ERT reiterates the recommendation in the previous review report that New Zealand further refine this procedure, allowing full confirmation of deforestation in the last reporting years, and report on this in it next annual submission.	**Implemented:** New Zealand's approach is described in section 11.4.2.
KP-LULUCF	Para 109: New Zealand reports for the first time CO_2 emissions from organic soils associated with reforestation and deforestation separately from CO_2 emissions from mineral soils. The ERT commends New Zealand for this improvement. In addition, CH_4 and N_2O emissions from biomass burning due to wildfires on reforested and deforested lands and controlled burning on deforested land were reported as 'NE' (not estimated). New Zealand is investigating attributing a proportion of wildfire activity to land converted to forest land, and informed the ERT during the review week that this improvement will be implemented in the 2012 submission. The ERT reiterates the recommendation from the previous review report that New Zealand provides estimates of these emissions in its next annual submission.	**Partially implemented:** New Zealand is now estimating CH_4 and N_2O from wildfire on reforested land (see section 11.3.1). A survey of planted forest based controlled burning activities was carried out in 2011 but it failed to provide activity data on burning associated with deforestation. New Zealand is investigating sources of information on wildfire occurring on deforested land.
	Para 109 (cont): New Zealand is also gathering activity data on controlled burning of residues following harvest and informed the ERT during the review that emissions from this activity will be included in the 2013 submission. The ERT welcomes these actions and looks forward to the results in future submissions.	**Implemented:** For the first time in 2011, estimates are provided for controlled burning associated with the clearing of natural forest prior to the establishment of exotic planted forest and the burning of post-harvest residue prior to restocking in forest land remaining forest land (see section 7.9.5). Research investigating sources of activity data on controlled burning practices on harvested A and R (afforestation and reforestation) land failed to provide data on the activity. Expert

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
		opinion suggests that controlled burning of post-harvest residues on A and R land does not occur due to the nature of harvest in short rotation forests grown for pulp (where most biomass is removed from site).
KP-LULUCF	Para 114: New Zealand started to use a combination of references for the mapping of deforestation in the period 2008–2009. In this process, areas of forest destocking that were unable to be confirmed as either harvesting or deforestation were flagged for tracking for four years from the date of clearing. The ERT recommends that New Zealand provides in its next annual submission data on these flagged areas.	**Implemented:** Area of land awaiting confirmation of deforestation is reported in section 11.4.3.
Waste: solid waste disposal on land – CH_4	Para 98: To improve the estimates of CH_4 flared or used for energy recovery under memo items.	**Work in progress.** New Zealand has confirmed that total CH_4 recovered for energy generation aligns between the waste and energy sector. However, there are some discrepancies at the individual landfill level. These values will be validated with the NZ ETS data (available in 2014). Upon validation, this information will be reported under memo items in biomass combustion.
Waste: wastewater handling – CH_4	Para 100: To improve the transparency of activity data for the wine and wool scouring industries.	**Work in progress.** Work to improve the transparency of the activity data is under way and is likely to be included in the 2014 submission.

10.2.2 Planned improvements

Priorities for inventory development are guided by the analysis of key categories (level and trend), uncertainty surrounding existing emission and removal estimates, and recommendations received from previous international reviews of New Zealand's inventory. The inventory improvement and quality-control and quality-assurance plans are updated annually to reflect current and future inventory development. The sector risk registers are useful in identifying potential improvements.

Figure 10.2.1 shows the five stages of New Zealand's planned improvement process, from identifying the improvement to acceptance into the inventory. Each stage is described in further detail below.

Figure 10.2.1 Overview of New Zealand's improvement process

Step 1: Identifying the improvements

Each sector compiler is responsible for ensuring that improvements are identified. Potential sources to identify improvements include recommendations and encouragement from the United Nations Framework Convention on Climate Change (UNFCCC) expert review team reports, sector risk registers, the key categories analysis, and verification using other independent sources of information (eg, New Zealand Emissions Trading Scheme emissions returns).

Step 2: Documentation, evaluation and prioritisation

Each sector compiler is responsible for ensuring that all improvements are evaluated, prioritised and documented. Each sector compiler develops a list of potential improvements using the sources identified in step one above and discusses the potential improvements with at least one other sector expert prior to developing a business case to obtain any additional resourcing to develop the improvement.

New Zealand has developed and trialled an improvement framework using multi-criteria decision analysis called 'Stakeholder Objective Analysis' (SOA) to evaluate all the improvements across all sectors in a consistent manner. The SOA divides all the national greenhouse gas inventory users into three stakeholder groups, namely: (1) the UNFCCC and international group, (2) the national greenhouse gas inventory users group and (3) the sector lead group. For each of the stakeholder groups, an evaluation criterion is developed and weighted. Each improvement is ranked against the criteria using a scale of 1 to 5. Score 1 represents least important or relevant and 5 represents the most important or relevant. The evaluation of each stakeholder group is then weighted to get an average score for each potential improvement. The tool has not been fully integrated into New Zealand's improvement plan as yet because it requires further user input and testing. However, New Zealand anticipates integrating the use of the tool into improvement decision making over the next two inventory submissions so it is fully in place for the new reporting requirements in the 2015 inventory submission.

Step 3: Obtaining approval

Obtaining approval for resourcing the development of an improvement starts with the initial identification of the improvement and ends with a decision for the improvement to proceed or not. This procedure depends on the sector, the scale of the improvement and the availability of resources. Broadly, all sectors present a business case to the sector governance responsible for resourcing the programme of work.

Step 4: Assessing the quality of the improvement work

Once improvement work is completed an important component of the procedure for assessing the quality of the improvement work is evaluating whether a 'Peer Review Change form' is required. A decision tree has been created, using the threshold developed for the updated UNFCCC guidelines for assessing significance. If the planned improvement results in a change greater than this threshold, the Peer Review Change form must be completed. The form specifically requires the reviewer to evaluate the evidence for the change, compare the new factor against other information sources, then recommend whether the inventory should adopt or reject the new method, activity data source, emissions factor or parameter.

Step 5: Acceptance of the improvement into the inventory

The procedure for accepting the improvement into the inventory is the same for all sectors. Each improvement is presented to the Reporting Governance Group (RGG) (refer to section 1.2.2 for further information about the RGG) for approval. This step is to ensure that the improvement has been agreed by all government agencies involved in the inventory compilation and that sufficient explanations for the improvement are well communicated within the national inventory report.

Chapter 10 References

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Chapter 11: KP-LULUCF

11.1 General information

In 2011, net removals from land subject to afforestation, reforestation and deforestation were 16,765.5 Gg carbon dioxide equivalent (CO_2-e) (table 11.1.1). This value is the net total of all emissions and removals from activities under Article 3.3 of the Kyoto Protocol and includes: removals from the growth of post-1989 forest and emissions from the conversion of land to post-1989 forest, the harvesting of forests planted on non-forest land after 31 December 1989, emissions from deforestation of all forest land subcategories, as well as emissions from liming, biomass burning and soil disturbance associated with land-use conversion to cropland of any land subject to afforestation, reforestation and deforestation since 1990.

These net emissions are reported separately for the North Island and South Island for the five carbon pools (figure 11.1.1). Afforestation, reforestation and deforestation are key categories for New Zealand (table 1.5.4).

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has categorised its forests into three subcategories: natural forest, pre-1990 planted forest and post-1989 forest. These subcategories are also used for greenhouse gas inventory reporting on the land use, land-use change and forestry (LULUCF) sector under the Climate Change Convention (see chapter 7). For the first commitment period, New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol.

All forest land that existed on 31 December 1989 has been categorised as either natural forest or pre-1990 planted forest. For these forests, only emissions from deforestation activities are reported in this chapter. For the post-1989 forests, emissions and removals from carbon losses and gains due to afforestation, reforestation and deforestation are reported for the first four years of the commitment period: 2008, 2009, 2010 and 2011.

Table 11.1.1 New Zealand's net emissions from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2011

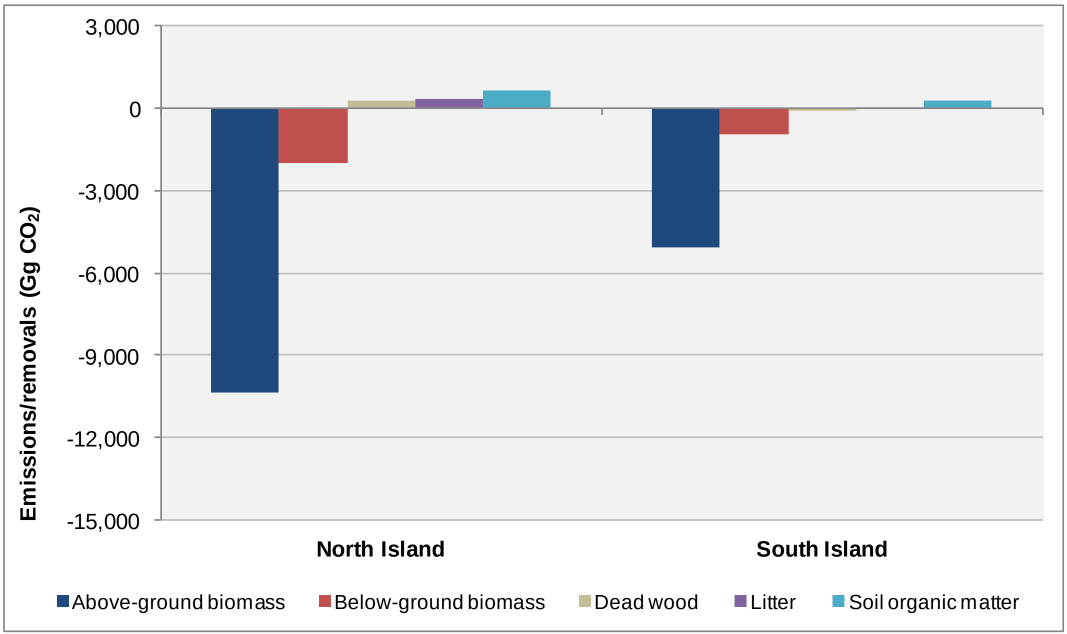
Source	Gross area (ha) 1990–2011	Net area (ha) 2011	Emissions in 2011 (Gg CO_2-e)
Afforestation/reforestation	618,053	599,269	–18,440.1
Forest land not harvested since the beginning of the commitment period (accounting quantity)		598,669	–18,551.5
Forest land harvested since the beginning of the commitment period	2,400	600	111.4
Deforestation	105,512	3,700	1,674.6
Net emissions			**–16,765.5**
Accounting quantity			**–16,876.9**

Note: Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 18,783.8 hectares of land in transition to post-1989 forest that has subsequently been deforested. The 2011 areas are as at 31 December 2011. The accounting quantity is calculated by deducting the emissions from afforestation/reforestation (AR) forest land harvested (ie, by applying the ARDC rule). Columns may not total due to rounding.

Between 1990 and 2011, 618,053 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 29,400 hectares per year (see figure 7.3.1 and table 11.1.1). During 2011, an estimated 12,000 hectares of new forest were planted, an increase from 6,000 hectares in 2010.

Deforestation of all subcategories of forest land (post-1989, pre-1990 planted and natural forest) during 2011 was estimated at 3,700 hectares. Since 1990, the area of deforestation of all subcategories of forest is estimated as 105,512 hectares. This deforestation has resulted in 1,658 Gg CO_2-e emissions for the commitment period so far.

Figure 11.1.1 New Zealand's net CO_2 emissions by carbon pool associated with afforestation, reforestation and deforestation activities in 2011



Note: Emissions shown are the result of changes in carbon stock only and do not include non-CO_2 emissions. Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

A breakdown of New Zealand's net emissions under Article 3.3 of the Kyoto Protocol by greenhouse gas source category is provided in table 11.1.2.

Table 11.1.2 New Zealand's net emissions under Article 3.3 of the Kyoto Protocol by greenhouse gas source category

Greenhouse gas source category	Net emissions in 2011 (Gg) Source form	Source emission	CO_2-equivalent
Carbon stock change	CO_2	–16,787.6	–16,787.6
Disturbance associated with forest conversion to cropland	N_2O	NO	NO
Agricultural lime application on deforested land	C	4.5	16.4
Biomass burning of afforestation/reforestation land	CH_4	0.3	6.0
Biomass burning of afforestation/reforestation land	N_2O	0.002	0.6
Total			**–16,764.5**

Note: NO = not occurring. Columns may not total due to rounding

Nitrous oxide (N_2O) emissions from disturbance associated with forest conversion to cropland are reported as NO (not occurring), as there is a net gain in soil organic carbon with land-use change to cropland using the Intergovernmental Panel on Climate Change (IPCC) default methodology. This would result in New Zealand reporting a net gain in N_2O with disturbance to cropland. NO is reported instead.

New Zealand is not reporting:

- non-CO_2 emissions from controlled burning following deforestation. A survey of planted forest based controlled burning activities was carried out in 2011 but it failed to provide data on this activity (Wakelin, 2012)
- emissions associated with nitrogen fertiliser use on deforested land, as these are reported in the agriculture sector.

Table 11.1.3 Summary of Article 3.3 reporting during CP1

Source	2008	2009	2010	2011
Afforestation/reforestation (AR)				
Net cumulative area since 1990 (ha)	580,765.0	583,964.8	588,769.0	599,269.0
Area in calendar year (ha)	1,900.0	4,300.0	6,000.0	12,000.0
Emissions from AR land not harvested in CP1 (Gg CO_2-e)	–18,199.5	–18,293.6	–18,455.9	–18,551.5
Emissions from AR land harvested in CP1 (Gg CO_2-e)	82.4	96.2	106.1	111.4
Emissions in calendar year (Gg CO_2-e)	**–18,117.1**	**–18,197.3**	**–18,349.8**	**–18,440.1**
Deforestation				
Net cumulative area since 1990 (ha)	95,937.3	99,195.9	101,811.9	105,511.9
Area in calendar year (ha)	3,467.0	3,259.0	2,616.0	3,700.0
Emissions in calendar year (Gg CO_2-e)	1,586.2	1,368.1	1,029.4	1,674.6
Total area subject to afforestation, reforestation and deforestation	676,702.3	683,160.8	690,580.9	704,780.9
Net emissions (Gg CO_2-e)	**–16,530.9**	**–16,829.3**	**–17,320.4**	**–16,765.5**
Accounting quantity (Gg CO_2-e)	**–16,613.3**	**–16,925.5**	**–17,426.5**	**–16,876.9**

Note: The areas stated are as at 31 December. They are net areas, that is, areas of afforestation and reforestation that were deforested during the period and are only included in the figures as deforestation. Afforestation/reforestation refers to new forests established since 1 January 1990. Deforestation includes deforestation of natural forest, pre-1990 planted forest and post-1989 forest. Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Columns may not total due to rounding.

Afforestation and reforestation

Between 1990 and 2011, it is estimated that 618,053 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities (table 11.1.3). The net area of post-1989 forest as at the end of 2011 was 599,269 hectares. The net area is the total area of new forest planted since 31 December 1989 minus the deforestation of post-1989 forest since 1 January 1990.

The new planting rate (land reforested or afforested) between 1990 and 2011 was, on average, 29,400 hectares per year. While new planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year), the rate of new planting declined rapidly from 1998 and reached a low of 1,900 hectares in 2008. The planting rate has slowly recovered over the past three years, with an estimated 4,300 hectares in 2009, 6,000 hectares in 2010 and 12,000 hectares in 2011.

Table 11.1.4 New Zealand's estimated annual net area of afforestation/ reforestation since 1990

Year	Annual area of post-1989 forest (ha)			
	New forest planting	Harvesting	Deforestation	Net cumulative area
1990	13,812	0	0	13,812
1991	13,462	0	0	27,274
1992	43,883	0	0	71,157
1993	53,848	0	0	125,005
1994	85,859	0	0	210,864
1995	64,470	0	0	275,334
1996	73,276	0	0	348,610
1997	55,761	0	0	404,371
1998	44,657	0	0	449,028
1999	34,767	0	0	483,795
2000	29,127	0	0	512,922
2001	26,148	0	0	539,069
2002	19,127	0	721	557,475
2003	17,212	0	2,273	572,413
2004	9,084	0	2,089	579,409
2005	5,136	200	2,376	582,168
2006	2,225	600	2,037	582,357
2007	2,000	600	4,889	579,468
2008	1,900	600	603	580,765
2009	4,300	600	1,100	583,965
2010	6,000	600	1,196	588,769
2011	12,000	600	1,500	599,269
Total	**618,053**	**3,800**	**18,784**	**599,269**

Note: Columns may not total due to rounding.

In 2008 and 2009, the New Zealand Government introduced legislation and government initiatives to encourage forest establishment and discourage deforestation of planted forests. These include:

- Climate Change Response Act 2002 (amended 8 December 2009)
- East Coast Forestry Project (Ministry of Agriculture and Forestry, 2007)
- Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008a)
- Hill Country Erosion Programme (Ministry of Agriculture and Forestry, 2008b)
- Afforestation Grant Scheme (Ministry of Agriculture and Forestry, 2009b).

The New Zealand Emissions Trading Scheme (NZ ETS) has been introduced under the Climate Change Response Act 2002. Forest land was introduced into the scheme on 1 January 2008. Under the scheme, owners of post-1989 forest land may voluntarily participate in the NZ ETS and receive emission units for any increase in carbon stocks in their forests from 1 January 2008.

New Zealand's post-1989 forests are described in further detail in section 7.2.

Deforestation

In 2011, deforestation emissions were 1,674.6 Gg CO_2-e, compared with 1029.4 Gg CO_2-e in 2010, 1,368.1 in 2009 and 1,586.2 Gg CO_2-e in 2008. These emissions are from the carbon stock loss caused by deforestation since 1990 that occurred in each year.

The estimated area of deforestation reported in 2011 was 3,700 hectares, higher (41.4 per cent) than the 2,616 hectares reported in 2010, and the higher deforestation emissions reported in 2011 reflect this. The 2011 deforestation area estimate is based on a range of data as described in section 7.2.3 and will be updated in next year's submission when deforestation mapping is completed for 2008–2012.

Table 11.1.5 shows the areas of forest land subject to deforestation since 1990, by forest subcategory, and total emissions from deforestation in 2011.

Table 11.1.5 New Zealand's forest land subject to deforestation in 2011, and associated emissions from carbon stock change

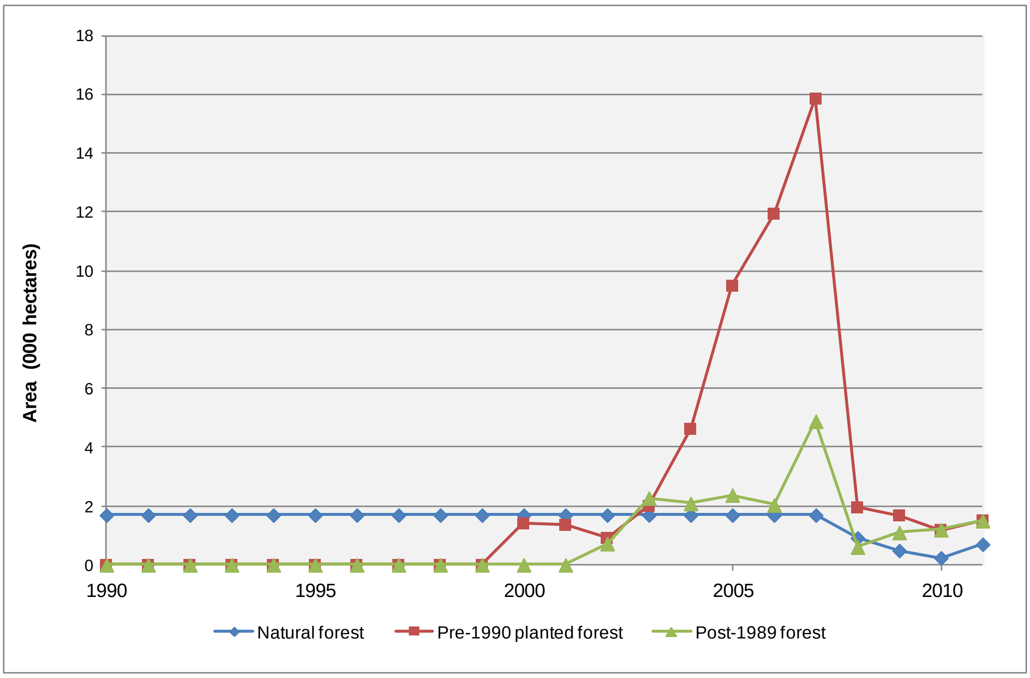
		Area of deforestation (ha)			
Forest land subcategory	**Since 1990**	**2008**	**2009**	**2010**	**2011**
Natural forest	32,826	919	487	240	700
Pre-1990 planted forest	53,902	1,945	1,672	1,180	1,500
Post-1989 forest	18,784	603	1,100	1,196	1,500
Total	**105,512**	**3,467**	**3,259**	**2,616**	**3,700**
Emissions from carbon stock change (Gg CO_2)		1,586.2	1,368.1	1,029.4	1,674.62

Note: 2008, 2009, 2010 and 2011 areas as at 31 December. Columns may not total due to rounding.

Figure 11.1.2 shows the annual areas of deforestation since 1990, by forest subcategory. This illustrates the increase in pre-1990 planted forest deforestation that occurred in the four years leading up to 2008.

While the conversion of land from one land use to another is not uncommon in New Zealand, plantation forest deforestation on the scale seen between 2004 and 2008 was a new phenomenon. Most of the area of planted forest that was deforested from the mid-2000s onwards has subsequently been converted to grassland. This conversion is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry, as well as to the anticipated introduction of the NZ ETS.

Figure 11.1.2 New Zealand's annual areas of deforestation from 1990 to 2011



There are no emissions from deforestation of pre-1990 planted forest or post-1989 forest estimated before 2000 as this activity was not significant and insufficient data exists to reliably report the small areas of deforestation that may have occurred.

Since the introduction of the NZ ETS in 2008, owners of pre-1990 planted forest are now able to deforest a maximum of 2 hectares in any five-year period without having to surrender emission units. Above this level of deforestation, they are required to surrender units equal to the reported emissions, with some exemptions for smaller forest owners (Ministry of Agriculture and Forestry, 2009b). This led to a significant reduction in the rate of deforestation of pre-1990 planted forest since the inception of the scheme. Post-1989 forest owners who are registered in the scheme also have legal obligations to surrender units if the carbon stocks in their registered forest area fall below a previously reported level (for example, due to deforestation, harvesting or fire). However, since the introduction of the NZ ETS, the carbon price has continued to fall. It is possible that the current low carbon price will result in increased pre-1990 planted forest deforestation by reducing the liability to forest owners in the NZ ETS.

The area of deforestation of natural forests prior to 2008 has been estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. As there was no quantitative information on the annual rate of natural forest deforestation between 1990 and 2007, the same annual rate of change was assumed for the entire period (1,693 hectares per year). However, a number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007, but instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before amendments were made to the Forests Act 1949 in 1993. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand from that time on. Both of these developments are likely to have reduced natural forest deforestation since 2002.

The estimated rate of natural forest deforestation has decreased since the start of the commitment period through to 2010. This reduced rate of natural forest deforestation has been confirmed in 2008, 2009 and 2010 through satellite image mapping of deforestation (see figure 7.2.5 under land-use mapping for details of the mapping process).

It is estimated that the rate of natural forest deforestation was still relatively low in 2011. However, the clearing of tree-weeds, which are predominately self-sown exotic species such as *Pinus contorta*, is likely to have increased the total natural forest deforestation. Under the NZ ETS, applications can be made for exemption from deforestation liabilities in order to clear tree-weeds, but these exemptions will lapse if the clearing is not completed prior to the end of 2012. It is therefore anticipated that this type of activity may occur in 2011 and 2012 and may lead to a small increase in natural forest deforestation in these two years.

Deforestation in New Zealand is described more fully in sections 7.2.3, 11.3.1 and 11.4.2.

11.1.1 Definitions of forest and any other criteria

New Zealand has used the same forest land definition as for the LULUCF sector under the Climate Change Convention reporting (chapter 7) and as defined in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). Table 11.1.6 provides the defining parameters for forest land.

Table 11.1.6 Parameters defining forest in New Zealand

Forest parameter	Kyoto Protocol range	New Zealand selected value
Minimum land area (ha)	0.05–1	1
Minimum crown cover (%)	10–30	30
Minimum height (m)	2–5	5

Note: The range values represent the minimum forest definition values as defined under the Kyoto Protocol, decision 16/CMP.1.

New Zealand also uses a minimum forest width of 30 metres, which removes linear shelterbelts from the forest category. The width and height of linear shelterbelts can vary, because they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely cropland and grassland as shelter to crops and/or animals.

The definition used for reporting to the Food and Agriculture Organization is different from that used for Climate Change Convention and Kyoto Protocol reporting. New Zealand has not adopted a formal definition of forest type for reporting to the Food and Agriculture Organization. New Zealand has instead used the international definition proposed in the United Nations Economic Commission for Europe/Food and Agriculture Organization *Temperate and Boreal Forest Resources Assessment 2000*: "…an association of trees and other vegetation typical for a particular site or area and commonly described by the predominant species, for example, spruce/fir/beech" (UNECE/FAO, 2000). For reporting to the Food and Agriculture Organization, New Zealand subdivided forests into two estates based on their biological characteristics, the management regimes applied to the forests and their respective roles and national objectives (Ministry of Agriculture and Forestry, 2002). The two estates are indigenous and planted production forest. The former estate largely equates to natural forest as reported in this submission, and the latter largely equates to pre-1990 planted forest and post-1989 forest. There is an overlap where post-1989 forest has been established with native species or is the result of growth of native species following a change in management regime, for example, retirement of pasture land.

11.1.2 Elected activities under Article 3.4

As stated in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol for the first commitment period.

11.1.3 Implementation and application of activities under Article 3.3

The area of afforestation/reforestation reported under the Kyoto Protocol is equal to the net area of post-1989 forest reported for land-use change to forest land reported in the LULUCF sector. Between 1990 and 2011, 618,053 hectares were reforested and 12,000 hectares of this occurred in 2011. Of the total area afforested or reforested between 1990 and 2011, an estimated 18,784 hectares were deforested between 1990 and 2011. Once an area has been identified as deforested it remains in this category for the first commitment period. Therefore, all subsequent stock changes and emissions and removals on this land are reported against units of land deforested.

Tracking of these deforestation areas during the calculation and land-use mapping processes (annex 3.2) ensures that land areas, once deforested, cannot be reported as afforestation or reforestation land and that the emissions and removals are reported under the land use the area is converted to.

New Zealand has chosen to account for all activities under Article 3.3 of the Kyoto Protocol at the end of the commitment period (Ministry for the Environment, 2006).

11.2 Land-related information

11.2.1 Spatial assessment unit

New Zealand is mapping land use to 1 hectare.

11.2.2 Methodology for land transition matrix

Mapping of land use as at the start of 1990 and of 2008 focused on the classes containing woody biomass (natural forest, pre-1990 planted forest, post-1989 forest and grassland with woody biomass). Satellite imagery was used to map woody classes as at 1 January 1990 and 1 January 2008. The mapping of land-use change prior to 2008 was based on these maps, high-resolution photography and field visits.

For 2008 and 2009, deforestation was mapped across all of New Zealand from 22-metre resolution DMC satellite imagery. For 2010, only a partial mapping was completed based on higher resolution 10-metre SPOT satellite imagery. Deforestation occurring in the unmapped areas was estimated based on the spatial distribution of deforestation that was observed in 2008 and 2009.

The use of higher resolution imagery for 2010 mapping highlighted that there were areas of 2008 and 2009 deforestation that had been missed in the earlier mapping activity. These areas were added to the deforestation totals for 2008 and 2009, and a further estimate was made of the remaining area of unmapped 2008 and 2009 deforestation that has occurred outside the area covered by high-resolution SPOT satellite imagery.

Deforestation occurring in 2011 has been estimated from a range of data sets as described in section 7.2.3. These estimates will be updated when national deforestation mapping for 2008–2012 is completed next year.

For the 2008, 2009, 2010 and 2011 years, afforestation was estimated from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2012). For the non-forest land uses, change was estimated based on the average annual change between 1 January 1990 and 1 January 2008. This is further explained in section 7.2.

Land-use change during the first commitment period will be confirmed following mapping at the end of 2012.

11.2.3 Identifying geographical locations

New Zealand has used Reporting Method 1 for preparing estimates of emissions and removals from afforestation, reforestation and deforestation, and has used a combination of Approaches 2 and 3 to map land-use change.

The geographic units chosen by New Zealand to report by are: the North Island, including Great Barrier and Little Barrier Islands; and the South Island, including Stewart Island, the Chatham Islands and New Zealand's offshore islands.

New Zealand's uninhabited offshore islands include the Kermadec Islands, Three Kings Islands and the sub-Antarctic Islands (Auckland Islands, Campbell Island, Antipodes Islands, Bounty Islands and Snares Islands) and are reported in a steady state of land use. These protected conservation areas total 74,052 hectares and are not subject to land-use change.

11.3 Activity-specific information

11.3.1 Carbon stock change and methods

Description of the methodologies and the underlying assumptions used

The methodologies and assumptions used for reporting under the Kyoto Protocol Article 3.3 activities are the same as those used for Climate Change Convention reporting and are described fully in chapter 7.

Carbon stock change

Emissions and removals from afforestation, reforestation and deforestation are determined using plot network based estimates for each subcategory of forest (natural forest, pre-1990 planted forest and post-1989 forest). Carbon analyses are performed to estimate the carbon per hectare per pool and are described in section 7.3.2.

Natural forest deforestation has been further sub-classified according to species composition, to identify the proportion of deforestation that was tall forest as opposed to younger or immature natural forest (shrubland that has the potential to meet the forest definition) areas (table 11.3.1). This has been determined using the ECOSAT spatial layer, which enables more accurate reporting of the dominant natural forest species within the deforested area, resulting in more accurate emission factors. For further information on the ECOSAT layer refer to: www.landcareresearch.co.nz/services/informatics/ecosat/about.asp.

Table 11.3.1 New Zealand's areas of natural forest deforestation by sub-classification in 2008, 2009, 2010 and 2011

	Area of natural forest deforestation since 2008 (ha)				
Natural forest sub-classification	**2008**	**2009**	**2010**	**2011**	**Total**
Shrub	838	422	209	616	2,085
Tall forest	81	65	30	84	260
Total	919	487	240	700	2,345
Per cent tall forest (%)	**8.8**	**13.3**	**12.7**	**12.0**	**12.5**

Note: Columns may not total due to rounding

The carbon densities for natural forest and post-1989 forest will be updated following scheduled re-measurement of these forests as described in section 7.3.2.

Following deforestation, carbon on the new land use then accumulates at rates given in table 7.1.4.

Liming

The activity data on lime and dolomite consumption is not attributed to land use subcategories. The activity data is provided for cropland and grassland by Statistics New Zealand. Lime and dolomite are attributed to deforested land by the proportion that this subcategory makes up of the total grassland area. Calculations and methodology are described further in section 7.9.4.

Non-CO_2 emissions

Direct N_2O emissions from nitrogen fertilisation

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions' (CRF 4D). The notation key IE (included elsewhere) is reported in the common reporting format (CRF) tables for the KP-LULUCF sector.

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion of land to cropland. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (GPG-LULUCF, section 3.3.2.3, IPCC, 2003).

With deforestation to cropland, the change in soil organic carbon is estimated to be a net gain. Calculating the net N_2O emissions based on this would result in removals of N_2O

with mineralisation of soil organic matter with land-use change, which is not appropriate, so the notation key NO (not occurring) is reported within the CRF tables instead.

Biomass burning

Non-CO_2 emissions from wildfires in land converted to forest land are reported under the post-1989 forest subcategory. The activity data does not distinguish between forest land subcategories; therefore, non-CO_2 emissions resulting from wildfire are attributed to the post-1989 forest subcategory by the proportion of area the post-1989 forest makes up of the total planted forest area. An age-based carbon yield table is then used to estimate non-CO_2 emissions in post-1989 forest. This approach assumes that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age each year throughout the time series (Wakelin, 2011). Carbon dioxide emissions resulting from wildfire events are not reported, as the methods applied do not capture subsequent regrowth (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003).

For calculating the emissions from controlled burning, New Zealand assumes that 20 per cent of grassland with woody biomass converted to forest land is cleared using controlled burning. This burning proportion was recently updated by a survey of forest owners and managers carried out to estimate controlled burning activity on forest land in New Zealand (Wakelin, 2012).

Research investigating sources of activity data on controlled burning practices on harvested post-1989 forest land failed to provide data on the activity (Wakelin, 2012). Expert opinion suggests that controlled burning of post-harvest residues on post-1989 forest land does not occur due to the nature of harvest in short rotation forest grown for pulp (where most biomass is removed from the site).

Conversions of planted forest land to grassland (pasture) have increased between 2004 and 2008. A survey of planted forest based controlled burning activities was carried out in 2011 but it failed to provide data on burning associated with this activity (Wakelin, 2012).

Justification when omitting any carbon pool or greenhouse gas emissions from activities under Article 3.3 and elected activities under Article 3.4

New Zealand has accounted for all carbon pools from activities under Article 3.3. New Zealand has not elected any activities under Article 3.4 for the first commitment period.

New Zealand has not estimated methane or N_2O emissions from controlled burning on land subject to deforestation under Article 3.3, as there is currently no data on this activity. A survey of planted forest based controlled burning activities was carried out in 2011 but it failed to provide data on burning associated with this activity (Wakelin, 2012).

Direct N_2O emissions from the application of nitrogen fertiliser to land subject to afforestation and reforestation are reported as IE (included elsewhere), as these emissions are reported in the agriculture sector under the category ‘direct soils emissions’.

Factoring out information

New Zealand does not factor out emissions or removals from:

- elevated carbon dioxide concentrations above pre-industrial levels

- indirect nitrogen deposition
- the dynamic effects of age structure resulting from activities prior to 1 January 1990.

Recalculations

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission to incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed in sections 7.1, 7.2 and chapter 10. The impact of the recalculations on New Zealand's 2010 Kyoto Protocol estimates is shown in table 11.3.2.

Table 11.3.2 Impact of the recalculations of New Zealand's net emissions under Article 3.3 of the Kyoto Protocol in 2010

Activity under Article 3.3 of the Kyoto Protocol	2010 net emissions ($Gg\ CO_2$-e) 2012 submission	2013 submission
Afforestation/reforestation	–19,357	–18,350
Forest land not harvested since the beginning of the commitment period	–19,512	–18,456
Forest land harvested since the beginning of the commitment period	155	106
Deforestation	1,050	1,029
Total	–18,307	–17,320

Note: Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

The largest factor influencing the recalculations results from the correction of an error that was detected following last year's inventory submission. In the 2012 submission, New Zealand applied an updated version of the Forest Carbon Predictor (FCPv3) to improve the post-1989 planted forest yield table. However, an error occurred in the calculation process that affected the results derived from the updated yield table. Last year's estimates of carbon stock and change in post-1989 forests were over estimated due to this error. The error has been corrected in the calculation process for this year's estimates.

Table 11.3.3 Recalculations to New Zealand's 2010 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2010 areas (ha) 2012 submission	2013 submission	Change from 2012 submission (%)
Afforestation/reforestation	593,821	588,769	–0.9
Forest land not harvested since the beginning of the commitment period	592,021	586,969	–0.9
New planting	6,000	6,000	0.0
Forest land harvested since the beginning of the commitment period	1,800	1,800	0.0
Deforestation	2,616	2,616	0.0
Natural forest	240	240	0.0
Pre-1990 planted forest	1,157	1,180	2.0
Post-1989 forest	1,220	1,196	–1.9

Uncertainty and time-series consistency

The uncertainty in net emissions from afforestation and reforestation is 17.6 per cent, based on the uncertainty in emissions from post-1989 forest (refer to table 11.3.4 for further details). The uncertainty in emissions from deforestation units is determined by the type of forest land deforested. This may be natural forest, pre-1990 forest or post-1989 forest (refer to table 11.3.4 for further details). Further detail on the uncertainty in emissions for natural forest, pre-1990 forest and post-1989 forest is provided in section 7.3.

Table 11.3.4 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2011

Variable	Uncertainty (%) at a 95% confidence interval			
	Afforestation/ reforestation	Deforestation		
Land-use subcategory	Post-1989 forest	Natural forest	Pre-1990 forest	Post-1989 forest
Activity data				
Uncertainty in land area	7.0	7.0	7.0	7
Emission factors				
Uncertainty in biomass carbon stocks	10.2	3.6	14.1	10
Uncertainty in soil carbon stocks	95.0	95.0	95.0	95
Uncertainty introduced into net emissions for Koyoto Protocol	**17.6**	**0.4**	**2.6**	**1.2**

Note: All land that has been afforested/reforested since 1 January 1990 is defined as post-1989 forest. Land deforested since 1 January 1990 may be natural forest, pre-1990 forest or post-1989 forest.

Total uncertainty in New Zealand's 2011 estimates from afforestation, reforestation and deforestation are shown in table 11.3.5.

Table 11.3.5 Total uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2011

Variable	Uncertainty (%) at a 95% confidence interval
Afforestation/reforestation uncertainty introduced into net emissions for Koyoto Protocol	17.6
Deforestation uncertainty introduced into net emissions for Koyoto Protocol	2.9
Total uncertainty for Kyoto Protocol	**17.8**

Other methodological issues

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, to be consistent with IPCC (2003) and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans were established for each type of data used to determine carbon stock and stock changes, as well as the areal extent and spatial location of land-use changes. All data was subject to an independent and documented quality-assurance process. Data validation rules and reports were established to ensure that all data is fit-for-purpose and is of consistent and known quality, and that data quality continues to be improved over time. The data used to derive the country-specific yield tables and average carbon values has also undergone quality assurance as described in section 7.3.4.

Year of the onset of an activity

Paragraph 18 of the annex to 16/CMP.1 (land use, land-use change and forestry) requires that New Zealand account for emissions and removals from Article 3.3 activities beginning with the onset of the activity or the beginning of the commitment period, whichever is later. In practical terms, paragraph 18 means there is a need to differentiate activities that occurred between 1 January 1990 and 31 December 2007 from those after this period.

During 2011, an estimated 12,000 hectares of post-1989 forest were established and 3,700 hectares of forest (natural forest, pre-1990 planted forest and post-1989 forest) were deforested.

The afforestation area is estimated from the *National Exotic Forest Description* survey, the Afforestation Grants Scheme and the East Coast Forestry Project (Ministry of Agriculture and Forestry, 2012). This information ensures that the activity is attributed to the correct year of onset.

The deforestation area is based on a combination of estimates, mapping from satellite imagery acquired in the summers of 2009–2010, 2010–2011 and 2011–2012, and oblique aerial photography. Where deforestation is detected in satellite imagery, other earlier imagery sources such as Landsat 7 are used to determine the date of clearance that corresponds to the onset of the activity. Where estimates are used, they are based on annual survey data (eg, *National Exotic Forest Description* and *Deforestation Intentions Survey*) and deforestation trends from previous years. Therefore the year of onset of the activity is clearly defined.

11.4 Article 3.3

11.4.1 Demonstration that activities apply

The United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines require that countries provide information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and that these activities are directly human-induced.

All land in New Zealand is under some form of management and management plan. Land is managed for a variety of reasons, including agriculture and/or forestry production, conservation, biodiversity, fire risk management (eg, fire breaks) and scenic and cultural values. Most land-use changes occur in agriculture and forestry landscapes. All land-use change, including deforestation, is therefore a result of human decisions to either change the vegetation cover and/or change the way land is managed. The only notable exception to this is the loss of natural forest due to erosion, which can be a non-anthropogenic land-use change.

New Zealand has used satellite imagery collected around the start of 1990 and 2008 to detect changes in land use between these two periods.

To estimate land-use change in 2008, 2009, 2010 and 2011, Land Use and Carbon Analysis System (LUCAS) mapping was augmented with data from the Ministry for Primary Industries Afforestation Grants Scheme, the NZ ETS and the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2012). This was used to estimate afforestation and reforestation during 2011. Deforestation occurring during 2008, 2009 and 2010 was mapped and estimated from satellite imagery (see section 7.2.2). Where non-anthropogenic destocking was identified during deforestation mapping it was delineated but not reported as deforestation.

Following the mapping of land use at the end of 2012, New Zealand will recalculate the area of land-use change due to afforestation, reforestation and deforestation during the first commitment period.

11.4.2 Distinction between harvesting and deforestation

The UNFCCC reporting guidelines require that countries provide information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation.

New Zealand has used the IPCC (2003) definition of deforestation: "Deforestation is the direct human-induced conversion of forested land to non-forested land". Deforestation is different from harvesting, in that harvesting is part of usual forest management practice and involves the removal of biomass from a site followed by reforestation (replanting or natural regeneration, ie, no change in land use).

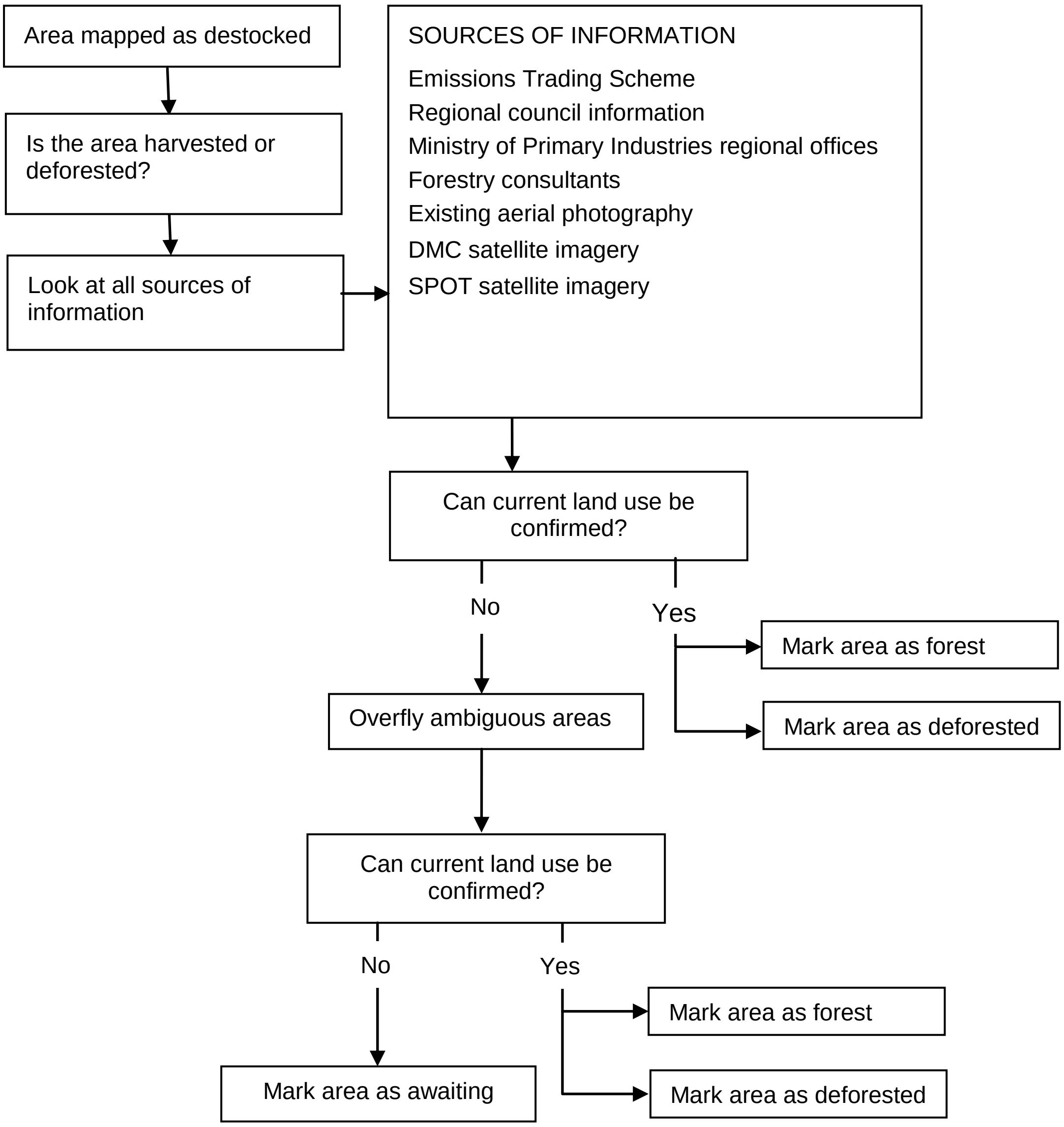
In New Zealand, temporarily unstocked or cleared areas of forest (eg, harvested areas and areas subject to disturbances) remain designated as forest land unless there is a confirmed change in land use or if, after four years, no reforestation (replanting or regeneration) has occurred. The four-year time period was selected because, in New Zealand, the tree grower and landowner are often different people. Forest land can be temporarily unstocked for a number of years while landowners decide what to do with land after harvesting.

Prior to the four-year time period, there are a number of activities that will be carried out to determine if land-use change has occurred, including the analysis of satellite imagery and oblique aerial photography. The use of oblique aerial photography is described in section 7.2.

Evidence from the NZ ETS is also used to confirm deforestation. Under the NZ ETS, owners of pre-1990 planted forest and owners of post-1989 forest who are participants in the scheme are required to notify the Government of any deforestation activity (Ministry of Agriculture and Forestry, 2009a). There is a data-sharing agreement that the Ministry for Primary Industries, the agency that administers the forestry aspects of the NZ ETS, will provide the Ministry for the Environment with regular updates of the area of confirmed deforestation.

A summary of the decision-making process for determining whether deforestation has occurred, including all sources of information, is shown in figure 11.4.1. Once a land-use change is mapped and confirmed, the deforestation emissions will be reported in the year of forest clearance.

Figure 11.4.1 Verification of deforestation in New Zealand



Note: DMC = Disaster Monitoring Constellation.

Following mapping at the end of 2012, the area of deforestation will be confirmed. To establish the total area of deforestation, including those areas still in transition at the end of 2012, New Zealand will use deforestation information from the NZ ETS, field information from the Ministry for Primary Industries compliance teams, and deforestation intention data from large-scale land-use conversion projects occurring in 2013 on land destocked prior to 2013. Together, these data sets will provide an accurate estimate of the total area of deforestation occurring between 2008 and 2012.

11.4.3 Unclassified deforestation

The UNFCCC reporting guidelines require that countries provide information on the size and geographical location of forest areas that have lost forest cover but that are not yet classified as deforested.

To identify these areas from 2010, deforestation mapping methodology was modified to allow destocked land to be mapped into three classes: Harvested (H), Deforested (D) and Awaiting (A). The awaiting areas are those areas where there is no clear evidence to support harvesting (replanting activity, forestry context) or deforestation (confirmed land-use change, such as pasture establishment, fences and stock). The areas are therefore awaiting a land-use determination.

Wall-to-wall mapping of harvested, deforested and awaiting areas for 2008 to 2012 is currently under way and will be included in next year's submission. Until this data is available, the best estimate of awaiting land is derived from the *2011 Deforestation Intentions Survey* (Manley, 2012). As part of this survey, forest owners are asked to report areas of intended deforestation for each year under a range of policy scenarios including the current policy context – the ETS scenario – and a No ETS scenario where there would be no penalties incurred for deforestation. By comparing the areas reported for these two scenarios, we obtain a measure of the area of land that has been destocked since 2008 but not yet converted to a different land use, that is, awaiting land.

As this survey only covers plantation forestry, no data is currently available to estimate natural forest awaiting land.

Table 11.4.1 Estimate of land destocked in New Zealand between 2008 and 2011 awaiting a land-use determination

	Natural forest	Pre-1990 planted forest and post-1989 forest	Total
2011 Awaiting land (ha)	NE	13,000	13,000

Note: NE = not estimated.

11.5 Article 3.4

New Zealand has not elected any activities under Article 3.4 of the Kyoto Protocol (Ministry for the Environment, 2006).

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities

Conversion to forest land (afforestation and reforestation) and conversion to grassland (deforestation) are key categories in both the level and trend analysis.

11.7 Information relating to Article 6

New Zealand is not involved in any LULUCF activities under Article 6 of the Kyoto Protocol.

Chapter 11: References

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Chapter 12: Information on accounting of the Kyoto Protocol units

12.1 Background information

Assigned amount and commitment period reserve

In January 2008 New Zealand's national registry was issued with New Zealand's assigned amount of 309,564,733 metric tonnes of carbon dioxide equivalent (CO_2-e).

The commitment period reserve of 278,608,260 metric tonnes (CO_2-e) is 90 per cent of the assigned amount, fixed after the initial review in 2007.

Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (table 12.2.2). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment website (www.mfe.govt.nz/ publications/climate/).

General note

Abbreviations used in this chapter include:

AAUs	Assigned Amount units
ERUs	Emission Reduction units
RMUs	Removal units
CERs	Certified Emission Reduction units
tCERS	Temporary Certified Emission Reduction units
ICERs	Long-term Certified Emission Reduction units
NZEUR	New Zealand Emission Unit Register
CDM	Clean Development Mechanism
NO	Not Occuring

Abbreviations used in *table 2b Annual external transactions* in table 12.2.2 in the column 'Transfers and acquisitions':

AT	Austria
AU	Australia
CDM	Clean Development Mechanism
CH	Switzerland
DE	Germany
ES	Spain
EU	European Union
FR	France
GB	United Kingdom of Great Britain and Northern Ireland
JP	Japan
NL	Netherlands
Sl	Slovenia

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2012, New Zealand's national registry held 306,248,485 assigned amount units, 530,346 emissions reduction units, 2,935,654 certified emission reduction units and 3,900,000 removal units (table 1 in table 12.2.2).

At the end of 2012, there were 306,041,662 assigned amount units, 16,153,534 emission reduction units, 8,680,399 certified emission reduction units and 9,050,000 removal units held in the New Zealand registry (table 4 in table 12.2.2).

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2012 (table 4 in table 12.2.2).

The transactions made to New Zealand's national registry during 2012 (tables 2(a), (b), (c) in table 12.2.2) are summarised below:

- 1 assigned amount unit was added to New Zealand's national registry from the United Kingdom of Great Britain and Northern Ireland. Of the assigned amount units, 3,001 were subtracted from the registry and were transferred to Switzerland (3,000) and the United Kingdom of Great Britain and Northern Ireland (1)
- 16,760,023 emission reduction units were added to New Zealand's national registry and 1,136,835 were subtracted. In respect to New Zealand verified projects under Article 6 of the Kyoto Protocol, 203,823 units were added. The biggest external addition of emission reduction units was 8,046,243 units from the United Kingdom of Great Britain and Northern Ireland. There were five external subtractions of emission reduction units, with the largest being 900,000 to Switzerland. There were no internal subtractions
- 13,638,382 certified emission reduction units were added to New Zealand's national registry and 7,893,637 were subtracted. The greatest addition was 10,309,366 certified emission reduction units from the United Kingdom of Great Britain and Northern Ireland. There were six external subtractions of certified emission reduction units, with the largest being 4,000,000 to Japan. There were no internal transactions
- 5,150,000 removal units were added to New Zealand's national registry. 900,000 removal units were added from France and 4,250,000 removal units were added from the United Kingdom of Great Britain and Northern Ireland. No removal units were subtracted from the New Zealand registry
- there were no transactions of temporary certified emission reduction units and long-term certified emissions reduction units.

During 2012, no Kyoto Protocol units were expired, replaced or cancelled.

Table 12.2.1 New Zealand's submission of the standard electronic format

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The SEF report for 2012 has been submitted to the UNFCCC Secretariat electronically and is included in this section (table 12.2.2).

Table 12.2.2 Copies of the standard report format tables (ie, tables 1–6) from New Zealand's national registry

Party	New Zealand
Submission year	2013
Reported year	2012
Commitment period	1

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	305642697	NO	NO	133150	NO	NO
Entity holding accounts	594582	530346	3900000	2801704	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	11206	NO	NO	800	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	306248485	530346	3900000	2935654	NO	NO

Party New Zealand
Submission year 2013
Reported year 2012
Commitment period 1

Table 2 (a). Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Article 6 issuance and conversion												
Party-verified projects		203823					203823		NO			
Independently verifed 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		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							6797	NO	NO	NO	NO	NO
Sub-total		203823	NO				210620	NO	NO	NO	NO	NO

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

Party	New Zealand
Submission year	2013
Reported year	2012
Commitment period	1

Add registry Delete registry

Table 2 (b). Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Transfers and acquisitions												
AT	NO	NO	NO	NO	NO	NO	NO	17430	NO	NO	NO	NO
AU	NO	NO	NO	1000	NO	NO	NO	NO	NO	50500	NO	NO
CDM	NO	NO	NO	194189	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	4138415	NO	720317	NO	NO	3000	900000	NO	490317	NO	NO
DE	NO	NO	NO	355000	NO	NO	NO	NO	NO	139435	NO	NO
ES	NO	577913	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	2989000	NO	882000	NO	NO	NO	NO	NO	NO	NO	NO
FR	NO	504000	900000	NO	NO	NO	NO	NO	NO	NO	NO	NO
GB	1	8046243	4250000	10309366	NO	NO	1	113891	NO	2064955	NO	NO
JP	NO	NO	NO	1176510	NO	NO	NO	60000	NO	4000000	NO	NO
NL	NO	NO	NO	NO	NO	NO	NO	45514	NO	1148430	NO	NO
SI	NO	300629	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	1	16556200	5150000	13638382	NO	NO	3001	1136835	NO	7893637	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	1	16760023	5150000	13638382	NO	NO	213621	1136835	NO	7893637	NO	NO

Party	New Zealand
Submission year	2013
Reported year	2012
Commitment period	1

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	305283254	4587043	3378146	4285112	NO	NO
Entity holding accounts	740405	11566491	5671854	4394487	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	18003	NO	NO	800	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	306041662	16153534	9050000	8680399	NO	NO

Party	New Zealand
Submission year	2013
Reported year	2012
Commitment period	1

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Issuance pursuant to Article 3.7 and 3.8	309564733											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	309564733	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	120000	NO	25108	NO	NO	120000	NO	NO	15800	NO	NO
Year 2 (2009)	1000	496567	NO	401000	NO	NO	1068018	568469	NO	401000	NO	NO
Year 3 (2010)	1	419880	NO	621002	NO	NO	1120979	447650	NO	100090	NO	NO
Year 4 (2011)	18530	1731931	3900000	4396232	NO	NO	1037988	1221913	NO	1991598	NO	NO
Year 5 (2012)	1	16760023	5150000	13638382	NO	NO	213621	1136835	NO	7893637	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	19532	19528401	9050000	19081724	NO	NO	3560606	3374867	NO	10402125	NO	NO
Total	309584265	19528401	9050000	19081724	NO	NO	3560606	3374867	NO	10402125	NO	NO

Table 5 (b). Summary information on replacement

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

Table 5 (c). Summary information on retirement

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

Party New Zealand
Submission year 2013
Reported year 2012
Commitment period 1

Add transaction | Delete transaction | No corrective transaction

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

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

Add transaction | Delete transaction | No corrective transaction

Table 6 (b). Memo item: Corrective transactions relating to replacement

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

Add transaction | Delete transaction | No corrective transaction

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.3 Discrepancies and notifications

New Zealand has not received any notification of discrepancies, failures or invalid units, as shown in table 12.3.1.

Table 12.3.1 Discrepancies and notifications from New Zealand's national registry

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E, paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2012. For completeness, the report R-2 is included with 'Nil' discrepant transactions during the reporting period.
15/CMP.1 annex I.E, paragraphs 13 & 14: List of CDM notifications	No CDM notifications occurred in 2012. For completeness, the report R-3 is included with 'Nil' CDM notifications for reversal of storage or non-certification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 15: List of non-replacements	No non-replacements occurred in 2012. For completeness, the report R-4 is included with 'Nil' non-replacement transactions during the reporting period.
15/CMP.1 annex I.E, paragraph 1 15: List of invalid units	No invalid units exist as at 31 December 2012. For completeness, the report R-5 is included with 'Nil' invalid units notification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 17: Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

New Zealand's national registry list of publicly accessible information is available at www.eur.govt.nz, 'Search the Register' tab. A list of publicly accessible information is provided in table 12.4.1.

Table 12.4.1 List of the publicly accessible information in New Zealand's national registry

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
44. Each national registry shall make non-confidential information publicly available and provide a publicly accessible user interface through the Internet that allows interested persons to query and view it.			
45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following:			
(a) Account name: the holder of the account.	Yes (refer Search the Register: Accounts).	Up to date (real-time).	N/A
(b) Account type: the type of account (holding, cancellation or retirement).	Yes (refer Search the Register: Accounts).	Up to date (real-time).	N/A
(c) Commitment period: the commitment period within which a cancellation or retirement account is associated.	Yes (refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report).	Up to date (real-time).	N/A
(d) Representative identifier: the representative of the account holder, using the Party identifier (the two-letter country code defined by ISO 3166) and a number unique to that representative within the Party's registry.	No – the representative identifiers for primary representatives are not publicly available and have been withheld for security reasons.	n/a	Section 27(1)(a) of the Climate Change Response Act 2002 does not require this information to be made publicly available. Only the holding account number for each account in the registry is publicly available under this section.
(e) Representative name and contact information: the full name, mailing address, telephone number, facsimile number and email address of the representative of the account holder.	Partial, publication of the personal email addresses, telephone and fax numbers of the representatives has been withheld for security reasons. (Refer Search the Register: Accounts: Click on Account Number, hyperlink to access Account Information Report: Representative Details.)	Up to date (real-time).	Section 13 of the Climate Change Response Act 2002 permits the Registrar to withhold access to the email address and phone and fax numbers of account holder's representatives on the grounds of security or integrity of the registry.

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
46. The information referred to in paragraph 44 shall include the following Article 6 project information, for each project identifier against which the Party has issued ERUs:			
(a) Project name: a unique name for the project.	Yes (refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	N/A
(b) Project location: the Party and town or region in which the project is located.	Yes (refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	N/A
(c) Years of ERU issuance: the years when ERUs have been issued as a result of the Article 6 project.	Yes (this information can be accessed either by clicking on the project ID under the Unit Conversions tab or through the Ministers' Directions menu item. This lists directions relating to the transfer of ERUs to individual Joint Implementation Projects. The NZEUR Unit Holding and Transaction Summary Report shows in aggregate the total ERUs converted from AAUs by year).	Joint Implementation (JI) Projects annually by 31 January for the previous calendar year. Ministers' directions – up to date (real-time).	N/A
(d) Reports: downloadable electronic versions of all publicly available documentation relating to the project, including proposals, monitoring, verification and issuance of ERUs, where relevant, subject to the confidentiality provisions in decision 9/CMP.1.	Partial – this information is published on the Ministry for the Environment website for Joint Implementation Projects at www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on the New Zealand's national registry website (www.eur.govt.nz). The following information for each JI project is published on the Ministry for the Environment website: • project description • non-host Party project approval • annual reports • verification reports. Project proposals are not included as they contain	This information becomes publicly available once New Zealand gives its approval to the JI Project. The information is then updated when necessary and annual reports are added annually.	N/A

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	financial information that is considered to be commercially sensitive and confidential.		
47. The information referred to in paragraph 44 shall include the following holding and transaction information relevant to the national registry, by serial number, for each calendar year (defined according to Greenwich Mean Time):			
(a) The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year.	Partial – aggregate unit holdings of ERUs, CERs, AAUs and RMUs for the previous calendar year are disclosed by 31 January of each year (refer Search the Register: NZEUR Holding & Transaction Summary). Total quantity of unit holdings in each account within the most recent calendar year is considered to be confidential information, therefore, the total quantity of unit holdings in each account provided is only those completed more than one year in the past. (Refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year. 1 January for the beginning of the previous calendar year.	Section 27(2) of the Climate Change Response Act 2002 only requires total holdings of AAUs, ERUs, CERs, ICERs, tCERs and RMUs to be publicly available by 31 January of each year for the previous calendar year). Section 27(3) of the Climate Change Response Act 2002 only requires holdings of Kyoto units by each holding account for the beginning of the previous calendar year to be made publicly available.
(b) The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	N/A

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(c) The total quantity of ERUs issued on the basis of Article 6 projects.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary – Units Converted to).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	N/A
(d) The total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries and the identity of the transferring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year (refer Search the Register: NZEUR Incoming Transactions for the Year). The identity of the individual transferring accounts is not available as it is considered to be confidential information.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	N/A Section 27(j) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred • total quantity and type of unit transferred • the identity of the transferring overseas registries including the total quantity of units transferred from each overseas registry and each type of unit transferred from each overseas registry.
(e) The total quantity of RMUs issued on the basis of each activity under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	N/A
(f) The total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries and the identity of the acquiring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	N/A Section 27(k) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	The identity of the individual acquiring accounts is not available as it is considered to be confidential information.		• total quantity and type of unit transferred • the identity of the acquiring overseas registries including the total quantity of units transferred to each overseas registry and each type of unit transferred to each overseas registry.
(g) The total quantity of ERUs, CERs, AAUs and RMUs cancelled on the basis of activities under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	N/A
(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.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	N/A
(i) The total quantity of other ERUs, CERs, AAUs and RMUs cancelled.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	N/A

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(j) The total quantity of ERUs, CERs, AAUs and RMUs retired.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	N/A
(k) The total quantity of ERUs, CERs and AAUs carried over from the previous commitment period.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year	N/A
(l) Current holdings of ERUs, CERs, AAUs and RMUs in each account.	Partial – aggregate unit holdings of ERUs, CERs, AAUs and RMUs from the previous calendar year are disclosed by 31 January. (Refer Search the Register: NZEUR Kyoto Unit Holdings by Account). Total quantity of unit holdings in each account within the most recent calendar year is considered to be confidential information, therefore, the total quantity of unit holdings in each account provided is only those completed more than one year in the past. (Refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year. 1 January for the beginning of the previous calendar year.	Section 27(2) of the Climate Change Response Act 2002 only requires total holdings of AAUs, ERUs, CERs, ICERs, tCERs and RMUs to be publicly available by 31 January of each year for the previous calendar year. Section 27(3) of the Climate Change Response Act 2002 only requires holdings of Kyoto units by each holding account for the beginning of the previous calendar year to be made publicly available.
48. The information referred to in paragraph 44 shall include a list of legal entities authorised by the Party to hold ERUs, CERs, AAUs and/or RMUs under its responsibility.	Yes (refer Search the Register: Account Holders for list of authorised entities).	Up-to-date (real time).	N/A

12.5 Calculation of the commitment period reserve

New Zealand's commitment period reserve calculation is based on the assigned amount and therefore fixed. The commitment period reserve is 278,608,260 metric tonnes of CO_2-e), 90 per cent of the assigned amount of 309,564,733, fixed after the review of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006).

The commitment period reserve level as at 31 December 2012 is:

Commitment period reserve limit:	278,608,260
Units held:	339,925,595
Commitment period reserve level:	339,925,595
Commitment period reserve level = (% of assigned amount):	109.81%

CPR level comprises of the following units:	
AAUs	306,041,662
ERUs (converted from AAUs)	16,153,534
CERs	8,680,399
RMUs	9,050,000
Total units	339,925,595

New Zealand's commitment period reserve level is also available at: www.eur.govt.nz, and is updated on a daily basis.

Chapter 12: References

Ministry for the Environment. 2006. *New Zealand's Initial Report under the Kyoto Protocol*. Wellington: Ministry for the Environment. Retrieved from www.mfe.govt.nz/publications/climate/new-zealands-initial-report-under-the-kyoto-protocol/index.html (14 July 2011).

Chapter 13: Information on changes to the national system

Development of expertise

New Zealand has continued to develop the expertise of the main inventory contributors. For this submission, additional government experts were trained as the sector leads for the land use, land-use change and forestry (LULUCF), industrial processes and solvent and other product use sectors. One government official passed their inventory reviewer exams under the Climate Change Convention for the energy sector, one government official participated in their first expert review of Annex I inventories (LULUCF sector) and one government official participated as a lead reviewer for the first time in an in-country review. One government official from the Ministry for the Environment took responsibility for the quality control and quality assurance (QA/QC) system for the National Inventory in October 2012 as the national QA/QC manager and coordinator.

Governance

The Terms of Reference for the Reporting Governance Group were reviewed to reflect improved clarity for modelling and projections, updated membership and to specify engagement with wider climate change governance. The next review of the Terms of Reference is due in late 2013.

Quality assurance

New Zealand's QA/QC system became more strongly process-based during 2012. Quality control procedures for each sector have been reviewed and relevant process maps created in consultation with each sector lead. The maps were used for refining sectoral QC processes and procedures.

All sector leads were encouraged to schedule QA audits of their systems at least every five years. The agriculture sector commenced a major QA review of its calculation models with an external party in 2012 (additional details can be found in chapter 6, sections 6.1.4 and 6.1.5). Regular meetings to discuss progress with QA/QC processes and relevant issues with each sector lead have been put in place.

The document 'New Zealand's National Inventory System Guidelines for compiling New Zealand's Greenhouse Gas Inventory' was updated in November 2012 to include post-submission error processing, alert processing and updated maps for the sectoral QC processes and procedures.

Other significant changes to the national system that relate to specific sectors include the following.

- Computerisation of some QC procedures in the waste sector. For example, an excel-based tool has been developed for a complete check of landfill data consistency to replace previously used manual spot-checking. The tool reads and compares data from multiple files and provides user-friendly diagnostics on whether the data compares as well as the scale and source of inconsistencies if they occur.

- Developing VBA-based modelling tool for the agriculture sector (to be completed in 2013).
- Applying a new approach in the energy sector to compare carbon dioxide implied emission factors with respect to the default Intergovernmental Panel on Climate Change (IPCC) range (see section 3.3 for further details).

Data security and recovery

To provide for data security and recovery in the event of disaster for the national inventory files, a distributive strategy for storage is in place. This includes storing the inventory files using different types of storage devices (network drives and physical devices) in different geographical locations. The changes to all files are backed up on a daily basis and the entire system is backed up on a weekly basis.

Chapter 14: Information on changes to the national registry

This chapter contains information required for reporting changes to New Zealand's national registry. The changes made to New Zealand's national registry since the 2012 submission are included in table 14.1.

New Zealand's response to the most recent recommendation made by the expert review team is included in table 14.2.

A list of reference documents included in the submitted zip file 'Chapter 14 2013' is provided in table 14.3.

Table 14.1 Changes made to New Zealand's national registry

Section subheading	New Zealand's response
15/CMP.1 Annex II.E, paragraph 32.(a): Change in the name or contact for the national registry	In 2012, the contact details for the national registry have been changed. Changes have been made to the Main Contact and the Release Manager. Refer to the table 14.4 below for details. The National Focal Point advised UN/ITL of these changes. The changes have taken effect from 02 July 2012.
15/CMP.1 Annex II.E, paragraph 32.(b): Change in cooperation arrangement	No change of cooperation arrangement occurred during the reporting period.
1/CMP.1 Annex II.E, paragraph 32.(c): Change to the database or the capacity of the national registry	No changes to the database or capacity of the national registry occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(d): Change in the conformance to technical standards	No changes to the conformance of technical standards occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(e): Change in the discrepancy procedures	No change of discrepancies procedures occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(f): Change in security	No changes occurred under the security during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(g): Change in the list of publicly available information	Changes were made to the publically available information reported on the New Zealand Registry website. The cellphone, telephone and fax numbers of account holders were removed for security reasons. These changes were introduced on 25 October 2012 as allowed under section 13 of the Climate Change Response Act 2002, which permits the Registrar to withhold access to email addresses and phone and fax numbers of account holders.
15/CMP.1 Annex II.E, paragraph 32.(h): Change to the internet address	No change of the registry internet address occurred during the reporting period. The internet address is www.eur.govt.nz.
15/CMP.1 Annex II.E, paragraph 32.(i): Change to the data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 Annex II.E paragraph 32.(j): Change of the test results	No changes occurred in the test results during this reporting period. New Zealand successfully completed the commitment period two (CP2) Annex H testing in its testing environment on 13 December 2012 in accordance with the International Transaction Log (ITL) initial testing period between 11 and 14 December 2012.

Table 14.2 Previous recommendations for New Zealand from the expert review team

Previous annual review recommendations	New Zealand addressed the recommendation as follows
2011 Standard Independent Assessment Report (SIAR)	No recommendations were made that require a response from the New Zealand national registry.

Table 14.3 Reference documents list – all zipped under 'Chapter 14 2013.zip'

ID	Document name	Document description
1	Document 14.3.1	RSA Change Form

Table 14.4 Contact details

Organisation designated as the administrator of New Zealand's national registry	Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 462 4289 Fax: +64 4 978 3661 Web: www.epa.govt.nz
Main contact	Guy Windley Team Leader, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5514 Fax: +64 4 978 3661 Email: guy.windley@epa.govt.nz
Alternative contact	Andrea Gray General Manager, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 910 9239 Fax: +64 4 978 3661 Email: andrea.gray@epa.govt.nz
Release Manager	Janine Manhart Senior Analyst, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5510 Fax: +64 4 978 3661 Email: janine.manhart@epa.govt.nz

Chapter 15: Information on minimisation of adverse impacts

This chapter provides information on New Zealand's implementation of policies and measures that minimise adverse social, environmental and economic impacts on non-Annex I Parties, as required under Article 3.14 of the Kyoto Protocol.

Most of this information is the same or very similar to that provided in the 2012 submission. However, some revised information is provided for the following:

- further information on market imperfections, fiscal incentives, tax and duty exemptions and subsidies (see section 15.2)
- information on capacity-building workshop around fossil fuel subsidy reform (see section 15.2)
- further information on solar energy electricity project on Tokelau (see section 15.6).
- information on New Zealand's involvement in activities to provide assistance to non-Annex I Parties that are dependent on the export and consumption of fossil fuels in diversifying their economies (see section 15.7).

15.1 Overview

New Zealand's Cabinet and legislative processes to establish and implement climate change response measures include consultation with the Ministry of Foreign Affairs and Trade and with members of the public. The Ministry of Foreign Affairs and Trade provides advice to the Government on international aspects of proposed policies. During the public consultation phase, concerns and issues about the proposed measure can be raised by any person or organisation.

Through the New Zealand Government's regular trade, economic and political consultations with other governments, including some non-Annex I Parties, there are opportunities for those who may be concerned about the possible or actual impacts of New Zealand policies to raise concerns and have them resolved within the bilateral relationship. To date, there have been no specific concerns raised about any negative impact of New Zealand's climate change response policies.

The New Zealand Government, through the New Zealand Aid Programme (www.aid.govt.nz), has regular Official Development Assistance programming talks with partner country governments, where partners have the opportunity to raise concerns about any impacts and to ask for or prioritise assistance to deal with those impacts. From these discussions, New Zealand works closely with the partner country to prepare a country strategic framework for development. These engagement frameworks are relatively long term (five or 10 years) and convey New Zealand's development assistance strategy in each country in which it provides aid. They are aligned to the priorities and needs of the partner country, while also reflecting New Zealand's priorities and policies.

On many of the issues related to the implementation of Article 3.14, New Zealand gives priority to working with countries broadly in the Pacific region. The New Zealand Aid Programme also works with partner developing countries to strengthen governance and improve their ability to respond to changing circumstances.

Climate change, including adaptation and finance, was a key part of discussions by leaders at the 42nd Pacific Island Forum meeting hosted by New Zealand, in September 2011. Climate change continues to be a focus for the Forum, and New Zealand continues to work with other Forum members in a wide range of technical, economic and political fields, addressing the climate change concerns raised by leaders.

New Zealand maintains a liberalised and open trading environment, consistent with the principles of free trade and investment, ensuring that both developed and developing countries can maximise opportunities in New Zealand's market regardless of the response measures undertaken.

15.2 Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

Annex I Parties are required to report any progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

New Zealand does not have any inefficient market imperfections, fiscal incentives, tax and duty exemptions or subsidies in greenhouse-gas-emitting sectors of this nature.

New Zealand has been working in a number of international fora to promote the global reform of inefficient fossil fuel subsidies. For example, New Zealand is helping to build capacity for the reform of inefficient fossil fuel subsidies within Asia-Pacific Economic Cooperation (APEC) member economies. New Zealand co-hosted awareness-raising workshops with the United States at both energy official and senior official levels in 2011, and will co-host a capacity-building workshop in March 2013. The 2013 workshop will be aimed primarily at energy officials from APEC economies and will focus on building support for reform through effective communication and consultation strategies.

New Zealand volunteered to be one of the first economies to present a submission under APEC's fossil fuel subsidy reform voluntary reporting mechanism in November 2012 (along with the United States, Canada and Thailand). In line with New Zealand's commitment to transparency, we reported all policy measures that directly or indirectly support fossil fuels. New Zealand's submission drew on information published by the Organisation for Economic Co-operation and Development (OECD) in its 2011 *Inventory of Estimated Budgetary Support and Tax Expenditures Relating to Fossil Fuels in Selected OECD Countries*. The OECD has not yet made any assessment of which support measures in its inventory might constitute inefficient subsidies. The New Zealand Government has reviewed the measures listed in its submission and is satisfied that they are efficiently achieving relevant policy objectives.

New Zealand is a member of 'the Friends of Fossil Fuel Subsidy Reform', an informal group of non-G20 countries that encourages and supports the G20 countries to meet their commitments to reform inefficient fossil fuel subsidies. The group's support for reform is based on the essential notion that it is incoherent to continue to underwrite the costs of emissions from fossil fuels at the same time as making concerted efforts to mitigate those emissions through actions elsewhere.

15.3 Removal of subsidies

Annex I Parties are required to report information concerning the removal of subsidies associated with the use of environmentally unsound and unsafe technologies. New Zealand does not have any subsidies of this nature.

15.4 Technological development of non-energy uses of fossil fuels

Annex I Parties are required to report on cooperation in the technological development of non-energy use of fossil fuels and support provided to non-Annex I Parties. The New Zealand Government has not actively participated in activities of this nature as yet.

15.5 Carbon capture and storage technology development

Annex I Parties are required to report on cooperation in the development, diffusion and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouragement of their wider use; and on facilitating the participation of non-Annex I Parties.

New Zealand is a member of the United States-led Carbon Sequestration Leadership Forum (www.cslforum.org), the Australian-led Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC – www.co2crc.com.au), Global Carbon Capture and Storage Institute (www.globalccsinstitute.com) and the International Energy Agency Greenhouse Gas Research and Development Programme (www.ieaghg.org).

15.6 Improvements in fossil fuel efficiencies

Annex I Parties are required to report how they have strengthened the capacity of non-Annex I Parties identified in Article 4.8 and 4.9 of the Climate Change Convention, by improving the efficiency in upstream and downstream activities related to fossil fuels and by taking into consideration the need to improve the environmental efficiency of these activities.

An example is New Zealand's commitment to a major energy programme in Tonga. Working closely alongside other development partners, New Zealand is at the forefront of supporting practical implementation of Tonga's Energy Roadmap, an ambitious 10-year sector-wide plan to improve Tonga's energy efficiency and energy self-reliance. As part of an NZ$8.5 million commitment, support has initially focused on upgrading Tonga's power distribution network.

Similar work is currently being planned in the energy sectors in Tuvalu and Tokelau – two of the most vulnerable island countries in the Pacific. Work reported in the 2011 submission on the upgrade of the Cook Islands energy supply network is ongoing. Tokelau has, until now, been 100 per cent dependent upon diesel for electricity generation, with heavy economic and environmental costs. A New Zealand-funded project to construct solar-based mini grids on three atolls has meant that nearly 100 per cent of Tokelau's electricity needs are now met through solar generation.

15.7 Assistance to non-Annex I Parties dependent on the export and consumption of fossil fuels for diversifying their economies

Annex I Parties are required to report on assistance provided to non-Annex I Parties that are highly dependent on the export and consumption of fossil fuels in diversifying their economies. New Zealand is a member of the International Renewable Energy Agency (IRENA), an intergovernmental organisation that aims to promote the widespread and increased adoption and the sustainable use of all forms of renewable energy. A large part of IRENA's work programme relates to promoting renewable energy development in less-developed countries. New Zealand is involved with a number of IRENA's work streams, including work related to the Pacific Islands and to geothermal energy in Latin America.

New Zealand is also a member of other multilateral institutions that play a role in these areas, for example, the International Energy Agency and APEC.

The New Zealand Government will co-host (with the European Union) a Pacific energy summit in March 2013 in Auckland, New Zealand. This summit aims to promote energy development in the Pacific Islands and will provide an opportunity for Pacific Island countries to showcase their energy plans and targets, and seek donor and private sector advice or finance to translate these plans into action.

The New Zealand Aid Programme provides support to a number of non-Annex I countries in relation to economic diversification and renewable energy (refer to section 15.6).

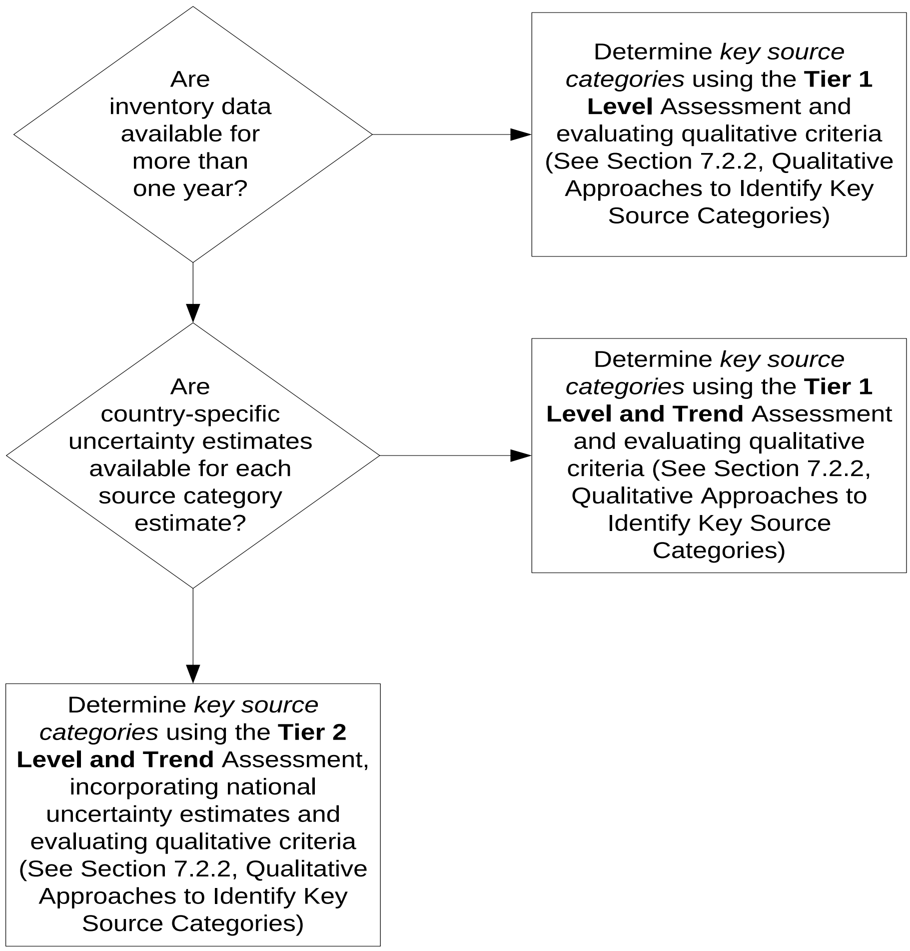
According to the International Monetary Fund, Timor-Leste is the world's most oil-dependent economy. In 2009, petroleum income accounted for almost 80 per cent of gross national income. New Zealand is helping to provide new economic opportunities in Timor-Leste through rehabilitating the coffee sector, to increase the quality, quantity and value of coffee products, and providing capacity and capability building for small business in rural areas, particularly those run by women. New Zealand's aim is to target one-third of its development assistance in Timor-Leste to support sustainable economic development through private sector investment.

Annex 1: Key categories

A1.1 Methodology used for identifying key categories

The key categories in the New Zealand inventory have been assessed according to the methodologies provided in the Intergovernmental Panel on Climate Change good practice guidance (IPCC, 2000). The methodology applied was determined using the decision tree shown in figure A1.1.1.

Figure A1.1.1 Decision tree to identify key source categories (Figure 7.1 (IPCC, 2000))



For this inventory submission, the Tier 1 level and trend assessments were applied, including the land use, land-use change and forestry (LULUCF) sector and excluding the LULUCF sector (IPCC 2000, 2003). The 'including LULUCF' level and trend assessments are calculated as per equations 5.4.1 and 5.4.2 of *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (GPG-LULUCF, IPCC, 2003). The 'excluding LULUCF' level and trend assessments are calculated as per equations 7.1 and

7.2 of the good practice guidance (IPCC, 2000). Key categories are defined as those categories whose cumulative percentages, when summed in decreasing order of magnitude, contributed 95 per cent of the total level or trend.

A1.2 Disaggregation

The classification of categories follows the classification outlined in table 7.1 of the good practice guidance (IPCC, 2000) by:

- identifying categories at the level of Intergovernmental Panel on Climate Change (IPCC) categories using carbon dioxide (CO_2) equivalent emissions and considering each greenhouse gas from each category separately
- aggregating categories that use the same emission factors
- including LULUCF categories at the level shown in GPG-LULUCF table 5.4.1.

There was one modification to the suggested categories to reflect New Zealand's national circumstances. The 'fugitive emissions from the oil and natural gas category' was divided into two categories: 'fugitive emissions from oil and gas operations' and 'fugitive emissions from geothermal operations'. This is to reflect that New Zealand generates a significant amount of energy from geothermal sources that cannot be included as oil or gas operations.

A1.3 Tables 7.A1–7.A3 of the IPCC good practice guidance

Table A1.3.1 Results of the key category level analysis for 99 per cent of the net emissions and removals for New Zealand in 2011

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2011				
IPCC categories	Gas	2011 estimate (Gg CO_2-e)	Level assessment (%)	Cumulative total (%)
Conversion to forest land	CO_2	27,227.0	23.9	23.9
Enteric fermentation – dairy cattle	CH_4	10,381.8	9.1	33.1
Forest land remaining forest land	CO_2	9,468.7	8.3	41.4
Enteric fermentation – sheep	CH_4	7,750.6	6.8	48.2
Transport – road transport – gasoline	CO_2	7,061.4	6.2	54.4
Agricultural soils – pasture, range and paddock	N_2O	5,705.4	5.0	59.4
Transport – road transport – diesel oil	CO_2	5,314.3	4.7	64.1
Enteric fermentation – non-dairy cattle	CH_4	4,860.6	4.3	68.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,622.1	3.2	71.6
Agricultural soils – indirect emissions	N_2O	2,578.4	2.3	73.8
Manufacturing industries and construction – gaseous fuels	CO_2	2,179.9	1.9	75.7
Grassland remaining grassland	CO_2	2,063.5	1.8	77.6
Other sectors – liquid fuels	CO_2	1,880.0	1.7	79.2
Agricultural soils – direct emissions	N_2O	1,874.8	1.6	80.9
Consumption of halocarbons and SF_6 –	HFCs &	1,798.3	1.6	82.4

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2011				
IPCC categories	**Gas**	**2011 estimate ($Gg\ CO_2$-e)**	**Level assessment (%)**	**Cumulative total (%)**
refrigeration and air conditioning	PFCs			
Manufacturing industries and construction – solid fuels	CO_2	1,752.5	1.5	84.0
Metal production – iron and steel production	CO_2	1,690.8	1.5	85.5
Conversion to grassland	CO_2	1,650.0	1.5	86.9
Energy industries – public electricity and heat production – solid fuels	CO_2	1,489.7	1.3	88.2
Solid waste disposal on land	CH_4	1,331.1	1.2	89.4
Manufacturing industries and construction – liquid fuels	CO_2	1,034.4	0.9	90.3
Transport – civil aviation – jet kerosene	CO_2	971.6	0.9	91.2
Energy industries – Petroleum refining – liquid fuels	CO_2	782.9	0.7	91.8
Fugitive emissions – flaring – combined	CO_2	780.6	0.7	92.5
Other sectors – gaseous fuels	CO_2	686.2	0.6	93.1
Manure management	CH_4	647.3	0.6	93.7
Fugitive emissions – geothermal	CO_2	626.8	0.6	94.3
Metal production – aluminium production	CO_2	571.2	0.5	94.8
Mineral products – cement production	CO_2	528.5	0.5	95.2
Enteric fermentation – deer	CH_4	478.2	0.4	95.6
Waste-water handling	CH_4	471.7	0.4	96.1
Other sectors – solid fuels	CO_2	434.0	0.4	96.4
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	427.4	0.4	96.8
Fugitive emissions – coal mining and handling	CH_4	390.7	0.3	97.2
Fugitive emissions – natural gas	CH_4	359.9	0.3	97.5
Cropland remaining cropland	CO_2	311.4	0.3	97.7
Transport – navigation – residual oil	CO_2	284.3	0.2	98.0
Chemical industry – ammonia production	CO_2	283.2	0.2	98.2
Chemical industry – hydrogen production	CO_2	253.2	0.2	98.5
Wastewater handling	N_2O	180.4	0.2	98.6
Transport – railways – liquid fuels	CO_2	140.8	0.1	98.7
Energy industries – petroleum refining – gaseous fuels	CO_2	127.84	0.1	98.9
Mineral products – lime production	CO_2	119.0	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Table A1.3.2 Results of the key category level analysis for 99 per cent of the net emissions and removals for New Zealand in 1990

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	23,198.2	25.9	25.9
Enteric fermentation – sheep	CH_4	11,736.1	13.1	39.0
Transport – road transport – gasoline	CO_2	5,582.2	6.2	45.2
Agricultural soils – pasture, range and paddock	N_2O	5,372.5	6.0	51.2
Enteric fermentation – non-dairy cattle	CH_4	4,983.8	5.6	56.8
Enteric fermentation – dairy cattle	CH_4	4,976.5	5.6	62.4
Forest land remaining forest land	CO_2	4,540.3	5.1	67.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3.3	70.8
Manufacturing industries and construction – solid fuels	CO_2	2,172.6	2.4	73.2
Agricultural soils – indirect emissions	N_2O	2,051.8	2.3	75.5
Other sectors – liquid fuels	CO_2	1,757.9	2.0	77.4
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	1.9	79.4
Manufacturing industries and construction – gaseous fuels	CO_2	1,619.7	1.8	81.2
Solid waste disposal on land	CH_4	1,514.4	1.7	82.9
Transport – road transport – diesel oil	CO_2	1,409.5	1.6	84.4
Metal production – iron and steel production	CO_2	1,306.7	1.5	85.9
Grassland remaining grassland	CO_2	1,074.1	1.2	87.1
Manufacturing industries and construction – liquid fuels	CO_2	847.0	0.9	88.0
Transport – civil aviation – jet kerosene	CO_2	842.5	0.9	89.0
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	0.9	89.8
Metal production – aluminium production	PFCs	629.9	0.7	90.5
Other sectors – gaseous fuels	CO_2	523.3	0.6	91.1
Other sectors – solid fuels	CO_2	512.1	0.6	91.7
Energy industries – public electricity and heat production – solid fuels	CO_2	469.3	0.5	92.2
Agricultural soils – direct emissions	N_2O	460.1	0.5	92.7
Manure management	CH_4	456.6	0.5	93.2
Metal production – aluminium production	CO_2	449.0	0.5	93.8
Mineral products – cement production	CO_2	448.7	0.5	94.3
Fugitive emissions – natural gas	CH_4	438.1	0.5	94.7
Waste-water handling	CH_4	385.1	0.4	95.2
Enteric fermentation – deer	CH_4	334.7	0.4	95.5
Cropland remaining cropland	CO_2	334.7	0.4	95.9
Chemical industry – ammonia production	CO_2	277.9	0.3	96.2
Fugitive emissions – coal mining and handling	CH_4	274.5	0.3	96.5
Transport – navigation – residual oil	CO_2	230.6	0.3	96.8
Fugitive emissions – flaring – combined	CO_2	228.9	0.3	97.0

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	Level assessment (%)	Cumulative total (%)
Fugitive emissions – geothermal	CO_2	228.6	0.3	97.3
Conversion to cropland	CO_2	214.8	0.2	97.5
Enteric fermentation – other	CH_4	209.6	0.2	97.8
Conversion to grassland	CO_2	201.5	0.2	98.0
Conversion to wetland	CO_2	167.3	0.2	98.2
Chemical industry – hydrogen production	CO_2	152.3	0.2	98.4
Wastewater handling	N_2O	145.0	0.2	98.5
Transport – road transport – gaseous fuels	CO_2	139.6	0.2	98.7
Transport – road transport – liquefied petroleum gases	CO_2	101.0	0.1	98.8
Conversion to settlement	CO_2	97.6	0.1	98.9
Mineral products – lime production	CO_2	82.6	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Table A1.3.3 Results of the key category trend analysis for 99 per cent of the net emissions and removals for New Zealand in 2011

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2011 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,736.1	7,750.6	0.050	18.8	18.8
Enteric fermentation – dairy cattle	CH_4	4,976.5	10,381.8	0.028	10.7	29.5
Forest land remaining forest land	CO_2	4,540.3	9,468.7	0.026	9.7	39.3
Transport – road transport – diesel oil	CO_2	1,409.5	5,314.3	0.024	9.3	48.5
Conversion to forest land	CO_2	23,198.2	27,227.0	0.015	5.9	54.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,798.3	0.012	4.7	59.1
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	427.4	0.012	4.6	63.8
Enteric fermentation – non-dairy cattle	CH_4	4,983.8	4,860.6	0.010	3.9	67.6
Conversion to grassland	CO_2	201.5	1,650.0	0.010	3.7	71.3
Agricultural soils – direct emissions	N_2O	460.1	1,874.8	0.009	3.4	74.7
Agricultural soils – pasture, range and paddock	N_2O	5,372.5	5,705.4	0.008	2.9	77.6
Manufacturing industries and construction – solid fuels	CO_2	2,172.6	1,752.5	0.007	2.6	80.3

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2011 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Energy industries – public electricity and heat production – solid fuels	CO_2	469.3	1,489.7	0.006	2.4	82.6
Metal production – aluminium production	PFCs	629.9	30.2	0.005	2.0	84.7
Grassland remaining grassland	CO_2	1,074.1	2,063.5	0.005	1.8	86.5
Solid waste disposal on land	CH_4	1,514.4	1,331.1	0.004	1.6	88.1
Fugitive emissions – flaring – combined	CO_2	228.9	780.6	0.003	1.3	89.3
Other sectors – liquid fuels	CO_2	1,757.9	1,880.0	0.002	0.9	90.3
Fugitive emissions – geothermal	CO_2	228.6	626.8	0.002	0.9	91.2
Enteric fermentation – other	CH_4	209.6	46.6	0.002	0.6	91.7
Other sectors – solid fuels	CO_2	512.1	434.0	0.001	0.6	92.3
Conversion to cropland	CO_2	214.8	70.5	0.001	0.5	92.8
Energy industries – petroleum refining – liquid fuels	CO_2	773.9	782.9	0.001	0.5	93.4
Fugitive emissions – natural gas	CH_4	438.1	359.9	0.001	0.5	93.9
Conversion to wetland	CO_2	167.3	20.9	0.001	0.5	94.4
Transport – road transport – gaseous fuels	CO_2	139.6	2.9	0.001	0.5	94.8
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3,622.1	0.001	0.4	95.3
Energy industries – petroleum refining – gaseous fuels	CO_2	0.0	127.8	0.001	0.3	95.6
Manufacturing industries and construction – gaseous fuels	CO_2	1,619.7	2,179.9	0.001	0.3	95.9
Cropland remaining cropland	CO_2	334.7	311.4	0.001	0.3	96.2
Transport – road transport – liquefied petroleum gases	CO_2	101.0	26.1	0.001	0.3	96.5
Transport – civil aviation – jet kerosene	CO_2	842.5	971.6	0.001	0.3	96.8
Conversion to settlement	CO_2	97.6	34.7	0.001	0.2	97.0
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	0.0	85.0	0.001	0.2	97.2
Chemical industry – ammonia production	CO_2	277.9	283.2	0.000	0.2	97.4
Manure management	CH_4	456.6	647.3	0.000	0.2	97.6
Chemical industry – hydrogen production	CO_2	152.3	253.2	0.000	0.2	97.7
Enteric fermentation – deer	CH_4	334.7	478.2	0.000	0.1	97.9
Fugitive emissions – geothermal	CH_4	46.0	110.1	0.000	0.1	98.0
Transport – road transport – gasoline	CH_4	50.5	20.3	0.000	0.1	98.1

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2011 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Transport – railways – liquid fuels	CO_2	77.6	140.8	0.000	0.1	98.2
Fugitive emissions – coal mining and handling	CH_4	274.5	390.7	0.000	0.1	98.4
Manufacturing industries and construction – liquid fuels	CO_2	847.0	1,034.4	0.000	0.1	98.5
Mineral products – cement production	CO_2	448.7	528.5	0.000	0.1	98.6
Transport – road transport – gaseous fuels	CH_4	31.4	0.0	0.000	0.1	98.7
Metal production – iron and steel production	CO_2	1,306.7	1,690.8	0.000	0.1	98.8
Transport – road transport – gasoline	CO_2	5,582.2	7,061.4	0.000	0.1	98.8
Agricultural soils – indirect emissions	N_2O	2,051.8	2,578.4	0.000	0.1	98.9
Emissions from solvents (N_2O use)	N_2O	41.5	27.9	0.000	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Annex 2: Methodology and data collection for estimating emissions from fossil fuel combustion

New Zealand emission factors are based on gross calorific value. Energy activity data and emission factors in New Zealand are conventionally reported in gross terms, with some minor exceptions. The convention adopted by New Zealand to convert gross calorific value to net calorific value follows the Organisation for Economic Co-operation and Development and International Energy Agency assumptions:

Emission factors for gas, coal, biomass and liquid fuels used by New Zealand are shown in tables A2.1–A2.4. Where Intergovernmental Panel on Climate Change (IPCC) default emission factors are used, a net-to-gross factor as above is used to account for New Zealand activity data representing gross energy figures:

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Table A2.1 Gross carbon dioxide emission factors used for New Zealand's energy sector in 2011 (before oxidation)

	Emission factor (t CO_2/TJ)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.37	14.3	1
Kapuni	53.68	14.6	1
McKee	53.30	14.5	3
Kaimiro	55.02	15.0	3
Ngatoro	54.56	14.9	3
TAWN	52.72	14.4	3
Mangahewa	53.19	14.5	3
Turangi	54.93	15.0	3
Pohokura	53.79	14.7	1
Rimu/Kauri	51.23	14.0	3
Maari	58.94	16.1	3
Weighted Average	53.27	14.5	
Kapuni LTS	85.84	23.4	1
Methanol - Mixed Feed – to 94	62.44	17.0	3
Methanol – LTS – to 94	83.97	22.9	3

	Emission factor ($t\ CO_2/TJ$)	Emission factor (t C/TJ)	Source
Liquid fuels			
Crude oil	69.81	19.0	5
Regular petrol	66.55	18.1	4
Petrol – premium	66.79	18.2	4
Diesel (10 parts (sulphur) per million)	69.64	19.0	4
Jet kerosene	68.53	18.7	4
Av gas	65.89	18.0	4
LPG	58.10	15.8	2
Heavy fuel oil	73.84	20.1	4
Light fuel oil	72.85	19.9	4
Power station fuel oil	74.12	20.2	4
Bitumen (asphalt)	76.98	21.0	4
Biomass			
Biogas	100.98	27.5	5
Wood (industrial)	104.15	28.4	5
Bioethanol	64.20	17.3	6
Biodiesel	62.40	16.8	6
Wood (residential)	104.15	28.4	5
Coal			
All sectors excl electricity (sub-bituminous)	91.99	25.1	7
All sectors (bituminous)	89.13	24.3	7
All sectors (lignite)	93.11	25.4	7

1. Derived by the transmission operator (Vector Ltd) through averaging daily gas composition data.
2. *New Zealand Energy Information Handbook* (Baines, 1993).
3. Specific gas field operator.
4. Refining New Zealand (formerly the New Zealand Refining Company).
5. IPCC guidelines (1996).
6. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions* (Eng, Bywater and Hendtlass, 2008).
7. *Reviewing Default Emission Factors in Draft Stationary Energy and Industrial Processes* (CRL Energy, 2009).

Table A2.2 Consumption-weighted average emission factors used for New Zealand's sub-bituminous coal-fired electricity generation for 1990 to 2011 (before oxidation factor)

	Emission factor (t CO_2/TJ)
1990	91.99
1991	91.99
1992	91.99
1993	91.99
1994	91.99
1995	91.99
1996	91.99
1997	91.99
1998	91.99
1999	91.99
2000	91.99
2001	91.99
2002	91.99
2003	91.99
2004	91.99
2005	91.99
2006	91.99
2007	92.45
2008	92.31
2009	92.38
2010	92.19
2011	92.01

Table A2.3 IPCC (1996) methane emission factors used for New Zealand's energy sector for 1990 to 2011

	Emission factor t CH_4/PJ	Source
Natural gas		
Electricity – boilers	.09	IPCC Tier 2 (table 1–15) natural gas boilers
Electricity – large turbines	5.40	IPCC Tier 2 (table 1–15) large gas-fired turbines > 3MW
Commercial	1.08	IPCC Tier 2 (table 1–19) natural gas boilers
Residential	0.90	IPCC Tier 2 (table 1–18) gas heaters
Domestic transport (CNG)	567.00	IPCC Tier 2 (table 1–43) passenger cars (uncontrolled)
Other stationary (mainly industrial)	1.26	IPCC Tier 2 (table 1–16) small natural gas boilers
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.86	IPCC Tier 2 (table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.86	IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	2.85	IPCC Tier 2 (table 1–16) residual oil boilers
Industrial – distillate oil	0.19	IPCC Tier 2 (table 1–16) distillate oil boilers
Industrial – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Commercial – residual oil	1.33	IPCC Tier 2 (table 1–19) residual oil boilers

	Emission factor t CH_4/PJ	Source
Commercial – distillate oil	0.67	IPCC Tier 2 (table 1–19) distillate oil boilers
Commercial – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Residential – distillate oil	0.67	IPCC Tier 2 (table 1–18) distillate oil furnaces
Residential – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Agriculture – stationary	0.19	IPCC Tier 2 (table 1–49) diesel engines (agriculture)
Mobile sources		
LPG	28.50	IPCC Tier 2 (table 1–44) passenger cars (uncontrolled)
Petrol	18.53	IPCC Tier 2 (table 1–27) passenger cars (uncontrolled – mid-point of average g/MJ)
Diesel	3.8	IPCC Tier 2 (table 1–32) passenger cars (uncontrolled – g/MJ)
Navigation (fuel oil and diesel)	6.65	IPCC Tier 2 (table 1–48) ocean-going ships
Aviation fuel/kerosene	0.48	IPCC Tier 2 (table 1–7) oil – aviation
Coal		
Combustion		
Electricity generation	0.67	IPCC Tier 2 (table 1–15) pulverised bituminous combustion – dry bottom, wall fired
Cement	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Lime	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Industry	0.67	IPCC Tier 2 (table 1–16) dry bottom, wall fired coal boilers
Commercial	9.50	IPCC Tier 2 (table 1–19) coal boilers
Residential	285.00	IPCC Tier 1 (table 1–7) coal – residential
Biomass		
Wood stoker boilers	14.25	IPCC Tier 2 (table 1–16) wood stoker boilers
Wood – fireplaces	285.00	IPCC Tier 1 (table 1–7) wood – residential
Bioethanol	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biodiesel	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biogas	1.08	IPCC Tier 2 (table 1–19) gas boilers

Table A2.4 IPCC (1996) nitrous oxide emission factors used for New Zealand's energy sector for 1990 to 2011

	Emission factor t N_2O/PJ	Source
Natural gas		
Electricity generation	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Commercial	2.07	IPCC Tier 2 (table 1–19) natural gas boilers
Residential	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Domestic transport (CNG)	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Other stationary (mainly industrial)	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.29	IPCC Tier 2 (table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.38	IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	0.29	IPCC Tier 2 (table 1–16) residual oil boilers
Industrial – distillate oil	0.38	IPCC Tier 2 (table 1–16) distillate oil boilers
Commercial – residual oil	0.29	IPCC Tier 2 (table 1–19) residual oil boilers

	Emission factor t N_2O/PJ	Source
Commercial – distillate oil	0.38	IPCC Tier 2 (table 1–19) distillate oil boilers
Residential (all oil)	0.19	IPCC Tier 2 (table 1–18) furnaces
LPG (all uses)	0.57	IPCC Tier 1 (table 1–8) oil – all sources except aviation
Agriculture – stationary	0.38	IPCC Tier 2 (table 1–49) diesel engines – agriculture
Mobile sources		
LPG	0.57	IPCC Tier 1 (table 1–8) oil – all sources except aviation
Petrol	1.43	IPCC Tier 2 (table 2.7 in GPG (IPCC, 2000))
		US gasoline vehicles (uncontrolled)
Diesel	3.71	IPCC Tier 2 (table 2.7 in GPG (IPCC, 2000)) all US diesel vehicles
Fuel oil (ships)	1.90	IPCC Tier 2 (table 1–48) ocean-going ships
Aviation fuel/kerosene	1.90	IPCC Tier 1 (table 1–8) oil – aviation
Coal		
Electricity generation	1.52	IPCC Tier 2 (table 1–15) pulverised bituminous combustion – dry bottom, wall fired
Cement	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Lime	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Industry	1.52	IPCC Tier 2 (table 1–16) dry bottom, wall fired coal boilers
Commercial	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Residential	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Biomass		
Wood (all uses)	3.80	IPCC Tier 1 (table 1–8) wood/wood waste – all uses
Biogas	2.07	IPCC Tier 2 (table 1–19) natural gas boilers

A2.1 Emissions from liquid fuels

A2.1.1 Activity data and uncertainties

The *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Business, Innovation and Employment is run as a census, meaning there is no sampling error. The only possible sources of error are non-sample error (such as respondent error and processing error). The 2011 statistical difference for liquid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2012) was 0.04 per cent. This is used as the activity data uncertainty for liquid fuels in 2011.

A2.1.2 Emission factors and uncertainties

The 2011 carbon dioxide emission factors are described in table A2.1. Table A2.5 shows a complete time series of gross calorific values, while table A2.6 shows a complete time series of carbon content of liquid fuels. This information is supplied Refining New Zealand (formerly the New Zealand Refining Company) and is used in the calculation of annual emission factors for liquid fuels.

A 2009 consultant report (Hale and Twomey, 2009) to the Ministry for the Environment estimates the uncertainty of carbon dioxide emission factors for liquid fuels at

±0.5 per cent. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A2.5 Gross calorific values (MJ/kg) for liquid fuels for 1990 to 2011

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	47.24	47.22	45.76	46.37	47.30	43.07	44.12	42.71	41.30
1991	47.17	47.17	45.73	46.38	47.30	43.02	44.07	42.70	41.30
1992	47.18	47.14	45.75	46.41	47.30	43.03	44.14	42.72	41.30
1993	47.09	47.14	45.74	46.36	47.30	43.01	44.13	42.75	41.31
1994	47.10	47.11	45.75	46.34	47.30	43.03	44.16	42.70	41.30
1995	47.07	47.14	45.59	46.31	47.30	43.03	44.01	42.69	41.30
1996	46.91	47.14	45.54	46.26	47.30	43.00	43.98	42.68	41.30
1997	46.93	47.17	45.58	46.32	47.30	42.92	43.92	42.56	41.30
1998	46.89	47.12	45.64	46.27	47.30	43.06	44.02	42.79	41.27
1999	46.92	47.13	45.56	46.29	47.30	43.09	43.93	42.79	41.28
2000	46.91	47.12	45.58	46.22	47.30	43.07	43.90	42.74	41.27
2001	46.92	47.15	45.64	46.25	47.30	43.08	43.96	42.76	41.27
2002	46.90	47.16	45.62	46.29	47.30	43.03	43.84	42.79	41.26
2003	46.87	47.11	45.61	46.23	47.30	43.06	43.79	42.77	41.27
2004	46.91	47.10	45.59	46.25	47.30	43.04	43.90	42.79	41.30
2005	46.95	47.10	45.73	46.28	47.30	43.11	43.94	42.78	41.30
2006	46.97	47.09	45.79	46.23	47.30	42.93	43.68	42.65	41.30
2007	46.97	47.10	45.77	46.23	47.30	42.97	43.72	42.66	41.30
2008	46.93	47.06	45.72	46.19	47.30	42.86	43.72	42.56	41.30
2009	46.95	47.03	45.72	46.17	47.30	42.89	43.75	42.56	41.29
2010	46.96	47.03	45.69	46.17	47.30	42.95	43.70	42.62	41.29
2011	46.96	47.04	45.69	46.19	47.30	42.89	43.72	42.61	41.27

Table A2.6 Carbon content (per cent mass) for liquid fuels for 1990 to 2011

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	84.87	84.92	86.28	85.92	85.00	86.22	86.67	86.03	86.57
1991	85.04	85.04	86.33	85.89	85.00	86.26	86.30	86.04	86.57
1992	85.03	85.13	86.29	85.84	85.00	86.25	86.18	86.03	86.57
1993	85.25	85.13	86.32	85.94	85.00	86.27	86.20	86.00	86.56
1994	85.21	85.19	86.30	85.99	85.00	86.25	86.13	86.04	86.57
1995	85.30	85.13	86.63	86.05	85.00	86.25	86.39	86.05	86.57
1996	85.66	85.13	86.73	86.16	85.00	86.28	86.45	86.05	86.57
1997	85.63	85.04	86.64	86.04	85.00	86.35	86.55	86.16	86.58
1998	85.72	85.17	86.52	86.14	85.00	86.22	86.39	85.97	86.63
1999	85.65	85.15	86.69	86.10	85.00	86.20	86.53	85.96	86.63
2000	85.67	85.16	86.64	86.25	85.00	86.22	86.58	86.01	86.63
2001	85.65	85.09	86.53	86.18	85.00	86.21	86.49	85.98	86.64
2002	85.68	85.06	86.57	86.10	85.00	86.25	86.68	85.96	86.66
2003	85.76	85.19	86.58	86.23	85.00	86.23	86.76	85.98	86.63
2004	85.66	85.22	86.62	86.20	85.00	86.24	86.58	85.97	86.58
2005	85.58	85.22	86.62	86.12	85.00	86.18	86.52	85.97	86.57
2006	85.54	85.25	86.57	86.24	85.00	86.34	86.93	86.08	86.57
2007	85.54	85.23	86.61	86.24	85.00	86.30	86.87	86.07	86.57
2008	85.63	85.32	86.70	86.32	85.00	86.39	86.87	86.16	86.57
2009	85.56	85.38	86.72	86.36	85.00	86.37	86.83	86.16	86.60

2010	85.54	85.40	86.77	86.35	85.00	86.31	86.90	86.11	86.59
2011	85.55	85.37	86.78	86.32	85.00	86.37	86.87	86.12	86.64

A2.2 Emissions from solid fuels

A2.2.1 Activity data and uncertainties

The *New Zealand Quarterly Statistical Return of Coal Production and Sales* conducted by the Ministry of Business, Innovation and Employment has full coverage of the sector, meaning there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2011 statistical difference for solid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2012) was 4.3 per cent. This is used as the activity data uncertainty for solid fuels in 2011.

A2.2.2 Emission factors and uncertainties

The estimated uncertainty in carbon dioxide emission factors for solid fuels is ±2.2 per cent. This is based on the difference between the range of updated emission factors for the three different ranks of coal used in New Zealand. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

A2.3 Emissions from gaseous fuels

A2.3.1 Activity data

Through the various surveys and information collected by the Ministry of Business, Innovation and Employment, it has full coverage of the natural gas sector. This means there is no sampling error in natural gas statistics and the only possible sources or errors are non-sample error (such as respondent error and processing error). The 2011 statistical difference for gaseous fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2012) was 3.7 per cent. This is used as the activity data uncertainty for gaseous fuels in 2011.

A2.3.2 Emission factors

The estimated uncertainty in carbon dioxide emission factors for gaseous fuels is ±2.4 per cent. This is based on the difference between the range of emission factors for the three largest gas fields in New Zealand. Together, these gas fields made up over 75 per cent of New Zealand's total gas supply in 2011. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A2.7 Emission factors for European gasoline and diesel vehicles – COPERT IV model (European Environment Agency, 2007)

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		Rural	Highway	Urban		Rural	Highway
	Cold	Hot			Cold	Hot		
Passenger car								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	38	22	17	8	45	26	16	14
Euro 2	24	11	4.5	2.5	94	17	13	11
Euro 3	12	3	2	1.5	83	3	2	4
Euro 4	6	2	0.8	0.7	57	2	2	0
Diesel								
pre-Euro	0	0	0	0	22	28	12	8
Euro 1	0	2	4	4	18	11	9	3
Euro 2	3	4	6	6	6	7	3	2
Euro 3	15	9	4	4	7	3	0	0
Euro 4	15	9	4	4	0	0	0	0
LPG								
pre-ECE	0	0	0	0	80	80	35	25
Euro 1	38	21	13	8	80	80	35	25
Euro 2	23	13	3	2	80	80	35	25
Euro 3 and later	9	5	2	1	80	80	35	25
Light duty vehicles								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	122	52	52	52	45	26	16	14
Euro 2	62	22	22	22	94	17	13	11
Euro 3	36	5	5	5	83	3	2	4
Euro 4	16	2	2	2	57	2	2	0
Diesel								
pre-Euro	0	0	0	0	22	28	12	8
Euro 1	0	2	4	4	18	11	9	3
Euro 2	3	4	6	6	6	7	3	2
Euro 3	15	9	4	4	7	3	0	0
Euro 4	15	9	4	4	0	0	0	0
Heavy duty truck and bus								
Gasoline – all technologies	6	6	6	6	140	140	110	70
Diesel								
GVW<16t	30	30	30	30	85	85	23	20
GVW>16t	30	30	30	30	175	175	80	70
Urban busses and coaches	30	30	30	30	175	175	80	70

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		Rural	Highway	Urban		Rural	Highway
	Cold	Hot			Cold	Hot		
CNG								
pre Euro 4					5,400	5,400	5,400	5,400
Euro 4 and later					900	900	900	900
Power two wheeler								
Gasoline								
<50 cm^3	1	1	1	1	219	219	219	219
>50 cm^3 2-stroke	2	2	2	2	150	150	150	150
>50 cm^3 4-stroke	2	2	2	2	200	200	200	200

A2.4 Energy balance for year ended December 2011

Table A.2.8 New Zealand energy balance for year ended December 2011 (Ministry of Economic Development, 2012)

Table B.2: Energy Supply and Demand Balance Calendar Year 2011

	Converted into Petajoules using Gross Calorific Values	Coal			Oil							
		Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks/ NGL	LPG	Petrol	Diesel	Fuel Oil	Av. Fuel/ Kero[1]	Others	Total
SUPPLY	Indigenous Production	122.87	4.90	127.77	99.05	7.32						106.36
	+ Imports	3.98	0.00	3.98	240.05	0.32	43.29	31.39	-	1.16	7.14	323.35
	- Exports	67.24	-	67.24	95.51	0.65	-	-	11.55	0.56	-	108.26
	- Stock Change	3.75	0.01	3.76	-7.78	-0.02	-2.75	3.45	5.12	-0.62	0.71	-1.89
	- International Transport						-	1.74	11.13	34.26	-	47.13
	TOTAL PRIMARY ENERGY	55.85	4.89	60.74	251.38	7.00	46.04	26.20	-27.79	-33.05	6.43	276.21
	ENERGY TRANSFORMATION	-35.40	-0.24	-35.64	-248.45	-0.16	62.64	84.34	32.68	48.14	5.49	-15.32
	Electricity Generation	-16.52	-	-16.52				-0.01	-0.00			-0.02
	Cogeneration	-6.80	-0.24	-7.04								
	Oil Production				-248.33		62.46	83.98	32.66	48.60	13.12	-7.52
	Other Transformation	-11.41	-	-11.41								
	Losses and Own Use	-0.66	-	-0.66	-0.12	-0.16	0.18	0.38	0.03	-0.47	-7.63	-7.78
	Non-energy Use										-11.92	-11.92
	CONSUMER ENERGY (calculated)	20.45	4.65	25.10	2.93	6.85	108.68	110.54	4.89	15.09	-	248.97
DEMAND	Agriculture, Forestry and Fishing	2.74	0.03	2.77		0.06	1.42	14.49	2.42	0.12		18.52
	Agriculture	2.74	0.02	2.76		0.06	1.42	9.88	-	0.11		11.47
	Forestry and Logging	-	0.01	0.01			0.00	2.92	0.01	0.00		2.94
	Fishing	-	-	-			0.00	1.69	2.41	0.01		4.10
	Industrial	15.53	3.65	19.19		2.49	0.13	11.11	1.02	0.09		14.84
	Mining	0.02	-	0.02			0.00	3.42	0.01	0.00		3.43
	Food Processing	9.86	3.62	13.48			-	-	-	-		-
	Textiles	0.11	-	0.11								
	Wood, Pulp, Paper and Printing	0.84	0.02	0.86								
	Chemicals	-	-	-								
	Non-metallic Minerals	3.50	0.01	3.51								
	Basic Metals	-	-	-			-	-	-	-		-
	Mechanical/Electrical Equipment	0.03	-	0.03								
	Building and Construction	0.00	-	0.00			0.01	4.15	0.02	0.08		4.26
	Unallocated	1.18	-	1.18		2.49	0.12	3.54	1.00	0.00		7.16
	Commercial	0.62	0.66	1.28		1.08	0.09	5.01	0.05	0.11		6.35
	Transport	0.04	-	0.04		0.45	107.07	79.78	4.00	14.84		206.15
	Residential	0.44	0.31	0.75		2.75	0.00	0.34	-	0.13		3.23
	CONSUMER ENERGY (observed)	19.38	4.65	24.03	-	6.85	108.71	110.75	7.49	15.29	-	249.08
	Statistical Differences	1.06	0.00	1.07	2.93	0.00	-0.03	-0.21	-2.60	-0.20	-	-0.11

	Converted into Petajoules using Gross Calorific Values	Natural Gas	Renewables								Electricity	Waste Heat	
		Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Wood	Total	Total	Total	TOTAL
SUPPLY	Indigenous Production	161.96	90.28	159.05	0.36	7.02	0.19	3.04	60.60	320.55		1.52	718.16
	+ Imports						0.05			0.05			327.37
	- Exports												175.51
	- Stock Change	3.28											5.15
	- International Transport												47.13
	TOTAL PRIMARY ENERGY	158.68	90.28	159.05	0.36	7.02	0.25	3.04	60.60	320.60		1.52	817.75
	ENERGY TRANSFORMATION	-78.33	-90.28	-149.75		-7.02	-0.25	-2.76	-5.12	-255.19	144.17	-1.52	-241.83
	Electricity Generation	-51.57	-90.28	-148.45		-7.02		-1.95		-247.70	150.50		-165.30
	Cogeneration	-18.65		-1.31				-0.82	-5.12	-7.25	9.68	-1.52	-24.78
	Oil Production	-					-0.25			-0.25			-7.76
	Other Transformation												-11.41
	Losses and Own Use	-8.12									-16.01		-32.58
	Non-energy Use	-24.41											-36.33
	CONSUMER ENERGY (calculated)	55.94		9.30	0.36	-	-	0.28	55.47	65.41	144.17	-	539.58
DEMAND	Agriculture, Forestry and Fishing	1.67		0.68						0.68	6.97		30.61
	Agriculture	1.65		0.68						0.68	6.25		22.81
	Forestry and Logging	0.02									0.19		3.16
	Fishing	-									0.54		4.64
	Industrial	45.03		6.21					48.07	54.28	54.60		187.92
	Mining	0.00									1.47		4.92
	Food Processing	14.72									6.78		34.98
	Textiles	0.84									0.43		1.37
	Wood, Pulp, Paper and Printing	5.13									11.61		17.60
	Chemicals	18.86									2.46		21.32
	Non-metallic Minerals	0.74									0.95		5.21
	Basic Metals	2.95									24.90		27.85
	Mechanical/Electrical Equipment	1.55									0.65		2.22
	Building and Construction	0.04									0.65		4.95
	Unallocated	0.20		6.21					48.07	54.28	4.71		67.52
	Commercial	5.54		2.10				0.28		2.38	32.71		48.26
	Transport	0.05						-		-	0.21		206.46
	Residential	5.70		0.31	0.36				7.40	8.08	46.36		64.13
	CONSUMER ENERGY (observed)	58.00	-	9.30	0.36	-		0.28	55.47	65.41	140.86	-	537.38
	Statistical Differences	-2.06		0.00	-	-		-	-	-	3.31	-	2.21

Notes to Table B.2: [1] The IEA considers all aviation fuel consumption to be "transport use". Here an aviation fuel use is reported in the sector to which it is sold.

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A2.5 Fuel flow diagrams for year ended December 2011

Figure A2.1 New Zealand coal energy flow summary for 2011

Notes to Figure C.6: [1] Includes use at production sites and distribution losses.

[2] Includes commercial, residential, agriculture and transport.

Figure A2.2 New Zealand oil energy flow summary for 2011

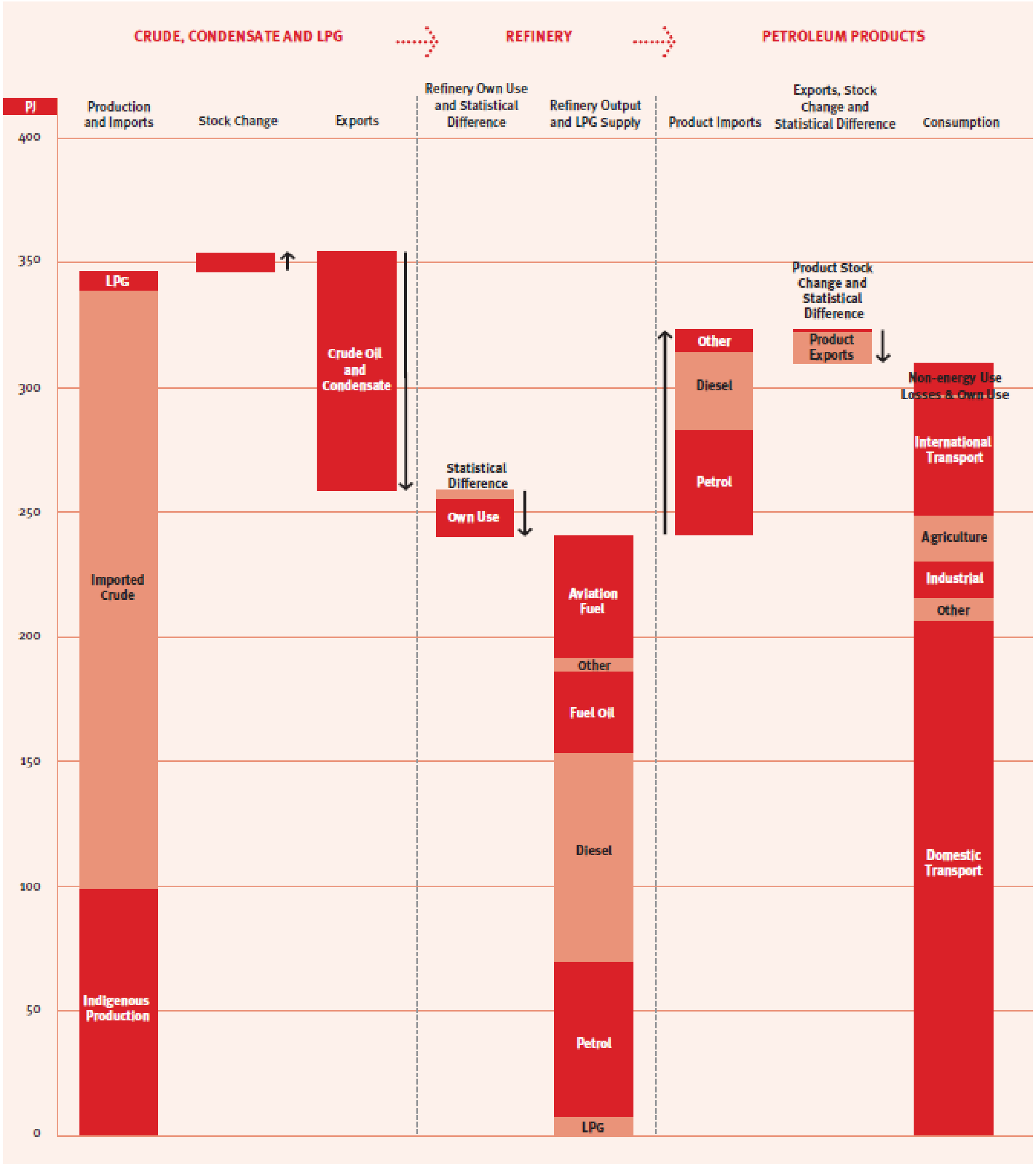


Figure A2.3 New Zealand natural gas energy flow summary for 2011

Notes:

1. Includes the Goldie well
2. Includes the Kauri well.
3. All gas from Tui field was flared.
4. Gas supplied through distribution systems is used by industry (including cogeneration) and the commercial, residential and transport sectors. Some co-generators and other industrial and commercial users are supplied directly.
5. Includes Transport, Agriculture, Forestry and Fishing.

Annex 3: Detailed methodological information for other sectors

A3.1 Agriculture

A3.1.1 Uncertainty of animal population data

Details of the surveys and census are included to provide an understanding of the livestock statistics process and uncertainty values. The information documented is from Statistics New Zealand. Full details of the surveys are available from the Statistics New Zealand website. For information about surveys and census see: www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/info-releases.aspx.

Agricultural production surveys

The target population for the 2011 Agricultural Production Survey was all businesses that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) or owned land that was intended for agricultural activity during the year ended 30 June 2011. The response rate was 83 per cent. These businesses represent 87 per cent of the total estimated value of agricultural output. Statistics New Zealand imputes using a random ‘hot deck’ procedure for values for farmers and growers who did not return a completed questionnaire. The imputation levels for the 2011 Agricultural Production Survey are provided in table A3.1.1.

The 2011 Agricultural Production Survey is subject to sampling error as it is a survey. Sampling error arises from selecting a sample of businesses and weighting the results rather than taking a complete enumeration, and is not applicable when there is a census. Non-sampling error arises from biases in the patterns of response and non-response, inaccuracies in reporting by respondents and errors in the recording and classification of data. Statistics New Zealand adopts procedures to detect and minimise these types of errors, but they may still occur and are not easy to quantify.

Table A3.1.1 Imputation levels and sample error for New Zealand’s 2011 Agricultural Production Survey

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Ewe hoggets put to ram	15	7
Breeding ewes, two tooth and over	14	4
Total number of sheep	14	4
Lambs marked and/or tailed from ewe hoggets	15	8
Lambs marked and/or trailed from ewes	14	4
Total number of lambs	14	4
Beef cows and heifers (in calf) two years and over	14	4
Beef cows and heifers (in calf) one to two years	16	8
Total number of beef cattle	16	3
Calves born alive to beef heifers/cows	14	5
Dairy cows and heifers, in milk or calf	20	5
Total number of dairy cattle	20	4

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Calves born alive to dairy heifers/cows	21	4
Female deer mated	14	7
Total number of deer	14	7
Fawns born on farm and alive at four months	14	7
Area of wheat harvested	17	8
Area of barley harvested	22	7

A3.1.2 Key parameters and emission factors used in the agriculture sector

Table A3.1.2 Parameter values for New Zealand's agriculture nitrous oxide emissions

Parameter (fraction)	Fraction of the parameter	Source	Parameter value
$Frac_{BURN}$ (kg N/kg crop-N)	Crop residue burned in fields	See 6.7.2	Crop specific survey data
$Frac_{BURNL}$ (kg N/kg legume-N)	Legume crop residue burned in fields	Ministry for Primary Industries (expert opinion)	0
$Frac_{FUEL}$ (N/kg N excreted)	Livestock nitrogen excretion in excrements burned for fuel	Practice does not occur in New Zealand	0
$Frac_{GASF}$ (kg NH_3-N + NO_x-N/kg of synthetic fertiliser N applied)	Total synthetic fertiliser emitted as NO_x or NH_3	Sherlock et al (2009)	0.1
$Frac_{GASM}$ (kg NH_3-N + NO_x-N/kg of N excreted by livestock)	Total nitrogen emitted as NO_x or NH_3	Sherlock et al (2009)	0.1
$Frac_{GRAZ}$ (kg N/kg N excreted)	Livestock nitrogen excreted and deposited onto soil during grazing	See table 6.3.1	Livestock specific
$Frac_{LEACH}$ (kg N/kg fertiliser or manure N)	Nitrogen input to soils that is lost through leaching and run-off	Thomas et al (2005)	0.07

Table A3.1.3 Parameter values for New Zealand's cropping emissions

Crop	HI	dmf	AG_N	Root Shoot ratio RatioBG	BG_N
Wheat	0.41	0.86	0.005	0.1	0.009
Barley	0.46	0.86	0.005	0.1	0.009
Oats	0.3	0.86	0.005	0.1	0.009
Maize grain	0.5	0.86	0.007	0.1	0.007
Field seed peas	0.5	0.21	0.02	0.1	0.015
Lentils	0.5	0.86	0.02	0.1	0.015
Peas fresh and process	0.45	0.86	0.03	0.1	0.015
Potatoes	0.9	0.22	0.02	0.1	0.01
Onions	0.8	0.11	0.02	0.1	0.01
Sweet corn	0.55	0.24	0.009	0.1	0.007
Squash	0.8	0.2	0.02	0.1	0.01
Herbage seeds	0.11	0.85	0.015	0.1	0.01
Legume seeds	0.09	0.85	0.04	0.1	0.01
Brassica seeds	0.2	0.85	0.01	0.1	0.008

Source: Curtin et al (2011).

Table A3.1.4 Emission factors for New Zealand's agriculture nitrous oxide emissions

Emission factor	Emissions	Source	Parameter value
EF_1 (kg N_2O-N/kg N)	Direct emissions from nitrogen input to soil	Kelliher and de Klein (2006)	0.01
EF_2 (kg N_2O-N/ha-yr)	Direct emissions from organic soil mineralisation due to cultivation	IPCC (2000), table 4.17	8
EF_{3AL} (kg N_2O-N/kg N excreted)	Direct emissions from waste in the anaerobic lagoons animal waste management systems	IPCC (2000), table 4.12	0.001
EF_{3SSD} (kg N_2O-N/kg N excreted)	Direct emissions from waste in the solid waste and drylot animal waste management systems	IPCC (2000), table 4.12	0.02
EF_{3PRP} (kg N_2O-N/kg N excreted)	Direct emissions from urine in the pasture, range and paddock animal waste management systems for cattle, sheep and deer, and direct emissions from manure waste in the pasture, range and paddock animal waste management systems for all other species	Carran et al (1995); Muller et al (1995); de Klein et al (2003)	0.01
$EF_{3(PRP\ DUNG)}$ (kg N_2O-N/kg N excreted)	Direct emissions from dung in the pasture, range and paddock animal waste management systems for cattle, sheep and deer	Luo et al (2009)	0.0025
EF_{3OTHER} (kg N_2O-N/kg N excreted)	Direct emissions from waste in other animal waste management systems	IPCC (2000), table 4.13	0.005
EF_{3OTHER} (kg N_2O-N/kg N excreted)	Direct emissions from waste in other animal waste management systems – poultry specific	Fick et al (2011)	0.001
EF_4 (kg N_2O-N/kg NH_x-N)	Indirect emissions from volatising nitrogen	IPCC (2000), table 4.18	0.01
EF_5 (kg N_2O-N/kg N leached and run-off)	Indirect emissions from leaching nitrogen	IPCC (2000), table 4.18	0.0025

Table A3.1.5 Emission factor for Tier 1 enteric fermentation livestock and manure management

Emission factor	Emissions	Source	Parameter value (kg/head/yr)
EF_{GOATS}	Enteric fermentation – goats	Lassey (2011)	8.5[42]
EF_{HORSES}	Enteric fermentation – horses	IPCC (1996), table 4.3	18
EF_{MULES}	Enteric fermentation – mules and asses	IPCC (1996), table 4.3	1.14
EF_{SWINE}	Enteric fermentation – swine	Hill (2012)	1.5
EF_{ALPACA}	Enteric fermentation – alpaca	IPCC (2006), table 10.10	8
MM_{GOATS}	Manure management – goats	IPCC (1996), table 4.5	0.18
MM_{HORSES}	Manure management – horses	IPCC (1996), table 4.5	2.1
MM_{MULES}	Manure management – mules and asses	IPCC (1996), table 4.5	10
MM_{SWINE}	Manure management – swine	Hill (2012)	20

[42] Value is for 2009. In 1990, the value was EF 7.4 kg CH_4/head/yr. Values for the intermediate years between 1990 and 2009 and for 2010 and 2011 are interpolated and extrapolated based on an assumption that the dairy goat population has remained in a near constant state over time.

Emission factor	Emissions	Source	Parameter value (kg/head/yr)
$MM_{BROILERs}$	Manure management – broilers	Fick et al (2011)	0.022
MM_{LAYERS}	Manure management – layer hens	Fick et al (2011)	0.016
$MM_{OTHER\ POULTRY}$	Manure management – other poultry	IPCC (1996), table 4.5	0.117
MM_{ALPACA}	Manure management – alpaca	New Zealand 1990 sheep value[43]	0.091

A3.2 Supplementary information for the LULUCF sector: Land Use and Carbon Analysis System (LUCAS)

A3.2.1 LUCAS Data Management System

The LUCAS Data Management System stores, manages and archives data for international greenhouse gas reporting for the LULUCF sector. These systems are used for managing the land-use spatial databases, plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting (figure A3.2.1).

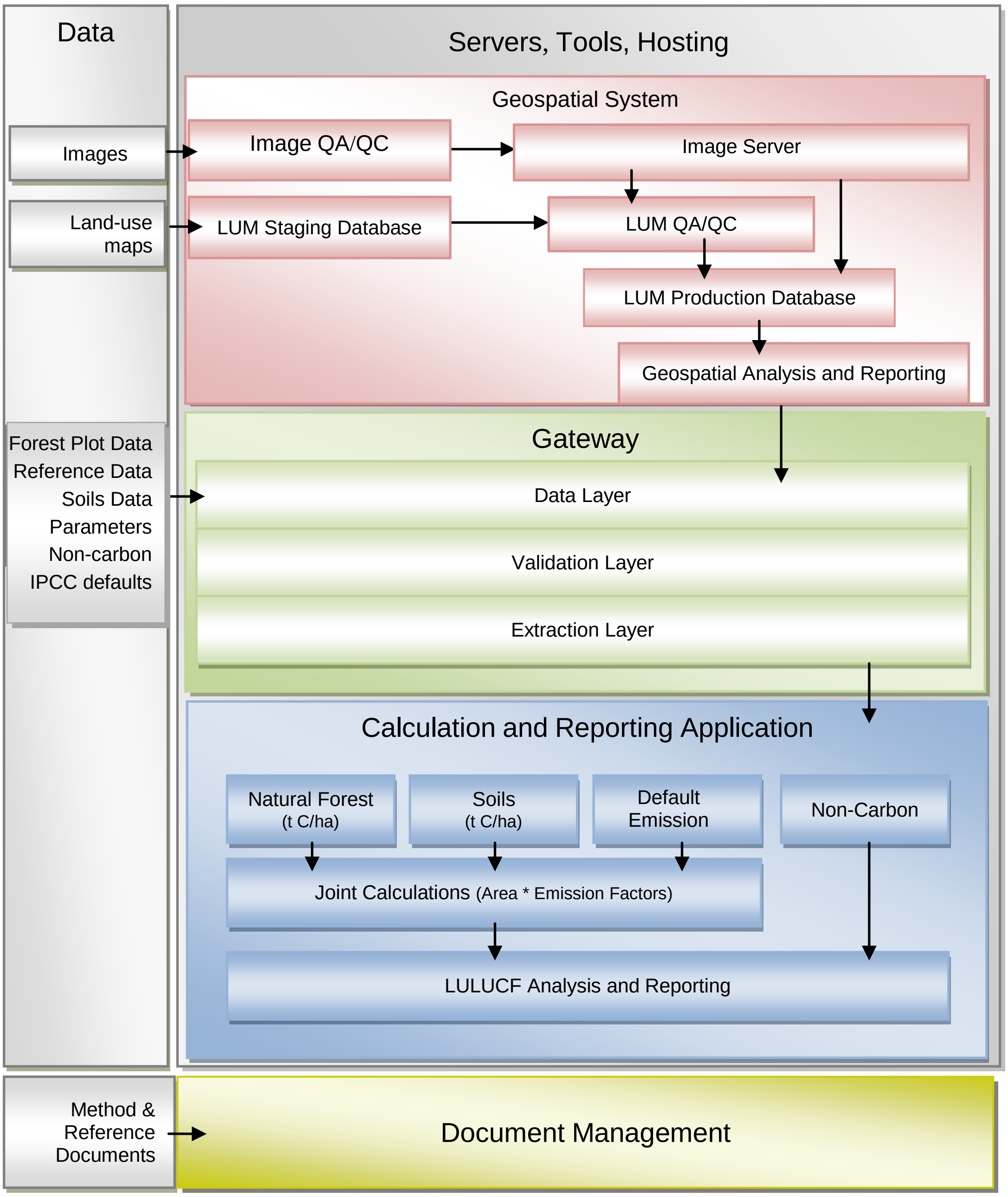
The data collected is stored and manipulated within three systems: the Geospatial System, the Gateway and the Calculation and Reporting Application.

The key objectives of these systems are to:

- provide a transparent system for data storage and carbon calculations
- provide a repository for the versioning and validation of plot measurements and land-use data
- calculate carbon stocks, emissions and removals per hectare for land uses and carbon pools based on the plot and spatial data collected
- calculate biomass burning and liming emissions by land use based on area and emission factors stored in the Gateway
- produce the outputs required for the LULUCF sector reporting under the Climate Change Convention and the Kyoto Protocol
- archive all inputs and outputs used in reporting.

[43] As was reported in the first year that alpacas were included in *New Zealand's Greenhouse Gas Inventory* (Ministry for the Environment, 2010).

Figure A3.2.1 New Zealand's LUCAS Data Management System



Note: LUM = land-use map. Joint calculations are described below.

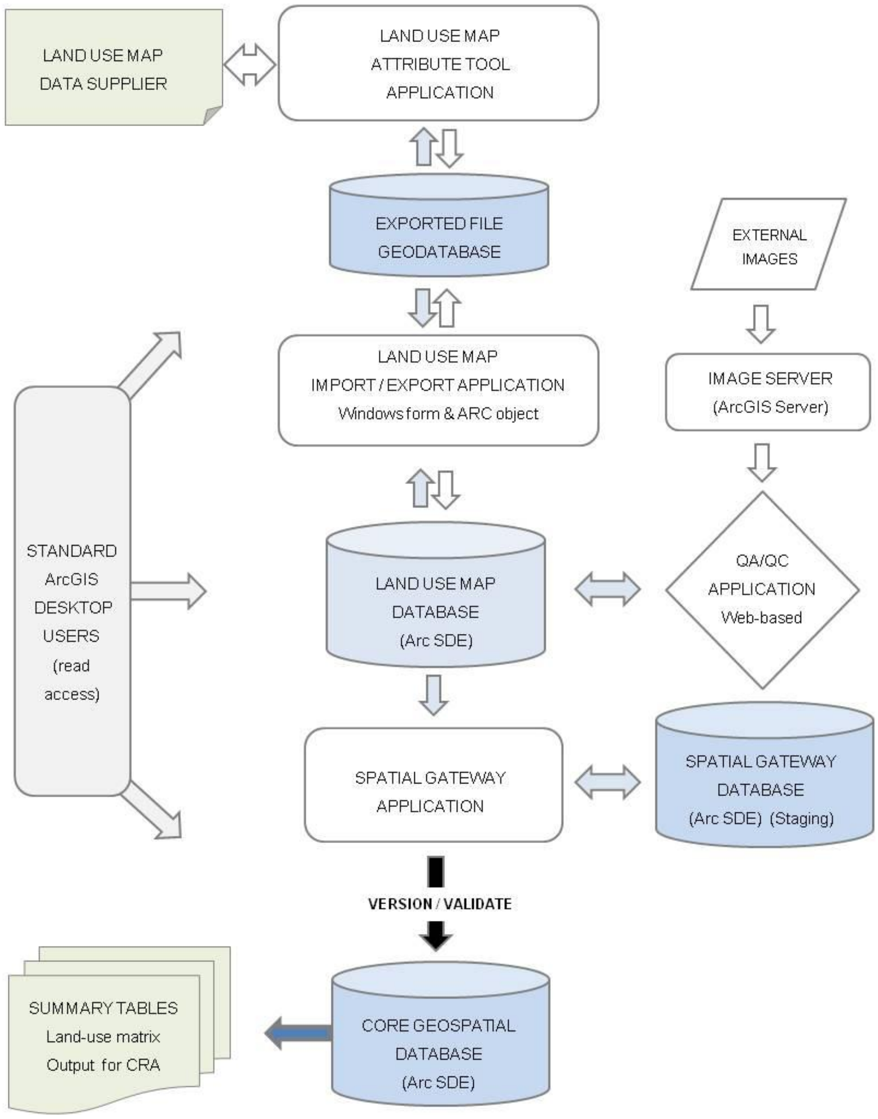
The module Joint Calculations refers to the process New Zealand uses to estimate national average carbon values by carbon pool for each land-use category and subcategory.

The Joint Calculation process is performed within the Calculation and Reporting Application. Within the Joint Calculations interface, the user selects the appropriate area data and emission factors. The results of the calculations are carbon gains, losses and net change for all land-use subcategories whether in a conversion state or land remaining land, by year, by carbon pool, and stratified by North Island or South Island.

Geospatial System

The Geospatial System consists of hardware and specific applications designed to meet LULUCF reporting requirements. The hardware largely comprises servers for spatial database storage, management, versioning and running web mapping applications. The core components of the Geospatial System are outlined below.

Figure A3.2.2 New Zealand's Geospatial System components



Land-use mapping functionality

The land-use mapping (LUM) functionality of the Geospatial System largely involves the editing and maintenance of time-stamped land-use mapping data. There are five components within the LUM functionality, as described below:

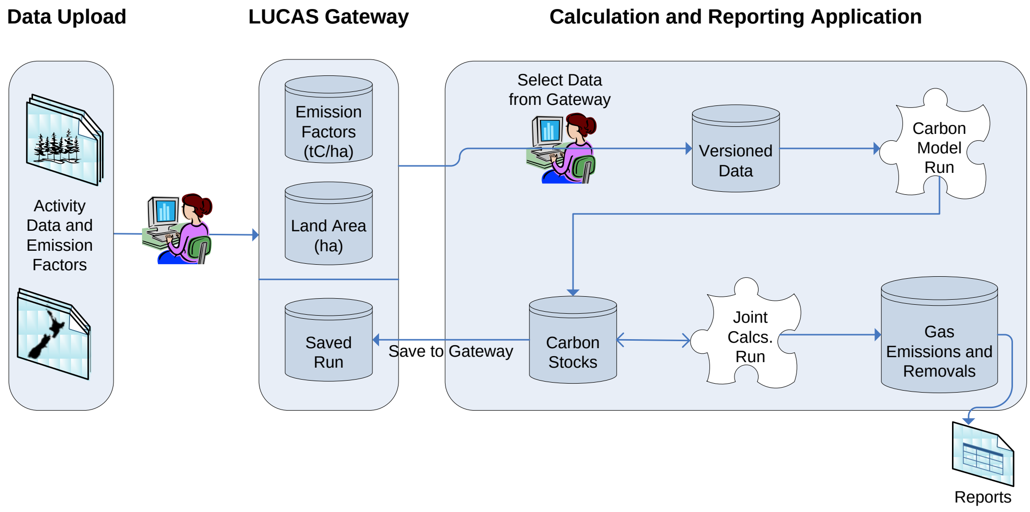
- LUM Import/Export Application – provides functionality for managing the importing and exporting of land-use mapping information in to and out of the database
- LUM Attribute Tool Application – an extension to the standard ArcGIS Desktop software that facilitates maintenance and updates to the land-use mapping data by external contractors

- LUM Database – a non-versioned GIS database for interim land-use mapping data and related quality assurance and control observation data
- Spatial Gateway Application – used to validate and version data from the LUM database prior to loading into the Core Geospatial Database. Spatial gateway rules are stored in the Spatial Gateway Database
- Core Geospatial Database – stores final versioned geospatial datasets that are used by the Summary Calculation application to generate land-use matrix data. It also stores the summary tables produced.

LUCAS Management Studio

The LUCAS Management Studio is the package of applications used to store activity data and calculate and report New Zealand's emissions and removals for LULUCF. The LUCAS Gateway is a data warehouse with the purpose of storing, versioning and validating activity data and emissions factors. The Calculation and Reporting Application sources all data from the Gateway and calculates and outputs New Zealand's emissions and removals for LULUCF for land remaining land and land converted to another land use, by pool and year.

Figure A3.2.3 LUCAS Management Studio



LUCAS Gateway

The LUCAS Gateway enables the storage of activity data such as: field plot data, land-use area, biomass burning, liming and other data, such as IPCC defaults, needed by the Calculation and Reporting Application.

The LUCAS Gateway provides a viewing, querying and editing interface to the source (plot, land-use area, carbon and non-carbon) data. The Gateway also stores any published or saved results from running the Calculation and Reporting Application.

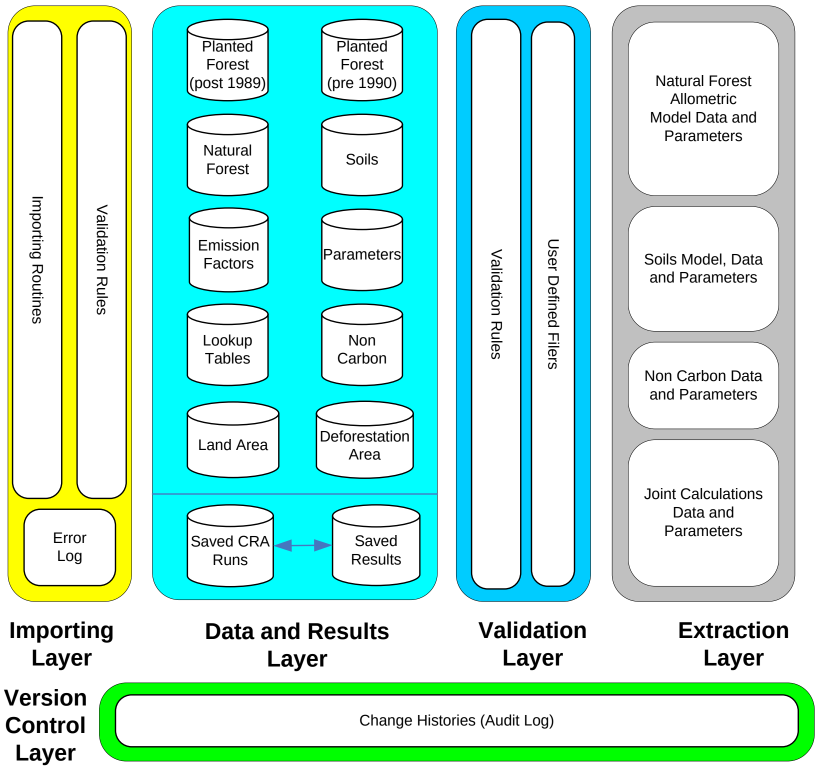
All activity data and emission factors are stored within the Gateway database (figure A3.2.4). Below is a description of the key components:

- a data and results layer contains all activity data (natural, planted forest, soils, default carbon, non-carbon, land-use areas, land-use change and reference tables). The user has the ability to create a 'snapshot' in time (a dataset archiving system) of the data held in the Gateway. This enables users of the Calculation and

Reporting Application to select from a range of data snapshots and also ensures past results can be replicated over time

- a validation layer allows users to judge the suitability of data for use in the Calculation and Reporting Application calculations, subsequent to passing primary validation. Where records are deemed not acceptable for use within published reports, they are tagged as 'invalid' in the LUCAS Gateway database
- an audit trail provides a history of any changes to the database tables within the Gateway
- versioning at a number of levels ensures any changes to data, schema or the database itself are logged and versioned, while providing the user with the ability to track what changes have been applied and roll back to a previous version if required. The results of saved or published reports within the Calculation and Reporting Application are also stored within the Gateway for repeatability and reference
- primary data validation, both during data capture and during import of the data into the Gateway, ensures only data that has passed acceptability criteria is available for a publishable Calculation and Reporting Application run
- hosting and application support provides hosting services, system security, backup and restore, daily maintenance and monitoring for the Gateway and Calculation and Reporting Application.

Figure A3.2.4 LUCAS Gateway database

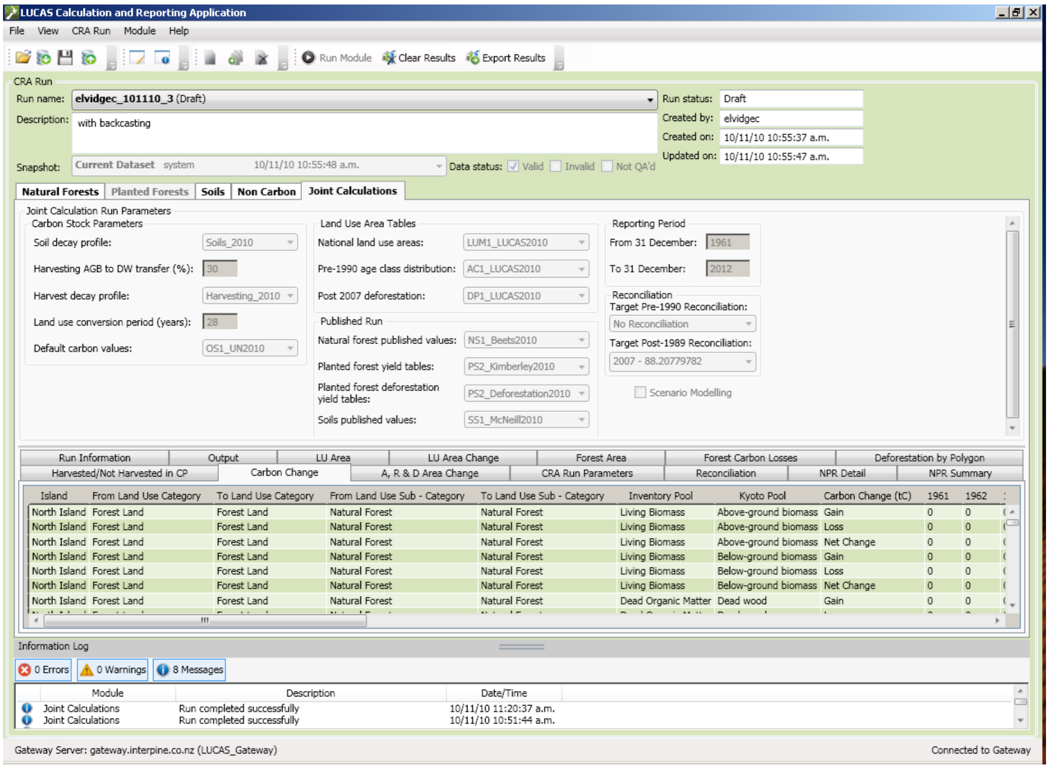


Calculation and Reporting Application

The Calculation and Reporting Application enables users to import carbon and non-carbon data from the Gateway and, by running the various modules, determine emissions and removals by New Zealand's forests, cropland, grassland and other land-use types. This information, combined with land-area data, enables New Zealand to meet its reporting requirements under the Climate Change Convention and Kyoto Protocol.

The Calculation and Reporting Application allows for the inclusion of other datasets, models and calculations without the complete redesign of the applications. All models, data and results are versioned, and the Calculation and Reporting Application allows the user to alter specific key values within a model or calculation (parameters) without the intervention of a programmer or technical support officer. The Calculation and Reporting Application is deployed as a client-based application that sources the required data from the Gateway.

Figure A3.2.5 Calculation and Reporting Application



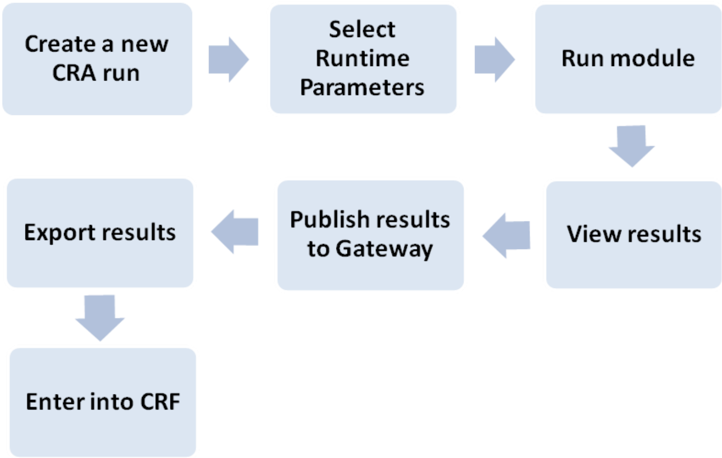
The Calculation and Reporting Application comprises four modules: natural forest, soils, non-carbon, and joint calculations. Any of these modules can be run independently or as a group. The results are provided as 'views' to the user at the completion of the run.

To activate the module, the user selects the module to run within the Calculation and Reporting Application, the version of the dataset to be used, the model version and other calculation parameters. The natural forest and soil carbon modules use R statistical language as the base programme language, while the non-carbon module and joint calculations module are developed in C Sharp programming language (C#).

Within the joint calculations module, the user has the option of using the carbon results from running the modules or using default carbon estimates (based on published reports) stored within the Gateway. The joint calculations module combines the carbon estimates with the land-use area to calculate carbon stock and change. The results represent carbon stock and change for every 'from' and 'to' land-use combination outlined by the IPCC since 1990.

On completion of running a module, the results can be saved or published back to the Gateway. This provides a versioned and auditable record of the results used for reporting. If the results are saved or published, other information, such as the time created, the user's identification and the module-particular parameters that were used, is also saved for tracking and audit control.

Figure A3.2.6 How New Zealand used the Calculation and Reporting Application for entry into the common reporting format database



Note: CRA = Calculation and Reporting Application; CRF = common reporting format.

The Calculation and Reporting Application is maintained and supported by Interpine Forestry Limited, a New Zealand-based company that specialises in forestry inventories and related information technology development. Interpine Forestry Limited also provides support services, such as database and application back-ups and system security (firewalls and virus control), day-to-day issue resolution and enhancement projects to the Gateway or Calculation and Reporting Application, as required.

Any changes to the data or table structure within the Gateway, or to people accessing the Gateway or Calculation and Reporting Application, are tracked via audit logs. For any changes to the data within the Gateway, the person making the change, the date, reason for change and the version are logged and reports are made available to the users for review.

A3.2.2 New Zealand's Tier 1 methodology for mineral soils

New Zealand uses a Tier 1 method to estimate soil carbon stock and stock change for mineral soils. The method estimates a steady state carbon stock for each land use in New Zealand, and calculates changes in soil carbon stocks associated with land-use change.

New Zealand has estimated a national reference value of soil organic carbon (SOC_{REF}) using an area-weighted average of climate/soil type combinations (section 7.1.3). A GIS analysis determined the area of each climate zone/soil type combination. The input layers to determine the climate zones are two of the underlying data layers of the Land Environments of New Zealand classification (Leathwick et al, 2002). These layers provide data about the temperature and moisture conditions necessary to characterise climate zones described in figure 3.1.3 of the IPCC good practice guidance (IPCC, 2003). The soil type information was derived from the Fundamental Soils Layer associated with the New Zealand Land Resources Inventory (Newsome et al, 2000), with soil types converted to IPCC classifications (Daly and Wilde, 1997).

- Temperature and moisture zone data was reclassified into the classes described in figure 3.1.3 of the IPCC good practice guidance (IPCC, 2003).

- Temperature data was reclassified into three classes: **Polar/boreal classes** have a temperature less than 0 C; **cold classes** have a temperature between 0 and 10 C; and **warm classes** have a temperature greater than 10 C. No areas of New Zealand have a temperature within the tropical class.
- Moisture zone data was reclassified into two classes: **Dry zones** have a ratio of precipitation to potential evapotranspiration less than 1 and **wet zones** have a ratio greater than 1.

- Temperature and moisture zone data was combined to determine the climate zones described in figure 3.1.3. The raster data is converted to vector data for use in the next steps of analysis.
- The climate data was overlaid with the soil type data to determine the climate soil zones.

Table A3.2.1 Choice of stock change factors for each land use

Land use	Land-use factor	Management regime factor	Input factor	IPCC-GPG reference	Reasoning (refer to table 7.2.2 for full land-use category descriptions)
Natural forest	1.0	1.0	1.0	Section 3.2.1.3	Under Tier 1, it is assumed that when forest remains forest, the carbon stock in soil organic matter does not change, regardless of changes in forest management, types and disturbance regimes.
Pre-1990 planted forest	1.0	1.0	1.0		
Post-1989 forest	1.0	1.0	1.0		
Cropland – annual	0.71	1.00	0.91	Table 3.3.4	Includes all annual crops and cultivated bare ground, ie, long-term cropping areas for predominantly annual crops. These areas receive substantial soil disturbance through full tillage, and low levels of residues are returned to the soil. Climate regimes are considered to be temperate wet.
Cropland – perennial	0.82	1.16	1.11	Table 3.3.4	Includes all orchards and vineyards, ie, long-term crops that are not annually cultivated. Soils are not tilled. Climate regimes are considered to be temperate wet.
Grassland – high producing	1.00	1.14	1.11	Table 3.4.5	This class receives additional management inputs/ improvements. This includes intensive dairy farming areas with high quality pasture species and fertiliser application.
Grassland – low producing	1.00	1.14	1.00	Table 3.4.5	This grassland class does not receive additional management inputs/improvements. This includes low fertility grassland on hill country that receives moderate grazing pressure and fertiliser. It also includes natural grassland, such as tussock grasslands and herbfields that do not receive managed grazing or improvements.

Land use	Land-use factor	Management regime factor	Input factor	IPCC-GPG reference	Reasoning (refer to table 7.2.2 for full land-use category descriptions)
Grassland – with woody biomass	1.00	1.00	NA	Table 3.4.5	The land defined under this class does not receive significant management improvements. It includes managed grasslands with erosion control or riparian planting, and grassland and herbfields with natural shrubland species that will not meet the forest criteria.
Wetlands – open water	0	0	0		No IPCC default values are given.
Wetlands – vegetated non-forest	1.0	1.0	1.0		In the absence of default stock change factors, it is assumed that, due to the natural conditions this land use represents, the reference soil organic stock value is used.
Settlements	1.00	0.70	1.00	Table 3.4.5	No IPCC default values are given. The values for severely degraded grassland imply a major long-term loss of productivity and vegetative land cover, and are appropriate for this land use.
Other land	1.0	1.0	1.0		In the absence of default stock change factors, it is assumed that, due to the natural conditions this land use represents, the reference soil organic stock value is used.

Annex 4: Carbon dioxide reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Information on the carbon dioxide reference approach and a comparison with sectoral approach is provided in section 3.2.1. A table of the national energy balance for the 2011 calendar year is provided in annex 2.

Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

An assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in section 1.8.

Annex 6: Additional information and supplementary information under Article 7.1

All supplementary information required under Article 7.1 of the Kyoto Protocol is provided in chapters 11 to 15.

Annex 7: Uncertainty analysis (table 6.1 of the IPCC good practice guidance)

Uncertainty estimates are an essential element of a complete emissions inventory. The purpose of uncertainty information is not to dispute the validity of the inventory estimates but to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice (IPCC, 2000). The good practice guidance also notes that inventories prepared following the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003) will typically contain a wide range of emission estimates. This range varies from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable nitrous oxide (N_2O) fluxes from soils and waterways (IPCC, 2000).

New Zealand has included a Tier 1 uncertainty analysis as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. Land use, land-use change and forestry sector (LULUCF) categories have been included using the absolute value of any removals of carbon dioxide (CO_2) (table A7.1.1). Table A7.1.2 calculates the uncertainty only in emissions, that is, excluding LULUCF removals.

A7.1 Tier 1 uncertainty calculation

The uncertainty in activity data and emission and/or removal factors shown in table A7.1.1 and A7.1.2 are equal to half the 95 per cent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 per cent confidence interval is that the value corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus x per cent'.

Where uncertainty is highly asymmetrical, the larger percentage difference between the mean and the confidence limit is entered. Where only the total uncertainty is known for a category, then:

- if uncertainty is correlated across years, the uncertainty is entered as the emission or the removal factor uncertainty and as zero in the activity data uncertainty
- if uncertainty is not correlated across years, the uncertainty is entered as the uncertainty in the activity data and as zero in the emission or the removal factor uncertainty.

In the Tier 1 method, uncertainties in the trend are estimated using two sensitivities.

- Type A sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and a greenhouse gas in both the base year and the current year.

- Type B sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and gas in the current year only.

Uncertainties that are fully correlated between years are associated with Type A sensitivities, and uncertainties that are not correlated between years are associated with Type B sensitivities.

In tables A7.1.1 and A7.1.2, the figure labelled ‘Uncertainty in the trend’ is an estimate of the total uncertainty in the trend in emissions since the base year. This is expressed as the number of percentage points in the 95 per cent confidence interval in the per cent change in emissions since the base year. The total uncertainty in the trend is calculated by combining the contribution of emissions factor uncertainty and activity data uncertainty to the trend across all categories using equation 3.1 (IPCC, 2000).

The values for individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

Table A7.1.1 The uncertainty calculation (including LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2011* (IPCC, Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – liquid fuels	CO_2	11,681.62	17,528.38	0.1	0.5	0.5	0.1	0.0576	0.1957	0.0288	0.0138	0.0	R	M
Energy – solid fuels	CO_2	3,161.21	3,679.88	4.3	3.5	5.5	0.2	0.0037	0.0411	0.0131	0.2475	0.2	M	M
Energy – gaseous fuels	CO_2	6,984.63	7,046.37	3.7	2.4	4.4	0.3	–0.0039	0.0787	–0.0094	0.4095	0.4	M	M
Energy – fugitive – geothermal	CO_2	228.58	626.82	5.0	5.0	7.1	0.0	0.0043	0.0070	0.0215	0.0495	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	228.88	780.56	2.6	2.4	3.5	0.0	0.0060	0.0087	0.0144	0.0318	0.0	M	M
Energy – fugitive – oil transport	CO_2	0.01	0.01	5.0	50.0	50.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.46	1.17	2.6	5.0	5.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	M
Industrial processes – mineral production	CO_2	561.85	699.68	100.0	7.0	100.2	0.7	0.0012	0.0078	0.0082	1.1049	1.1	D	D
Industrial processes – chemical industry	CO_2	430.20	536.43	2.0	6.0	6.3	0.0	0.0009	0.0060	0.0054	0.0169	0.0	D	D
Industrial processes – metal production	CO_2	1,755.71	2,262.01	5.0	7.0	8.6	0.2	0.0045	0.0253	0.0315	0.1786	0.2	D	D
LULUCF – forest land	CO_2	27,738.48	17,758.32		64.7	64.7	12.1	–0.1292	0.1983	–8.3594	0.0000	8.4	M	R
LULUCF – non-forested land	CO_2	2,094.49	4,152.30		32.2	32.2	1.4	0.0216	0.0464	0.6945	0.0000	0.7	M	R
Waste – waste incineration	CO_2	12.91	0.92	50.0	40.0	64.0	0.0	–0.0001	0.0000	–0.0057	0.0007	0.0	D	D
Energy – liquid fuels	CH_4	56.85	29.45	0.1	50.0	50.0	0.0	–0.0003	0.0003	–0.0172	0.0000	0.0	D	M
Energy – solid fuels	CH_4	23.78	5.81	3.5	50.0	50.1	0.0	–0.0002	0.0001	–0.0108	0.0003	0.0	D	M
Energy – gaseous fuels	CH_4	56.42	40.30	3.7	50.0	50.1	0.0	–0.0002	0.0004	–0.0108	0.0023	0.0	D	M
Energy – biomass	CH_4	57.38	60.39	5.0	50.0	50.2	0.0	0.0000	0.0007	–0.0002	0.0048	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.02	110.14	5.0	5.0								D	D

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – fugitive – venting/flaring	CH_4	54.29	57.70	3.7	50.0	50.1	0.0	0.0000	0.0006	0.0001	0.0034	0.0	D	M
Energy – fugitive – coal mining and handling	CH_4	274.47	390.67	4.3	50.0	50.2	0.2	0.0011	0.0044	0.0559	0.0263	0.1	D	M
Energy – fugitive – transmission and distribution	CH_4	235.16	156.24	3.7	5.0	6.2	0.0	–0.0010	0.0017	–0.0052	0.0091	0.0	D	M
Energy – fugitive – other leakages	CH_4	202.94	203.70	5.0	50.0	50.2	0.1	–0.0001	0.0023	–0.0062	0.0161	0.0	D	D
Energy – fugitive – oil transportation	CH_4	4.79	6.11	5.0	50.0								D	D
Agriculture – enteric fermentation	CH_4	22,240.82	23,517.71	0.0	16.0	16.0	4.0	–0.0003	0.2626	–0.0049	0.0000	0.0	M	M
Agriculture – manure management	CH_4	456.63	647.27	5.0	30.0	30.4	0.2	0.0018	0.0072	0.0549	0.0511	0.1	M	M
Agriculture – savanna burning	CH_4	22.23	6.10	20.0	60.0	63.2	0.0	–0.0002	0.0001	–0.0117	0.0019	0.0	D	R
Agriculture – burning of residues	CH_4	19.00	15.80	0.0	40.0	40.0	0.0	0.0000	0.0002	–0.0019	0.0000	0.0	D	R
LULUCF	CH_4	57.56	51.49	5.0	42.4									
Waste – solid waste disposal	CH_4	1,514.39	1,331.08	0.0	40.0	40.0	0.6	–0.0030	0.0149	–0.1215	0.0000	0.1	M	R
Waste – wastewater handling	CH_4	385.14	471.68	0.0	100.0	100.0	0.5	0.0007	0.0053	0.0714	0.0000	0.1	D	R
Waste – waste incineration	CH_4	0.00	0.00	50.0	100.0	111.8	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – liquid fuels	N_2O	118.36	180.67	0.1	50.0	50.0	0.1	0.0006	0.0020	0.0309	0.0001	0.0	D	M
Energy – solid fuels	N_2O	16.29	18.98	4.3	50.0	50.2	0.0	0.0000	0.0002	0.0010	0.0013	0.0	D	M
Energy – gaseous fuels	N_2O	8.27	6.79	3.7	50.0	50.1	0.0	0.0000	0.0001	–0.0011	0.0004	0.0	D	M
Energy – biomass	N_2O	46.29	73.20	5.0	50.0	50.2	0.0	0.0003	0.0008	0.0135	0.0058	0.0	D	D
Solvents – N_2O use	N_2O	41.54	27.90	10.0	0.0	10.0	0.0	–0.0002	0.0003	0.0000	0.0044	0.0	R	

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Agriculture – agricultural soils	N_2O	7,884.46	10,158.56	0.0	74.0	74.0	7.9	0.0202	0.1134	1.4956	0.0000	1.5	M	M
Agriculture – manure management	N_2O	25.71	35.66	5.0	100.0	100.1	0.0	0.0001	0.0004	0.0094	0.0028	0.0	R	R
Agriculture – savanna burning	N_2O	8.12	2.23	20.0	60.0	63.2	0.0	–0.0001	0.0000	–0.0043	0.0007	0.0	D	R
Agriculture – burning of residues	N_2O	4.96	3.99	6.0	40.0	40.4	0.0	0.0000	0.0000	–0.0006	0.0004	0.0	D	R
LULUCF	N_2O	25.04	14.35		79.7	79.7	0.0	–0.0001	0.0002	–0.0108	0.0000	0.0	R	R
Waste – wastewater handling	N_2O	144.98	180.44	25.0	1,200.0	1,200.3	2.3	0.0003	0.0020	0.3611	0.0712	0.4	D	R
Waste – waste incineration	N_2O	1.63	1.28	50.0	100.0	111.8	0.0	0.0000	0.0000	–0.0005	0.0010	0.0	D	D
Industrial processes – consumption of halocarbons and SF_6	HFCs	0.00	1,885.07	11.0	5.0	12.1	0.2	0.0210	0.0210	0.1052	0.3274	0.3	R	R
Industrial processes – aluminium production	PFCs	629.87	30.18	5.0	30.0	30.4	0.0	–0.0071	0.0003	–0.2132	0.0024	0.2	R	D
Industrial processes – consumption of halocarbons and SF_6	PFCs	0.00	IE,NA,NE,NO	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	R	R
Industrial processes – metal production	SF_6	2.87	IE, NA, NO	60.0	10.0	60.8	0.0	0.0000	0.0000	–0.0003	0.0000	0.0	R	R
Consumption of halocarbons and SF_6 – electrical equipment	SF_6	9.47	14.75	20.0	5.0	20.6	0.0	0.0001	0.0002	0.0003	0.0047	0.0	R	R
Industrial processes – Consumption of halocarbons and SF_6 – other sources of SF_6	SF_6	2.87	2.87	60.0	10.0	60.8	0.0	0.0000	0.0000	0.0000	0.0027	0.0	R	R
Total emissions/removals		**89,558.63**	**94,811.38**		**Uncertainty in the year**		**15.3%**		**Uncertainty in the trend**			**8.6%**		

Note: D = default; IE= included elsewhere; M = measurements; NA = not applicable; NE = not estimated; NO = not occurring; R = national referenced information.

Table A7.1.2 The uncertainty calculation (excluding LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2011* (IPCC, Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – liquid fuels	CO_2	11,681.6	17,528.4	0.1	0.5	0.5	0.1	0.1	0.3	0.0	0.0	0.0	R	R
Energy – solid fuels	CO_2	3,161.2	3,679.9	4.3	3.5	5.5	0.3	0.0	0.1	0.0	0.4	0.4	R	R
Energy – gaseous fuels	CO_2	6,984.6	7,046.4	3.7	2.4	4.4	0.4	0.0	0.1	–0.1	0.6	0.6	R	R
Energy – fugitive – geothermal	CO_2	228.6	626.8	5.0	5.0	7.1	0.1	0.0	0.0	0.0	0.1	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	228.9	780.6	2.6	2.4	3.5	0.0	0.0	0.0	0.0	0.0	0.1	R	R
Energy – fugitive – oil transport	CO_2	0.0	0.0	5.0	50.0	50.2	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.5	1.2	2.6	5.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Industrial processes – mineral production	CO_2	561.9	699.7	100.0	7.0	100.2	1.0	0.0	0.0	0.0	1.7	1.7	D	D
Industrial processes – chemical industry	CO_2	430.2	536.4	2.0	6.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Industrial processes – metal production	CO_2	1,755.7	2,262.0	5.0	7.0	8.6	0.3	0.0	0.0	0.0	0.3	0.3	D	D
Waste – waste incineration	CO_2	12.9	0.9	50.0	40.0	64.0	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – liquid fuels	CH_4	56.8	29.4	0.1	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – solid fuels	CH_4	23.8	5.8	3.5	50.0	50.1	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – gaseous fuels	CH_4	56.4	40.3	3.7	50.0	50.1	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – biomass	CH_4	57.4	60.4	5.0	50.0	50.2	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.0	110.1	5.0	5.0								D	D
Energy – fugitive – venting/flaring	CH_4	54.3	57.7	3.7	50.0	50.1	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Energy – fugitive – coal mining and handling	CH_4	274.5	390.7	4.3	50.0	50.2	0.3	0.0	0.0	0.0	0.0	0.1	R	R
Energy – fugitive – transmission and distribution	CH_4	235.2	156.2	3.7	5.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	R	R

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – fugitive – other leakages	CH_4	202.9	203.7	5.0	50.0	50.2	0.1	0.0	0.0	0.0	0.0	0.0	D	D
Energy – fugitive – oil transportation	CH_4	4.8	6.1	5.0	50.0								D	D
Agriculture – enteric fermentation	CH_4	2,2240.8	2,3517.7	0.0	16.0	16.0	5.2	–0.1	0.4	–1.0	0.0	1.0	M	M
Agriculture – manure management	CH_4	456.6	647.3	5.0	30.0	30.4	0.3	0.0	0.0	0.0	0.1	0.1	M	M
Agriculture – savanna burning	CH_4	22.2	6.1	20.0	60.0	63.2	0.0	0.0	0.0	0.0	0.0	0.0	D	R
Agriculture burning of residues	CH_4	19.0	15.8	0.0	40.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	D	R
Waste – solid waste disposal	CH_4	1,514.4	1,331.1	0.0	40.0	40.0	0.7	0.0	0.0	–0.3	0.0	0.3	M	R
Waste – wastewater handling	CH_4	385.1	471.7	0.0	100.0	100.0	0.6	0.0	0.0	0.0	0.0	0.0	D	R
Waste – waste incineration	CH_4	0.0	0.0	50.0	100.0	111.8	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – liquid fuels	N_2O	118.4	180.7	0.1	50.0	50.0	0.1	0.0	0.0	0.0	0.0	0.0	D	D
Energy – solid fuels	N_2O	16.3	19.0	4.3	50.0	50.2	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – gaseous fuels	N_2O	8.3	6.8	3.7	50.0	50.1	0.0	0.0	0.0	0.0	0.0	0.0	D	D
Energy – biomass	N_2O	46.3	73.2	5.0	50.0	50.2	0.1	0.0	0.0	0.0	0.0	0.0	D	D
Solvents – N_2O use	N_2O	41.5	27.9	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	R	
Agriculture – agricultural soils	N_2O	7,884.5	10,158.6	0.0	74.0	74.0	10.3	0.0	0.2	0.7	0.0	0.7	M	M
Agriculture – manure management	N_2O	25.7	35.7	5.0	100.0	100.1	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Agriculture – prescribed burning	N_2O	8.1	2.2	20.0	60.0	63.2	0.0	0.0	0.0	0.0	0.0	0.0	D	R
Agriculture – burning of residues	N_2O	5.0	4.0	6.0	40.0	40.4	0.0	0.0	0.0	0.0	0.0	0.0	D	R
Waste – wastewater handling	N_2O	145.0	180.4	25.0	1,200.0	1,200.3	3.0	0.0	0.0	0.1	0.1	0.1	D	R
Waste – waste incineration	N_2O	1.6	1.3	50.0	100.0	111.8	0.0	0.0	0.0	0.0	0.0	0.0	D	D

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2011 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2011 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty (%)	Uncertainty in trend in national total introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in the national total (%)	Emission/ removal factor quality indicator	Activity data quality indicator
Industrial processes – consumption of halocarbons and SF_6	HFCs	0.0	1,885.1	11.0	5.0	12.1	0.3	0.0	0.0	0.2	0.5	0.5	R	R
Industrial processes – aluminium production	PFCs	629.9	30.2	5.0	30.0	30.4	0.0	0.0	0.0	–0.4	0.0	0.4	R	D
Industrial processes – consumption of halocarbons and SF_6	PFCs	0.0	IE, NA, NE, NO	20.0	5.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Industrial processes – metal production	SF_6	2.9	IE, NA, NO	60.0	10.0	60.8	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Consumption of halocarbons and SF_6 – electrical equipment	SF_6	9.5	14.8	20.0	5.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Industrial processes – Consumption of halocarbons and SF_6 – other sources of SF_6	SF_6	2.9	2.9	60.0	10.0	60.8	0.0	0.0	0.0	0.0	0.0	0.0	R	R
Total emissions		**59,643.1**	**72,834.9**		**Uncertainty in the year**		**12.0%**		**Uncertainty in the trend**			**2.3%**		

Note: D = default; IE= included elsewhere; M = measurements; NA = not applicable; NE = not estimated; NO = not occurring; R = national referenced information.

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